BEFORE THE CONNECTICUT SITING COUNCIL

JOINT APPLICATION OF THE CONNECTICUT LIGHT AND POWER COMPANY AND THE UNITED ILLUMINATING COMPANY FOR A CERTIFICATE OF ENVIRONMENTAL COMPATIBILITY AND PUBLIC NEED FOR A 345-KV ELECTRIC TRANSMISSION LINE FACILITY AND ASSOCIATED FACILITIES BETWEEN SCOVILL ROCK SWITCHING STATION IN MIDDLETOWN AND NORWALK SUBSTATION IN NORWALK	)	**Docket No. 272**

TESTIMONY OF

TORBEN AABO

ON BEHALF OF

THE OFFICE OF CONSUMER COUNSEL

25 MAY 2004

I. INTRODUCTION

Q. Please state your name and address.

A. My name is Torben Aabo and my office is at 220 Sweetman Road, Ballston Spa, NY 12020-3211.

Q. By whom are you employed and in what capacity?

A. I am the president and principal engineer of Power Cable Consultants, Inc.

Q. Please review your educational background.

A. I earned a Bachelor's Degree in electrical engineering from Aarhus Technical College, Denmark in 1967, and have done graduate work in electrical engineering and industrial management at Fairleigh Dickinson University, New Jersey.

Q. Please outline your relevant work experience and professional achievements.

A. I have been involved with transmission cable system manufacturing, design, installation, and maintenance since 1970. I teach the cable course, "Underground Cable Systems: Principles and Practices" sponsored by Power Delivery Consultants in St. Petersburg Beach, Florida, every fall, and have done this for about five years. This course teaches engineers about transmission cable technology. I am a voting member of the Institute of Electrical and Electronic Engineers (IEEE) Insulated Conductors Committee (ICC). I chair the working group for the development of a testing guide for XLPE cables up to 161 kV. Attachment A is my resume.

Q. On whose behalf are you appearing in this matter?

A. I am appearing on behalf of the Office of Consumer Counsel.

Q. What documents have you reviewed in preparing your prefiled testimony?

A: I reviewed various documents filed by Northeast Utilities and United Illuminating

Company for the Middletown to Norwalk line, as well as other documents submitted to the Siting Council in this Docket. More detailed information on this point is presented in my answer to the CL&P-003 interrogatory.

Q. Did you review the testimony of Marc D. Montalvo?

A. Yes. I have reviewed both Mr. Montalvo's initial testimony (filed March 9, 2004) and his supplemental testimony (filed May 25, 2004).

Q. What is the purpose of your testimony in this case?

A: This testimony presents my evaluation of the merits of undergrounding sections of the proposed 345 kV transmission line and reviews the Companies' undergrounding proposal.

<u>SUMMARY</u>

Q. Please summarize your testimony.

A. My testimony is presented in seven sections. My key findings are as follows:

(1) Given the number of water crossings and its operating and maintenance cost benefits, if undergrounding is approved, I recommend the use of XLPE type cable rather than HPFF type cable for segments 3 and 4 of the project.

(2) Additional cost benefit study and assessment of land use issues are required before the optimum route can be established.

(3) Review of the available information suggests that study of the modified East Shore Alternative that Mr. Montalvo recommends may resolve the thermal and voltage overload conditions identified as failings in the original configuration.

(4) There appears to be no technical reason at this time to favor undergrounding the segments of the project between Norwalk and Middletown.

Q. How did you assess the merits of undergrounding sections of the transmission line?

A: I reviewed material filed in the case and noted that several segments of the line already are proposed for undergrounding. I visited part of the proposed undergrounding route, from Norwalk to the proposed Singer Substation and further on to the existing East Devon Substation. This area is sufficiently congested with homes and businesses that it would be very difficult to obtain the required ROW for an overhead transmission line. Given this congestion, undergrounding appears to be the most viable solution for the proposed line in this area. Also, the Norwalk Substation is on a large parcel, with adequate room for the required cable termination structures and other equipment.

II. CHOICE OF UNDERGROUND CABLE TYPE

Q. Is the Companies' choice of underground cable type appropriate for Segments 3 and 4, given the particular characteristics of the proposed route?

A. From the information I have reviewed regarding cable type for this route, it appears that the Companies have selected the high-pressure fluid-filled (HPFF) cable system. I recommend a non-fluid-filled cable type, such as the cross-linked polyethylene (XLPE) cable construction, for this installation. Several water inlets and/or rivers cross the proposed cable route. The photographs in Volume 8 and the aerial photographs in Volume 9 of the application show the water crossings, several of which may be candidates for the Horizontal Directional Drilling (HDD) installation method. According to the information supplied by the Applicants, the cable route will cross more than a dozen rivers, creeks, and brooks. The XLPE system would eliminate the potential for water contamination through leakage of dielectric fluids in case of cable system problems.

Q. What are the main differences between the HPFF and XLPE cable systems?

A. The HPFF cable employs a pressurized dielectric fluid, and the XLPE cable system employs a solid extruded insulation.

Q. Please discuss the HPFF cable system.

A. Three cables per circuit would be installed in a common steel pipe. Manholes with splices would be installed every 2,000 to 2,500 feet. To calculate the amount of dielectric fluid in the HPFF cable system, I used the HPFF example shown in the PDC's report included in Volume 6, "Evaluation of Potential 345-kV and 115-kV Cable Systems as Part of the Middletown-Norwalk Project." In Appendix A of this report, Figure A-2 shows an 18,000 gallon tank at the Norwalk Substation, a 24,000 gallon tank at Singer, and an 18,000 gallon tank at East Devon Substation. The volume of dielectric fluid in the cable pipe is on the order of 1 gallon per foot. Assuming that the tanks are about half-full and assuming a total of 23.6 miles of cable, the total amount of fluid would be 374,000 gallons in three pipes and 30,000 gallons in the tanks, for a total of 404,000 gallons of dielectric fluid for the Norwalk to East Devon cable circuits.

Q. Please discuss the maintenance issues for the HPFF cable system.

A. In order to assure the integrity of the steel pipe, a cathodic protection system must be installed and maintained. A cathodic protection survey should be performed on a yearly basis. The cable pipes must be pressurized, and thus pressurization plants need to be installed and maintained. These plants need to be inspected on a regular basis, at least monthly. A fluid leak detection system should be installed and maintained to assure early detection in case of any leaks. Cathodic protection devices (either an electronic unit or a liquid-filled cell) would be located at the terminal locations. These units should be checked at least every five years, and also whenever the cable circuit has experienced a fault current. The termination structures should be visually inspected every six months to assure the integrity of the porcelains. An emergency generator also should be part of the accessory equipment, to assure continued operation of the pressurization plant in case of power failure.

Q. Please discuss the XLPE cable system.

A: The three cables per circuit would be installed in separate ducts in a duct bank, or they could be direct buried as is often done in Europe. Manholes for the splicing of the cables would be installed 2,000 – 2,500 feet apart. The only dielectric fluid in this type of cable system could be a few liters in each termination located at the substations.

Q. Please discuss the maintenance issues for the XLPE cable system.

A. In order to assure the jacket integrity, a voltage test of the jacket should be performed every five years. Because the cable sections will be cross-bonded and grounded at link boxes at the manhole locations and terminations, these boxes should be checked at the time of the jacket test. The link boxes also should be checked if the system has experienced a failure, since short circuit currents may have reached the boxes. The terminations should be visually inspected every six months to assure the integrity of the porcelains.

III. TOTAL LENGTHS FOR UNDERGROUND INSTALLATION

Q. How do the proposed underground segments compare with existing cable installations with which you are familiar?

A: Both New York and Denmark present specific cable installations that are relevant in this context.

In New York City, Consolidated Edison has several long (20 plus miles) 345 kV underground cables connected to long overhead lines at the substations. These lines start at substations and are part of the primary feed of electric power to the city. Because of the densely settled city environment, Con Ed's only transmission option was this underground construction.

In Denmark, there is a 400 kV line with a total length of 87 miles now being constructed. This line will pass through a high density urban environment, so that several sections of this Danish line will be undergrounded. Specifically, a total of 8.7 miles, at three separate locations along the route, will be XLPE cable. The three sections are 2.8, 1.6, and 4.3 miles long. Because one of the cable sections crosses a bay, installation will require horizontal directional drilling and ducts for the cables. . Two of the cable sections are direct buried together with several ducts to carry fiber optic communication cable and temperature monitoring cables. This circuit is scheduled to be commissioned in 2004.

Q. Are you aware of other relevant industry data or planned underground lines?

A. The CCI Engineering Report 117, issued to the Companies on 22 December 2001, also provides a useful perspective. It indicates that several long (more than 20 miles) cable systems at 300 kV and above have been installed throughout the world. These circuits were installed underground because it was the preferred option at the locations where the power delivery was required. No information is available to determine why the lines were undergrounded. It is known that one 220 kV line is installed in part on a bridge crossing a large body of water. In the United States, several 230 kV lines are proposed for underground installation within the next few years. In most of these cases, undergrounding is the only option, based on the environment and possible future use of the properties near which the line is located. For example, the construction of a 230 kV XLPE cable circuit 26 miles long is scheduled to start this year in California. California state and local regulations requiring the evaluation of land use and aesthetic issues provide the principal basis for undergrounding the line.

Q. What are the longest installed (230 kV and above) transmission cable circuits of which you are aware?

A. The literature I have seen indicates the following: In Tokyo in 2000, a 500 kV XLPE double circuit line 40 km (29 miles) long was installed in tunnels. In Copenhagen in 1997, two 400 kV XLPE cable circuits were installed, direct buried. One of these is 22 km (14 miles) long and the other is 10 km (6 miles) long. In Berlin in 1998, two 400 kV XLPE circuits were installed in tunnels.

Q. What is significant about tunnel installations?

A. Cables installed in tunnels are supported at certain intervals allowing the thermal expansion and contraction to be confined to between the supports.

Q. Are you aware of any operating problems that these circuits have experienced?

A. No. I believe that in the Berlin project one joint was replaced before being placed in service because of measured partial discharges within the joint.

Q. Any other failures or problems?

A. Installation problems do occur on any of the transmission cable systems in use today. I am not aware of any "cable system failure" that can be attributed to faults of the specific cable technology. The CCI report I referred to earlier provides a list of XLPE cable system problems. However, the author of the report did not collect and present the same type of data for the HPFF cable systems.

Q. Are you aware of any recent HPFF cable system problems?

A. Yes. Several failures have occurred on 345 kV cable feeders over the last few years. No official statistics are available so I present information I have learned as a participant in industry organizations and my work as a consultant. In one situation, a 345 kV HPFF splice failed. Investigations showed potential problems with the cable so several cable sections were replaced. Also, a splice failed when problems occurred with pressurization of the cable pipe.

Q. How many miles of transmission HPFF cable circuits are installed across the world?

A. I am aware of only a few HPFF cable circuits installed outside the United States, with about 12 km at 220 kV installed in France and several lower voltage 115 – 145 kV, installed in other countries. For the US I have seen numbers on the order of 4,000 miles total of which 250 miles is 345 kV rated.

Q. Are you aware of any past operating problems on these 345 kV HPFF cable systems?

A. 345 kV HPFF cables were first installed in 1964. After about seven years of operation, several splices failed because the thermal movement of the cables had pushed some cable into the splicing area. This problem was solved eventually, after extensive research that led to retrofitting of many of the joints. Concerns regarding movement into the pipe led EPRI to perform extensive research on the cables. The research defined specific HPFF manufacturing parameters that were prone to failure.

Q. You noted that the 400 kV XLPE cables were installed direct buried or in tunnels. Do you have any comments regarding the installation of these cables in ducts?

A. It is my understanding that EPRI has performed modeling and analytical work covering this topic. However, I am not aware of any planned or completed testing. It could be that the analytical work showed that one does not need to be concerned about the issue as long as expansion and contraction are controlled in the manholes. In France, 225 kV XLPE cables are installed in ducts and I am not aware of any operational problems in those systems.

IV. THE PROPOSED ROUTE AND ALTERNATIVES A & B

Q. Have you studied the route the Companies favor and their two alternatives (A & B)?

A. Yes. Of these three possibilities, the route the Companies favor requires the least amount of new ROW easement and property acquisition. It also requires the most underground cable, about 35% of the total linear length. Several changes have been incorporated based on community inputs, and additional inputs/improvements to the route may still be forthcoming. Based on articles in the local press, additional undergrounding of the line may be proposed. I reviewed the photographs of the proposed route presented in Volume 8 of the Application. Several parts of this route are in rural settings (wooded or cleared land), such as the town of Wallingford. Based on these photographs, I did not see any areas where underground transmission cable could not be installed. However, I saw no buildings in these photos, so the higher cost of undergrounding may not be justified for these areas.

Q. Is future land use a consideration that the Siting Council should take into account in evaluating this Application?

A. Yes. I see no information in the Application on the proposed future land use for these areas. Careful consideration should be given to this aspect, particularly in light of the findings presented in the transient and harmonics studies performed by GE. Those studies indicate that there may be considerable limitations and restrictions on operating practice and on future modifications. This tells me that future land use should be carefully considered during the design and construction of the line. To the extent that there are known plans regarding future land use along the proposed ROW, underground cable may result in fewer restrictions than would overhead construction. However, as far as I am aware, no plans regarding future land use along the northern portions of the ROW have been submitted in this proceeding that would suggest that overhead construction would be inappropriate at this time.

Q. Do you have an opinion about the viability of Alternatives A and B?

A. Yes. Alternative Route A incorporates about 18% of its length underground. However, given the additional property purchases that would be required, the initial capital cost of this option is the highest of the three proposals. Considering that a full review of this option was not performed, and that additional undergrounding is likely to be proposed, this route does not seem to offer any advantages that would require additional investigation.

Alternative Route B is the longest route but only calls for about 3% of its length to be underground. According to the Applicants, this option would require the least initial capital cost. It requires the purchase of 29 houses and other buildings. This option seems to be the one with the most direct impact on people, because of the relocation of families and businesses along the route. This factor may not justify the estimated cost savings of $2.1M. While this route has only 2 miles of proposed undergrounding, that could increase if a full review of the route was initiated. With an added section of underground cable, the initial cost advantage would be eliminated.

V. <u>THE EAST SHORE ALTERATIVE</u>

Q. Please explain further your evaluation of the route the Applicants favor, as well as the so-called "East Shore Alternative."

A. The total length of the proposed route is approximately 69 miles. These plans include 45 mile of overhead and 24 miles of underground, with all of the undergrounding located in the southern/western section of the route. I also reviewed the "East Shore Alternative". In doing so, I used the existing and proposed substations and switching stations as listed in Volume 1 of the Application, starting on page H-43.b. Based on all such information, the proposed route includes a total of ten substations, switching stations and junctions. The two proposed underground cable sections would be located between three substations. The East Shore Alternative also would include ten substations, switching stations and junctions. The additional 13 miles of underground cable would be between the East Shore Substation and the East Devon Substation. This alternative would have a total of three cable sections.

Q. For these two possible routes (the Applicants' main proposal and the East Shore Alternative), what are the main advantages and disadvantages?

A. The original proposed route has less underground cable. The proposed East Shore route potentially could increase the amount of underground cable in the line by approximately 13 miles. To date, I have not evaluated any operating studies for this East Shore proposal. However, the Applicants have stated their opposition to the East Shore Alternative. In their Supplemental Filing dated December 16, 2003 (at p. 13), the Companies state that preliminary load flow results suggest that any East Shore solution probably would not be long lasting. They indicate that the added underground cable would make the system more susceptible to voltage excursions and harmonic distortions during normal system operation. Generally, their view is that adding more underground cable to the circuit creates more operating problems. However, this conclusion should not be taken as the final word on this subject. For instance, if the studies suggested by Mr. Montalvo's 5/25/04 testimony show an acceptable system loading for this section of the line, then these operational concerns may be minimized and could be solved.

Q. What operating problems are you referring to?

A. My own particular expertise does not lie in the intricacies of systems operations, so that I cannot speak to each problem that could arise. However, I can say the following: I reviewed the harmonics studies that GE performed. In the report "Connecticut Cable

Transient and Harmonic Study for Middletown to Norwalk Project, East Devon-Beseck 40-mile Cable Option (MIN-P1), final Report November 2003", the System Model section lists modeling three parallel 345 kV cables. In the report "Connecticut Cable Transient and Harmonic Study for Middletown to Norwalk Project, East Devon-Beseck 20-mile Cable Option (MIN-P2), final Report December 2003, the System Model section lists the modeling of two sets of three parallel 345 kV cables. The studies indicate that problems could occur under certain situations. . However, there are further questions that need answering in this context. If XLPE cables were utilized, would the cable characteristics be different enough to change the conclusions of the GE studies? And if other changes were made, would it be possible to require only two cable circuits rather than the proposed three in one of the studies? Again, would changes in the cable characteristics be enough to change the GE study recommendations? Could compensations be added at any of the number of substations and junctions included along both routes? (In principle, such compensation units could be installed so they are switchable to match the load requirements and operating conditions at any given time.) For the final design of the line, a complete set of studies should be performed to assess the need for compensating equipment.

VI. ISO NEW ENGLAND'S VIEWS ON UNDERGROUNDING

Q. Have you reviewed Stephen G. Whitley's testimony in this proceeding, as it concerns undergrounding?

A. Yes. On page 19 of Mr. Whitley's testimony, dated March 9,2004, starting at line 405, Mr. Whitley discusses what he describes as the "unforeseen threats to reliability."

Q. Please describe the nature of these threats.

A. It is not clear what the unforeseen threats are. However, Mr. Whitley discusses that underground cables have different impedance from that of overhead lines. He also refers to the fact that because of the lower impedance of the cable, the circuit with cables may carry more than its share of the load within the transmission network.

Q. Can the transmission system be designed to minimize such threats?

A. Yes. Underground transmission cable at the 345 kV level has been in operation starting in 1964 (see Underground Transmission Systems Reference Book, 1992 Edition, published by Electric Power Research Institute). Such cable has successfully kept the power flowing into New York City as well as other large cities. With available tools, such as computer based monitoring systems and compensation equipment, a hybrid or porpoised (i.e., combined overhead and underground) transmission system can be designed to operate as reliably as would a system featuring only overhead lines or only underground cables.

Q. What are the incremental costs associated with adding the monitoring and compensation equipment mentioned above?

A: Because the line has not been designed, it is difficult to give a cost for the required compensation equipment. The cost estimates prepared by the Companies that I have reviewed do not have the cost breakdown of the system components. The cost of undergrounding is very site specific. Industry cost comparisons of installed cost of underground and overhead estimate a cost increase of four to 14 times to underground the line.

VII EMFs AND CONNECTICUT'S NEW LAW

Q. What electromagnetic fields (EMFs) are produced by underground cable circuits?

A. Very little. First, since the cables are shielded, they generate no electric fields. They will generate a magnetic field. However, when the cables are installed in a common steel pipe, the generated magnetic field is very small and may not be measurable compared to the ambient field. For single conductor cables installed in a ductbank, as would be the case for this project if XLPE cables were specified, the magnetic field directly on top of the ductbank could be similar to that from an overhead line. However at about 20 feet from the center of the line, the field drops to a level less than the 100 foot value for overhead lines. Attachment B is a paper written by Jay Williams on this subject and Mr. Williams' Figure 5 shows an example.

Q. Are you familiar with House Bill Public Act 04-246, An Act Concerning Electric Transmission Line Siting Criteria recently passed by the Connecticut General Assembly?

A. Yes, I reviewed material on this bill. It appears to favor underground construction of transmission lines when those lines are adjacent to certain land uses. It requires the Siting Council to use the best management practice for EMF issues, including use of current federal guidelines. However, the bill gives the Siting Council ultimate decision-making power on whether undergrounding will be required.

Some of the studies presented in this current case show that numerous technical issues must be carefully evaluated before the decision of overhead and/or underground installation can be made. Other states have regulations or guidelines regarding transmission line designs and EMF issues. Some states such as New York and Florida already have guidelines for EMF limitations for the electric lines at the edge of the ROW. The Netherlands and Denmark are two countries that have implemented regulations requiring utilities to install all electric lines up through 145 kV underground. The rules in these two countries allow larger lines (230 kV through 400 kV) to be constructed overhead lines once a thorough review process has been completed.

VIII. PLACING SEGMENTS 1 & 2 UNDERGROUND

Q. As a matter of general engineering practice, under what conditions is underground cable used?

A. Underground transmission cables are used where it is impractical to install overhead lines. They are also used where aesthetic issues must be addressed. Further they are used where planned or future use of the land affected by the line requires the lines to be undergrounded.

Q. You stated earlier that undergrounding might be the most viable option for the southern segments of the project, given the geography of that area. Is it your opinion that the geography of northern segment between Norwalk and Middletown militates against the use of underground cable rather than overhead construction?

A. The aerial photos presented in Volume 9 that I reviewed show large sections of this part of the line to be in rural areas following property lines and passing over pastures and through wooded lots. If future uses of this land include more intensive development for homes or industry (such as already is in place for the more southern segments of the proposed route), this could be a basis for considering the added cost of undergrounding. However, the normal transmission construction over such open land, if the area is expected to retain that status, would be an aerial line.

Q. Would you consider the use of underground cable in the northern segments of the project to be based primarily on aesthetic considerations, or would such use of cable have technical merits?

A. As mentioned, the future use of the land should be evaluated before any final decision is made regarding overhead or underground construction. If aesthetic considerations are the basis for the underground preference, such benefit must be carefully evaluated in order to justify the additional cost of undergrounding the line. In addition, the technical issues associated with additional cable in the circuit must be carefully studied before the underground option is selected.

Q. Does this conclude your testimony?

A. Yes