January 2, 2004

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

Re: Docket No. 272 - Middletown-Norwalk 345kV Transmission Line

Dear Ms. Katz:

This letter provides the response to requests for the information listed below.

Response to D-W-01 Interrogatories dated 10/24/2003
D-W - 044 , 045 , 047

Very truly yours,

Anne Bartosewicz
Project Director - Transmission Business

ABB/ssn
cc: Service List

**Witness:** **Peter T. Brandien**
**Request from:** **Towns of Durham and Wallingford**

**Question:**
Regarding the steady state voltage issues discussed on pages H-8 and H-9:

a On a state-of-the art 345 kV underground transmission system, describe and provide materials supporting how long it takes to isolate a typical phase-to-phase fault and a typical phase to ground fault?
b. Please describe and provide information detailing the technical capabilities of devices and/or technologies, including but not limited to the referenced surge arrestors, available to control the voltage transients.
c. Please describe and provide information detailing the installation cost, the operating costs, and maintenance costs of devices and/or technologies, including but not limited to the referenced surge arrestors, available to control voltage transients.
d. Please describe and provide information detailing the physical space requirements of devices and/or technologies, including but not limited to the referenced surge arrestors, available to control voltage transients.

**Response:**
The integrated system is comprised of thousands of components. The action and interaction of the integrated components allows the system to respond appropriately to most system disturbances, with the purpose of preventing cascading outages to a wider area. Refer to the Part 3 of the Supplemental Filing of December 16, 2003 and the studies referenced there as Exhibits B, C and D, which provide analysis of the 345-kV underground system and the dynamics of the integrated system.

a. Most 345-kV faults can be cleared in 4 cycles. In general the total clearing time is determined by the time it takes the protective relaying scheme to sense the fault and make the logical determination to trip the associated line terminal (2 cycles), plus the time to operate the circuit breakers (an additional 2 cycles).

b. Voltage transients can occur when a circuit breaker is opened/closed to de-energize/energize an overhead or underground transmission line, a capacitor, a section of a substation bus, or a transformer. Transients can also occur when a circuit breaker opens to isolate a fault on the transmission system, or when the transmission system experiences an instantaneous change in voltage or current flow primarily associated with the loss of generation, a disturbance on an adjacent transmission system or a large change in customer load (load rejection). In most, but not all, cases voltage transients can be controlled by the strategic placement and sizing of shunt reactors, static var compensators (SVC), static synchronous var compensators (STATCOM) and surge arresters.

Shunt reactors are used to control steady-state voltages. They absorb reactive power from the AC system, and are typically connected in parallel with the transmission line. They are typically switched into service during light-load conditions and switched out of service during heavy-load conditions. However, as the amount of underground cable increases, reactors may be required to be energized at the same time as lines are energized. Studies are necessary to determine their size, location, and ability to react to varying disturbances.

Surge arresters are used to control overvoltage transients. Energy absorption requirements need to be identified to determine the appropriate arrester characteristic and size. Surge arresters should be connected as close as possible to the system electrical equipment they are protecting.

SVCs and STATCOMs provide adjustable shunt compensation and effectively control overvoltage or undervoltage transients by absorbing and/or generating reactive power. The optimum size and location of these type of var compensators are determined from network system studies.

c. The direct installed cost of a 345-kV 150 MVAR shunt reactor and associated switching device is approximately $4.0 million. The Companies believe the cost of maintaining a variable reactor to be appreciable because of its unique design.

   345-kV surge arresters cost approximately $6,000 and require minimal maintenance.

   The direct installation cost of a 345-kV 150 MVAR SVC with only one coupling transformer is $20-25 million plus interconnection costs which can vary greatly depending on location. The O&M cost is approximately $500,000 per year. The direct installation cost of a 345-kV 150 MVAR STATCOM with only one coupling transformer is $25-30 million plus interconnection costs, which can vary greatly depending on location. The O&M cost is approximately $500,000 per year.

d. Typically, the space required to install a 345-kV shunt reactor and its associated switching equipment is approximately one-half acre. Surge arresters occupy minimal space. The space to install a static var compensator (150 MVAR STATCOM or SVC) and its associated switching equipment is at least one acre.

**Witness:** **Peter T. Brandien**
**Request from:** **Towns of Durham and Wallingford**

**Question:**
Regarding the power quality concerns related to the generation and magnification of harmonics discussed on page H-9:

a Please describe and provide information detailing the technical capabilities of devices and/or technologies available to control harmonics generation and/or harmonics magnification.

b. Please describe and provide information detailing the installation cost, the operating costs, and maintenance costs of devices and/or technologies available to control harmonics generation and/or harmonics magnification.

c. Please describe and provide information detailing the physical space requirements of devices and/or technologies available to control harmonics generation and/or harmonics magnification.

d. Please provide copies of CL&P and UI tariff pages addressing the responsibilities, if any, of customers to limit the harmonics that are propagated onto the utility distribution and/or transmission systems from their facilities.

**Response:**
Studies performed by General Electric indicate that the proposed cable route could result in voltage distortion levels exceeding accepted IEEE limits. The large capacitive reactance of underground cables can significantly affect the harmonic frequency response of the Companies' systems. Low-order harmonic resonances are to be expected. Harmonic distortion exists in any power system due to nonlinear customer loads and power electronic equipment. The introduction of significant lengths of high voltage underground cables into a predomonantly overhead high voltage transmisison system may amplify harmonic distortion avove accepted IEEE limits.

a. The extensive use of semiconducting devices (nonlinear loads) by residential, commercial and industrial customers has significantly increased the generation of harmonics. Loads such as computer systems, variable frequency drives, AC/DC converters, electronic ballasts, x-ray machines, MRI equipment and uninterruptible power supplies cause harmonic currents to flow into the electric power system.

Harmonic generation/magnification can be locally controlled by the use of harmonic filters, consisting of capacitors, reactors and/or resistors. Harmonic filters are tuned to the specific harmonic frequency(s) which has voltage distortion greater than the limits established in standard IEEE-519-1992. When excessive voltage distortion levels are detected at customer or utility facilities, detailed harmonic studies are necessary to determine the design of the filter device.

The capacitive reactance of a high voltage underground transmission line is extremely high and harmonic interaction occurs when the underground lines are interconnected with a predominantly overhead transmission system like that of the CL&P and UI systems in SWCT. Overhead transmission lines have small levels of capacitive reactance, which is the reason harmonic problems are a significantly smaller concern on an overhead transmission

system.

The introduction of high voltage cable systems in close proximity to HVDC systems (such as the Cross Sound HVDC converter rterminal) can cause harmonic system resonances which can interact and cause instability of HVDC control devices. Extensive studies must be undertaken to determine the impact of these harmonic interactions and the system modifications necessary to mitigate them.

b. The cost of harmonic filters depends on the system voltage level at which they are to be connected. Harmonic filters at the higher voltages will be more expensive than at lower voltage systems due to additional components, higher insulated equipment and more physical space required. A harmonic filter installed at the 345-kV system could cost approximately $2 million. A harmonic filter of a similar size installed at the 115-kV system would cost approximately $700,000. Harmonic filters can be installed on voltages less than 115-kV and at a lower cost. However the number of locations where harmonic filters must be installed and total costs depend on the voltage level at which they are connected and the harmonic order that is being filtered. The operating and maintenance costs have not been quantified but harmonic filter equipment will require frequent inspection and maintenance.

c. The physical space occupied by a harmonic filter depends on the voltage level at which it is connected. For example, a 345-kV harmonic filter and its associated switching device will occupy an area of approximately one-third acre.

d. Attached is a copy of the Network Operating Agreement contained in NU's Open Access Transmission Service Tariff No. 10. Section 5 "Character of Service" requires customer loads, connected to CL&P, to limit harmonic propagation into the CL&P electric systems in accordance with IEEE-519 criteria. Copied below is an excerpt from Section 6 of the UI Network Operating Agreement (which is Attachment G to UI's Open Access Transmission Tariff (OATT)) that requires network loads to report on conformance to harmonic and voltage fluctuation limits.

The United Illuminating Company Open Access Transmission Tariff
Second Revised Volume No. 4
Original Sheet No. 159

6.0 Reporting Obligations

The Network Customer shall be responsible for all information required by NPCC, NEPOOL, or the Transmission Provider for dispatching functions. The Network Customer shall respond promptly and completely to the Transmission Provider's reasonable requests for information, including data necessary for operations, maintenance, regulatory requirements, planning and analysis. In particular, that information may include, but is not limited to:

For Network Loads:

- 10-year forecast of load, by transmission voltage level and the Transmission Provider substation;
- Amount and location of interruptible loads;
- Load Power Factor performance;
- Underfrequency load shedding and block load shedding capability;
- Disturbance/interruption reports;
- Conformance to harmonic and voltage fluctuation limits;
- Protection system setting, testing, and maintenance conformance;

- Planned changes to protection systems;
- Metering testing and maintenance conformance;
- Planned changes in transformation capability; and
- Voltage Reduction capability conformance

Network Operating Agreement .doc

**ATTACHMENT A**

**Network Operating Agreement**

This Network Operating Agreement is an appendix to NU Companies Open Access Transmission Service Tariff No. 10 (Tariff No. 10) and operates as an implementing agreement for Network Integration Transmission Service under Tariff No. 10. This Network Operating Agreement is subject to and in accordance with Part III of Tariff No. 10. All definitions and other terms and conditions of Tariff No. 10 are incorporated herein by reference.

**1.0 Definitions:**

1.1 Data Acquisition Equipment: Supervisory control and data acquisition ("SCADA"), remote terminal units ("RTUs") to obtain information from a Party's facilities, telephone equipment, leased telephone circuits, fiber optic circuits, and other communications equipment necessary to transmit data to remote locations, and any other equipment or service necessary to provide for the telemetry and control requirements of this Tariff.

1.2 Data Link: The direct communications link between the Transmission Customer's energy control center and the NU Companies' designated location(s) that will enable the NU Companies to receive real time telemetry and data from the Transmission Customer.

**1.3** Metering Equipment: High accuracy, solid state kW, kVAR, kWh meters, metering cabinets, metering panels, conduits, cabling, high accuracy current transformers and high accuracy potential transformers, which directly or indirectly provide input to meters or transducers, metering

recording devices, telephone circuits, signal or pulse dividers, transducers, pulse accumulators, metering sockets, test switch devices, enclosures, conduits, and any other metering, telemetering or communication equipment necessary to implement the provisions of Tariff No. 10.

**1.4** Protective Equipment: Protective relays, relaying panels, relaying cabinets, circuit breakers, conduits, cabling, current transformers, potential transformers, coupling capacitor voltage transformers, wave traps, transfer trip and fault recorders, which directly or indirectly provide input to relays, fiber optic communication equipment, power line carrier equipment and telephone circuits, and any other protective equipment necessary to implement the protection provision of Tariff No. 10.

**2.0 Term:**

The term shall be as provided in the Service Agreement consistent with Section 29 of Tariff No. 10(including, but not limited to, application procedures, commencement of service, and effect of termination).

**3.0 Point(s) Of Interconnection:**

Network Integration Transmission Service will be provided by the NU Companies at the point(s) of interconnection specified in Appendix __, as amended from time to time. Each point of interconnection in this listing shall have a unique identifier, meter location, meter number, metered voltage, terms on meter compensation and designation of current or future year of in service.

**4.0 Cogeneration And Small Power Production Facilities:**

If a Qualifying Facility is located or locates in the future on the System of the Transmission Customer, and the owner or operator of such Qualifying Facility sells the output of such Qualifying Facility to an entity other than the Transmission Customer, the delivery of such Qualifying Facility's power shall be subject to and contingent upon transmission arrangements being established with the NU Companies prior to commencement of delivery of any such power and energy.

**5.0 Character Of Service:** Network Transmission Service at the points of interconnection shall be in the form of single phase or balanced three-phase alternating current at a frequency of sixty (60) hertz. The Transmission Customer shall operate and maintain its electric system in a manner that avoids: (i) the generation of harmonic frequencies exceeding the limits established by the latest revision of IEEE-519; (ii) voltage flicker exceeding the limits established by the latest revision of IEEE-141; (iii) negative sequence currents; (iv) voltage or current fluctuations; (v) frequency variations; or (vi) voltage or power factor levels that could adversely affect the NU Companies' electrical equipment or facilities or those of its customers, and in a manner that complies with all applicable NERC, NPCC, NEPOOL and the NU Companies', operating criteria, rules, regulations, procedures, guidelines and interconnection standards as amended from time to time.

**6.0 Continuity Of Service:** (a) The NU Companies and the Transmission Customer shall operate and maintain their respective network systems, in accordance with Good Utility Practice, and in a manner that will allow the NU Companies

to safely and reliably operate the NU Transmission System in accordance with Tariff No. 10, so that either Party shall not unduly burden the other Party; provided, however, that notwithstanding any other provision of Tariff No. 10, the NU Companies shall retain the sole responsibility and authority for all operating decisions that could affect the integrity, reliability and security of the NU Transmission System.

(b) The NU Companies shall exercise reasonable care and Due Diligence to ensure Network Integration Transmission Service hereunder in accordance with Good Utility Practice; provided, however, that the NU Companies shall not be responsible for any failure to ensure electric power service, nor for interruption, reversal or abnormal voltage of the service, if such failure, interruption, reversal or abnormal voltage is due to a Force Majeure.

**7.0 Power Factor:**

(a) Where Network Integration Transmission Service provided under Tariff No. 10 is for delivery of power to a load center of the Transmission Customer served from the NU Companies' Transmission System, the Transmission Customer shall maintain load power factor levels, during both on- and off- peak hours, appropriate to meet the operating requirements of the NU Companies, and shall follow NEPOOL standards and practices, as set forth in the Service Agreement.

(b) Where Network Integration Transmission Service provided under Tariff No.10 is for delivery of power from a generating facility connected to the NU Companies' Transmission System, the Transmission Customer shall deliver

power at a lagging or leading power factor as set forth in the Service Agreement.

(c) Where Network Integration Transmission Service provided under Tariff No. 10 is for delivery of power from outside the NU Companies' Transmission System, the obligation to maintain proper sending and receiving end voltages rests with the Transmission Customer, as set forth in the Service Agreement.

(d) In the event that the power factor levels and reactive supply requirements set forth in the Service Agreement are not maintained by the Transmission Customer, the NU Companies shall thereupon have the right to take the appropriate corrective action and to charge the Transmission Customer for the costs thereof. The NU Companies shall have the right, at any time, unilaterally to make a Section 205 filing with the Commission for the recovery of any such costs.

**8.0 Metering:**

(a) The Transmission Customer shall, at its expense, purchase all necessary metering equipment to accurately account for the electric power being transmitted under Tariff No. 10. The NU Companies may require the installation of telemetering equipment for the purposes of billing, power factor measurements and to allow the NU Companies to maximize economic and reliable operation of their transmission system. Such metering equipment shall meet the specifications and accepted metering practices of the NU Companies and NEPOOL CRS-13, or such successor rules and standards. At the NU Companies' option, communication

metering equipment may be installed in order to transmit meter readings to the NU Companies' designated locations.

(b) Electric power being transmitted under Tariff No. 10will be measured by meters at all points of interconnection and/or on generating facilities (Network and non-Network Resources) located on and outside the Transmission Customer's system as required by the NU Companies.

(c) The Transmission Customer shall purchase meters capable of time-differentiated (by hour) measurement of the instantaneous flow in kW and net active power flow in kWh and of reactive power flow. All meters shall compensate for applicable line and/or transformer losses in accordance with Good Utility Practice when measurement is made at any location other than the point of interconnection.

(d) The NU Companies reserve the right: (i) to determine metering equipment ownership; (ii) to determine the equipment installation at each point of interconnection; (iii) to require the Transmission Customer to install the equipment -- or -- install the equipment with the Transmission Customer supplying without cost to the NU Companies a suitable place for the installation of such equipment; (iv) to determine other equipment allowed in the metering circuit; (v) to determine metering accuracy requirements; (vi) to determine the responsibilities for operation, maintenance, testing and repair of metering equipment.

(e) The NU Companies shall have access to metering data, including telephone line access, which may reasonably be required to facilitate measurement and billing under Tariff

No. 10. The NU Companies may require the Transmission Customer provide, at its expense, a separate dedicated voice grade telephone circuit for the NU Companies and the Transmission Customer to remotely access each meter. Metering equipment and data shall be accessible at all reasonable hours for purposes of inspection and reading.

(f) All metering equipment shall be tested in accordance with practices of the NU Companies, NEPOOL CRS-13 or upon the request by the NU Companies. If at any time metering equipment fails to register or is determined to be inaccurate, in accordance with the NU Companies' practices and NEPOOL CRS-13, the Transmission Customer shall make the equipment accurate as soon thereafter as practicable, and the meter readings and rate computation for the period of such inaccuracy, insofar as can reasonably be ascertained, shall be adjusted; provided, however, that no adjustment to charges shall be required for any period exceeding two (2) months prior to the date of the test. Representatives of the NU Companies will be afforded opportunity to witness such tests.

**9.0 Network** Load: The Transmission Customer shall provide the NU Companies with the actual hourly Network Load for each calendar month by the seventh day of the following calendar month.

**10.0 Data Transfer:**

(a) The Transmission Customer shall provide timely, accurate real time information to the NU Companies in order to facilitate performance of its obligations under Tariff No. 10.

(b) The selection of real time telemetry and data to be received by the NU Companies and the Transmission Customer shall be necessary for safety, reliability, security, economics, and/or monitoring of real-time conditions that affect the NU Transmission System. This telemetry shall include, but is not limited to, loads, line flows (MW and MVAR), voltages, generator output, and status of substation equipment at any of the Transmission Customer's transmission and generation facilities. To the extent that the NU Companies or the Transmission Customer requires data that are not available from existing equipment, the Transmission Customer shall, at its expense and at locations designated by the NU Companies or the Transmission Customer, install any metering equipment, data acquisition equipment, or other equipment and software necessary for the telemetry to be received by the NU Companies or the Transmission Customer. The NU Companies shall have the right to inspect equipment and software associated with the data transfer in order to assure conformance with Good Utility Practices.

**11.0 Maintenance of Equipment:**

The Transmission Customer shall, on a regular basis in accordance with Network Operating Committee procedures, practices of the NU Companies, NEPOOL CRS-13 or at the request of the NU Companies, and at its expense, test, calibrate, verify and validate the data link, metering equipment, data acquisition equipment, transmission equipment, protective equipment and other equipment or software used to implement the provisions of Tariff No. 10. The NU Companies shall have the right to inspect such tests, calibrations, verifications and validations of the

data link, metering equipment, data acquisition equipment, transmission equipment, protective equipment and other equipment or software used to implement the provisions of Tariff No. 10. Upon The NU Companies' request, the Transmission Customer will provide the NU System Companies a copy of the installation, test and calibration records of the data link, metering equipment, data acquisition equipment, transmission equipment, protective equipment and other equipment or software. The NU Companies shall, at the Transmission Customer's expense, have the right to monitor the factory acceptance test, the field acceptance test, and the installation of any metering equipment, data acquisition equipment, transmission equipment, protective equipment and other equipment or software used to implement the provisions of Tariff No. 10.

**12.0 Notification:**

(a) The Transmission Customer shall notify and coordinate with the NU Companies prior to the commencement of any work or maintenance by the Transmission Customer, Network Member, or contractors or agents performing on behalf of either or both, which may directly or indirectly have an adverse effect on the Transmission Customer or The NU Companies' data link, or the reliability of the NU Transmission System. All notifications for scheduled outages of the data link, metering equipment, data acquisition equipment, transmission equipment, protective equipment and other equipment or software must meet the requirements of NEPOOL and the NU Companies.

**13.0 Emergency System Operations:**

(a) The Transmission Customer, at its expense, shall be subject to all applicable emergency operation standards promulgated by NERC, NPCC, NEPOOL and the NU Companies which may include but not limited to underfrequency relaying equipment, load shedding equipment and voltage reduction equipment.

(b) The NU Companies reserve the right to take whatever actions they deem necessary to preserve the integrity of the NU Companies' Transmission System during emergency operating conditions. If the Network Integration Transmission Service at the points of interconnection is causing harmful physical effects to the NU Transmission System facilities or to its customers (e.g., harmonics, undervoltage, overvoltage, flicker, voltage variations, etc.), the NU Companies shall promptly notify the Transmission Customer and if the Transmission Customer does not take the appropriate corrective actions immediately, the NU Companies shall have the right to interrupt Network Integration Transmission Service under Tariff No. 10in order to alleviate the situation and to suspend all or any portion of Network Integration Transmission Service under Tariff No. 10 until appropriate corrective action is taken.

(c) In the event of any adverse condition or disturbance on the NU Transmission System or on any other system directly or indirectly interconnected with the NU Transmission System, the NU Companies may, as they deem necessary, take actions or inactions that, in the NU Companies' sole judgment, result in the automatic or manual interruption of Network Integration Transmission Service in order to: (i) limit the extent or damage of the adverse condition or disturbance; (ii) prevent damage to generating or

transmission facilities; (iii) expedite restoration of service; or (iv) preserve public safety.

**14.0 Cost Responsibility:**

(a) The Transmission Customer shall be responsible for the costs incurred by the Transmission Customer and the NU Companies to implement the provisions of Tariff No. 10 including, but not limited to, engineering, administrative and general expenses, material and labor expenses associated with the specifications, design, review, approval, purchase, installation, maintenance, modification, repair, operation, replacement, checkouts, testing, upgrading, calibration, removal, and relocation of equipment, or software.

(b) Additionally, the Transmission Customer shall be responsible for all costs incurred by the Transmission Customer and the NU Companies for on-going operation and maintenance of the metering, telecommunications and safety protection facilities and equipment required to implement the provisions of Tariff No. 10. Such work shall include, but not limited to, normal and extraordinary engineering, administrative and general expenses, material, and labor expenses associated with the specifications, design, review, approval, purchase, installation, maintenance, modification, repair, operation, replacement, checkouts, testing, upgrading, calibration, removal, or relocation of equipment required to accommodate service under Tariff No. 10.

**15.0 Default:**

The Transmission Customer's failure to implement the terms and conditions of this Network Operating Agreement will be

deemed to be a default under Tariff No. 10 and will result in the NU Companies seeking, consistent with FERC rules and regulations, immediate termination of service under Tariff No. 10.

**16.0 Regulatory Filings:**

Nothing contained in Tariff No. 10 or any associated Service Agreement, including this Network Operating Agreement, shall be construed as affecting in any way the right of the NU Companies to unilaterally make application to the Commission for a change in any portion of this Network Operating Agreement under Section 205 of the Federal Power Act and pursuant to the Commission's rules and regulations promulgated thereunder.

IN WITNESS WHEREOF, the Parties have caused this Network Operating Agreement to be executed by their respective authorized officials as of the date written.

Date: _____

Northeast Utilities Service Company

by: _____

its Vice President

Transmission Customer

by: _____

its _____

**Witness:** **Peter T. Brandien**
**Request from:** **Towns of Durham and Wallingford**

**Question:**
Regarding the concerns expressed on pages H-50 and H-51 regarding the charging power of underground 345 kV facilities:

a Please describe and provide information detailing the technical capabilities of devices and/or technologies available to control the charging power of underground 345 kV facilities.

b. Please describe and provide information detailing the installation cost, the operating costs, and maintenance costs of devices and/or technologies available to control the charging power of underground 345 kV facilities.

c. Please describe and provide information detailing the physical space requirements of devices and/or technologies available to control the charging power of underground 345 kV facilities.

**Response:**
To describe the technical capabilities of devices and/or technologies available to control charging power of underground 345-kV facilities first requires a brief overview.

The electric bulk power system contains many integrated components designed to respond appropriately for varying conditions. For example, should the electric bulk power system experience a disturbance, the system needs to respond in a number of different time intervals i.e., milliseconds, seconds and minutes. The strength of the system is measured by the ability of the integrated components to respond appropriately to any disturbance. How the individual components react and interact with other system components in the transient (milliseconds and seconds) as well as within the steady state mode (i.e., minutes) to the dynamic variations in voltage, current, and frequency associated with a disturbances is critical. Each component has individual limitations which must be carefully designed and thoroughly verified when incorporated into an electric network so as not to create system constraints or limitations.

In comparison to the rest of the New England bulk power system the SWCT electric system is relatively weak and hence the introduction of 345-kV underground cable in a predominately overhead system creates significant challenges. The system must be designed to withstand NERC, NPCC, and NEPOOL specified transient disturbances and where permissible operator reaction time to adjust the system within appropriate time constraints in anticipation of the next possible contingency. Complex and sophisticated modeling and testing is used to determine the effects of varying system operating conditions and contingencies. Refer to the supplemental testimony filed on December 16, 2003, which addresses many of the technical and dynamic issues involved with putting 345-kV cable in SWCT. Also, refer to data responses D-W-01, Q-D-W-044 and Q-D-W-045.

a) Capacitive charging power produced by 345-kV underground cables can be absorbed by the placement of fixed shunt reactors, variable reactors or static var compensators (SVCs or STATCOMs) at the terminals. Shunt reactors provide a fixed amount of reactive compensation. Variable reactors and static var compensators provide a range of reactive compensation. Variable reactors have a limited range of compensation, are slow to adjust and likely require operator evaluation and manual adjustments. SVCs and STATCOMs continuously monitor system conditions and provide reactive power compensation within the range capability of the hardware

independent of operator intervention.

b) The installation of a 345-kV 150 MVAR variable shunt reactor along with its associated switching device would have a direct cost of approximately $4.0 million plus interconnection costs, which can vary greatly depending on location. The installation of a static var compensator (STATCOM of similar MVAR size as the shunt reactor - 150 MVAR) with only one coupling transformer would have a direct cost of approximately $25-30 million plus interconnection costs, which can vary greatly depending on location.

c) Typically, the space required to install a 345-kV shunt reactor and its associated switching equipment is approximately one-half acre. The space to install a static var compensator and its associated switching equipment is at least one acre.