middletown | norwalk

August 16, 2004

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

Re: **Docket 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 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

Dear Chairman Katz:

After the June 2004 hearings in Connecticut Siting Council Docket No. 272, The Connecticut Light and Power Company and The United Illuminating Company (together, "the Companies") and ISO-New England, Inc. formed a Reliability and Operability Committee ("ROC" or "ROC group") to consider potential project modifications that would enable the maximum feasible use of underground cable for the Middletown to Norwalk Project, but would still enable the Project to meet operability and reliability requirements and electric system need. Mr. Whitley on behalf of ISO-NE and I, on behalf of the Companies, are pleased to submit a copy of the ROC group's Report. This Report discusses the ROC goal, challenges and procedures, the development of the cases for study by the ROC group, the results of the case studies, and a discussion of Case 7 (a case that may be marginally acceptable in terms of technological feasibility) and next steps.

If you have any questions about this filing, please call me. We look forward to discussing this Report with the Connecticut Siting Council.

Very truly yours,

Roger C. Zaklukiewicz

Roger Zaklukiewicz
Vice-President of Transmission Projects
Northeast Utilities Service Company

Stephen G. Whitley
Senior Vice President & Chief Operating Officer

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Stephen G. Whitley

REPORT OF THE RELIABILITY AND OPERABILITY COMMITTEE

August 16, 2004

After the June 2004 hearings in Connecticut Siting Council Docket No. 272, The Connecticut Light and Power Company ("CL&P") and The United Illuminating Company ("UI") (together, "the Companies") and ISO-New England, Inc. ("ISO-NE") formed a Reliability and Operability Committee ("ROC" or "ROC group"). As discussed in this Report to the Connecticut Siting Council ("Council"), and as reflected in the weekly ROC status update calls with docket participants and the reports filed with the Council on July 16 and August 2, the ROC group has undertaken and accomplished significant work to consider potential project modifications that would enable the maximum feasible use of underground cable for the Middletown to Norwalk Project ("Project"), but would still enable the Project to meet operability and reliability requirements and electric system need.

This Report includes an Executive Summary and four parts:

I. Overview of the ROC goal, challenges and procedures

II. ROC work: Development of the cases for study by the ROC group

III. ROC work: Results of case studies

IV. ROC work: Discussion of Case 7 and next steps.

The Report includes as appendices the various documents and studies related to the ROC work and its distribution of information concerning that work during the June-August 2004 period.

Executive Summary

In the March and April hearings in this docket, ISO-NE and the Companies testified that they were working to resolve design issues but did not yet have a resolution satisfactory to all regarding the effects of installation of underground cables. (March 9, 2004 Prefiled Testimony of ISO-NE, p. 26; 3/23/04 Tr. at 49-51; 4/21/04 Tr. at 121-22.) CL&P and UI's consultant, GE Power Systems Energy Consulting ("GE"), discussed harmonics and explained the effects of low order resonant frequency at the June hearings. (CL&P/UI Exhibit 110, GE Energy Report on "Risks Related to System Resonant Behavior Introduced by Transmission Cables," dated June 2004). ISO-NE testified in June in this docket that "the Project, as proposed and presently designed, will not operate reliably" because it "would introduce too much capacitance to a relatively weak system, resulting in low order harmonic resonances. This phenomenon can cause system failures, including cascading outages, and damage to equipment, including transformers." (June 7, 2004 Supplemental Prefiled Testimony of ISO-NE, p. 6.) ISO-NE therefore determined it could not support the electrical characteristics of the initial Project proposed by the Companies in the application to the Council because, as proposed, the frequency of first resonance was not above the third harmonic. (6/17/04 Tr. at 58, 91.)

After the June hearings, the Companies and ISO-NE formed the ROC. The ROC group developed a series of case studies that focused on a combination of new, complex and unique transmission technologies and on modified Project design in order to determine the maximum linear length of underground 345-kV transmission cable that can be undertaken for the Project, consistent with the reliable operation of the electric system. This approach enabled the ROC group, while investigating the maximizing of underground cable, to look at expected system operation and the ability to meet electric system need.

As discussed in Section I of this Report, the ROC group faced an enormous challenge and accomplished substantial work within a short period of time, given the complexity of electric systems, the weakness (i.e., short circuit strength) of the electric system in Connecticut and Southwest Connecticut, the critical system needs that must be addressed by the Project, and the consequences of an inoperable and unreliable electric system. The ROC group undertook its activities while simultaneously briefing parties and intervenors (and other interested persons and entities) of its work. The mission and work of the ROC group is unprecedented in New England and, to the knowledge of the ROC group participants, is unprecedented nationwide in terms of the linear length of 345-kilovolt ("kV") electric transmission cable considered for underground installation and the weakness of the electric system in this area.

At the outset of the ROC process, the ROC group identified twelve cases for potential study. The ROC group added several more cases for study based upon review of the results of studies as they were being obtained over the course of the summer. (Section II of this Report describes the development of the cases for study.) The cases included many technologies and a spectrum of equipment, including the potential novel use of both technology and equipment. The first focus of the studies, as the ROC group discussed during its weekly calls, was to determine if any of the potential project modifications would achieve the desired results of mitigating the resonance problem identified with respect to the proposed Project by removing capacitance from the system in Southwest Connecticut, strengthening the system, or both. While resonant frequency was the "gate" for further study of a case, if a case seemed likely to pass the resonant frequency gate, the ROC group case study plan provided that other electric system issues would need to be addressed as well, including transients, thermal, voltage, stability and short circuit current.

The development of potential technology modifications focused on maximizing the linear length of undergrounding of the Project, consistent with the reliable operation of the electric system. As discussed in this Report, it was a significant challenge to be able (1) to maintain a project that meets the system needs that the Project must meet; (2) to address the resonance problem by reducing capacitance on the electric system in Southwest Connecticut sufficiently to result in a point of first system resonance above the third harmonic (3.0, or 180 Hz); (3) to achieve acceptable results with respect to short circuit, transients, thermal and stability aspects of electric system operation and reliability; and (4) to track new risks to system operability and reliability that are introduced when seeking to develop an atypical transmission design. As a result, and because of the complexity of the electric system, any modification must be studied as to its own characteristics and as to the potential impacts on the electric system.

The results of the case studies are discussed in Sections III and IV of this Report. In considering the modifications discussed in this Report, the ROC group has specifically addressed reliability and operability issues and, to assist the Council, has also discussed cost and environmental factors.

As reflected in the weekly ROC update calls, it was extremely difficult to develop system modifications that would mitigate the harmonics problem and result in a first resonant frequency greater than the third harmonic. When the study results for the initial cases including 24 linear miles of underground cable (Cases 5 and 6) had unacceptable resonance results, the ROC group considered different technologies and novel uses of equipment to try to develop project modifications that would not reduce the amount of underground cable from the 24 linear miles of underground cable proposed in the application.

The ROC group work included consideration of high voltage direct current ("HVDC") technology. Embedding an HVDC line into an alternating current ("AC") system would be unprecedented. Based upon study results to date and utilizing the expertise of an HVDC expert, the ROC group believes that HVDC technology, either alone or in conjunction with AC technology, cannot be utilized to increase the feasible amount of underground cable for the

Project. The use of HVDC would result in a project that does not meet the electric system needs and, in addition, would result in unacceptable reliability and operability risks. (The potential use of HVDC technology is discussed in Section III of this Report.)

This Report sets forth project modifications, reflected in Case 7, that include the unprecedented use of multiple static synchronous compensators ("STATCOMs"). Case 7 includes approximately 24 linear miles of underground 345-kV cable, a change in cable type from high pressure fluid-filled ("HPFF") to cross-link polyethylene ("XLPE"), 900 MVARs of STATCOMs, and energizing only one of the HPFF cables in the Bethel to Norwalk Project during most hours of operation. The Companies and ISO-NE are cautiously optimistic based on analysis to date that Case 7 can be made workable from the perspective of reliability and operability. Case 7 is the only case studied that "passes" the frequency scan to determine system resonances. The ROC group has also reviewed the results of initial thermal, voltage and short circuit studies. The ROC group is now undertaking a limited number of additional studies of the Case 7 project modifications with specific lines out and a more detailed representation of the proposed STATCOMs in Southwest Connecticut. The studies, which will be completed by the end of September, will complete the determination that there is no insurmountable problem associated with the Case 7 modifications. Case 7 is discussed in Section IV of this Report.

Absent the legislative direction to maximize the underground cable installation to the extent technologically feasible, the ROC group would neither design nor advocate a system as represented in Case 7. However, the ROC group believes that the reliability and operability of the Project and the electric system after the Project is constructed could be marginally acceptable from the standpoint of technological feasibility, although it has significant reliability and operability drawbacks that make it undesirably complex.

The ROC group has concluded, based upon its review of all the studies related to the Project and potential modifications, as well as discussion with the Companies' consultants and ISO-NE's consultant, that the approximately 24 miles of underground 345-kV cable included in Case 7 is the maximum amount of 345-kV underground cable that is technologically feasible. Moreover, given the unique engineering solutions utilized for Case 7 (e.g. the use of STATCOMs), the ROC group did not study a modified Case 7 with a greater linear length of underground cable. The results for Case 7 with 24 linear miles of 345-kV underground cable will be difficult, at best, to operate. Adding more cable and therefore more capacitance (or adding more STATCOMs and therefore more complexity to attempt to compensate for the capacitance from the additional cable) would render the project modifications not technologically feasible.

There are several additional considerations associated with the use of STATCOMs that should be noted. First, to the extent the use of technology and equipment represented by Case 7 increases Project costs (an estimated $250 million or more for the STATCOMs alone), ISO-NE cautions that such increased costs are unlikely to qualify for regional cost support and is concerned that Connecticut residents and businesses understand that these additional costs may well not be shared with others in New England. Additionally, the use of STATCOMs will mean added design and operational complexities that will need to be considered and addressed by Project and ISO-NE engineers. Finally, as for any project, a formal analysis will be required in the ISO-NE approval process under Section 18.4 of the Restated NEPOOL Agreement. This Report does not replace that process or represent approval under Section 18.4. The additional analyses now being undertaken by GE will provide a more detailed look at Case 7, designed to indicate whether there are likely to be any insurmountable barriers with respect to the Case 7 modifications. Based upon the review of these analyses by ISO-NE and its consultant, ISO-NE expects to be able to determine by the end of September its support for the Project, as modified. While this support is not a guarantee of 18.4 approval, it would indicate ISO-NE's good faith belief that no insurmountable barriers to approval appear to exist.

This Report details the ROC goal, challenges, studies, results, and next steps.

I. Overview of the ROC Goal, Challenges and Procedures

ROC group goal and challenges

The mission of the ROC is:

> To utilize the Companies' existing proposed route as a starting point for determining the maximum linear length of undergrounding of the proposed 345-kV line that is technologically feasible, reliably operable and meets system need as defined by RTEP [Regional Transmission Expansion Plan] for the Middletown to Norwalk Project, consistent with ISO-NE's responsibilities of assuring the reliable day-to-day operation of New England's bulk power system and with the designing and planning of that system in accordance with Good Utility Practice and national and regional reliability criteria. The goal of the [Reliability and Operability] Committee is to file with the Connecticut Siting Council by August 16, 2004 a document that sets forth project modifications that would be supported by ISO-NE through the Restated NEPOOL Agreement, Section 18.4 process.

As is clear from this mission statement, and as discussed at the June 23 process meeting, the aim of the ROC group has been to consider modifications to the Project that maximize the linear length of undergrounding along the route but still enable the Project to meet operability and reliability requirements and system need while operating at a first resonant frequency above the third harmonic. The mission and work of the ROC group is unprecedented in New England and, to the knowledge of the ROC group participants, is unprecedented anywhere in the country in terms of the linear length of underground 345-kV electric transmission relative to the strength (here, the weakness) of the system in the area.

The challenge faced by the ROC group is enormous, given the complexity of the electric system and the consequences of an inoperable and unreliable electric system. The unprecedented use of technology and electronics for this Project carries the risk that the system will not perform as designed and could, while addressing some system concerns, actually exacerbate other concerns. The electric system in Connecticut and, in particular, Southwest Connecticut is a weak system. This weakness and the system needs for Southwest Connecticut have been identified in ISO-NE's regional planning process since 2001, and have been addressed in its periodic Transmission Expansion Advisory Committee ("TEAC") meetings and in its annual Regional Transmission Expansion Plans ("RTEP").

The Connecticut General Assembly, through its amendments to the Public Utility Environmental Standards Act ("PUESA") in the 2004 legislative session, has enacted a statutory presumption that 345-kV electric transmission lines are to be placed underground near certain types of facilities (listed in the legislation) unless it is not technologically feasible to do so. The Companies had already proposed an unprecedented amount of underground cable (approximately 24 miles) for this Project, in recognition of the interest of residents and government officials in the State of Connecticut in having 345-kV lines installed underground. That amount of underground cable, as discussed below, significantly adds to the capacitance of the electric system in Southwest Connecticut, raising concerns about system operability and reliability.

The legislative presumption for underground 345-kV transmission has required the ROC to go beyond established electric transmission system design. In order to meet the statutory direction to maximize the amount of technologically feasible 345-kV cable installed near listed types of facilities, the ROC group has considered AC technology, HVDC technology (which is typically used for underwater installations or to provide an asynchronous connection between control areas), as well as electric system devices that are typically used to mitigate specific system conditions rather than to extend the amount of underground installation, including STATCOMs and synchronous condensers, in varying combinations.

The electric transmission system in Southwest Connecticut fails to meet national and regional electric reliability standards. The system is subject to a large number of potential thermal overloading conditions due to its inability simultaneously to serve load, transport local generation and import external generation. There are short circuit and stability issues that, together with thermal concerns, limit the flexibility to operate the system and increase the risk of system failures. The system already has unusually high capacitance resulting from the addition of capacitors to enable the importation of generation into Connecticut and Southwest Connecticut.

The need to upgrade the area's weak electric system is not in dispute. However, the objective of maximizing the linear miles of underground 345-kV cable used in the Project is difficult to achieve because of the weakness of the existing system (i.e., short circuit strength) in Southwest Connecticut and the already high level of capacitance on the system. The increased capacitance associated with 345-kV underground cables can reduce the point of first resonant frequency to levels where there is an increased risk of overvoltage conditions, equipment damage and system failure, including cascading outages.

Procedures of the ROC group

The ROC group worked under the direction of Stephen Whitley, ISO-NE's Chief Operating Officer, and Roger Zaklukiewicz, the Vice-President of Transmission Projects for Northeast Utilities Service Company. The ROC group followed the plan for work, communications and studies that was included in the document provided by the Companies and ISO-NE to the Council and docket participants at the June 23 process meeting in this docket. (A copy of this document is included as Appendix A to this Report.)

ROC has held weekly conference calls, beginning July 6, 2004, to provide progress updates to all parties and intervenors (and other interested persons and entities) regarding the work of the ROC group. The calls were open to representatives of the media on a listen-only basis. Council staff and the Council's technical consultant, KEMA, also listened to the weekly updates. In order to facilitate future communications, the first conference call was also a "live" meeting. A skilled communications facilitator moderated the weekly calls, and an agenda for each call was provided in advance of the call. The format of each call included an introduction by Mr. Whitley, a progress update on studies by Anne Bartosewicz and/or John Prete (project directors for CL&P and UI, respectively), discussion of case studies or reports as appropriate, and questions by docket participants. These weekly calls were well attended, and the docket participants utilized their opportunity to ask questions. (Copies of the agendas for the calls, documents distributed with the agendas or at the calls, and attendance lists for the calls are included in Appendix B.)

The ROC group also prepared bi-weekly reports, listing the work that had been done during the preceding time period, the studies that would be undertaken in the future, and the expected schedule for the completion of the studies. (Copies of the bi-weekly reports are included in Appendix C.)

The first task of the ROC was to develop cases for study and analysis, as discussed in Section II of this Report.

II. ROC Work: Development of the Cases for Study by the ROC Group in Order to Maximize the Amount of Underground Cable

The ROC group initially defined 12 cases to be considered for study. The ROC developed the cases in an effort to establish an approach and a starting point for its work and the issues involved in determining the maximum feasible underground length by including a spectrum of underground lengths and technological modifications to the Project. (A copy of the initial Middletown – Norwalk Project Study Cases is included as part of Appendix D.) Cases 1 through 7 include the same linear length of underground cable as the proposed route submitted by the Companies in their application to the Council – approximately 24 miles – but with varying modifications to the technology and equipment. Cases 8 through 12 have a shorter linear length of underground cable than the 24 miles proposed by the Companies. As explained below, the progressive study of these cases was intended to serve as a platform for determining whether it would be possible to extend the underground cable beyond the original 24 mile proposal.

The ROC group determined that the first step in the sequencing of the studies should be to address system resonance. As stated in the Study Cases document, the cases were ordered to facilitate sequencing of cases and studies. If, for example, Case 5 appeared to meet concerns about system resonance, this would provide an indication that Case 4 should be investigated. If Case 4 then appeared to be acceptable in terms of the frequency scan, Case 3 would be evaluated, and so on. If, on the other hand, the results of the Case 5 study were not acceptable from the standpoint of a frequency scan, this would provide an indication that Case 6 should be evaluated because it would appear to have a greater likelihood of being acceptable (and so on for Cases 7 - 12).

As set forth in the initial Study Cases document and discussed at the first ROC status call, if a case appeared to have the potential to be acceptable from the standpoint of the frequency scan, further studies would be undertaken to evaluate a case from the standpoint of other system requirements: thermal and voltage studies, a transient analysis on a limited scope basis to determine if a case appeared to have any obvious fatal flaws, followed (if a case continued to appear to have a high likelihood of being acceptable) by stability and short circuit evaluations. If a case appeared to meet technical feasibility criteria, then the ROC could evaluate whether there appeared to be any potential for increasing the linear length of underground cable beyond what was in the case, including an extension of underground cable beyond the 24 miles originally proposed.

The development of cases for study by the ROC group has been an iterative process. Because the first several cases studied did not meet even the first resonant frequency "gate" based upon the frequency scans, ROC added modified cases to the study list. Cases 5a, 5b, 5c, and 5d were added to reflect the continued desire to look at the point of first resonance for project designs including other potential technology variations and modifications. Cases 5a, 5b and 8a reflect the potential use of HVDC for some or all of the Project. Cases 5c and 5d reflect the potential use of synchronous condensers. (A copy of the revised Study Cases document, which was attached to the Second Biweekly Report of the ROC group, is included as part of Appendix D.)

Sections III and IV discuss the results of the case studies.

III. ROC Work: Results of Case Studies

At the March 23, 2004 hearing, Mr. Whitley testified as to ISO-NE's concern about the amount of underground cable proposed by the Companies for the Project, the charging (capacitance) from the cables, and the resulting complexity of the Project. (3/23/04 Tr. at 147-48.) At that hearing, in response to a question about the amount of undergrounding proposed by the Companies and the potential for increasing the linear miles of underground cable, ISO-NE's Mr. Kowalski testified that "we're certainly at the limit. I'm not sure if we're past the limit." (Id., at 150.) As Mr. Zakukliewicz testified, "[W]e've been studying it now for probably more than a year ... [W]e have been trying to make this work. And to date there are still some in the technical community who are not in full agreement or buy in that what is proposed before you will totally work. And some of the issues have to do with the capacitance of the 24 miles out there...." (4/21/04 Tr. at 121-22.)

In its June 7, 2004 supplemental prefiled testimony, ISO-NE stated its position that "the Project, as proposed and presently designed, will not operate reliably" because it "would introduce too much capacitance to a relatively weak system, resulting in low order harmonic resonances. This phenomenon can cause system failures, including cascading outages, and damage to equipment, including transformers." (June 7, 2004 Supplemental Prefiled Testimony of ISO-NE, p. 6.) ISO-NE also referenced the preliminary harmonics and transients analyses prepared by GE and an evaluation of such analyses and attendant recommendations made by ISO-NE's consultant, PB Power.

The ROC work and the case studies were undertaken and evaluated in the context of these concerns about the Project as proposed and the requirements for any modifications. The harmonics study reports prepared by GE are included in Appendix E to this Report. For the convenience of the readers of this Report, ROC has included as Appendix F a chart showing the frequency of first system resonance (per unit of 60 Hz) in varying system configurations, including the proposed Project and Cases 5, 5a, 5b, 5c, 5d, 6 and 7.

Case 5: Start with the M-N Project, replace both 345-kV HPFF cables between East Devon and Singer with XLPE, replace both 345-kV HPFF cables between Singer and Norwalk with XLPE, and remove one of the 345-kV HPFF cables in the Bethel to Norwalk Project from service.[1]

The ROC group started with Case 5 in order to determine generally the reduction of capacitance on the system (and accordingly the scope of modifications) that would be required to achieve a first system resonant frequency that would likely be acceptable. The replacement of HPFF cable with XLPE cable is a significant technology change, given the more limited experience with XLPE cable at 345-KV compared to the industry experience over a period of many years with 345-kV HPFF cable. Nevertheless, given the need to maximize the linear length of underground cable, the difference in capacitance between HPFF cable and XLPE cable (approximately 21 MVARs/mile for HPFF and approximately 12 MVARs/mile for XLPE), and the growing body of experience with XLPE at 345-kV over the last few years, the Companies suggested that the ROC group utilize this case as the first case to be studied.

The study of Case 5 also provided guidance to the ROC group on the effect on first system resonant frequencies of removing capacitance from the system, compared to the proposed Project (i.e., whether the first resonant frequency would increase significantly for Case 5 compared to the proposed Project). The GE studies indicate that the first resonant frequency only increased from 2.4 for the proposed Project to 2.8 for Case 5 with all capacitors in service ("caps in") and light generator dispatch. With no capacitors in service ("caps off") and light generator dispatch, the first system resonant frequency increased from 2.8 for the proposed Project to 3.5 for Case 5.

1 The study model "remove[d] one of the 345-kV HPFF cables in the Bethel to Norwalk Project from service." This reflects the electrical performance of the system if both Bethel to Norwalk cables are installed, and only one is energized during most hours of operation.

Because the first resonant frequency was 2.8 for Case 5, the ROC group determined that Case 5 did not meet the resonant frequency "gate" for further review. Since Case 5 did not meet criteria for further study, the ROC did not undertake studies of Cases 1 through 4. Instead, the ROC group proceeded along the case study spectrum to consider Case 6.

Case 6: Start with the M-N proposed Project, replace both 345-kV HPFF cables between East Devon and Singer with XLPE, replace both 345-kV HPFF cables between Singer and Norwalk with XLPE, remove one of the 345-kV HPFF cables in the Bethel to Norwalk Project from service, remove the 115-kV capacitors at Plumtree from service, reduce the capacitors at Glenbrook to 75 Mvar, and reduce the capacitors at Frost Bridge to 205 Mvar in the "all caps in" cases.

In developing Case 6, the ROC group determined to look at the reduction of capacitance on the system not only through the substitution of XLPE cable for HPFF cable in Case 5, but also through reducing the number of shunt capacitors used on the system. Prior to studying Case 6, the ROC group evaluated the results of Case 5, and noted that the point of first resonance is moved in this case from 2.8 to 3.5 as system capacitors are removed from service. This indicated that reducing the amount of shunt capacitors used on the system may achieve an increase in the first resonant frequency. Based upon a review of the thermal and voltage studies that had previously been performed with respect to the proposed Project at a New England load level of 27.7 GW, the Companies suggested that Case 6 utilize a reduced amount of capacitors at Glenbrook, Plumtree and Frost Bridge.

For Case 6, GE performed a frequency scan to evaluate harmonics, and simultaneously, EPRO was contracted to perform a thermal and voltage evaluation of the transmission system at both a 27.7 GW New England load level and a 30 GW load level. Evaluating the 30 GW load level would enable the ROC group to determine whether or not load growth would require the use of these capacitor banks in the future.

The point of first resonance for the "caps in" and light generation scenario was between 2.9 and 3 for Case 6. For "caps off" and light generation, the first resonant frequency was 3.5. In addition, the EPRO study of voltage performance of the system for Case 6 demonstrated voltage concerns as the load in the Southwest Connecticut area grows. Therefore, the ROC group determined that Case 6 did not provide a solution that meets reliability and operability considerations and system need.

Case 5a: Start with the M-N proposed Project, replace both 345-kV HPFF cables between East Devon and Singer and Singer to Norwalk with XLPE, replace 345-kV overhead between Beseck and East Devon with HVDC lines, and remove one of the 345-kV HPFF cables in the Bethel to Norwalk Project from service.

In preparation for the July hearings, the Companies asked GE to study two potential configurations where the portion of the Project that is presently proposed to be overhead -- from East Devon to Beseck -- was replaced with approximately 1200 MW of transfer capability utilizing HVDC technology. The first design configuration utilized conventional HVDC technology and the second utilized voltage source converter HVDC ("VSC-HVDC") technology. These design configurations comprise Case 5a. The GE report on this case, run as a preliminary study to look at the feasibility of HVDC, indicates that the frequency of first resonance is substantially lower for this case than for Case 5 or Case 6. For conventional HVDC, the "caps in" first resonant frequency is 1.8 – 2.1 (with local generation out of service), depending on whether HPFF cable or XLPE cable would be used for the portion of the route from East Devon to Norwalk. The results for VSC-HVDC were also unacceptable. The "caps in" first resonant frequency is 2.0 (local generation out of service) for HPFF cable from East Devon to Norwalk; an XLPE configuration for East Devon to Norwalk was not evaluated based on the relative first resonance numbers with XLPE vs. HPFF for the conventional HVDC configuration. Because the "caps in" resonant frequency numbers were so low for both HVDC configurations from Beseck to East Devon, "caps off" was not studied.

HVDC between Beseck and East Devon is not acceptable, regardless of the type of HVDC between Beseck and East Devon and regardless of the type of cable (HPFF or XLPE) between East Devon and Norwalk. As discussed above, the two basic ways of addressing the harmonics problem are to reduce capacitance or increase the short circuit strength of the system. Replacing the proposed AC line between Beseck and East Devon with HVDC technology reduces system strength compared to the proposed Project. The AC line in the proposed Project between Beseck and East Devon provides significant short circuit strength to the area. Without that line in place, the capacitance ("charging") from the underground cables between East Devon and Norwalk caused an unacceptably low first resonant frequency for Case 5a.

Case 5b: Start with the M-N proposed Project, replace both 345-kV HPFF cables between East Devon and Singer with XLPE, replace both 345-kV HPFF cables between Singer and Norwalk with HVDC lines, and between Beseck and East Devon with HVDC lines, and remove one of the 345-kV HPFF cables in the Bethel to Norwalk Project from service.

The ROC group reviewed the results of the Case 5a study, and used them to develop Case 5b. In this case, the expectation was that removing further capacitance from the system, by replacing the AC cables proposed between Singer and Norwalk with HVDC, would increase the first resonant frequency. This study assumed the use of VSC-HVDC, because VSC-HVDC does not need the same filtering (capacitors) required with conventional HVDC. AC cables were used between East Devon Substation in Milford and Singer Substation in Bridgeport, to allow the Bridgeport Energy generator to be interconnected to the 345-kV AC system, thus reducing its short circuit contribution to the 115-kV bus at Pequonnock Substation. These 345-kV cables would also provide an additional outlet for the power from Milford Power, rather than relying solely on the two 115-kV lines to Devon.

The GE study of Case 5b indicated that while the change to HVDC between Singer and Norwalk removed a significant amount of capacitance from the system, it also isolated the underground 345-kV cables between Singer and East Devon from any other 345-kV interconnection. This significantly weakened the short circuit strength in the area. Under these conditions, the point of first resonance was 2.9.

There is a significant difference in potential system operation and reliability between a system with a first resonant frequency of 2.9 and a system that operates above 3.0. Because many pieces of equipment are sources of third harmonic current, a system that has a point of first resonance at the third harmonic has the potential for significant overvoltages and is susceptible to flashover and equipment damage. System resonance is of greatest concern when the frequency of system resonance coincides exactly with a multiple of the fundamental frequency, 60 Hz. Generally, sources of harmonic currents produce smaller and smaller amounts of currents at higher frequencies. Therefore, in system planning, designing the system such that the first resonant frequency is generally above the third harmonic (and preferably much higher) greatly reduces the potential for harmonic resonances to result in damage to the system and to customer equipment.

ABB, the vendor of VSC-HVDC, is working on developing a case that utilizes an all VSC-HVDC technology. The Companies and ISO-NE have discussed with ABB the requirement that a project meet the electric system needs in Southwest Connecticut:

- The need to move power into Southwest Connecticut (transfer capability of approximately 1200 MW of power injection required)
- Resolving short circuit issues at Pequonnock Substation in Bridgeport and at Devon in Milford

- Resolving generation interdependencies at Pequonnock, Devon and Norwalk Harbor
- Improving the point of first system resonance to above 3.0 or higher
- Providing a means of interconnecting new generation (potential additions of generation at East Devon, Bridgeport, Pequonnock or Norwalk Harbor)
- Providing flexibility to add new load serving substations
- The ability to operate throughout a load cycle throughout the year with varying dispatches and line outages, and in particular identification of all conditions where manual operator intervention would be needed to maintain reliable operation
- No new overloads can be caused as a result of the project
- The system must be dynamically stable
- The project must provide adequate voltage on the system
- Project operation cannot degrade system capabilities and must respect existing contracts
- Any potential for subsynchronous torsional interaction must be mitigated

The Companies and ISO-NE have discussed these system issues with ABB and have provided extensive information to ABB to assist ABB in its study work. The ROC group has received a preliminary concept from ABB and expects to receive a full report by mid-September. The Companies and ISO-NE remain concerned that the use of HVDC would preclude the Project from meeting electric system need (see criteria, above) and would result in a system that has severe operability and reliability risks.

As discussed in this Report and with ABB, trying to embed an HVDC line into New England's AC system will create operational challenges. System conditions that may be handled instantaneously and automatically in an AC system could require significant manual operator intervention to adjust a DC line. Immediate voltage collapse could occur before the manual adjustment could be made. HVDC is also not likely to resolve short circuit or resonance issues on the system. Moreover, even if these immediate issues could be resolved, use of HVDC increases the complexity and decreases the flexibility to address future system expansion. For example, HVDC does not allow system planners to add a load serving substation without the use of a new HVDC converter, and interconnecting new generation is also likely to require the generator to purchase a new converter.

Case 5c: Start with the M-N proposed Project, replace both 345-kV HPFF cables between East Devon and Singer with XLPE, replace both 345-kV HPFF cables between Singer and Norwalk with XLPE, remove one of the 345-kV HPFF cables in the Bethel to Norwalk Project from service, and add a 500 MVA synchronous condenser at East Devon.

The ROC group considered the results of the study of Cases 5 and 6. It appeared that the worst cases were those with no generation in service, demonstrating that the point of first resonance is directly tied to short circuit strength in Southwest Connecticut. One way of adding short circuit strength is to require more generation to be in service at all times. However, requiring more generation to be in service at all times would have significant economic costs and be contrary to the long-term operation of a competitive wholesale generation market. It would also result in increased environmental impacts from the additional generation.

Instead of actual generation, therefore, the ROC group looked at the addition of synchronous condensers. As discussed at one of the weekly ROC update calls, a synchronous condenser is essentially a generator that does not have a turbine attached to it. Rather than using steam or some sort of combustion engine to force the machine to turn at synchronous speed, the generator is operated like a motor where the power system provides real power, MW, to turn the machine. However, since the machine has its own excitation system, it is able to generate both capacitive and inductive reactive power. Additionally, this excitation system allows the machine to provide short circuit strength. The Companies hoped that the addition of a synchronous condenser would add enough short circuit strength at 345-kV to resolve the harmonics issues associated with the Project, without impacting the short circuit concerns on the 115-kV system. In Case 5c, a 500 MVA synchronous condenser was added at East Devon to the Case 5 system (i.e., the HPFF cables from East Devon to Norwalk were replaced with XLPE cables and, for modeling purposes, it was assumed that one HPFF cable in the Bethel to Norwalk Project was in service).

The results of the GE study of Case 5c showed that the addition of the 500 MVA synchronous condenser at East Devon increased the point of first resonance to 2.9, a small improvement over the point of first resonance of 2.8 with the same system without the synchronous condenser. The ROC group determined that this case was not acceptable. The first resonant frequency was not above the third harmonic and, in addition, there were significant on-going economic and environmental costs.

Synchronous condensers incur significant real power losses to provide the energy required to spin the device and to cover losses in the winding and step-up transformer. The losses are generally on the order of 3% of the MVA rating of the machine. Therefore a 500 MVA synchronous condenser would be estimated to have 15 MW of losses. These losses would occur every hour of every day of the year, because the synchronous condenser would be on all the time. With a $45/MWh price of electricity (the price on August 15, 2004, per the ISO-NE web site), the estimated on-going annual cost of 15 MW of losses is approximately $5.9 million. If two condensers were used (see Case 5d), the estimated annual cost of losses would be double that amount. In addition, the 15 MW of system losses per condenser means that generation equivalent to the 15 MW would need to operate to compensate for these losses, with resulting environmental impact from generation operation.

Case 5d: Start with the M-N proposed Project, replace both 345-kV HPFF cables between East Devon and Singer with XLPE, replace both 345-kV HPFF cables between Singer and Norwalk with XLPE, remove one of the 345-kV HPFF cables in the Bethel to Norwalk Project from service, add a 500 MVA synchronous condenser at East Devon, and add a 500 MVA synchronous condenser at Singer.

The Companies requested that GE evaluate the same system as Case 5c (all XLPE cables from East Devon to Norwalk, only one HPFF cable in service in the Bethel to Norwalk Project, and a 500 MVA synchronous condenser at East Devon) with the further addition of a 500 MVA synchronous condenser at Singer. The results of the GE testing showed that the point of first resonance was 3.0 with capacitors in service and light generator dispatch, an increase of 0.1 over the previous case. While the addition of the synchronous condensers was moving the system in the proper direction from the standpoint of harmonics, the ROC group determined that the system impacts of significant losses and the additional fault current were unacceptable from a reliability and operability standpoint. Therefore, the ROC group determined that it would not be appropriate to investigate the use of additional synchronous condensers. The benefit of additional devices would be outweighed by the system impacts, system losses, cost and environmental impact.

Case 7: Start with the M-N proposed Project, replace both 345-kV HPFF cables between East Devon and Singer with XLPE, replace both 345-kV HPFF cables between Singer and Norwalk with XLPE, remove one of the 345-kV HPFF cables in the Bethel to Norwalk Project from service, remove the 115-kV capacitors at Plumtree from service, reduce the capacitors at Glenbrook to 75 Mvar, and reduce the capacitors at Frost Bridge to 205 Mvar in the "all caps in" cases, and investigate fixed capacitor replacements with dynamic reactive control devices.

As noted above, Case 7 is the only case studied in which the resonant frequency scan results indicated a point of first resonance above 3.0. Case 7 is discussed in Section IV of this Report.

IV. ROC Work: Discussion of Case 7 and Next Steps

Case 7: Start with the M-N proposed Project, replace both 345-kV HPFF cables between East Devon and Singer with XLPE, replace both 345-kV HPFF cables between Singer and Norwalk with XLPE, remove one of the 345-kV HPFF cables in the Bethel to Norwalk Project from service, remove the 115-kV capacitors at Plumtree from service, reduce the capacitors at Glenbrook to 75 Mvar, and reduce the capacitors at Frost Bridge to 205 Mvar in the "all caps in" cases, and investigate fixed capacitor replacements with dynamic reactive control devices.

The Companies requested that GE evaluate the system with the addition of STATCOMs at Glenbrook (in Stamford), Stony Hill (in Brookfield), Frost Bridge (in Watertown), and Southington substations. The logic behind this system design began with an evaluation of the results of Case 5 (all XLPE cable from East Devon to Norwalk and one HPFF cable in service in the Bethel to Norwalk Project). In Case 5, the point of first resonance with all capacitors in service and light generator dispatch is 2.8. With most of the capacitors removed, the point of first resonance is 3.5. Therefore, the Companies believed that the complete removal of large capacitor installations could shift the point of first resonance with all capacitors in service above the third harmonic.

Rather than continuing to add more synchronous condensers (for the reasons discussed above), the ROC elected to use STATCOMs since they would be installed at the sites of existing capacitor banks, where any fault contribution is expected to be manageable and would not adversely affect Devon and Pequonnock. In Case 7, all of the fixed capacitors were removed from service at Glenbrook, and an additional 150 MVAR STATCOM was added, incremental to the existing STATCOM at Glenbrook. At Stony Hill, a 150 MVAR STATCOM was added, and the fixed capacitor banks at Stony Hill and Rocky River were removed. At Frost Bridge and Southington, all fixed capacitors were removed and a 300 MVAR STATCOM was added at each substation. These changes represent a significant change in the amount of fixed capacitance in the vicinity of Southwest Connecticut.

The results of the harmonic studies of Case 7 indicate that these modifications did indeed increase the point of first resonance compared to other cases that had been studied. A copy of the GE report that adds Case 7 to the study group is included in Appendix E. The improvement in the harmonics results for Case 7 compared to other cases studied is clear from the report. The point of first resonance for Case 7 with "caps in" and light load generator dispatch is 3.2 – 3.4 for Case 7. With "caps in" and local generation off, the point of first resonance is 2.9 – 3.1 for Case 7. For the convenience of the readers of this Report, the ROC group is including here a copy of Table 5 from page 10 of the GE report, entitled "Variation in Frequency of First Resonance Points (pu 60 Hz)":

115 kV Capacitor Bank Conditions	M/N Project with HPFF Cable (Original Light Load Generator Dispatch)	M/N Project with XLPE Cable (Original Light Load Generator Dispatch)	M/N Project with XLPE Cable (Local Generators Off)
All in service (Case 5)	2.4	2.8	2.5
Reduced banks (Case 6)		2.9-3.0	2.6-2.7
Further reduced banks (Case 7)		3.2-3.4	2.9-3.1
All out of service (Case 5)	2.8	3.5	3.3

Based upon GE's analysis of Case 7, the ROC group has determined that the results of the frequency scans are marginally acceptable. With respect to further harmonics studies, ROC has asked GE to study Case 7 with specific lines out and to prepare a more detailed representation of the proposed STATCOMs in Southwest Connecticut to evaluate their impact on system resonance and transient switching. Simultaneously, EPRO has been contracted to evaluate the same STATCOM additions and capacitor bank removals to ensure that the system is still adequate from a steady state voltage perspective. UI and CL&P have performed a short circuit analysis. The Companies believe that the remaining study results will either be acceptable to ISO-NE or will not pose insurmountable problems to implementing the Case 7 modifications. The ROC group expects these studies to be completed by the end of September.

While the Case 7 project modifications could be marginally acceptable in terms of reliability and operability, they are undesirably complex. The 900 MVARs of STATCOMs considered in the Case 7 modifications for installation in Southwestern Connecticut is likely to equal the entire STATCOM MVARs in service throughout the rest of the entire country. Control of such a large number of STATCOMs in such close proximity could represent additional design and operational challenges, and there is no precedent on which to base predictions regarding the replacement of static capacitors with so many STATCOMs on the same system.

Absent the legislative presumption that 345-kV transmission be installed underground near certain listed types of facilities unless it is not technologically feasible to do so, neither ISO-NE nor the Companies would consider the use of multiple STATCOMs as outlined in Case 7 to be a desirable means of reducing capacitance on the electric system. The use of STATCOMs increases operational complexity, decreases operational flexibility, and increases the initial investment cost by approximately $250 million.

The increased losses on the system resulting from the use of STATCOMs will increase on-going economic and environmental costs. Generally, STATCOMs are used to provide dynamic system support, but are operated near the point of 0 MVAR output through the use of fixed shunt capacitors in order to minimize losses. However, since the proposed modifications involve the use of STATCOMs and the complete removal of the shunt capacitors at these locations, the devices will often be operated toward their maximum capability, which is the point of highest losses.

Moreover, even with marginally acceptable study results, there are greater risks associated with using equipment and technology in unprecedented ways. The system challenges that are identified and addressed in studies are an attempt to identify and assess actual system challenges and operation, but the actual system challenges could differ from those shown in the studies. Because there are no similar actual applications, there is little real world experience.

For all of these reasons, the ROC group has concluded that the 24 linear miles of underground cable included in Case 7 is the maximum amount of underground 345-kV transmission that can be utilized in the Project. Results of the Case 7 studies provide a sound basis for believing that the Project, with the Case 7 modifications, will be marginally acceptable. Any additional underground cable utilized in the Project would be unacceptable as inconsistent with the reliable day-to-day operation of New England's bulk power system and with the designing and planning of that system in accordance with Good Utility Practice and national and regional reliability criteria. The ROC group did not study further modifications with additional linear underground cable or additional STATCOMs. Adding more cable and therefore more capacitance (or adding more STATCOMs and therefore more complexity to attempt to compensate for the capacitance from the additional cable) would render the project modifications not technologically feasible.

Conclusion

The ROC group appreciates the interest of residents and governmental entities in the ROC process of evaluating project modifications with the goal of maximizing the linear miles of underground 345-kV cable used in the Project, consistent with meeting system need and designing and operating a reliable electric system. The challenge of placing extensive lengths of high voltage electric transmission cable underground presents complex design issues that affect the reliability and operability of the electric system. Efforts to maximize the amount of 345-kV transmission that can feasibly be placed underground are accompanied by greater risks to reliable operation of the electric system and greater uncertainties regarding the possible consequences of system conditions in the future.

The Companies and ISO-NE believe that the Project modifications in Case 7, involving the significant and unparelled use of STATCOMs, have passed preliminary tests indicating that such modifications can be made to work within the New England system. The completion of additional GE analyses by the end of September will identify whether there are likely to be any insurmountable electric system problems with Case 7. Finally, as for any project, following the Siting Council's issuance of a certificate, a formal analysis will be required in the ISO-NE approval process under Section 18.4 of the Restated NEPOOL Agreement. This Report does not replace that process or represent such approval under Section 18.4. Based upon the review of the GE analyses by ISO-NE and its consultant, ISO-NE expects to be able to determine by the end of September its support for the Project, as modified. While this support is not a guarantee of 18.4 approval, it would indicate ISO-NE's good faith belief that no insurmountable barriers to approval appear to exist.

The work undertaken by the ROC group has represented a tremendous effort in a short period of time to develop project modifications that are consistent with meeting electric system need and reliability and operability of the electric system, while recognizing the legislative direction to install 345-kV transmission lines underground where that is technologically feasible. Given its responsibilities to FERC and to users of the bulk power grid throughout New England, as well as in Connecticut, the support of ISO-NE cannot be given lightly, and it has been a difficult challenge to design project modifications that could enable ISO-NE to support the approximately 24 linear miles of 345-kV underground cable in Case 7. This case represents the maximum amount of underground 345-kV transmission that is technologically feasible for this Project.