INTERIM REPORT OF THE RELIABILITY AND OPERABILITY COMMITTEE

October 8, 2004

On August 16, 2004, the Reliability and Operability Committee ("ROC" or "ROC group") submitted a report (the "August Report") to the Connecticut Siting Council ("Council") in Council Docket No. 272 providing a summary of the ROC group's work to that date in considering 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.

The ROC group submits this interim report to update the Council, docket participants, and others with respect to the progress of the work. This report addresses three areas:

I. Case 5

II. Case 7

III. Installation of high voltage direct current ("HVDC") in Southwest Connecticut.

In this report, ROC will review the analysis that has led to the following conclusions:

<u>Case 5:</u>

- The preliminary results of the transient network analysis ("TNA") of Case 5 performed by GE are very troubling and demonstrate the seriousness of the transient overvoltage issues;
- ROC is continuing to evaluate the studies in order to better understand the source of these transient overvoltages;
- ROC is exploring possible solutions to address these problems; and
- While the ROC has not yet reviewed a case that includes less than 24 miles of underground cable, this may be necessary if ROC is unable to sufficiently mitigate the Case 5 problems.

Case 7:

- ROC has conducted additional analysis regarding the multiple STATCOM configuration described in Case 7;
- ROC has concluded that, based on design complexity, operating concerns, and limited availability , a multiple STATCOM solution in close electrical proximity will not result in a reliable solution to the electric needs of SWCT; and
- ROC is not planning to perform any additional studies regarding Case 7.

HVDC:

- ROC has only recently received the lengthy ABB proposal regarding the potential use of voltage source converter ("VSC") HVDC technology to address the electric needs of Southwest Connecticut and has conducted a preliminary review of the ABB proposal;
- Based on this preliminary review, ROC has serious concerns about the technical feasibility of ABB's unprecedented and unproven proposal for a VSC-HVDC configuration; and
- ROC will conduct further review and evaluation of ABB's proposal before it can reach its ultimate conclusion regarding ABB's VSC-HVDC proposal.

The Work Process Since August 16, 2004

Since the August Report was submitted, the ROC group, comprised of The Connecticut Light and Power Company ("CL&P") and The United Illuminating Company ("UI") (together, "the Companies") and ISO-New England, Inc. ("ISO-NE"), has continued to analyze the reliability and operability aspects of cases studied by ROC. The work has been discussed at status update calls with docket participants on September 7, 21, and 28, 2004.

While the ROC group is still evaluating portions or aspects of the documents discussed in this interim report, and believes all cases should be evaluated on the reliability and operability criteria set forth in Section III, the Companies and ISO-NE believe it is important that interested persons be aware of the issues that are now being addressed by ROC.

I. Case 5

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]

As discussed in the August Report, the Companies' consultant, GE Power Systems Energy Consulting ("GE"), performed frequency scans on Case 5 to make an initial examination of system resonance. Because the first resonant frequency was not greater than 3.0, the ROC group proceeded to look at other cases.

As first suggested in the March hearings, and as discussed in detail at the June hearings, a major problem associated with low first resonant frequencies is the potential for severe overvoltages. While the frequency scans can provide a guide, a transient network analysis ("TNA") is necessary when low resonant frequencies are observed to understand the full potential for overvoltages on the system. In September, while further considering Case 7 (see below), the ROC group determined to reinstitute analysis of Case 5 and take a more detailed look at the potential for overvoltages.

GE has performed the TNA for the ROC group. While the GE report of its analyses is not yet final, the results of the analyses are troubling and demonstrate the seriousness of transient overvoltage issues. The TNA for Case 5 indicates that in many of the individual case scenarios, combinations of system operating conditions such as location of generation in service, transmission equipment in service, line outages and fault duration resulted in voltages that

[1] As noted in the August Report, the study model "remove[d] one of the 345-kV HPFF cables in the Bethel to Norwalk Project from service." This reflects the electric performance of the system if both Bethel to Norwalk cables are installed, and only one is energized.

exceeded the equipment rating, in some cases rising above 600-kV on 345-kV equipment, and that these overvoltages are sustained for a significant number of cycles. The ROC and its consultants are in the process of working through these individual case scenario results to determine how serious these concerns are and whether the potential for overvoltages can be mitigated. Hundreds of cases must be reviewed individually, and this work is extremely labor-intensive and time consuming.

II. Case 7

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 discussed in the August Report, GE evaluated the system with the modification of the Project to include changing the type of cable from high pressure fluid filled ("HPFF") to cross-link polyethylene ("XLPE") for the Project, operating only one of the HPFF cables for the Bethel to Norwalk Project, and the addition of static synchronous compensators ("STATCOMs") at Glenbrook (in Stamford), Stony Hill (in Brookfield), Frost Bridge (in Watertown), and Southington (in Southington) substations. 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.

As noted in the August Report, the GE frequency scans indicated that the point of first resonance for Case 7 with "caps in" and light load generator dispatch is 3.2 – 3.4. With "caps in" and local generation off, the point of first resonance is 2.9 – 3.1. Additionally, frequency scans have been performed on Case 7 with various lines removed from service. This analysis showed that the point of first resonance could be as low as 2.9 - 3.0 with a light load generator dispatch and 2.5 - 2.7 with local generation off.[2]

The ROC group determined in August that the results of the frequency scans are marginally acceptable. (See discussion of Case 7 in the August Report at page 22.) As discussed in the August Report, the Case 7 project modifications are undesirably complex. Control of a large number of STATCOMs in close electrical proximity could represent additional design, reliability, and operational challenges. ISO-NE retained PB Power ("PB") to consider further the unprecedented use of multiple STATCOMs studied in Case 7. PB has indicated that the STATCOM technology is not a mature, reliable technology for this application and that there are serious availability problems with large STATCOMs, as envisioned by Case 7. STATCOMs in use today are generally small in scale or have been used in conjunction with other technologies, such as mechanically switched capacitors, to provide reactive injection/absorption. The use of such a large number of STATCOMs in such a small area would be unprecedented anywhere in the world. The following table summarizes the generally disappointing experience with STATCOM technology to date:

[2] The study entitled, "Connecticut Cable Resonance Study for XLPE Alternative in Middletown to Norwalk Project – Case 7 with Transmission Line Outages" is attached to this interim report.

Installation	Manufacturer	Comment
Vermont	Mitsubishi	Component failures, issues coordinating with Highgate, noise complaints, went into blocking mode during phase angle regulator failure, catastrophic failure of inverter #4, control software issues, coolant leaks, goes into blocking mode when needed. Now considering synchronous condenser for Granite Substation project.
California	Mitsubishi	Commissioning took 5 months to resolve problems but now operating smoothly although contingency for which it is largely required has not occurred.
Tennessee	Westinghouse & Siemens	Significant initial problems with cooling and horizontal shaft pumps along with other issues subsequent to which it has had two long duration outages - one lasting over a year and the other several months due to pole failures. Concerns remain over performance under severe voltage collapse, as they require pumps for cooling. TVA installing capacitor banks to avoid reliance on STATCOM.
Connecticut	Alstom	Software and cooling problems. Been experiencing 1 trip per week since June installation.
New York	Westinghouse & Siemens	Failures primarily associated with gate drives but have also had cooling failures. Experiencing failures at the rate of 10-12 per year. Gate drive failures sometimes lead to thyristor failures.
Texas	ABB	Module problems, control issues.
Kentucky and Texas	Westinghouse & Siemens	Gate drive failures, module problems, cooling issues, ruptured cooling lines leading to extensive water damage, software control issues, devices being taken out-of-service for voltage fluctuations on supply lines. No longer considering voltage-source converter technology for any of their applications.

Based on design complexity, operating concerns, and limited availability, ROC has concluded that a multiple STATCOM solution in close electrical proximity will not result in a reliable solution.

III. HVDC

While HVDC transmission facilities can provide great value to the bulk power system (and are in fact utilized in New England), embedding a multi-terminal short HVDC system into a small portion of an integrated alternating current ("AC") system would be unprecedented. In the August Report, the ROC group stated that based upon study results then reviewed and utilizing the expertise of an HVDC expert, ROC believed that HVDC technology would not reliably satisfy the needs of SWCT. (See discussion of HVDC in the August Report at pages 4, 17; Applicants' Exhibit 123 (Direct Testimony of Roger Zaklukiewicz Regarding the Potential Use of HVDC), dated July 19, 2004; ISO-NE Exhibit 9 (Supplemental Prefiled Testimony of Richard Kowalski), dated July 19, 2004.)[3] In January 2003, the Working Group on Southwest Connecticut and the Task Force on Long Island Sound observed that, "HVDC interconnection does not provide valuable system support immediately following a contingency as does an AC interconnection."[4] Nevertheless, in light of concerns expressed at the Siting Council, and as indicated in the August Report, the ROC group undertook to look further at the potential for using VSC-HVDC technology. As noted at page 18 of the August Report, the Companies and ISO-NE discussed with ABB, the vendor of VSC-HVDC, the requirement that a project meet the electric system needs in Southwest Connecticut as defined by 13 criteria. The Companies and

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[3] Traditionally, HVDC lines have been used as links between systems of different frequencies and for point-to-point deliveries from one system to another, and they are normally scheduled for constant power flows over longer time periods. They have seen little, if any, integration within AC systems, primarily because they do not respond to changing system conditions. In contrast, AC lines will respond to changing system conditions, and automatically support the system without operator intervention during contingency events and load cycling. In general, DC facilities have lower availability and reliability than AC facilities. Converter station failure modes can also be quite extensive and outages of a year and longer have been reported.

[4] *See Comprehensive Assessment and Report Part I Energy Resources and Infrastructure of Southwest Connecticut,* prepared by Working Group on Southwest Connecticut and the Task Force on Long Island Sound, pursuant to Public Act 02-95 and Executive Order No. 26 (Jan. 1, 2003) at 56.

ISO-NE met with ABB and provided technical information to ABB to enable ABB to develop a case that utilizes all VSC-HVDC technology.

On October 5, 2004, the Companies received two final reports, including appendices, from ABB. The two reports, a technical feasibility report entitled "Middletown – Norwalk Transmission Project Technical Description of VSC HVDC Converter and Cable Technology," and a non-technical report entitled "Middletown – Norwalk Transmission Project VSC HVDC System Feasibility Study," are attached to this interim ROC report. The Companies and ISO-NE are now reviewing and evaluating these reports.

Based upon the operating and planning experience of the Companies and ISO-NE personnel, the ROC group remains concerned about the ability of VSC-HVDC to meet the system need in SWCT upon installation and into the future. The ROC group is concerned that conclusions in the ABB reports do not realistically address identified criteria, and are based in large part upon theory rather than operating experience. Models do not currently exist to analyze the system response to several of the criteria. Utilizing VSC-HVDC in a project of this type and scale would be the first of its kind. There is no significant or comparable experience with a VSC-HVDC project of this magnitude, complexity and scope in the world which addresses even a fraction of the many aspects of system need that must be resolved in Southwest Connecticut.

The use of VSC-HVDC in Southwest Connecticut would require an unprecedented number of converter stations in one portion of a system, converter stations of a size not yet used anywhere, and control technologies that are still in their infancy and never employed in the middle of a 3,500 MW load center with limited transmission infrastructure and capacity. It would also demand extremely complex operating procedures that are not practical given the complexities of the AC system in Southwest Connecticut. Consistent with prior testimony provided on this matter, the ROC group is therefore concerned that going forward with only a VSC-HVDC project, even after substantial further study, would amount to a "a science project" for the sole reason of attempting to utilize more linear length of underground cable, while hoping that reliability and operability are not impaired.

ABB's reports list the 13 system criteria that the Project must meet, and include in a table ABB's summary conclusions that VSC-HVDC proposed by ABB meets each criterion. (See Middletown – Norwalk Transmission Project VSC HVDC System Feasibility Study, Table ES-1, System Criteria for Middletown to Norwalk Project). For the convenience of the readers of this interim report, the ROC group has included below (1) the system criteria; and (2) the ROC group's initial comments on the ABB conclusion.

Criterion 1: Moving approximately 1,200 MW of power into SWCT. Approximately 1,200 MW of power injection (800 MW incremental after Phase II, and Phases I & II give 1,400 MW; comparison of transfer capacity for both AC and DC line outages.)

This objective was to provide the ability to move approximately 1,200 MW into SWCT. ABB has submitted projects which are claimed to add 800 MW of transfer capability to the system using converters that have never been employed in commercial operation anywhere in the world. The ABB HVDC alternatives did not demonstrate at least a 1,200 MW net increase in "all lines in" SWCT import capability over what the Bethel-Norwalk project did.

Criterion 2: Resolving short circuit issues at Pequonnock 115kV and Devon 115kV and Devon 115kV target of 90% of 63kA or below.

The HVDC options appear to rely heavily upon placing large series reactors in the generator leads for Bridgeport Energy and Bridgeport Harbor 3, an approach which diminishes area reactive reserves necessary for voltage control, diminishes transient stability performance, and increases the potential for transient overvoltages.

Criterion 3: Resolve generation interdependencies at Pequonnock, Devon, and Norwalk Harbor.

Assuming that the DC terminals are optimally dispatched, all three options proposed by ABB have the ability to resolve the generation interdependencies which exist at Pequonnock, Devon, and Norwalk Harbor. However, such optimal dispatching may result in yet further interdependencies in that all of the HVDC terminals must now be coordinated with all of the generator outputs at all load levels.

Criterion 4: Improve the point of the first system resonance to 3rd harmonic or higher.

Pending further review, it appears that frequency scans for ABB's proposal indicate a point of first resonance above 3.0.

Criterion 5: Provide a means of interconnecting new generation.

ABB states that new generators could be added through their interconnection to the existing AC system and may not require the addition of new converters. It is difficult to understand how additional generation could be added without the installation of a converter station to mitigate the fault current contribution from a new generator and to prevent overloading of existing 115-kV transmission lines. Further, under current NEPOOL rules, the charges for system changes which are required to interconnect a new generator are the sole responsibility of the new generator. Therefore, a generator that must interconnect to the DC system is at a competitive disadvantage as compared to a generator that is able to interconnect to the AC system.

Criterion 6: Have the ability to add new load serving stations as required.

ABB suggests that in order to connect new load serving substations along the project path, the Companies could either install new 115-kV cables or add a new HVDC converter. This configuration would be more expensive and complex than a conventional substation connection (using an autotransformer). HVDC station additions would create further operational coordination issues.

Criterion 7: Must be able to operate throughout a load cycle and throughout the year with varying dispatches and line outages.

Unlike an AC transmission systems, HVDC systems will continue to transmit an assigned amount of power unless automatic control systems or operators provide new direction to the terminals. This fundamental difference introduces a great deal of operational complexity to each of the proposed HVDC options. While it is asserted that HVDC's control allows great flexibility, the ABB study results indicate considerable variation in the settings of the HVDC terminals. This suggests that an unreasonable number of significant and immediate changes would need to be made by system operators to the settings of each of the HVDC terminals in order to have a reliable and secure dispatch. This requirement would be constant as load changes minute by minute, and it would be further complicated by the need to respond to sudden changes such as the loss of a generator, a transmission element, or an HVDC facility. This complexity would place an unacceptable burden on system operators.

Criterion 8: The project cannot cause any new overloads on the system.

ABB in its summary states that remaining system overloads are similar to the proposed Project. However, the ABB report (Section 3.1 of the Power Flow Analysis) indicates additional transmission facility overloads. The Companies are evaluating the discrepancies in these two sections. This illustrates that the HVDC solution may lack the responsiveness of an AC system, requiring complex manual intervention to address any problem.

Criterion 9: Respect technical and physical limitations.

While it may be possible to obtain the space to physically install the converter terminal equipment, the system configurations selected represent a number of world-wide "firsts." VSC-HVDC over 330 MW is unproven, as is multi-terminal VSC-HVDC operation.

Criterion 10: The project needs to result in a dynamically stable system.

ABB's stability analysis can be considered as very preliminary. From the report it does not appear that ABB modeled the series reactors listed in the short circuit report. (See discussion of Criterion 2 above). There are certain contingency conditions and faults which typically produce the worst system results that were not tested as part of this analysis, for example, a fault at Pequonnock where the 22T circuit breaker fails to open.

Shut-down during critical system events would not be problematic for a typical point-to-point application of HVDC, which would appear as just a loss of a single source. However, during a "typical" disturbance, the concurrent mis-operation of an embedded HVDC facility that is providing critical parallel path capability in SWCT could readily result in a complete failure of the SWCT system. Such a failure could cascade into the rest of Connecticut and into the Eastern Interconnection.

Criterion 11: The project needs to provide adequate voltage on the system.

The ABB report does not state the reactive capability which was assumed in either the stability or thermal reports. However, it is reasonable to expect that the use of VSC-HVDC would provide adequate voltage support.

Criterion 12: Respect existing contracts and system capabilities – cannot degrade capabilities such as the 352 MW (330 MW net) capability of the Cross Sound Cable and 200MW across the 1385 submarine cable between Norwalk Harbor and Northport, L.I.

The ABB thermal testing respected the required flows on the Cross Sound Cable and 1385 cable between Connecticut and Long Island. This criterion appears to have been met.

Criterion 13: Adverse Sub-synchronous Torsional Interaction (SSTI) effects should not be present – System must not act to destabilize torsional modes of nearby generators.

ABB states that the VSC-HVDC will not cause sub-synchronous torsional interaction (SSTI) with local generation. However, the increased employment of VSC-HVDC converter terminals increases the likelihood of mis-tuning over the full range of operating and maintenance conditions, resulting in unanticipated sub-synchronous interaction with generators.

The ROC group is undertaking with GE a comprehensive review of the ABB reports. At best, there are significant issues relating to the fact that the ABB proposals call for the construction and reliance on never before constructed equipment with untested operational characteristics, as well as the associated potential for equipment interaction on the system. More detailed comments on the potential use of VSC-HVDC may follow after the ROC completes it evaluation of the ABB reports. ROC's preliminary review of this report leads to serious reservations concerning ABB's claim that the VSC-HVDC configurations are an acceptable system solution for Southwest Connecticut.

Conclusion

This interim report provides an update on the status of the ROC's evaluations of Case 5, Case 7 and HVDC. The ROC continues to work to develop project modifications that are consistent with meeting electric system reliability needs while recognizing the legislative direction to maximize the underground installation of 345-kV transmission lines where feasible. The task to maintain (or to try to expand upon) the 24 linear miles of underground cable included by the Companies in the Middletown to Norwalk Project is extremely complex due to the inherent weakness of the transmission system in Southwest Connecticut, as detailed study results have revealed.

Given the discouraging pace of progress with respect to Case 5, the results of Case 7, and the operating and reliability concerns with the use of VSC-HVDC, other studies will have to be undertaken to better understand and attempt to mitigate the problematic results of Case 5. If mitigation proves impractical, the ROC Group will go on to consider adding synchronous condensers and reducing the amount of underground cable, if necessary.

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