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KEMA
KEMA, INC.

January 19, 2005

VIA HAND DELIVERY

Mr. S. Derek Phelps
Executive Director
Connecticut Siting Council
10 Franklin Square
New Britain, CT 06501

RE: Docket No. 272

Dear Mr. Phelps:

As requested by the Connecticut Siting Council, KEMA Inc. has prepared the attached white paper, entitled "Observations on the Reliability and Operability Committee's Final Report," for use by the Council in its deliberations on this docket. Please contact me if you have any questions regarding our findings.

Sincerely,

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Observations on the Reliability and Operability Committee's Final Report

By

KEMA, Inc.

January 18, 2005

Background and Introduction

At the request of the Connecticut Siting Council (CSC), KEMA Inc. has conducted a detailed review of the Reliability and Operability Committee's (ROC's) Final Report, dated December 20, 2004, and the associated results and findings. Further, KEMA assisted the CSC in cross-examination of the ROC investigators during public hearings held in New Britain, Connecticut, on January 11 and 13, 2005. After careful review and consideration of the filed documents and the ROC panel's responses to cross-examination questions by the CSC and others, KEMA summarizes its findings in this white paper.

Key Findings on the Maximum Amount of Undergrounding

The key findings of the ROC Final Report are:

1. Options including either 13 miles or 24 miles of underground cable between Norwalk and Devon are acceptable

2. Additional undergrounding beyond 24 miles is not feasible

3. Neither C-Type filters or other types of mitigation will help

4. VSC HVDC solutions are not feasible for the SWCT system

Some of these findings are directly supported by analytical results presented in the report itself or in accompanying consultant reports and appendices. However, the report provides little or no direct support for other findings. This section discusses the analytical support provided for the ROC Final Report's key findings on the maximum feasible amount of undergrounding. Discussion of the ROC Final Report's responses to related studies performed by KEMA Inc. and ABB are discussed in the following section.

- **Finding 1: Options including either 13 miles or 24 miles of underground cable between Norwalk and Devon are acceptable**

  In the "Executive Summary and Conclusion" of its Final Report the ROC Group concludes "Based upon the study results and findings… the ROC group has identified Case 2 and Case 5 as technologically feasible. Case 2 includes 13 linear miles of underground cable, between East Devon Substation (in Milford) and Singer Substation (in Bridgeport) and Hawthorne Transition Station (in Fairfield). Case 5 includes 24 linear miles of underground cable from East Devon Substation (in Milford)…to the Norwalk Substation." The feasibility of Case 5, however, requires that certain "… existing equipment is upgraded and other specific required actions occur." These upgrades and required actions include 1) the use of XLPE cable rather than HPFF cable, 2) the replacement of approximately 1200 surge arresters and associated equipment, and 3) changes to remedy local area problems at the Rocky River Substation.

  Although the ROC group members clearly state their preference for Case 2, which includes only 13 miles of undergrounding, their Final Report presents few analytical results to support its feasibility. Presumably, the reduced capacitance of the Case 2 solution would yield reduced problems from temporary overvoltages (TOVs). If Case 2 is adopted, however, a fuller set of results for this option should be presented and discussed.

  Case 5 was studied thoroughly by GE and by other ROC consultants, including EnerNex and PB Power. GE's transient network analysis studies alone addressed 23 case scenarios, and GE simulated either 24 or 30 conditions for each scenario. Resulting TOVs were then catalogued and compared for three separate time windows following fault clearing. In each instance, TOVs for 2 cycles and 6 cycles were compared to established thresholds for typical 345 kV surge arresters. The thresholds of 1.60 for 2-cycle TOVs and 1.55 for 6-cycle TOVs included a margin to account for certain system variations.

  KEMA finds these studies to be complete and thorough, and agrees that the study results confirm the technical feasibility of Case 5.

- **Finding 2: Additional undergrounding beyond 24 miles is not feasible**

  As clearly stated in its Final Report, "…the ROC Group has concluded that Case 5 is at the limit of technological feasibility and that addition of more cable to the Project from East Devon toward Beseck would impose unacceptable risk." The report goes on to cite "supporting data and analyses" in the accompanying reports by EnerNex and General Electric (GE). However, this supporting data does not confirm the conclusion that additional amounts of undergrounding necessarily lead to unacceptable overvoltages.

GE performed studies of an additional 1, 2, and 5 miles of underground cable (beyond the 24 miles in Case 5). These were "sensitivity studies" that assumed 1) further weakening of the SWCT system and 2) the addition of new capacitor banks not currently existing on the system. The results did show a progressive increase in TOVs, but only the 5 mile case resulted in a 2-cycle TOV that exceeded the criterion of 1.60, and even for this case all of the 6-cycle TOVs were less than the criterion of 1.55. Further, as cited in GE's report, "...the highest magnitude observed (1.67) was similar to the highest TOV observed in all of the other cases summarized in Table 8." (This table summarized the worst TOVs for the base case that includes 24 linear miles of undergrounding.)

If the ROC investigators expected that increased amounts of undergrounding would continue to increase TOVs, these expectations were not realized by the numerical results of their consultants. Indeed, the EnerNex TOV study results for an additional 10 and 20 miles of undergrounding were actually better than those for an additional 5 miles of undergrounding. Further, on cross-examination before the CSC, Mr. Gunther of EnerNex agreed that the worst TOVs for an additional 10 miles of undergrounding were "equal to or better than" those for the base case with 24 miles of undergrounding. He also confirmed that the (most critical) 6-cycle TOVs were approximately equal to or better than those for the base case for both an additional 10 miles and an additional 20 miles of undergrounding.

In describing these results the ROC Final Report states, "A cursory review of the results could lead one to believe that the addition of more cable beyond the length of 5 miles between East Devon and Beseck would actually result in improved system performance." After concluding that such results were "counterintuitive," the ROC Group sought a "better understanding of the results." Accordingly, "...EnerNex performed frequency scans at the Norwalk 345-kV bus for a given system condition with the Plumtree to Long Mountain line out of service." At this location and for this specific contingency condition, EnerNex demonstrated that the observed TOV increase at 5 miles and decreases at 10 and 20 miles could be explained by shifts in second resonance peaks. According to EnerNex, these second resonance peaks become increasingly larger and continue to shift to lower frequencies for 5, 10 and 20 miles of additional undergrounding.

Based on the results observed by EnerNex for this one specific case, the ROC Group assumed that there was volatility for all (or many) other contingency and noncontingency cases and concluded, "Because of the potential for extreme volatility, the ROC group believes that a system with additional underground cable, beyond the 24 linear miles from East Devon to Norwalk, would not be technologically feasible."

However, this conclusion is not supported by other results presented by the ROC consultants. Specifically, frequency scans presented by GE for its examination of 1, 2 and 5 miles of additional undergrounding do not demonstrate such volatility. On cross-examination before the CSC, Ms. Elizabeth Pratico of GE agreed that for the contingency case GE examined, the shift in the second resonance peak as additional cable is added, "...doesn't look like a significant shift, but there's some difference." Also, additional frequency scans provided by EnerNex during the CSC hearings on January 13 (Applicant Exhibit No. 178) show that the volatility observed by EnerNex for the first 5 miles actually disappears for increased amounts of undergrounding. Indeed, after approximately 7 miles of additional undergrounding, the harmonic impedances are remarkably stable with increasing cable lengths.

In conclusion, despite an apparent expectation that additional undergrounding would produce increasingly large TOVs and growing volatility, the results presented in the ROC Final Report confirmed neither result for additional undergrounding scenarios of 10 miles and higher.

ROC Group Findings Regarding Studies by Other Consultants

- **Finding 3: Neither C-Type filters or other types of mitigation will help**

  The ROC Final Report discusses the KEMA Report Filed on October 18, 2004. This report described investigations of the maximum length of the proposed Middletown-Norwalk 345-kV line that could be installed underground by investigating several mitigation schemes, including C-Type filters and/or STATCOMs in place of the existing capacitor bank installations. KEMA performed only frequency domain screening of the Southwest Connecticut system operating under normal conditions, without consideration of system contingencies.

  It was however recommended in the KEMA report that:

  - An optimal application of C-Type filters, either alone or in combination with one or two STATCOMs, should be developed. In so doing, the tuned C-Type filters should be optimized for specific substations and for the entire system.

- Transient analysis studies should be conducted, based on a detailed system model of the selected configuration.

In the main portion of the ROC Final Report, discussions on the application of C-Type filters were included. A single composite result of the C-Type filter performance was included in Figure 3, with some associated discussion. However, no discussion and only limited spreadsheet results of the C-Type filter mitigation option were provided in the various consultants' reports.

The only other C-Type filter results in the ROC Final Report were found on the last pages of Appendix E, as prepared by PB Power. Subsequently, at the hearings on January 13, 2005, some additional results on the performance of C-Type filters were presented by EnerNex, but these results were not discussed in either the EnerNex or GE Reports. Further, PB Power did not present a discussion report on its results, making it difficult to fully evaluate the ROC Groups analysis of C-Type filters.

It is clear from the ROC Final Report and subsequent cross-examination that no further optimization was done for the C-Type filters in the performance evaluation. The substation locations where the filters were proposed by KEMA were not optimized. Neither was the C-Type filter's tuned frequency (3^{rd} harmonic) varied at selected substations so as to improve performance from the filters. Finally, in those instances where additional future capacitor banks were modeled at Ansonia, Bunker Hill, and Hawthorne, the inclusion of C-Type filters at these locations was not included as a potential mitigation measure.

Because of the unoptimized filter designs, and the fact that the filters were only added at distant substations (Southington, Frost Bridge, and Berlin), the results from the C-Type filters presented in Figure 3 of the ROC Final Report are not encouraging. KEMA agrees that the use of unoptimized C-Type filter designs as a generic mitigation option for TOV problems would not be effective.

In the results presented by EnerNex on January 13, 2005 during the CSC hearings, the C-Type filters improved the harmonic impedance results for the studied system contingency case with 15 to 30 miles of extended undergrounding, even without any design optimization. The associated resonance peaks were reduced appreciably in the 20-mile extended undergrounding range.

It should be noted that the application of C-Type filters is not a novel concept. In the UK, Europe, South Africa, USA, Canada, and others, these C-Type designs are the preferred design in AC systems to minimize harmonic resonance impacts and to add system damping for new capacitor bank installations.

No other mitigation options using filters were investigated in order to extend feasible undergrounding beyond 24 miles. However, other mitigation options do exist. For example, one option worthy of investigation includes integrating passive filters into the shunt compensation reactors at selected cable terminations, such as Plumtree, Norwalk, Singer and Devon. By integrating 2^{nd}, 3^{rd} and /or 4^{th} harmonic passive filters, designed as part of the shunt reactive compensation at the cable terminations, transformer inrush current harmonics could be filtered to minimize TOVs during contingencies. Because these tuned filters would not be C-Type filters, the added capacitance at these substations would be negligible, and the filters could remain in effect at low load levels.

- **Finding 4: VSC HVDC solutions are not feasible for the SWCT system**

The ROC Final Report also discusses the ABB Report Filed on October 3, 2004. This report investigated the maximum length of the proposed Middletown-Norwalk 345-kV line that could be installed underground, by investigating possible point-to-point and multi-terminal Voltage Source Converter-based, High Voltage Direct Current (or "VSC HVDC") solutions.

ABB performed an extensive feasibility study on this VSC HVDC technology. The ROC report did not provide evidence for their conclusions but mainly discussed the ABB report. The ROC report concluded that the ABB proposal was not technologically feasible. Their conclusions are primarily based on the following:

- No previous VSC HVDC experience in a project of this type, where HVDC is tightly interconnected with AC networks.
- The number of converters, control issues and scale of the project.
- Complex operating procedures that are not practical given the complexities of the AC system
- The additional cost of new generation interconnection
- Higher unavailability rates of HVDC systems

- The fact that ABB is currently the sole supplier of VSC HVDC technology

- The high converter losses and associated operating costs.

KEMA agrees with the ROC Final Report's findings on the VSC HVDC alternatives presented by ABB. The one alternative that may have some merit is a single point-to-point HVDC link between East Devon and Beseck. However, this alternative would still present unnecessary operational complexity to ISO-NE.

KEMA's Conclusions

The ROC group has done extensive harmonic impedance studies and transient network analysis studies to evaluate the feasibility of undergrounding various portions of the proposed Phase 2 transmission line between Middletown and Norwalk. After careful review of the ROC Final Report and associated appendices, KEMA concludes that:

1. The studies made and the results presented <u>do</u> support the conclusion that 24 miles of undergrounding between Norwalk and East Devon is feasible;

2. The results presented do <u>not</u> justify the conclusion that additional undergrounding beyond the base 24 miles is not technologically feasible;

3. The results presented <u>do</u> support KEMA's prior conclusion that an additional 10 to 20 miles of undergrounding would be technically feasible.

In conclusion, no clear solutions to the efforts to identify opportunities to provide for additional underground construction can be drawn either from the ROC Final Report or from the cross-examination that occurred on January 11, and 13, 2005. Thus, without the full cooperation of the Applicant, we believe that limited value would result from additional studies by KEMA alone.

It remains possible that the Applicant's conclusions are justified based on other factors not clearly brought forth in the ROC Final Report. Also, complete unanimity on technical feasibility may be difficult, or impossible, to achieve. Meanwhile, there is consensus on the importance of completing the Phase 2 line and associated improvements in order to ensure the continued provision of reliable electric service to Connecticut consumers.