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Technical Memorandum

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DATE: May 4, 2016

PROJECT: Bridgeport Harbor Generating Station
Project No. 1603547.000

SUBJECT: **Magnetic Field Calculations for Bridgeport Harbor Generator Lead**

Background

PSEG Power Connecticut LLC proposes to construct a 485-megawatt, dual fuel combined-cycle electric generating facility at the existing Bridgeport Harbor Station located at 1 Atlantic Street, Bridgeport, Connecticut (see Connecticut Siting Council petition No. 1218). The proposed project includes the construction of a short, ~800 foot, 345-kV underground generator lead interconnection from the Bridgeport Harbor Station to the Singer Substation operated by The United Illuminating Company. The proposed 345-kVgenerator lead will consist of three phase-conductors in a duct bank in vertical configuration at 4.33 feet burial depth as shown in Figure 1. The conductors will be single core with cross-linked polyethylene insulation, and each conductor shall be 3000 kcmil of segmented copper wires, with limited amounts of 3500 kcmil in areas where 3000 kcmil cannot meet ampacity requirements. The outer diameter of each cable will be 4.82 inches, and each will be installed in an 8-inch PVC pipe. The maximum generator rating of 651 MVA at 345-kV (including a 6% margin) was used to calculate a peak loading of 1089 Amperes. Although expected to operate at peak loading for much of the time, a representative loading of 83% of peak loading is also presented as an example 'average' load. [1]

Objective

The objective of the assessment described in this memorandum is to present calculations of the magnetic field from the proposed generator lead, to demonstrate compliance with the requirements re EMF in the Connecticut Siting Council's Application Guide for an Electric Generating Facility, February 2016[2], and relevant portions of the Councils EMF Best Management Practices, dated February, 2014.[3]

[1] Yearly operating hours are projected to be 7600 with a capacity factor of 83%.
[2] http://www.ct.gov/csc/lib/csc/guides/2016guides/elec_gen_application_guide_0216.pdf#55847
[3] http://www.ct.gov/csc/lib/csc/emf_bmp/revisions_updates/754bmpfinal.pdf

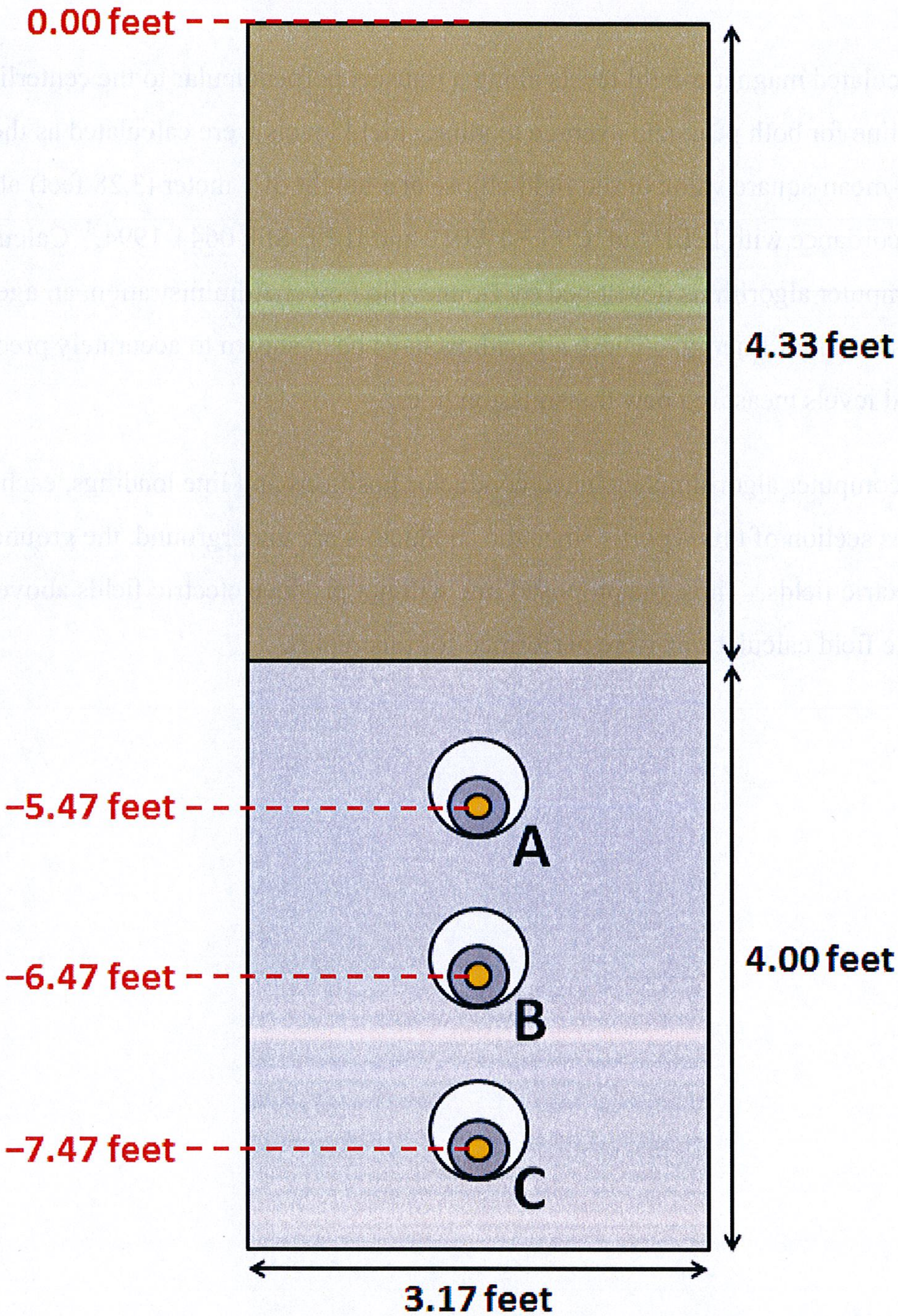

Figure 1. Proposed configuration of the 345-kV underground generator lead and depth of burial of phase conductors below ground.

Methods

Exponent calculated magnetic-field levels along a transect perpendicular to the centerline of the transmission line for both peak and average loading. Field levels were calculated as the resultant root-mean-square value of the field ellipse at a height of 1 meter (3.28 feet) above ground, in accordance with IEEE Std. C95.3.1-2010 and IEEE Std. 0644-1994.[4] Calculations employed computer algorithms developed by Bonneville Power Administration, an agency of the U.S. Department of Energy.[5] These algorithms have been shown to accurately predict magnetic-field levels measured new transmission lines.[6]

Inputs to the computer algorithms included conductor positions and line loadings, each detailed in the previous section of this report. Since the conductors are underground, the ground itself will block electric fields. Thus, the proposed line will not produce electric fields above ground and no electric field calculations were performed for this report.

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[4] Institute of Electrical and Electronics Engineers (IEEE). Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines (ANSI/IEEE Std. 644-1994). New York: IEEE, 1994; Institute of Electrical and Electronics Engineers (IEEE). IEEE Recommended Practice for Measurements and Computations of Electric, Magnetic, and Electromagnetic fields with respect to Human Exposure to Such Fields, 0 Hz to 100 kHz. New York: IEEE. IEEE Std. C95.3.1-2010.

[5] Bonneville Power Administration (BPA). Corona and Field Effects Computer Program. Portland, OR: Bonneville Power Administration, 1991.

[6] Chartier VL and Dickson LD. Results of Magnetic Field Measurements Conducted on Ross-Lexington 230-kV Line. Report No. ELE-90-98. Bonneville Power Administration, 1990.

Results and Discussion

The calculated magnetic-field levels are summarized in Table 1, and profiles plotted transverse to the route of the transmission line as shown in Figure 2. The maximum calculated magnetic-field level is 132 mG at peak loading, and 109 mG for an example 'average' loading, both maxima occur directly above the proposed transmission line.[7] Field levels decrease symmetrically with distance from the transmission line centerline, falling to 17 mG or less beyond ±25 ft, and falling to less than 5 mG beyond ±50 ft. These calculated field levels are compared to magnetic-field exposure guidelines and to background levels measured at the perimeter of the Singer Substation submitted in Docket 272.

Table 1. Calculated magnetic-field levels (mG) for Peak and Average loading

Loading	−50 ft	−25 ft	Max	+25 ft	+50 ft
Peak	4.8	17	132	17	4.8
Average	4.0	14	109	14	4.0

[7] Due to the design of the transmission line magnetic field levels at any other loading level (e.g., 50%) can be calculated from the peak values listed in Table 1. For example a 25% or 50% loading level would result in a maximum magnetic field level of 33 mG or 66 mG, respectively (132 x 0.25 = 33; 132 x 0.5 = 66).

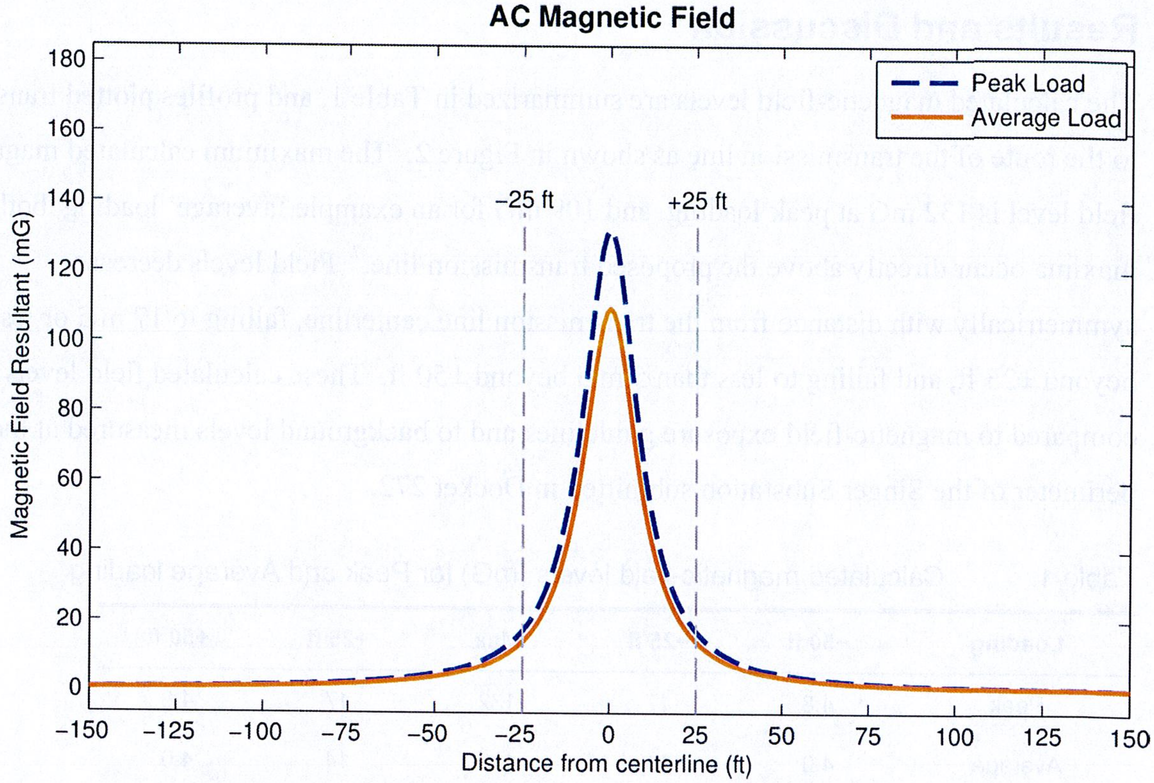

Figure 2. Magnetic field profile across transmission line cross-section for peak and average loading

Field levels out to a distance of ±300 feet to either side of the transmission line are included in Table A-1 of Appendix A.

International scientific organizations, the International Committee on Electromagnetic Safety (ICES) and International Commission on Non-Ionizing Radiation Protection (ICNIRP) each developed magnetic-field exposure guidelines to protect health and safety.[8,9] These guidelines were based upon extensive review and evaluation of the relevant health research, and the World Health Organization (WHO) has recommended that policy makers adopt international exposure limit guidelines like those from ICNIRP and ICES.[10] The ICNIRP and ICES guidelines for magnetic-field exposure are summarized in Table 2 alongside the maximum calculated magnetic-field levels associated with the proposed 345-kV line. The maximum calculated magnetic-field levels are less than 7% of the ICNIRP general public guideline, and less than 2% of the ICES general public guideline. At distances beyond ±25 ft from the transmission line, calculated magnetic-field levels are less than 1% of either the ICNIRP or the ICES guidelines for general public exposure.

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[8] International Committee on Electromagnetic Safety (ICES). IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields 0 to 3 kHz C95. 6-2002. Piscataway, NJ: IEEE, 2002.

[9] International Commission on Non-Ionizing Radiation Protection (ICNIRP). Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz – 100 kHz). Health Physics 99:818-826, 2010.

[10] World Health Organization (WHO). Fact sheet No. 322: Electromagnetic Fields and Public Health – Exposure to Extremely Low Frequency Fields. World Health Organization, June 2007.

Table 2. ICNIRP and ICES guidelines for magnetic-field exposure, compared to maximum calculated magnetic-field levels for the proposed 345-kV line

	Magnetic-Field Exposure (60 Hz)
ICNIRP	
Occupational	10 G (10,000 mG)
General Public	2 G (2,000 mG)
ICES	
Occupational	27.1 G (27,100 mG)
General Public	9.040 G (9,040 mG)
Maximum Calculated	
Peak Loading	132 mG
Example : 'Average' Loading	109 mG

Background measurements of the electric and magnetic fields around the Singer Substation to which the generator leads will connect were reported in the Post-Construction EMF Monitoring Report 12/18/09 for the Singer Substation in Docket 271.[11] Spot measurements on two occasions of the electric field levels were measured as 0.0 kV/m and the magnetic fields around the substation were reported as varying between about 0 mG and about 110 mG. The maximum magnetic field from the proposed generator lead is calculated to be slightly higher than the upper end of the reported spot measurements around the substation; however the magnitude of the latter measurements is subject to the load demand on the station at the time measurements were taken. On other days, the magnetic field measured might be higher or lower.

In the U.S., there are no state or federal exposure standards for 60-Hz magnetic fields based on demonstrated health effects, and the Connecticut Siting Council (CSC) recognizes that "a causal link between power-line [magnetic field] exposure and demonstrated health effects has not been established, even after much scientific investigation in the U.S. and abroad." The CSC continues "its cautious approach to transmission line siting that has guided its Best Management Practices since 1993," advocating "the use of effective no-cost and low-cost technologies and management techniques on a project-specific basis to reduce [magnetic field] exposure to the

[11] http://www.ct.gov/csc/cwp/view.asp?a=3&q=453782 Appendix E, p. 4.

public while allowing for the development of efficient and cost-effective electrical transmission projects."[12] Specifically, the CSC expects an examination of the following engineering controls to limit magnetic-field levels in public places: distance, height, conductor separation, conductor configuration, optimum phasing, increased voltage, and underground installation. Each of these potential low- or no-cost measures has been addressed as detailed below.

- Distance – Placing the transmission line underground allows for a relatively small (approximately 1 foot) conductor separation which enhances magnetic-field cancellation and results in magnetic field levels decreasing very rapidly with distance so that at distances beyond ±25 feet from the duct bank field levels will fall to 17 mG or less. No residential structures or statutory facilities are abutters to this project. See also Conductor Separation and Conductor Configuration below.
- Height of Support Structures – The proposed 345-kV line will reside in an underground duct bank, and thus structure height is not applicable.
- Conductor Separation – The proposed 345-kV line will be buried in an underground duct bank, allowing for relatively small (approximately 1 foot) conductor separation. This conductor separation, which is small relative to that of typical overhead lines, provides additional magnetic-field cancellation and results in magnetic field levels decreasing very rapidly with distance.
- Conductor Configuration – Constructing the duct bank in a vertical configuration effectively moves two of the phase conductors further below ground, and hence reduces maximum magnetic field levels relative to a horizontal configuration where all conductors are at the same burial depth.
- Optimum Phasing – Since the 345-kV line will be the only line present in the proposed duct bank, its phasing will not affect the calculated magnetic-field levels, and thus is not a candidate for phase optimization.

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[12] Connecticut Siting Council. "Electric and Magnetic Fields Best Management Practices for the Construction of Electric Transmission Lines in Connecticut." Revised on February 20, 2014.

- Increased Voltage – By operating the proposed transmission line at 345-kV, the Applicant has already increased the voltage relative to other lower-voltage (e.g., 115 kV or 230 kV) interconnection options.
- Underground Installation – The proposed 345-kV line will be buried in an underground duct bank, allowing for relatively small (approximately 1 foot) conductor separation. This conductor separation, which is small relative to that of typical overhead lines, provides additional magnetic-field cancellation and results in magnetic field levels decreasing very rapidly with distance. Underground installation also effectively blocks the electric field from the phase conductors.

While no pre-construction measurements of EMF around the proposed generating site are available at this time, it is well known that because of their design that the dominant sources of EMF at the boundaries of facilities like substations and generating plants are the transmission lines that connect these facilities to the electrical grid.[13] At maximum load, the proposed generating lead from the Bridgeport Harbor Station will produce a magnetic field above the cables marginally higher than measured magnetic fields at its termination at the Singer Substation. This will be achieved by design considerations that will minimize the magnetic field as called for by the Connecticut Siting Councils guides for substations and transmission lines. These actions and the absence of statutory abutting land uses defined in Section 16-50p(i) of the Connecticut General Statutes demonstrate consistency with the Connecticut Siting Council's EMF Best Management Practices.

[13] IEEE Standard 1127 states that "[i]n a substation, the strongest fields near the perimeter fence come from the transmission and distribution lines entering and leaving the substation. The strength of fields from equipment inside the fence decreases rapidly with distance, reaching very low levels at relatively short distances beyond substation fences." IEEE Guide for the Design, Construction, and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility. New York: IEEE. IEEE Std 1127-2013, p. 26.

Appendix A

Calculated Magnetic-Field Levels at 25 ft Increments

Table A-1. Calculated magnetic-field levels (mG) for Peak and Average loading at 25 ft increments from −300 ft to +300 ft from the transmission line centerline

Distance from Centerline (ft)	Magnetic Field (mG)	
	Peak Loading	Average Loading
−300	0.1	0.1
−275	0.2	0.1
−250	0.2	0.2
−225	0.2	0.2
−200	0.3	0.3
−175	0.4	0.3
−150	0.5	0.5
−125	0.8	0.7
−100	1.2	1.0
−75	2.2	1.8
−50	4.8	4.0
−25	17	14
0	132	109
25	17	14
50	4.8	4.0
75	2.2	1.8
100	1.2	1.0
125	0.8	0.7
150	0.5	0.5
175	0.4	0.3
200	0.3	0.3
225	0.2	0.2
250	0.2	0.2
275	0.2	0.1
300	0.1	0.1