Electrical and Semiconductor Practice

Health Sciences Practice - Center for
Exposure Assessment and Dose
Reconstruction

Exponent®

EMF and Audible Noise Modeling: Maine Power Reliability Program

EMF and Audible Noise Modeling: Maine Power Reliability Program

Prepared for

Maine Public Utilities Commission

Regarding Petition for Finding of Public Convenience & Necessity for the Maine Power Reliability Program Consisting of the Construction of Approximately 350 Miles of 345-kV and 115-kV Transmission Lines (MPRP)

Docket No. 2008-255

At the request of

Central Maine Power Company

Prepared by

Exponent
420 Lexington Avenue
New York, NY 10170

October 15, 2008

Contents

Executive Summary

The levels of electric and magnetic fields (EMF) and audible noise (AN) were modeled based upon conservative assumptions for conditions relating to the operation of existing 12.5-kV, 34.5-kV, 115-kV, and 345-kV transmission lines and to the operation of a new 345-kV and 115-kV transmission line and re-rated/upgraded existing lines proposed as the Maine Power Reliability Program (MPRP). The results show that MPRP generally would produce modest increases in the levels of EMF and AN at the edges of rights-of-way (ROW).[1] Neither the federal government nor the State of Maine has enacted standards for EMF from power lines or other sources at power frequencies, but the calculated field levels at the edges of the MPRP ROWs and beyond would be well below exposure limits for the general public recommended by the International Committee on Electromagnetic Safety (ICES) and the International Committee on Nonionizing Radiation Protection (ICNIRP) to address health and safety issues. A discussion of these exposure limits and of health research on EMF can be found in the Exponent report "Current Status of Research on Power Frequency Electric and Magnetic Fields," dated September 12, 2008 and filed in this proceeding.

The transmission line conductors can give rise to AN, and the levels at the edges of ROWs in fair weather were calculated to be below the noise standard of the Maine Department of Environmental Protection. Higher levels of AN would occur during foul weather but would be masked by the background noise of rain and wind.

In summary, comparisons of the calculated values with appropriate criteria do not indicate that the proposed project would have adverse effects on health or unacceptable noise impacts.

---

[1] Central Maine Power has requested that Exponent perform additional research to determine what changes in the electrical phasing of new and reconfigured lines would lead to reductions in magnetic field levels and the practicality of implementing such changes. Exponent is conducting additional research that is underway but not yet completed to respond to this request.

Introduction

The Maine Power Reliability Program (MPRP) involves the construction of new 345-kV line (246.5 miles) as well as the rebuilding (10 miles), and re-rating/upgrade (3.4 miles) of existing 345-kV lines on 45 segments of existing ROWs. In addition, 80 miles of new 115-kV lines, the re-rating/upgrade of 39.5 miles of existing 115-kV lines, and the removal of 16.7 miles of 34.5 kV distribution lines are proposed on these line segments (MPRP CPCN Petition, Exhibit C).

The majority of the proposed changes to the existing ROWs would be made on segments that have no or few residents within a few hundred feet of the ROW. Therefore, CMP requested that Exponent model the EMF and AN levels for those segments where residences were clustered near the ROW. CMP, Power Engineers, and Exponent reviewed aerial maps of the proposed line route and selected 43 line sections from 11 segments for study based on the above criterion. These segments are summarized below in Table 1. The configurations of the lines on the ROW for each of these line sections can be viewed in the MPRP CPCN Petition, Exhibit C.

To characterize the potential effect of the proposed project on the existing levels of EMF and AN, Exponent modeled the levels of these parameters for conditions relating to the operation of existing transmission lines, the new 345-kV and 115-kV transmission lines, and re-rating/upgrades of existing lines.

Table 1. Segments and Cross Sections Selected for Modeling

Segment	Section	Description	Cross Section	Sheet
10	67	Albion Rd Substation to Maxcy's Substation	XS-1A	N5-10-1
			XS-1B	
			XS-1C	
			XS-2A	N5-10-2
			XS-2B	
			XS-3A	N5-10-3
			XS-3B	
19	102	Intersection of 102/166/167 to Elm St Substation	XS-4	S1-E-19-1
			XS-5	S1-E-19-3 through S1-E-19-14
27	250	Quaker Hill Substation to Three Rivers Substation	XS-6	S1-E-27-9
			XS-7	S1-E-27-4
		Maguire Rd Substation to Quaker Hill Substation	XS-8	S1-E-27-2
			XS-9	S1-E-27-1B
15	212	Bowman St Substation to Gulf Island Substation	XS-10*	N5-15-5
			XS-11A*	N5-15-6
			XS-11B*	
			XS-11C*	
			XS-11D*	
			XS-11E*	
			XS-11F*	
			XS-11G*	
			XS-11H*	
			XS-12*	N5-15-7
			XS-13A	N5-15-8
			XS-13B	
			XS-13C	
			XS-14	N5-15-10
			XS-15	
			XS-16	
18	167	Surdwiec Substation to Elm Substation	XS-17	S1-E-18-2
9	67	Detroit Substation to Albion Rd Substation	XS-18A	N5-9-1
			XS-18B	N5-9-2
			XS-19	
			XS-20	N5-9-4
1	388	Maxcy's Substation to Orrington Substation	XS-21	N5-1-1
			XS-22	N5-1-2
			XS-23A	N5-1-3
			XS-23B	N5-1-3
3	203	Detroit Substation to Bucksport Substation	XS-24	N5-3-2
39B	229	Riley Substation to Rumford IP Substation	XS-25	N5-39-4
14	200	Livermore Falls Substation to Gulf Island Substation	XS-26	N5-14-3
24	219	South Gorham Substation to Louden Substation	XS-27A	S1-E-24-3
			XS-27B	

* Data was not available to calculate EMF or AN for these cross sections.

Methods

Modeling Data

Power Engineers, the lead design engineer for CMP for this project, provided information on the configuration of existing and proposed lines.[2] Cross section diagrams showing these configurations are shown in MPRP CPCN Petition, Exhibit C. The loading on existing and proposed lines was provided by RLC Engineering, LLC based upon modeling of system loads at annual average and annual peak loading. Other details about the load forecast methodology are described in Exhibit B-2 of the MPRP CPCN Petition.[3]

Electric and Magnetic Fields

Pre- and post-construction EMF levels were calculated using computer algorithms developed by the Bonneville Power Administration (BPA), an agency of the U.S. Department of Energy.[4] These algorithms have been shown to accurately predict EMF measured near power lines. The inputs to the program are data regarding voltage, current flow, circuit phasing, and conductor configurations. The resultant fields associated with power lines were estimated along profiles perpendicular to lines at the point of lowest conductor sag, i.e., closest to the ground. All calculations were referenced to a height of 1 m (3.28 ft) above ground according to standard practice.[5] The program assumed that the transmission conductors were at a typical mid-span height for the entire distance between structures and flat terrain, and was instructed to model balanced currents on all

---

[2] The configurations studied are those available from the preliminary design efforts, and are subject to change as design and real estate efforts progress.

[3] Docket No. 2008-255. Available online at http://www.mainepower.com/library.asp

[4] Bonneville Power Administration (BPA). Corona and Field Effects Computer Program, 1991.

[5] Institute of Electrical and Electronics Engineers (IEEE). IEEE recommended practice for instrumentation: specifications for magnetic flux density and electric field strength meters-10 Hz to 3 kHz. IEEE Standard 1308-1994, 1994.

phases. The electric field from the overhead line conductors was also calculated using the typical mid-span height. The program assumed an overvoltage condition of 10 percent for 345-kV transmission lines and 5 percent for transmission lines with voltages below 345 kV. As magnetic field exposures at peak loading would be expected to occur only for a limited number of hours, on a limited number of days each year, the calculated field levels at annual average loading provide a better estimate of typical potential exposures and so are summarized in both tables and graphical profiles for ease of reference in Appendices A and B.

Audible Noise

AN results from the partial electrical breakdown of the air around the conductors of a transmission line. In a small volume near the surface of the conductors, energy and heat are dissipated. Part of this energy is in the form of small local pressure changes that result in AN. This AN can be characterized as a hissing, crackling sound that may be accompanied by a 120-Hz hum. The conductors of 345-kV transmission lines are designed to be free of AN under ideal conditions. However, protrusions on the conductor surface—particularly water droplets on or dripping off the conductors—cause the electric field intensity at the conductor surface to exceed the breakdown strength of air, producing AN. Therefore, audible noise from transmission lines is generally a foul-weather (wet-conductor) phenomenon. Wet conductors can occur during periods of rain, fog, snow, or ice.

The amplitude of a sound wave is the incremental pressure resulting from sound above atmospheric pressure. The sound-pressure level is the fundamental measure of AN; it is generally measured on a logarithmic scale with respect to a reference pressure. The sound-pressure level (SPL) in decibels (dB) is:

$$\text{SPL} = 20 \log_{10} (P/P_0)\text{dB}$$

where P is the effective rms (root-mean-square) sound pressure and P_0 is the reference pressure of 20 micropascals (µPa). The human response depends on frequency, with the most sensitive range roughly between 2000 and 4000 Hz. The frequency-dependent sensitivity is reflected in various weighting scales for measuring AN. The A-weighted scale weights the various frequency components of a noise in approximately the same way that the human ear responds. In this report, AN levels are expressed in decibels on the A-weighted scale (dBA) as L50 values, which are the sound-pressure levels exceeded 50 percent of the time. Foul-weather AN levels for MPRP in dBA units weighted by the sensitivity of the human ear were calculated using computer algorithms developed by the BPA. Fair weather levels were calculated by the subtraction of 25 dBA from the calculated foul-weather values as recommended by the BPA.[6]

An altitude of 2,000 feet was used for all sections in the calculation and an assumed height of a sound receiver of five feet. At lower altitudes the levels of AN will be lower.

Audible Noise Levels Associated with Common Sources

Comparisons of the relative sound intensity of measurements expressed in dB are sometimes difficult for people to understand. An increase in the sound intensity by a factor of 10 increases the decibel rating by adding 10 dB. Increasing the sound intensity by a factor of 100 increases the decibel rating by adding 20 dB. The threshold of hearing for the average human is approximately 20 microPascals (20 millionths of a Pascal –a Pascal is a unit of sound intensity that is power per area squared). The *perceived* loudness of a sound, however, is not linearly proportional to the intensity of the sound. The ear perceives a tenfold increase in the sound intensity as much less than a tenfold increase in the sound level. The human ear requires almost a doubling of the sound intensity (3 dB) in order to perceive a noticeable increase or just-noticeable-difference (JND) in the loudness of the sound. The range of AN levels from the threshold of hearing to the threshold of pain is provided in Table 2. The sound pressure level in

---

[6] Bonneville Power Administration (BPA). 1991. Corona and Field Effects Computer Program.

Pascals, the noise level in dBA, and examples of various noise levels are also provided in the table.

Table 2. Examples of Audible Noise Levels*

Sound Pressure	dBA	Condition
	140	
100 Pa	134	Threshold of Pain
	130	
	|	Pneumatic Wood Chipper; Jackhammer
	120	
10 Pa	114	Loud Auto Horn (~ 3'); Rock Concert
	110	
	|	
	100	
1 Pa	94	Inside Subway Train (NY)
	90	
	|	Inside Bus
	80	
100 milli-Pa	74	Traffic on Street Corner
	70	
	|	Conversational Speech
	60	
10 milli-Pa	54	Typical Business Office
	50	
	|	Suburban Living Room
	40	
1 milli-Pa	34	Quiet Library
	30	
	|	Quiet Bedroom at Night
	20	
100 micro-Pa	14	Broadcast Studio
	10	
	|	
20 micro-Pa	0	Threshold of Hearing

*Adapted from EPRI Transmission Line Reference Book: 345-kV and Above. Palo Alto, CA: EPRI, 1982.

Applicable Standards and Guidelines

Electric and Magnetic Fields

Neither the federal government nor the State of Maine has enacted standards for magnetic fields or electric fields from power lines or other sources at power frequencies. Several other states have statutes or guidelines that apply to fields produced by new transmission lines but these guidelines are not health based. For example, New York and Florida have limits on EMF that were designed to limit fields from new transmission lines to levels produced by existing transmission lines, i.e., to maintain the *status quo*.

More relevant are exposure limits recommended by scientific organizations that were developed to protect health and safety that are based upon reviews and evaluations of relevant health research. These include exposure limits for the general public recommended by ICES[7] and ICNIRP[8] to address health and safety issues. These standards and guidelines are discussed in further detail in Exponent's report "Current Status of Research on Power Frequency Electric and Magnetic Fields", dated September 12, 2008 and filed as Testimony in this proceeding.

Audible Noise

Under the Maine Site Location Law, the Department of Environmental Protection has set forth noise standards that describe fair weather allowable noise levels.[9] The standard

---

[7] 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.

[8] International Commission on Non-Ionizing Radiation Protection (ICNIRP). Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Phys. 74:494-522, 1998.

[9] Department of Environmental Protection "No Adverse Environmental Effect Standard of the Site Location Law," Available online at http://www.maine.gov/sos/cec/rules/06/096/096c375.doc

described in Chapter 375, Section 10 as the “nighttime hourly limit” level for any location that is “not predominantly commercial, transportation or industrial” sets the allowable level at 50 dBA.[10] If the pre-development ambient hourly sound level is equal to or less than 35 dBA, then the nighttime hourly limit is reduced to 45 dBA.[11] The standard also describes that the “developer need not measure or estimate the pre-development ambient hourly sound levels … if he demonstrates by estimate or example, that the hourly sound levels resulting from routine operation of the development will not exceed 50 dBA in the daytime or 40 dBA at night.”[12]

The standard describes measurement methods as using a microphone “positioned at a height of approximately 4 to 5 feet above the ground”[13] and that measurement is avoided when “precipitation would affect the measurement results.”[14]

---

[10] Chapter 375, Section 10 C (1) (a) (ii).
[11] Chapter 375, Section 10 C (1) (a) (v).
[12] Chapter 375, Section 10 C (1) (a) (vi).
[13] Chapter 375, Section 10 H (2) 2.4 (c).
[14] Chapter 375, Section 10 H (2) 2.4 (f).

Results

Electric and Magnetic Fields

Appendix A contains results of EMF calculations for the cross sections listed in Table 1. The tabulated results show the EMF levels at the edge of the ROWs and the maximum within the ROW for annual average and peak loading cases. Appendix B contains graphs displaying magnetic field profiles calculated at annual average loading for the cross sections listed in Table 1.

The EMF levels are highest on the ROW and decrease with distance away from the transmission lines resulting in lower EMF levels at the edge of the ROW and beyond. The effect of the proposed project on existing levels of EMF, however, is complex and varies by cross section.

Generally, the existing magnetic field levels at average load levels will increase along both edges of the ROW in most cross sections after construction; however, the modeled field levels are well below health-based exposure limits recommended by international agencies and also well below standards adopted in the two states (New York and Florida) with limits on magnetic field from transmission lines. In cross sections XS-2A, 7, 17, 18B, 19, 22, and 26, the magnetic field levels will increase on one edge of the ROW and decrease on the other edge of the ROW. For cross sections XS-27A and 27B, the magnetic field will decrease on both sides of the ROW. The change in the magnetic field levels in either direction is less than 25 mG. The electric field levels at the edges of the cross sections under existing conditions range from 0.01 to 0.45 kV/m. After construction, the edge of ROW levels will increase by less than 1.2 kV/m. The magnetic field levels at the edges of ROWs computed at peak loading are not much greater (< 10 mG) than levels at average loading for most cross sections. The computed electric field levels will not change appreciably between average and peak loading conditions because the voltage on conductors, not load, is the source of the electric field. The electric field levels at the edge of the ROW would be less than 1.34 kV/m.

Techniques exist that in some circumstances may reduce magnetic fields by optimizing phase orientations as part of the design process. At the direction of CMP, Power Engineers, in consultation with Exponent, is pursuing these mitigation techniques where possible as part of its more detailed design work, and these efforts may result in the reduction of the modeled magnetic field levels on some or all of the modeled segments.

Audible Noise

Appendix C contains the results of AN calculations summarized in tabular form for the cross sections listed in Table 1.

The AN levels calculated for the proposed lines at the edge of the ROWs are below 25 dBA in fair weather. These fair weather levels are below the “nighttime hourly limit” set by the Maine Site Location Law. In foul weather the noise levels are higher (but less than 50 dBA) at the edge of the ROW but the noise levels during foul weather will be masked by the increase in background AN due to the sound of the rain and wind. These levels are below the level of conversational speech and between the AN levels that might be found in a living room or a business office.