APPENDIX E

ELECTRIC AND MAGNETIC FIELDS AND AUDIBLE NOISE REPORT

United Power Phase III
Transmission Line Project

Electric and Magnetic Fields and Audible Noise

Prepared for

Tri State Generation and Transmission Association
1100 W. 116th Ave.
Westminster, CO 80234

CH2M HILL
9193 South Jamaica Street
Englewood, CO 80112-5946

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UNITED POWER PHASE III TRANSMISSION LINE PROJECT

Introduction

The Tri State Generation and Transmission Association, Inc. (Tri State) is building a new 115 kilovolt (kV) single circuit electric transmission lines to connect Bromley to Prairie Center. The project is called the United Power Phase III Transmission Line Project.

This report describes the modeling of electric and magnetic fields and audible noise produced from corona for the United Power Phase III Transmission Line Project.

Electric and Magnetic Fields from United Power Phase III Transmission Line Project

Electric transmission lines produce EMF when they are in operation. EMF is a term that refers to electric and magnetic fields. These fields are caused by different aspects of the operation of a transmission line and can be evaluated separately.

Electric fields are produced whenever a conductor is connected to a source of electrical voltage. An example of this is the plugging of a lamp into a wall outlet in a home. When the lamp is plugged in, a voltage is induced in the cord to the lamp which causes an electric field to be created around the cord.

Magnetic fields are produced whenever an electrical current flows in a conductor. In the lamp example, if the lamp is turned on allowing electricity to flow to the lamp, a magnetic field is created around the lamp cord in addition to the electric field.

Modeling Methodology

The United Power Phase III Transmission Line Project was modeled for its resulting EMF using EMF Workstation: ENVIRO (Version 3.52), a Windows-based model developed by the Electric Power Research Institute (EPRI). It is a program that accurately predicts the electric and magnetic fields produced by linear transmission lines such as those in the United Power Phase III Transmission Line Project.

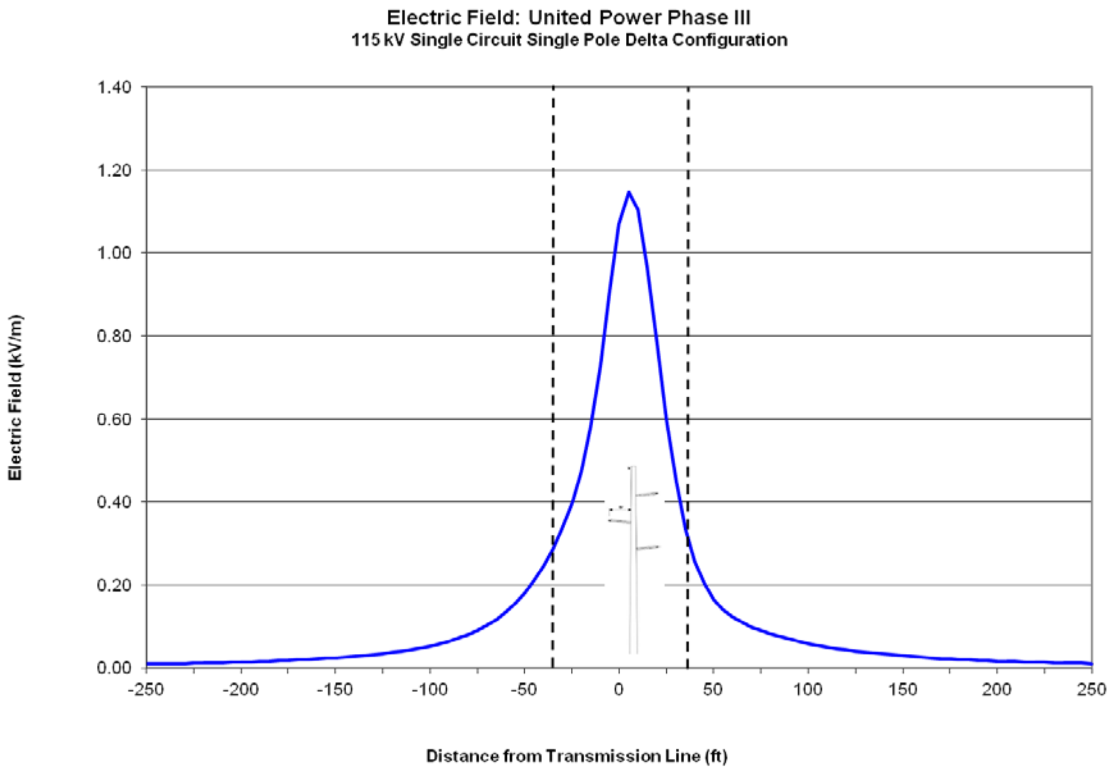
To perform this modeling, detailed information was received from Tri State on the design of the line, which included projected electrical power flows, operating voltage, tower configuration, conductor size and type, the height and horizontal location of each conductor, conductor sag, and conductor phasing. The modeling was conducted with a maximum load power flow. Table A of Appendix A shows the transmission line characteristics used to perform this modeling.

These data were input into the ENVIRO program which produced the lateral profiles of the electric and magnetic fields out to 250 feet on each side of the centerline. These profiles were then plotted to produce the graphs that are presented below. The profiles were calculated with the lowest phase conductor at 28 feet above the ground, the minimum ground clearance per the National Electrical Safety Code (NESC), which coincides with the lowest point of conductor sag, providing the most conservative results. The calculations are computed at a height of 1 meter (3.3 feet) above the ground. The accuracy of the modeling is dependent on the accuracy of the input data (i.e., if the average phase current is higher than what was modeled, so will the resulting magnetic fields). The resulting field plots are within a few percent of the true value for the conditions modeled.

Modeling Results

The United Power Phase III 115 kV transmission line was modeled as a single circuit steel monopole structure. The electric results are presented in Figure 1. The magnetic field results are presented in Figure 2 for the typical and peak load. The transmission line right-a-way (ROW) is 75 feet wide, 37.5 feet on each side of the transmission line, which is shown as vertical dashed lines in Figures 1 and 2.

Figure 1 – Electric Field.



The results of the electric field modeling plotted in Figure 1 show that on the left edge of the ROW the electric field is approximately 0.27 kilovolts per meter (kV/m). On the right edge of the ROW the electric field is approximately 0.30 kV/m. The maximum electric field within the ROW is approximately 1.15 kV/m.

Figure 2 – Magnetic Field at Typical and Peak Load.

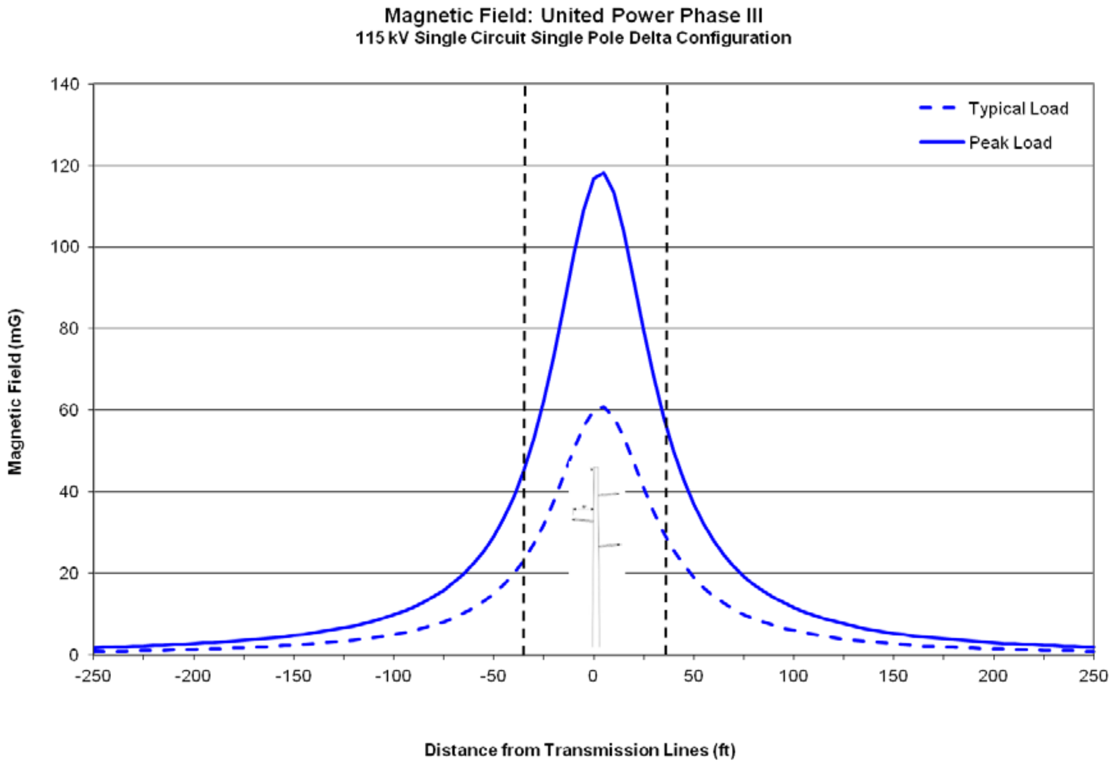


Figure 2 shows the results of the magnetic field modeling with a typical current of 600 A, and a peak current of 1,167 A.

For typical current, on the left edge of the ROW the magnetic field is approximately 21.6 milliGauss (mG). On the right edge of the ROW the magnetic field is approximately 27.9 mG. The maximum magnetic field within the ROW is approximately 60.8 mG.

For peak current, on the left edge of the ROW the magnetic field is approximately 42.0 milliGauss (mG). On the right edge of the ROW the magnetic field is approximately 54.2 mG. The maximum magnetic field within the ROW is approximately 118.3 mG.

Corona Audible Noise from United Power Phase III Transmission Line Project

Corona is the electrical ionization of the air that occurs near the surface of the energized conductor and suspension hardware due to very high electric field strength. Corona may result in audible noise being produced by the transmission lines.

The amount of corona produced by a transmission line is a function of the voltage of the line, the diameter of the conductors, the locations of the conductors in relation to each other, the elevation of the line above sea level, the condition of the conductors and hardware, and the local weather conditions. Power flow does not affect the amount of corona produced by a transmission line. Corona typically becomes a design concern for transmission lines at 345 kV and above and is less noticeable from lines like these that are operated at lower voltages.

The electric field gradient is greatest at the surface of the conductor. Large-diameter conductors have lower electric field gradients at the conductor surface and, hence, lower corona than smaller conductors, everything else being equal.

Irregularities (such as nicks and scrapes on the conductor surface or sharp edges on suspension hardware) concentrate the electric field at these locations and thus increase the electric field gradient and the resulting corona at these spots. Similarly, foreign objects on the conductor surface, such as dust or insects, can cause irregularities on the surface that are a source for corona.

Corona also increases at higher elevations where the density of the atmosphere is less than at sea level. Audible noise will vary with elevation with the relationship of A/300 where A is the elevation of the line above sea level measured in meters (EPRI 2005). Audible noise at 600 meters elevation will be twice the audible noise at 300 meters, all other things being equal. The United Power Phase III Transmission Line Project transmission lines were modeled with an elevation of 5,000 feet.

Raindrops, snow, fog, hoarfrost, and condensation accumulated on the conductor surface are also sources of surface irregularities that can increase corona. During fair weather, the number of these condensed water droplets or ice crystals is usually small and the corona effect is also small. However, during wet weather, the number of these sources increases (for instance due to rain drops standing on the conductor) and corona effects are therefore greater. During wet or foul weather conditions, the conductor will produce the greatest amount of corona noise. However, during heavy rain the noise generated by the falling rain drops hitting the ground will typically be greater than the noise generated by corona and thus will mask the audible noise from the transmission line.

Corona produced on a transmission line can be reduced by the design of the transmission line and the selection of hardware and conductors used for the construction of the line. For instance the use of conductor hangers that have rounded rather than sharp edges and no protruding bolts with sharp edges will reduce corona. The conductors themselves can be made with larger diameters and handled so that they have smooth surfaces without nicks or burrs or scrapes in the conductor strands.

Modeling Methodology

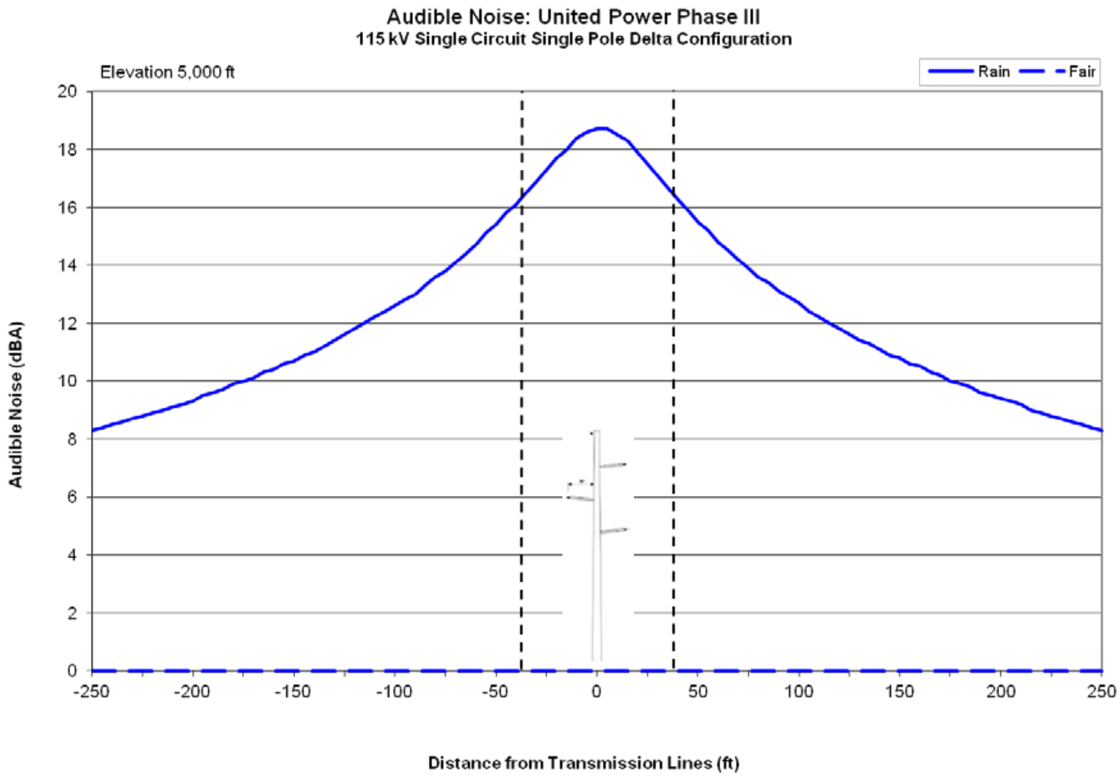
The audible noise from the proposed transmission lines was predicted using EMF Workstation: ENVIRO (Version 3.52), a Windows-based model developed by the EPRI.

The data presented in Table A of Appendix A were input into the ENVIRO program to calculate the corona audible noise, with the addition of elevation of the line above sea level. The United Power Phase III Transmission Line Project transmission lines were modeled with an elevation of 5,000 feet. Because the equations that predict audible noise were created from empirical measurements, the accuracy of the model is as good as these measurements that produced the original equations. In addition, the model is as good as the accuracy of the parameters input to the model (e.g. the actual elevation of the transmission line at a particular location rather than the average elevation of the entire project). Therefore given these potential uncertainties, the resulting field plots are within a few percent of the true value for the conditions modeled.

Modeling Results

The United Power Phase III 115 kV transmission line was modeled as a single circuit steel monopole structure. The corona audible noise plot is presented in Figure 3. The transmission line ROW is 75 feet wide, 37.5 feet on each side of the transmission line, which is shown as vertical dashed lines in Figure 3. The figure shows two conditions, fair and rain. This is to show the range in corona effects due to changing weather.

Figure 3 – Corona Audible Noise.



The results of the corona audible noise modeling plotted in Figure 3 show that across the ROW the audible noise is negligible in fair weather. In wet weather, the audible noise is 16.3 dBA on the left ROW edge and 16.5 dBA on the right ROW edge. The maximum noise that occurs on the ROW is 18.7 dBA in wet weather.

APPENDIX A

ENVIRO Modeling Inputs

Table A – Transmission Line Characteristics for Input to ENVIRO Modeling

Circuit	Voltage (kV)	Power Flow (Amps)	Conductor[1]	Phase (top to bottom/ right to left)	Horizontal Location (ft)	Vertical Location (ft)
Single	115	1167 (Peak) 600 (Typical)	795 kcmil, 26/7, ACSR, “Drake”, 1.108 inch diameter	A	4.4	46
				B	-4.4	37
				C	4.4	28
				Ground	0	54.5

[1] 3/8 EHS with diameter of 0.360 inches used from ENVIRO Database for shield wire.