Appendix J – Electric and Magnetic Field (EMF) Report

CROCKER WIND FARM

Clark County, SD

TITLE:

Electric and Magnetic Field (EMF) Report

345 kV Transmission Line

PRELIMINARY

NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	BY
AA	2/17/17	Preliminary	JEP/SSF
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1 EXECUTIVE SUMMARY

This report focuses on the Electric and Magnetic Fields (EMF) studies that were performed on the Crocker Wind 345kV Transmission Line. The purpose of the EMF analysis is to determine the maximum electric and magnetic fields that will be produced by the proposed 345kV Transmission Line. The study is broken into two separate calculations: Electric field and Magnetic field. The electric field is a function of the overall operating voltage of the proposed transmission line, which increases in intensity around a given conductor as voltage increases. Magnetic field is a function of the maximum operating current of the proposed transmission line, which increases around a given conductor as current increases. Both electric field and magnetic field values are affected by line geometry and distance from the energized conductor.

The electric and magnetic field calculations in this report were based on the use of 954 54/7 "Cardinal" ACSR conductor in a 2-bundle configuration. Wire heights were based on a minimum ground clearance of 27'-9", and the typical tangent structure. The typical tangent structure upon which the calculations were based is a single pole, braced post structure with 15' vertical phase spacing and braced posts that extend horizontally approximately 14.5' from the pole centerline. The right-of-way width being studied is 150 feet. The Crocker Wind Farm turbine output will be 200MW, which equates to approximately 375 amps at 345kV.

The calculated maximum electric field intensity for the Crocker wind 345kV transmission line is 6.74kV/m occurring at 15 feet from the proposed transmission line centerline, and 1.11kV/m at the edge of the proposed right-of-way. The calculated maximum magnetic field intensity for the Crocker Wind 345kV transmission line is 62.98 MilliGauss at 10 feet from the proposed transmission line centerline, and 12.41 MilliGauss at the edge of the proposed right-of-way.

These calculated values are well-within industry standards, and no adverse impacts are expected due to the presence of the electric and magnetic fields caused by the proposed Crocker Wind 345kV transmission line.

2 ADDITIONAL INFORMATION

Concerns about health effects of EMF from power lines were first raised in the late 1970s. Since then, considerable research has been conducted to determine if exposure to magnetic fields, such as those from high-voltage power lines, causes biological responses and health effects. Initial epidemiological studies completed in the late 1970s showed a weak correlation between surrogate indicators of magnetic field exposure (such as wiring codes or distance from roads) and increased rates of childhood leukemia (Wertheimer et. al, 1979). Toxicological and laboratory studies have not shown a biological mechanism between EMF and cancer or other adverse health effects. In 2007, the World Health Organization ("WHO") concluded a review of health implications from magnetic fields and concluded, "virtually all of the laboratory evidence and the mechanistic evidence fail to support a relationship between low-level ELF magnetic fields and changes in biological function or disease status" (WHO, 2007). Natural and human-made electromagnetic fields are present everywhere in our environment. Natural electric fields in the atmosphere range from background static levels of 10 to 120 volts per meter ("V/m") to well over several kilovolts per meter ("kV/m") produced by the build-up of electric charges in thunderstorms. The Earth itself has a magnetic field that ranges from approximately 300 to 700 milligauss ("mG"). In addition to the presence of the earth's steady state electric field, an average home experiences additional magnetic fields of 0.5 mG to 4 mG which arise from the general wiring and appliances located in a typical home (National Cancer Institute, 2009).

Considerable research has been conducted throughout the past three decades to determine whether exposure to power-frequency (60 hertz) EMF causes biological responses and health effects. Epidemiological and toxicological studies have shown no statistically significant association or weak associations between EMF exposure and health risks. In 1999, the National Institute of Environmental Health Sciences ("NIEHS") issued its final report on "Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields" in response to the Energy Policy Act of 1992. NIEHS concluded that the scientific evidence linking EMF exposures with health risks is weak and that this finding does not warrant aggressive regulatory concern. However, because of the weak scientific evidence that supports some association between EMF and health effects, and the common exposure to electricity in the United States, passive regulatory action, such as providing public education on reducing exposures, is warranted. Minnesota, California and Wisconsin have all conducted literature reviews or research to examine this issue. In 2002, Minnesota formed an Interagency Working Group to evaluate the body of research and develop policy recommendations to protect the public health from any potential problems resulting from high voltage transmission line EMF effects. The Working Group consisted of staff from various state agencies. The Working Group published its findings in a White Paper on EMF Policy and Mitigation Options in September 2002 (Minnesota Interagency Working Group, 2002). The findings of the Working Group are summarized in the following paragraph: "Research on the health effects of EMF has been carried out since the 1970s. Epidemiological studies have mixed results — some have shown no statistically significant association between exposure to EMF and health effects, some have shown a weak association. More recently, laboratory studies have failed to show such an association, or to establish a biological mechanism for how magnetic fields may cause cancer. A number of scientific panels convened by national and international health agencies and the United States Congress have reviewed the research carried out to date. Most researchers concluded that there is insufficient evidence to prove an association between EMF and health effects; however, many of them also concluded that there is insufficient evidence to prove that EMF exposure is safe."

The State of Minnesota's Public Utilities Commission and before them, the Minnesota Environmental Quality Board ("EQB") have recently addressed the matter of EMF with respect to new transmission lines in a number of separate dockets over the past few years. Recently, in the Brookings County – Hampton 345 kV Route Permit proceeding, after extensive testimony on the issue, the Commission adopted the administrative law judge's findings that "there are no demonstrated impact on human health and safety that is not adequately addressed by the existing State standards for [electric fields or magnetic fields] exposure." In the Matter of the Route Permit Application by Great River Energy and Xcel Energy for a 345 kV Transmission Line from Brookings County, South Dakota to Hampton, Minnesota, Docket No. ET2/TL-08-1474, ALJ Findings of Fact, Conclusions and Recommendation at Finding 216 (April, 22, 2010 and amended April 30, 2010; adopted by the Commission in its Order Granting Route Permit, at 12 (September 14, 2010).

3 STUDY CRITERIA

3.1 Study Purpose

The purpose of this EMF analysis is to determine the maximum predicted electric and magnetic field levels produced by the 345kV Transmission Line at the location of their maximum intensities, and at the edge of the proposed right-of-way.

3.2 Software Used

The software used for both electric and magnetic field calculations was developed by Bonneville Power Administration (BPA). Two different programs were used; MF CALC (for the magnetic field), and EF CALC (for the electric field). The BPA method for calculating electric and magnetic fields is an empirical method developed from long-term measurements on a number of full-scale operating or test lines. It is specifically designed to calculate electric and magnetic fields based on phase configuration, conductor size, number of conductors, and voltage (electric field), and current flow (magnetic field).

3.3 Assumptions

The proposed conductor for the 345kV Transmission Line is 954 54/7 ACSR "Cardinal."

- 1.196 in. diameter
- Two conductors per phase

Typical single circuit direct-embedded steel poles in delta configuration

- 15.0 feet spacing between phases
- Minimum ground clearance of 27'-9" feet when conductor is at max sag

Right-of-way width is 150 feet for the purposes of these calculations.

4 RESULTS

Magnetic Field

Magnetic fields are present around any electrical conductor and electrical device, including household wiring, electrical distribution lines, substation equipment, and household appliances. The magnetic field intensity, or magnetic flux density, is measured in MilliGauss, and is proportional to the current flow on the transmission line. It is calculated at one meter (3.28 feet) above the ground, with maximum turbine output and at the lowest point of sag. Measurable magnetic field will only occur in the immediate vicinity of transmission lines, as it decreases in strength the further away from the energized conductors.. Some examples of common sources of magnetic fields, and their intensities, measured in MilliGauss (mG), is listed below.

Appliance	Distance from Source		
	6 inches	1 foot	2 feet
Hair Drier	300	1	--
Electric Shaver	100	20	--
Can Opener	600	150	20
Electric Stove	30	8	2
Television	NA	7	2
Portable Heater	100	20	4
Vacuum Cleaner	300	60	10
Copy Machine	90	20	7
Computer	14	5	2

Source: *EMF In Your Environment* (EPA 1992).

The calculated peak magnetic field expected from the proposed Crocker Wind 345kV transmission line is 62.98 mG, which occurs at approximately 10 feet from the proposed transmission line centerline. At 75 feet from the proposed centerline transmission line (the edge of the right-of-way), the calculated peak magnetic field is 12.41 mG. The peak magnetic field intensities occur at the maximum turbine output from the Crocker Wind farm, which is approximately 375 amps at 345kV. The magnetic field's maximum intensity occurs at 10 feet from the centerline due to the delta phase configuration of the transmission line tangent structure (two phase conductors are on one side of the pole, and the third phase is on the other side of the pole). Maximum field levels occur under the conductors on the side of the structure with two phases.

Because the magnetic field varies with current flow through the conductors on the transmission line, the normal magnetic field when the Crocker Wind project is in operation will be of much weaker intensity. Actual current flow (and associated magnetic fields) will vary throughout the day as wind speed changes, and turbine output varies. Peak output of the wind project is only anticipated a limited number of times throughout a given year.

There are no federal regulations on maximum magnetic field intensity, however, Florida and New York both limit the magnetic fields on new transmission lines to 200 MilliGauss at the edge of the right of way. The peak magnetic field intensity on the Crocker Wind project, as described above, is far below this level.

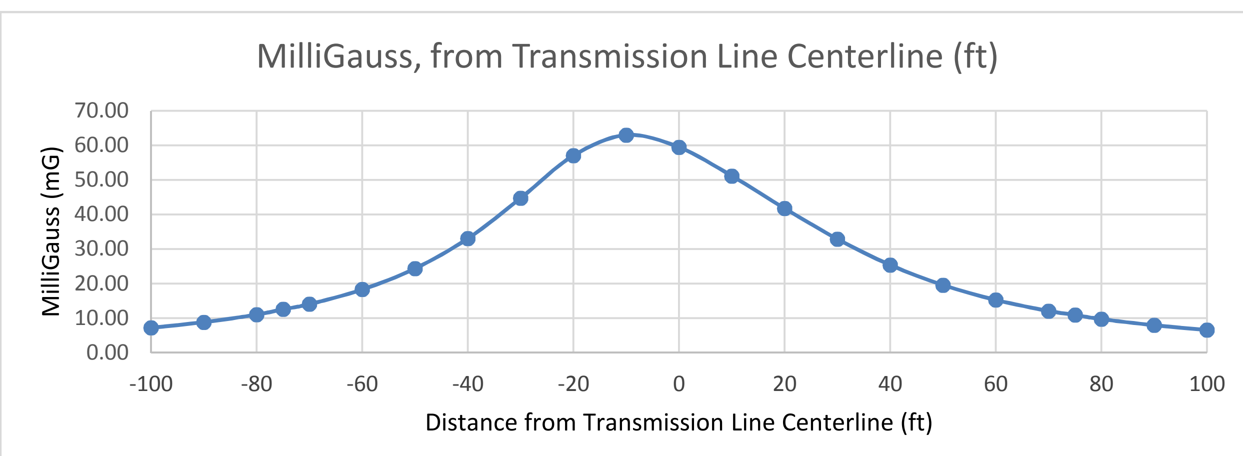
Table 1: Input Data, with maximum combined turbine output

Conductor	X-feet	Y-feet	Amps	Phase (deg)
1	14.5	57.5	375	0
2	-14.5	42.5	375	120
3	14.5	27.5	375	240

Table 1a: Calculated Magnetic Field Results

Magnetic Field Results, MilliGauss																	
	Left								CL	Right							
Feet from CL	-75	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	75
MilliGauss	12.41	14.05	18.29	24.37	33.06	44.75	57.06	62.98	59.45	51.16	41.77	32.87	25.38	19.58	15.26	12.07	10.81

Graph 1: Maximum Magnetic Field (in MilliGauss) at one meter above ground at distances in feet from centerline of transmission line (single pole delta configuration).



Electric Field

Electric fields, like magnetic fields, generally only occur within the immediate vicinity of transmission lines, and are present around any electrical device. The further away from the energized conductors (or device), the weaker the electric field strength. However, unlike magnetic fields, electric fields increase intensity with voltage, rather than current. Electric fields can induce current on nearby conductor objects, such as metal shovels, metal tanks, metal fences, etc. It is also possible for humans to also become electrically charged when underneath a transmission line. This normally goes unnoticed, and is generally harmless.
The electric field is measured in kilovolts per meter (kV/m) and is proportional to the voltage on the transmission line. It is calculated at one meter (3.28 feet) above the ground, with maximum line voltage, and at lowest point of sag. Maximum conductor voltage is defined as the phase-to-ground operating voltage plus 5% to account for potential overvoltage situations. (5% overvoltage is an industry standard value used as voltage can vary slightly depending on system conditions.) This equates to 209 kV when considering a transmission line with phase-to-phase voltage of 345kV. Table 2 below shows the input values for the calculation.

The maximum electric field for the Crocker Wind project is calculated to be 6.73 kV/m at 15 feet from the proposed transmission line centerline. At 75 feet from the proposed transmission line centerline (the edge of the proposed right-of-way), the calculated electric field is 1.11 kV/m. The maximum electric field occurs 15 feet offset from the transmission line centerline due to the delta phase configuration of the transmission line poles (two phase conductors are on one side of the pole, and the third phase is on the other side of the pole). Maximum field levels occur directly under the phase conductor on the side of the structure with two phases. Graph 2 below illustrates the electric field intensity as compared to the proposed transmission line centerline.

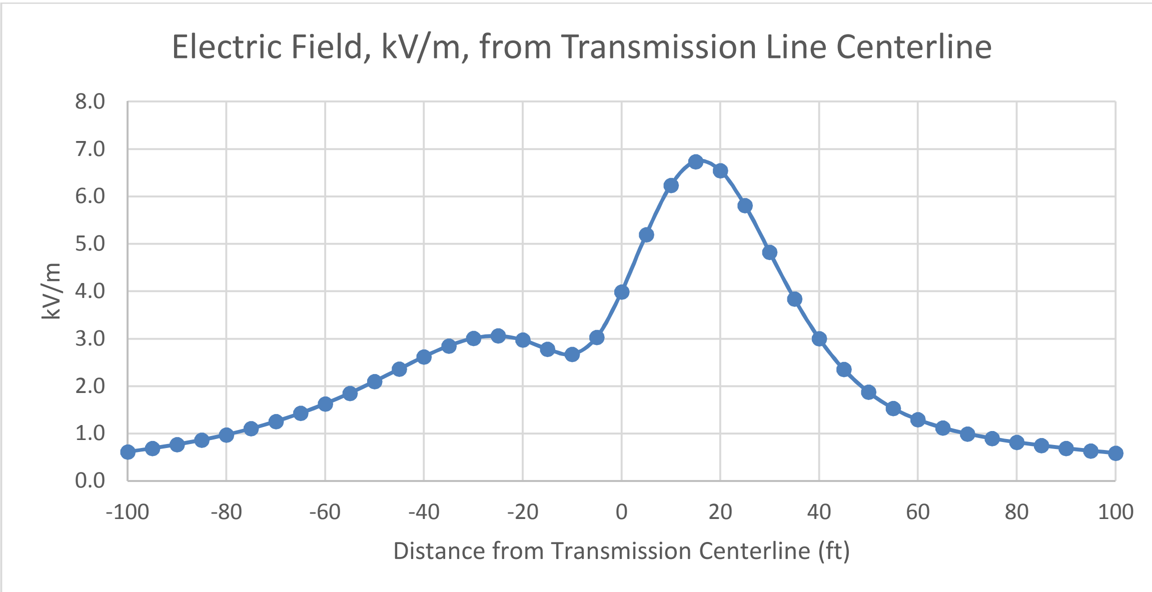
Table 2: Input Data at 5% overvoltage

Conductor	X-feet	Y-feet	N cond	Conductor Diameter (in.)	Phase-Ground voltage (with overvoltage) (kV)	Phase (deg)
1	14.5	57.5	2	1.196	209	0
2	-14.5	42.5	2	1.196	209	120
3	14.5	27.5	2	1.196	209	240

Table 2a: Calculated Electric Field Results

Electric Field Results, kV/m																	
	Left								CL	Right							
Feet from CL	-75	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	75
kV/m	1.11	1.26	1.63	2.10	2.62	3.01	2.98	2.67	3.99	6.24	6.55	4.82	3.01	1.88	1.29	1.00	0.90

Graph 2: Maximum Electric Field in kV per meter at one meter above ground, at distances in feet from the centerline of the transmission line (single pole, delta configuration)



There are currently no regulations in the state of South Dakota for maximum electric field intensity from a power transmission line. However, neighboring states North Dakota and Minnesota do require that new transmission lines limit maximum electric fields to 9 kV/m and 8 kV/m, respectively, within the right-of-way. The Crocker Wind project electric field levels will be below these thresholds.

5 CONCLUSIONS

Based on the results in Section 3, both the electric and magnetic field levels are well within industry recommendations when calculated with 2-bundle 954 54/7 ACSR "Cardinal" conductor. No adverse impacts are anticipated based on the study results, therefore no mitigation is required at this time.

6 REFERENCES

Minnesota State Interagency Working Group on EMF Issues. September 2002. A White Paper on Electric and Magnetic Field (EMF) Policy and Mitigation Options. http://mn.gov/commerce/energyfacilities/documents/EMF%20White%20Paper%20-%20MN%20Workgroup%20Sep%202002.pdf.

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