Calumet to Comanche Transmission Line Project

Magnetic Fields and Audible Noise

A report prepared by

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SAN LUIS VALLEY-CALUMET-COMANCHE PROJECT

Introduction

Xcel Energy (Xcel) in partnership with Tri State Generation and Transmission Association, Inc. (Tri State) are building a new set of electric transmission lines to connect the San Luis Valley of South Central Colorado to the Colorado Front Range. The project is called the San Luis Valley-Calumet-Comanche Project.

Three segments of lines will be built. The first lines will run from the San Luis Valley Substation north of Alamosa east over La Veta pass to a new Calumet Substation to be built north of Walsenburg. The Calumet Substation will then be connected by Tri State to the existing Walsenburg Substation. The Calumet Substation will also be connected by Xcel Energy to the Comanche Substation at the Comanche Power Plant near Pueblo.

This report describes the modeling of magnetic fields and audible noise produced from corona for Calumet to Comanche 345 kilovolts (kV) double circuit line. Tri State will model and report on the magnetic fields and audible noise for the two segments from San Luis Valley to Calumet and from Calumet to Walsenburg for the project.

Magnetic Fields from San Luis Valley-Calumet-Comanche 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. Magnetic fields are evaluated in this report.

Magnetic fields are produced whenever an electrical current flows in a conductor. An example of this is the plugging of a lamp into a wall outlet in a home. When the lamp is plugged in and turned on allowing electricity to flow to the lamp, a magnetic field is created around the lamp cord.

Modeling Methodology

The transmission lines of the San Luis Valley-Calumet-Comanche Project were modeled for their resulting magnetic fields using EMF Workstation: ENVIRO (Version 3.51), a Windows-based model developed by the Electric Power Research Institute (EPRI). It is a program that accurately predicts the magnetic fields produced by linear transmission lines such as those in the San Luis Valley-Calumet-Comanche project.

Two scenarios were modeled for this segment of the project. The first was a new double circuit 345 kV line built in the center of the proposed 200 foot ROW. The second was a new double circuit 345 kV line built adjacent to the existing Tri State single circuit 230 kV line.

To perform this modeling, the design of each of these lines, 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 three cases of power flows: Case #1 with normal load flows for 2015, Case #2 with the maximum normal loading on the line, and Case #3 with emergency outage capacity of the conductors. Table A-1 of Appendix A shows the power flows for each circuit in Cases #1, #2, and #3, and the conductor size and type and operating voltage used for each circuit in the two locations modeled. Table A-2 of Appendix A presents the height and horizontal location of each conductor, conductor sag, and conductor phasing.

The new Calumet to Comanche 345 kV double circuit line was modeled with a single steel pole structure for scenario 1. For scenario 2, the same double circuit 345 kV structures were modeled next to the existing Comanche to Walsenburg 230 kV single circuit line.

These data were input into the ENVIRO program which produced the lateral profiles of the electric and magnetic fields. These profiles were then plotted to produce the graphs that are presented below. The program calculated the profiles at the lowest point of conductor sag. 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.

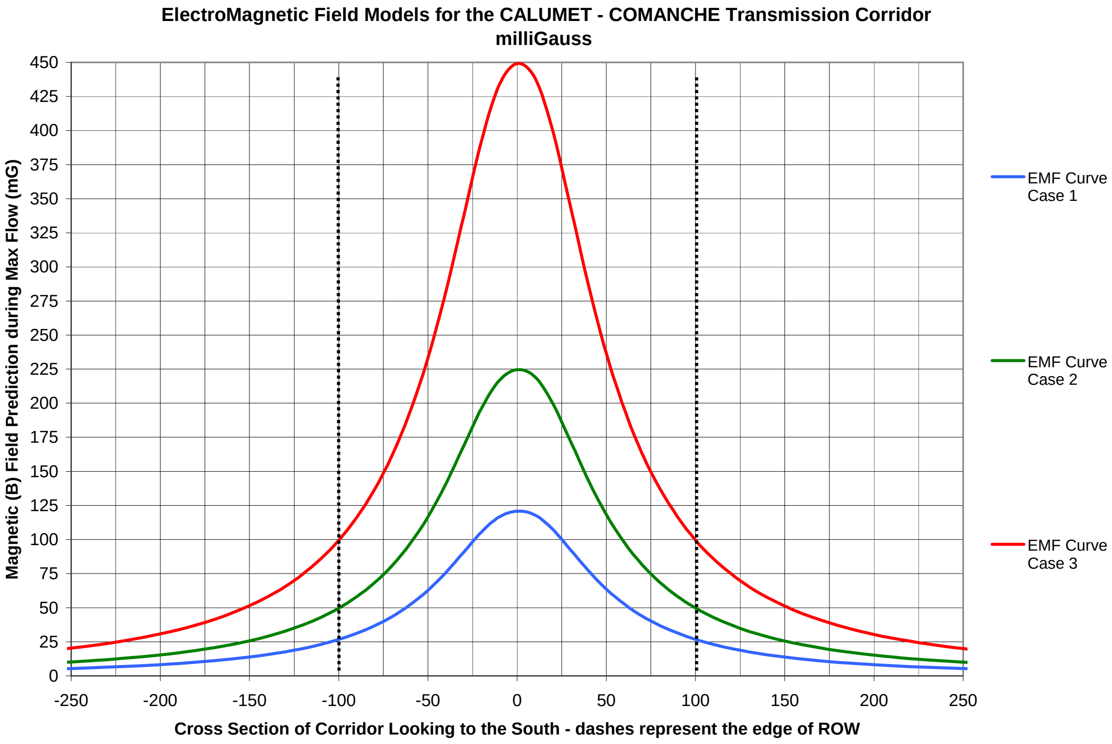
Modeling Results

The magnetic field plots for Case #1, Case #2, and Case #3 for the new Calumet to Comanche 345 kV double circuit line, scenario 1 are presented in Figure 1.

The magnetic field plots for Case #1, Case #2, and Case #3 for the new Calumet to Comanche 345 kV double circuit line, scenario 2 are presented in Figure 1.

Calumet to Comanche, Scenario 1

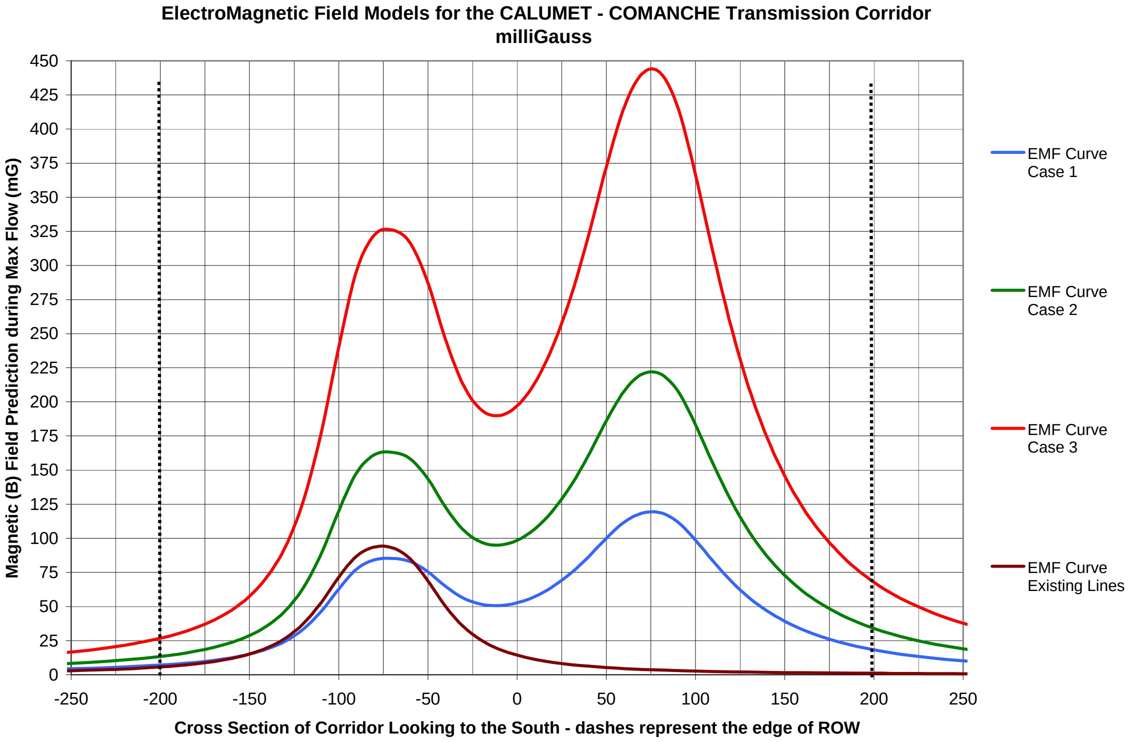
Figure 1, Magnetic field plot for Case #1, Case #2, and Case #3 for Calumet to Comanche 345 kV double circuit line, scenario 1. The conductor phasing on this structure configuration have been rotated to reduce the magnetic fields.



The results of the magnetic field modeling plotted in Figure 1 show that on both the right and left ROW edge the magnetic field is 26.8 mG for Case #1, 49.8 mG for Case #2, and 99.6 mG for Case #3.

Calumet to Comanche, Scenario 2

Figure 2, Magnetic field plot for Case #1, Case #2, and Case #3 for the Calumet to Comanche 345 kV double circuit line, scenario 2.



The results of the magnetic field modeling plotted in Figure 2 show that on the ROW edge the magnetic field are 15.1 mG & 18.3 mG for Case #1, 28.8 mG & 33.9 mG for Case #2, and 57.6 mG & 67.9 mG for Case #3.

Corona Audible Noise from San Luis Valley-Calumet-Comanche 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 therefore only one set of corona results is predicted for each modeled location: the new Calumet to Comanche 345 kV double circuit line scenario 1 and the Calumet to Comanche 345 kV double circuit line scenario 2.

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. The conductors chosen for the Calumet to Comanche line were selected to have large diameters and to utilize a two conductor bundle. This reduces the potential to create audible noise.

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. An increase in 1000 feet of elevation will result in an increase in audible noise of approximately 1 dB(A). Audible noise at 5000 feet in elevation will 5 dB(A) higher than the same audible noise at sea level, all other things being equal. The new Calumet to Comanche 345 kV double circuit line was modeled with an elevation of 6000 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. The transmission lines proposed here are designed to reduce corona generation.

Modeling Methodology

CPUC Rule 3102 requires that the applicant for a CPCN for a new transmission line model the potential noise levels that the line could produce.

The audible noise from the proposed transmission lines was predicted using EMF Workstation: ENVIRO (Version 3.51), a Windows-based model developed by the Electric Power Research Institute (EPRI).

The data presented in Tables A-1 and A-2 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 new Calumet to Comanche 345 kV double circuit line was modeled with an elevation of 6,000 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

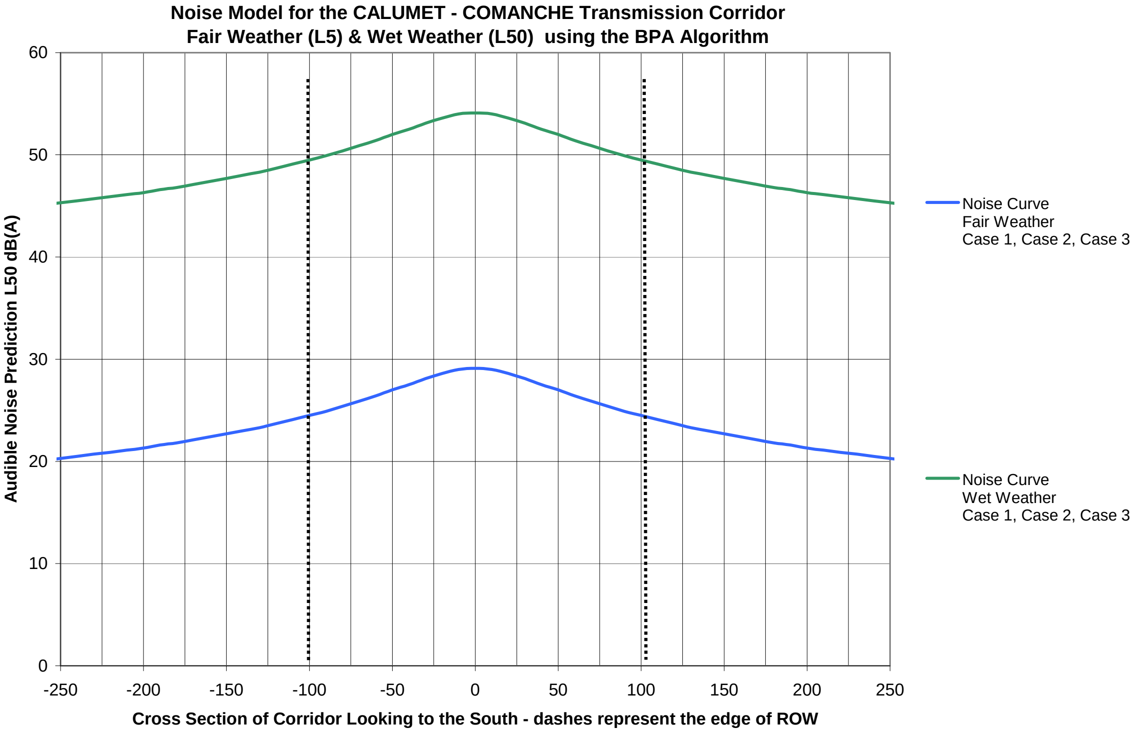
Figure 3 shows the audible noise modeled for the new Calumet to Comanche 345 kV double circuit line, scenario 1.

Figure 4 shows the audible noise modeled for the Calumet to Comanche 345 kV double circuit line scenario 2.

The figures show two conditions, fair and rain. This is to show the range in corona effects due to changing weather.

Calumet to Comanche, Scenario 1

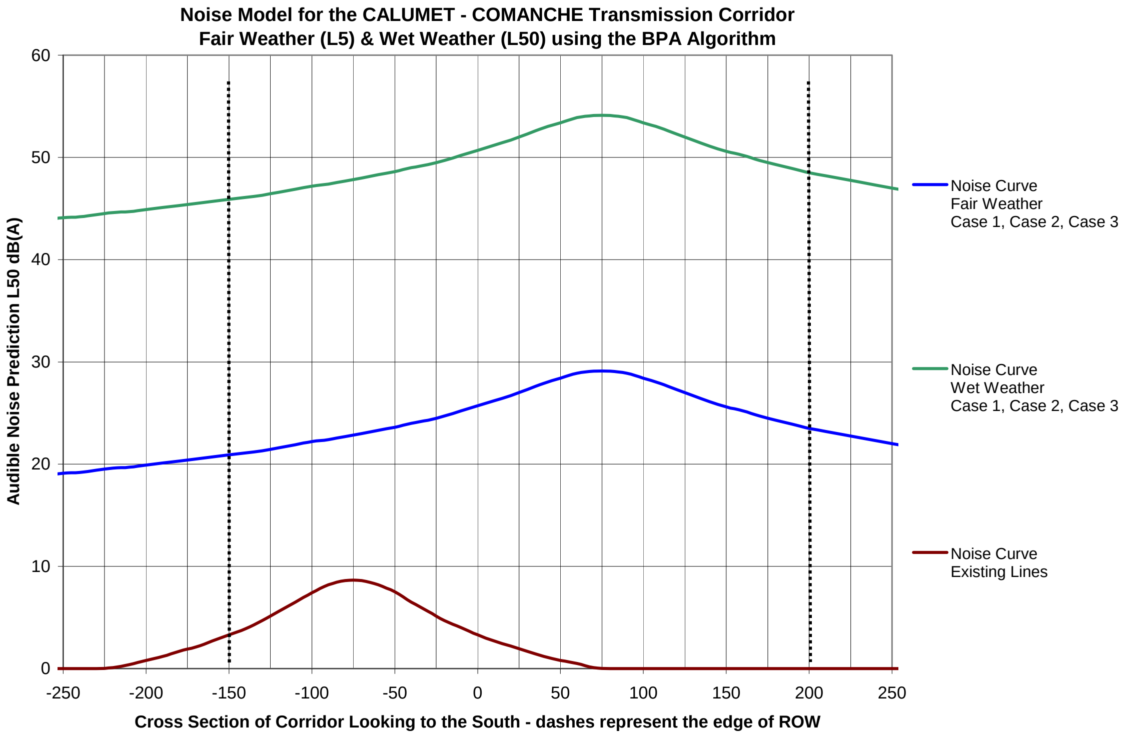
Figure 3, Audible noise for the Calumet to Comanche 345 kV double circuit line scenario 1.



The audible noise at both the right and left ROW edge is 24.5 dB(A) in fair weather and 49.5 dB(A) in wet weather. The maximum noise that occurs within the ROW is 29.1 dB(A) in fair weather and 54.1 dB(A) in wet weather.

Calumet to Comanche, Scenario 2

Figure 4, Audible noise for Calumet to Comanche 345 kV double circuit line scenario 2.



The audible noise that is modeled at the ROW edge will be 20.9 dB(A) & 22.8 dB(A) in fair weather and 45.9 dB(A) & 47.8 dB(A) in wet weather. The maximum noise that occurs within the ROW is 29.1 dB(A) in fair weather and 54.1 dB(A) in wet weather.

APPENDIX A
ENVIRO Modeling Inputs

Table A-1 – Projected Electrical Power Flows, Conductor Size and Type, and Operating Voltage

		New Calumet to Comanche 345 kV double circuit line, Scenario 1		**New Calumet to Comanche 345 kV double circuit line, Scenario 2**		
	Line	**Calumet to Comanche #1 line**	**Calumet to Comanche #2 line**	**Existing Comanche – Walsenburg 230 kV Single Circuit**	**Calumet to Comanche #1 line**	**Calumet to Comanche #2 line**
	Conductor Type	Two conductor bundle 1272 MCM ACSR Bittern[1]	Two conductor bundle 1272 MCM ACSR Bittern[1]	One conductor 1272 MCM ACSR Bittern[1]	Two conductor bundle 1272 MCM ACSR Bittern[1]	Two conductor bundle 1272 MCM ACSR Bittern[1]
Case 1						
CASE #1	**Typical forecasted 2015 peak flow, (Amperes)**	780	780	380	780	780
Case 2						
CASE #2	**Maximum Non-emergency peak flow, (Amperes)**	1450	1450	725	1450	1450
Case 3						
CASE #3	**Maximum Emergency peak flow, (Amperes))**	2900	2900	1450	2900	2900

[1] 1272 ACSR Bittern conductor has a diameter of 1.345 inches.

Table A-2 – Conductor Height and Horizontal Location, Conductor Sag, and Conductor Phasing

Line	Phase (top to bottom/ left to right)	Horizontal Location (ft)	Height (ft)	Minimum Ground Clearance (ft)
New Calumet to Comanche 345 kV double circuit line, Scenario 1				
Calumet to Comanche #1 line	A	-11	80	34
	B	-13	57	34
	C	-21	34	34
	Ground	-10	90	
Calumet to Comanche #2 line	C	11	80	34
	B	13	34	34
	A	11	57	34
	Ground	21	120	
New Calumet to Comanche 345 kV double circuit line, Scenario 2				
Existing Comanche - Walsenburg 230 kV Single Circuit	C	-95.5	34	28
	B	-75	34	28
	A	-55..5	34	28
	Ground	-85	52	
	Ground	-65	52	
Calumet to Comanche #1 line	A	64	80	34
	B	62	57	34
	C	64	34	34
	Ground	54	90	
Calumet to Comanche #2 line	C	88	57	34
	B	86	34	34
	A	86	80	34
	Ground	96	90	