San Luis Valley to Calumet to Walsenburg Transmission Line Project

Magnetic Fields and Audible Noise

Prepared for

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Introduction

The Tri State Generation and Transmission Association, Inc. (Tri State) in partnership with Xcel Energy (Xcel) 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 the two segments from San Luis Valley to Calumet and from Calumet to Walsenburg. Xcel will model and report on the magnetic fields and audible noise for the Calumet to Comanche 345 kilovolts (kV) double circuit line segment of 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 3.52), 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 locations were modeled: the new San Luis Valley to Calumet 230 kV double circuit line, and the Calumet to Walsenburg Transmission Corridor, which consists of the existing Comanche to Walsenburg 230 kV single circuit line on the east side of the corridor, the new double circuit line occupying the center of the corridor with the Calumet to Walsenburg 230 kV circuit on the east side of the structure and the Stem Beach to Walsenburg 115 kV circuit on the west side of the structure, and the existing ARCO to Walsenburg 115 kV single circuit line on the west side of the corridor.

To perform this modeling, detailed information was received from Tri State on 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 no generation injection, Case #2 with 2,000 megawatts (MW) of total injection (1,000 MW to the San Luis Valley, and 1,000 MW to Calumet), and Case #3 with full thermal limit 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 San Luis Valley to Calumet 230 kV double circuit line was modeled with a single steel pole structure; however a lattice steel structure is being considered as well. The slight differences in configuration should not significantly alter the modeling results. For the Calumet to Walsenburg Transmission Corridor, the existing Comanche to Walsenburg 230 kV single circuit line on the east side of the corridor was modeled with an H-frame structure, the new double circuit line occupying the center of the corridor with the Calumet to Walsenburg 230 kV circuit on the east side of the structure and the Stem Beach to Walsenburg 115 kV circuit on the west side of the structure was modeled with a single steel pole structure, and the existing ARCO to Walsenburg 115 kV single circuit line on the west side of the corridor was modeled with an H-frame structure.

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 mid-span, the lowest point of conductor sag. For the two locations modeled a span length of 800 feet was used, therefore mid-span occurred at approximately 400 feet. 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.

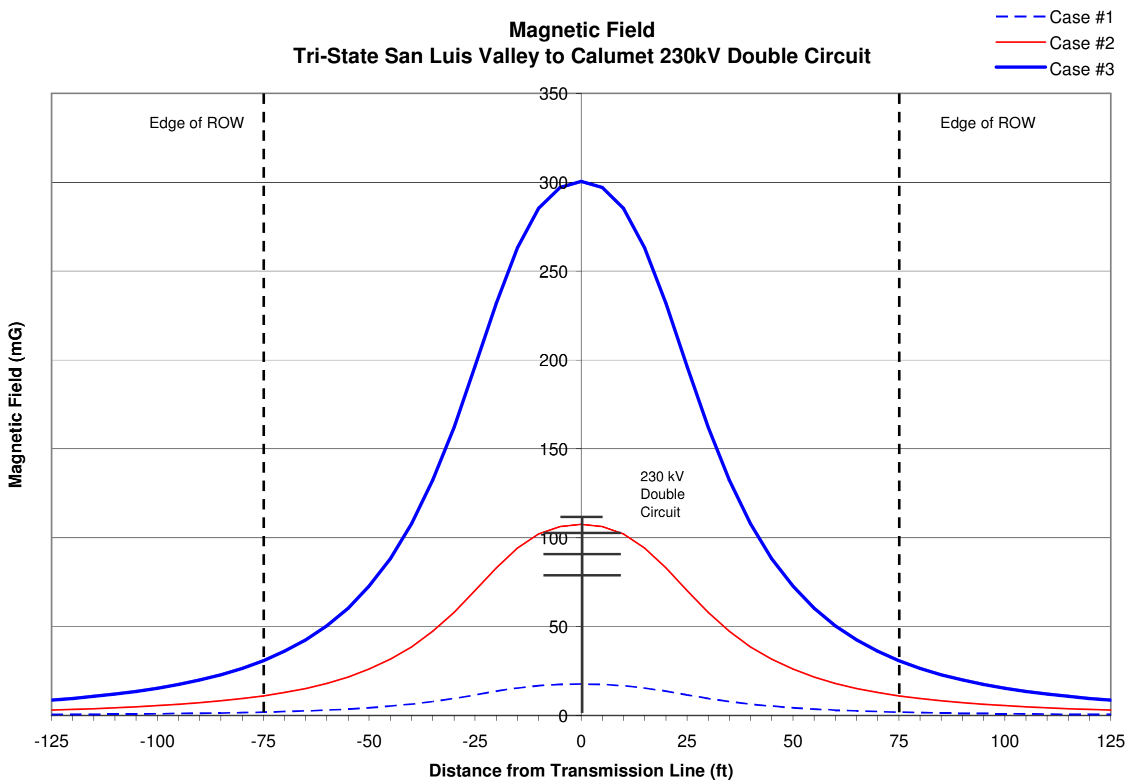
Modeling Results

The magnetic field plots for Case #1, Case #2, and Case #3 for the new San Luis Valley to Calumet 230 kV double circuit line are presented in Figure 1.

The magnetic field plots for Case #1, Case #2, and Case #3 for the Calumet to Walsenburg Transmission Corridor are presented in Figure 2.

San Luis Valley to Calumet

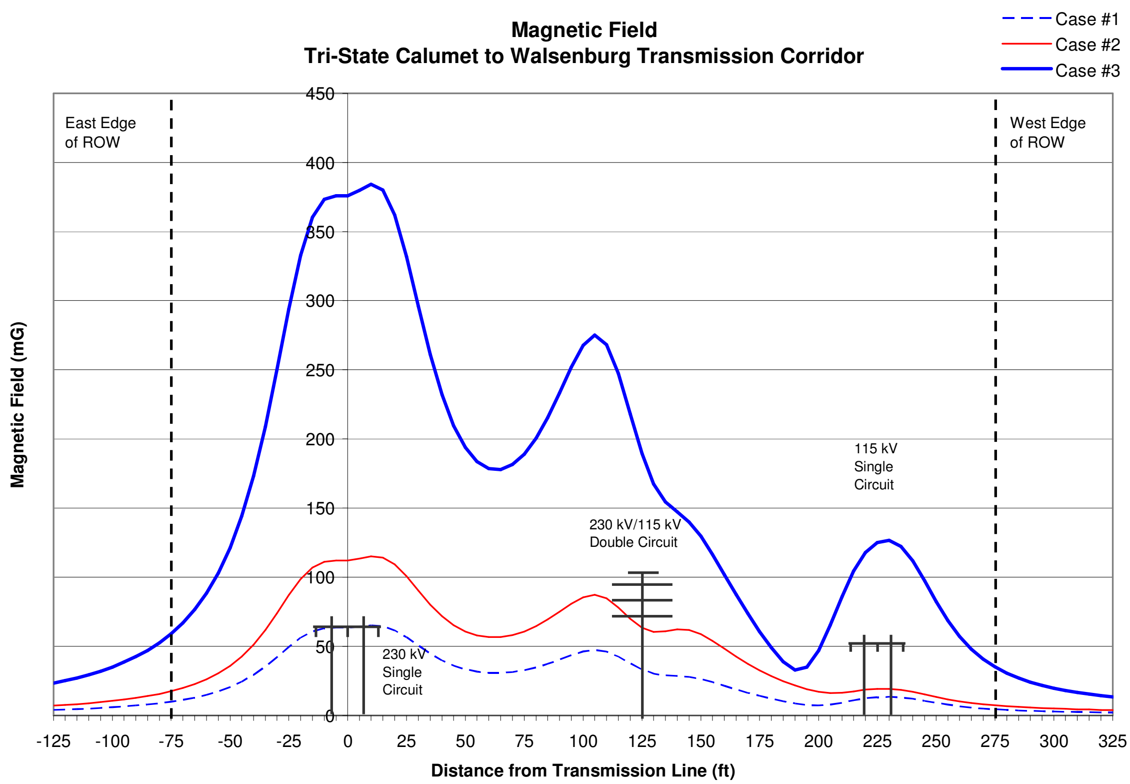
Figure 1, Magnetic field plot for Case #1, Case #2, and Case #3 for San Luis Valley to Calumet 230 kV double circuit line. The conductor phasing on this structure configuration have been rotated as shown in Table A-2 of Appendix A to reduce the magnetic fields.



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 1.8 mG for Case #1, 11.0 mG for Case #2, and 30.8 mG for Case #3. The maximum magnetic field within the ROW is 17.6 mG for Case #1, 107.5 mG for Case #2, and 300.6 mG for Case #3.

Calumet to Walsenburg Transmission Corridor

Figure 2, Magnetic field plot for Case #1, Case #2, and Case #3 for the Calumet to Walsenburg Transmission Corridor. The corridor is depicted looking south from the Calumet Substation.



The results of the magnetic field modeling plotted in Figure 2 show that on the east ROW edge the magnetic field is 9.9 mG for Case #1, 17.5 mG for Case #2, and 59.1 mG for Case #3. On the west ROW edge the magnetic field 4.4 mG for Case #1, 7.3 mG for Case #2, and 35.1 mG for Case #3. The maximum magnetic field within the ROW for Case #1 is 65.0 mG, 115.1 mG for Case #2, and 384.2 for Case #3. Because there are several lines in this corridor, representative structure drawings are included in the figure to show the locations of the structures.

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 San Luis Valley to Calumet 230 kV double circuit line, and the Calumet to Walsenburg Transmission Corridor. 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. The conductors chosen for the SLV to Calumet line were selected to have large diameters and thus a reduced 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 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 new San Luis Valley to Calumet 230 kV double circuit line was modeled with an elevation of 9,413 feet (2869 meters), the highest elevation of La Veta Pass. The Calumet to Walsenburg Transmission Corridor was modeled with an elevation of 5,600 feet (1707 meters), which is approximately the average elevation along the corridor.

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 3.52), 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 San Luis Valley to Calumet 230 kV double circuit line was modeled with an elevation of 9,413 feet (2869 meters), the highest elevation of La Veta Pass. The Calumet to Walsenburg Transmission Corridor was modeled with an elevation of 5,600 feet (1707 meters), which is approximately the average elevation along the corridor. 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

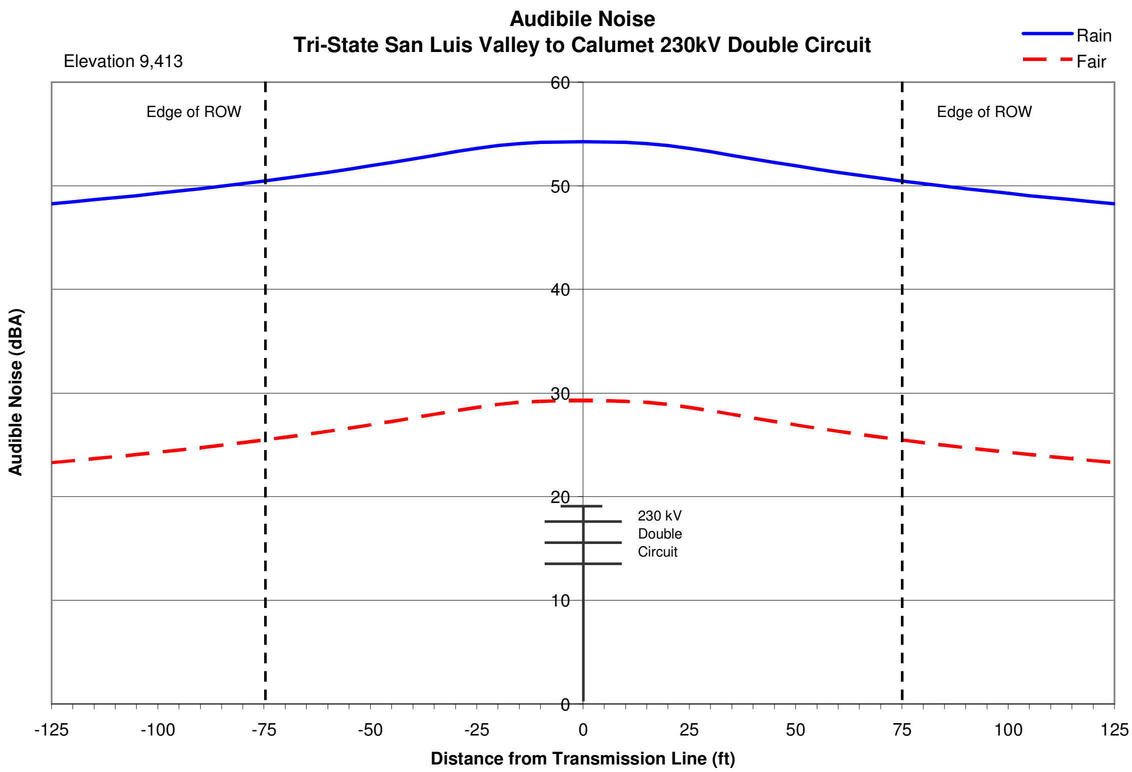
Figure 3 shows the audible noise modeled for the new San Luis Valley to Calumet 230 kV double circuit line at the top of La Veta Pass.

Figure 4 shows the audible noise modeled for the Calumet to Walsenburg Transmission Corridor.

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

San Luis Valley to Calumet

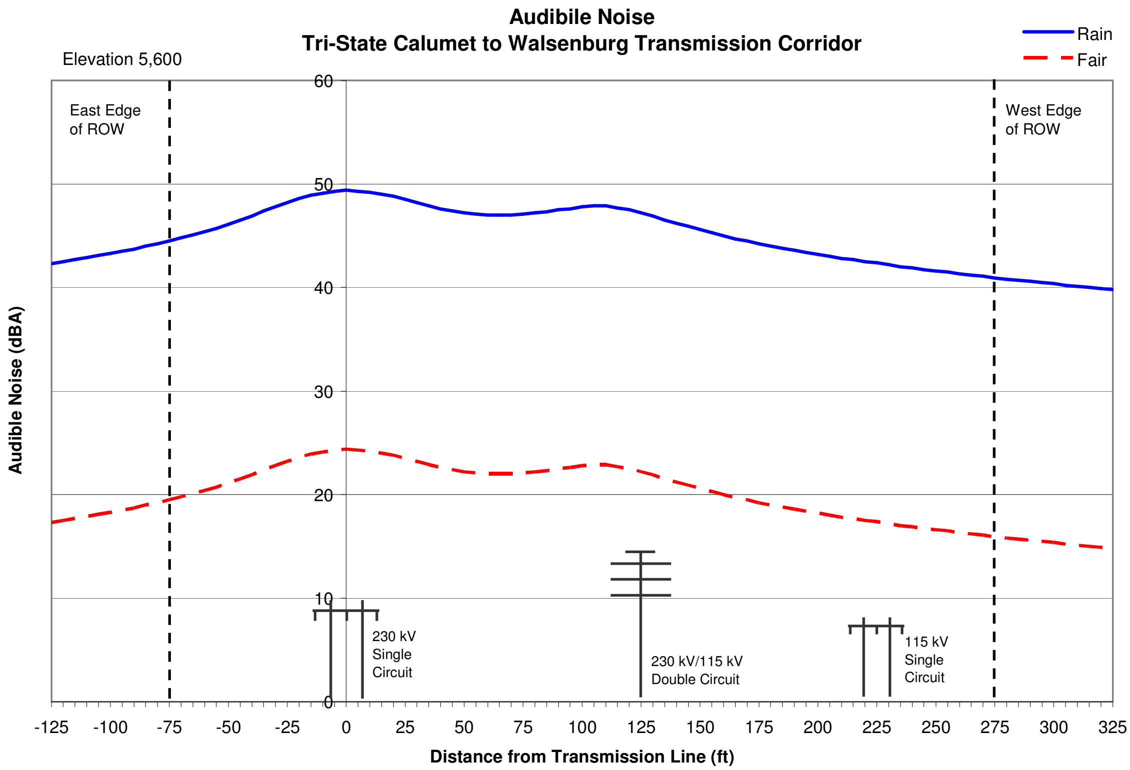
Figure 3, Audible noise for the San Luis Valley to Calumet 230 kV double circuit line.



The audible noise at both the right and left ROW edge is 25.5 dBA in fair weather and 50.5 dBA in wet weather. The maximum noise that occurs within the ROW is 29.3 dBA in fair weather and 54.3 dBA in wet weather.

Calumet to Walsenburg Transmission Corridor

Figure 4, Audible noise for the Calumet to Walsenburg Transmission Corridor. Corridor is depicted looking south from Calumet Substation.



The audible noise that is modeled at the east ROW edge is 19.5 dBA in fair weather and 44.5 dBA in wet weather. At the west ROW edge the audible noise is 15.9 dBA in fair weather and 40.9 dBA in wet weather. The maximum noise that occurs within the ROW is 24.4 dBA in fair weather and 49.4 dBA in wet weather.

APPENDIX A
ENVIRO Modeling Inputs

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

		New SLV – Calumet 230 kV Double Circuit		Calumet to Walsenburg Transmission Corridor			
					New Double Circuit		
	Line	**#1 line**	**#2 line**	**Existing Comanche – Walsenburg 230 kV Single Circuit**	**Calumet – Walsenburg 230 kV**	**Stem Beach – Walsenburg 115 kV**	**Existing ARCO – Walsenburg 115 kV Single Circuit**
	Conductor Type	One conductor 1272 MCM ACSR Bittern[1]	One conductor 1272 MCM ACSR Bittern[1]	One conductor 1272 MCM ACSR Bittern[1]	One conductor 1272 MCM ACSR Bittern[1]	Stem Beach – Calumet 477ACSR Hawk Calumet – Walsenburg 1272 ACSR Bittern[1]	477 ACSR Hawk[2]
	No injections in the Valley						
CASE #1	**Maximum forecasted 2015 peak flow, (Amperes)**	90	90	260	260	110	40
	1000 MW of New injections in the Valley & 1000 MW of New injections in the Calumet						
CASE #2	**Maximum forecasted 2015 peak flow, (Amperes)**	550	550	460	460	280	40
	Full Thermal Capacity of the Line						
CASE #3	**Maximum forecasted 2015 peak flow, (Amperes)**	1538	1538	1538	1538	477	477

[1] 1272 ACSR Bittern conductor has a diameter of 1.345 inches.
[2] 477 ACSR Hawk conductor has a diameter of 0.858 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)	Sag (ft)
New SLV - Calumet 230 kV Double Circuit					
#1 line		A	-14.5	100	34
		B	-16	80.5	34
		C	-14.5	61	34
		Ground	-10	120	44
#2 line		C	14.5	100	34
		B	16	80.5	34
		A	14.5	61	34
		Ground	10	120	44
Calumet to Walsenburg Transmission Corridor					
Existing Comanche - Walsenburg 230 kV Single Circuit		C	-19.5	62	35
		B	0	62	35
		A	19.5	62	35
		Ground	-9.75	79	35
		Ground	9.75	79	35
New Double Circuit	Calumet - Walsenburg 230 kV	A	109.5	97.5	31.5
		B	108	78	31.5
		C	109.5	58.5	31.5
		Ground	115	115	31.5
	Stem Beach - Walsenburg 115 kV	C	140.5	97.5	31.5
		B	142	78	31.5
		A	140.5	58.5	31.5

		Ground	135	115	31.5
Existing ARCO - Walsenburg 115 kV Single Circuit		C	212.5	47	20
		B	225	47	20
		A	237.5	47	20
		Ground	218.75	56.5	20
		Ground	231.25	56.5	20