Vollmer Substation and Transmission Line Project

Analysis of Audible Noise and Magnetic Fields

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Project Description

Tri State Generation and Transmission Association, Inc. (Tri State) and Mountain View Electric Association (MVEA) is planning to construct a new Vollmer Transmission and Distribution Substation and associated transmission tap line (the Project) to serve the Sterling Ranch Development area east of Colorado Springs, Colorado. The Vollmer Substation will be located in eastern El Paso County within a portion of the planned Sterling Ranch Planned Use Development in the SE quarter of Section 34, township 12 south, range 65 west. The substation will be located approximately 2.9 miles northwest of the town of Falcon, Colorado.

The Project will connect to the existing Black Squirrel to Fuller 115 kV line with a new single circuit 1.3 mile long 115 kV transmission tap line. The tap line will cross under the Xcel Energy 345 kV Midway to Daniels Park transmission lines and then proceed west to new Vollmer Substation. Within the Vollmer Substation, the voltage will be stepped from 115 kV down to 12.47 kV with two 40 MVA transformers that will each supply power to five primary distribution feeder lines owned by MVEA. The feeder lines will be run into the surrounding Sterling Ranch area to serve MVEA customers.

Purpose of this Report

Tri State is applying to for a 1041 permit for site selection and construction of a transmission line and substation within El Paso County. As part of the application process Tri-State and MVEA asked Tetra Tech to study and prepare a report satisfying requirements outlined in Chapter 5, Article 5.201, Section (9) (11) (a) of the El Paso County Guidelines and Regulations for Areas and Activities of State Interest (1041 Regulations) provided below:

> “Applications seeking a permit for the site selection and construction of transmission lines or substations shall submit the following additional documents and information:
>
> (a) Computer modeled electromagnetic field measurement within the proposed transmission line easement for that portion of the transmission line easement for that portion of the transmission line between substation or transition sites…”

This report addresses the referenced El Paso County land use code by providing an analysis of the magnetic fields and audible noise of the proposed transmission line and substation. The Colorado Public Utilities Commission (PUC) outlines standards for magnetic field and noise analyses being prepared for the substation and transmission lines (PUC rules 3206(e) and 3206(f), respectively). The results of these analyses, including a description of the methods that were used, are presented in this report and will be included in the 1041 application.

Noise Modeling Analysis

An acoustic analysis of the proposed new Vollmer Substation was conducted using the Cadna/A® model. Cadna/A is a noise modeling software program that is widely recognized by both regulators and acousticians alike.

Two transformers will be installed as part of the substation. Both will be 115 to 12.47-kV distribution transformers rated at 40 MVA. Received sound levels were calculated throughout the Project study area on the A-weighted scale (dB(A)) to determine compliance with the applicable noise regulations prescribed by PUC rule 3206(f). The analysis predicts that the noise from the new transformers at the Vollmer Substation, would be in compliance with the most stringent residential limit as described in the section below.

Regulatory Limits and Project Target Noise Level

Offsite environmental noise resulting from the operation of transmission facilities is subject to the limits in PUC rule 3206(f).[1] Specific audible noise levels that are deemed reasonable are found in rule 3206 (f)(II). The limits vary by zone where the transmission facilities are located and are summarized in Table 1.

Table 1:
PUC Maximum Permissible Noise Limits

Zone	Allowable Noise Level dB(A)
Residential	50
Commercial	55
Light industrial	65
Industrial	75

PUC rule 3206(f) states that "The filing shall include the projected level of noise radiating beyond the property line or right-of-way (as applicable) at a distance of 25 feet." Section 3206(f) (II) of the rule states that "Proposed levels of noise at or below the values listed are deemed reasonable by rule and need not be mitigated to a lower level."

The Vollmer Substation will be located in within the planned Sterling Ranch Planned Use Development property. Currently, one residence is located approximately 0.2 miles northeast of the substation site and two others approximately 0.3 miles to the southwest. The PUC does not give an applicable noise limit for the agricultural land located immediately adjacent to the substation; therefore, compliance was assessed relative to the most stringent 50 dB(A) residential noise limit at a distance of 25 feet from the property line.

Given the inherent uncertainties in estimation and measurement of noise, a design margin of 3 to 5 dB(A) below the regulatory limit is desirable, although not always feasible. In addition, the limits provided in

[1] PUC rule 3206(f) refers to "transmission facilities" and does not specifically distinguish between transmission lines and substations. For purposes of this analysis, Tetra Tech has assumed that "transmission facilities" includes the Vollmer Substation.

Table 1 are absolute and independent of the existing acoustic environment; therefore, a collection of ambient sound data is not required to assess conformity. The modeled sound levels represent solely the Project sound contribution and do not account for contribution of existing ambient sound levels.

Transformers as Noise Sources

The primary noise sources associated with the substation expansions will be the two new transformers. Noise is generated primarily from transformers, i.e., from movement of the transformer core at frequencies that are multiples of the frequency of the electrical current, which is 60 Hertz (Hz) in the United States. Therefore, the fundamental frequency is 120 Hz, with harmonics at multiples of this frequency. Cooling fan and radiator systems will also add to the transformer noise. NEMA Standards Publication TR 1 (Reference 1) has ratings for “standard” transformers of various capacities. These ratings are essentially the average near field A-weighted sound pressure levels (0.3 meter from the transformer walls, except 2.0 meters from the walls opposite cooling areas).

The sound power levels from the transformers to be used in the noise model are calculated following methods described in References 2, 3, and 4. These methods are based on the specified sound pressure level and the area of the envelope surrounding the transformer at which that level applies. References 3 and 4 provide guidance for calculating the octave-band sound power levels that correspond to the overall A-weighted sound power level calculated as described above. The distribution of the transformer sound power into the standard octave bands (center frequencies from 31.5 Hz to 8,000 Hz) was based on typical distributions from Reference 3 and 4.

Noise Modeling and Evaluation

Standard acoustical engineering methods were used in the noise analysis. The computer software noise model, Cadna/A® by DataKustik GmbH. The model is a sophisticated model that is capable of fully modeling very complex facilities. The sound propagation algorithms and factors used in the model have been adopted in accordance with the International Organization for Standardization (ISO) Standard 9613-2, “*Acoustics—Sound Attenuation during Propagation Outdoors*.” The engineering methods specified in this standard consist of full (1/1) octave band algorithms that incorporate geometric spreading due to wave divergence, reflection from surfaces, atmospheric absorption, screening by topography and obstacles, ground effects, source directivity, heights of both sources and receptors, seasonal foliage effects, and meteorological conditions.

Offsite topography was determined using U.S. Geological Survey (USGS) digital elevation data for the study area. Ground absorption rates are described by a numerical coefficient. For pavement, the absorption coefficient is defined as G = 0 to account for reduced sound attenuation and higher reflectivity. In contrast, ground covered in vegetation, including suburban lawns and agricultural fields covered by crops, are acoustically absorptive and aid in sound attenuation, i.e., G = 1.0. For the acoustic modeling analysis, multiple absorption rates were used. The areas within the substation fence line were set to G =0. As a measure of conservatism, the remaining offsite areas were set to the G = 0.5. No credit was taken for tree cover and foliage effects, thereby assuming worst case wintertime defoliated conditions.

The two new transformers were modeled as noise sources at the expected transformer tank heights. Octave-band sound power levels were assigned to the transformers as described in the previous section. The model then calculated the sound pressure levels that would occur at the point of compliance, which in this case is at 25 feet from the substation property line.

Proposed Vollmer New Transformer Noise Evaluation

A review of the site on Google Earth© was conducted. Existing county roads were found to be located southeast of the substation property owned by Tri State. In addition, residences are located to the northeast and southwest from the substation.

Noise modeling was conducted for the two proposed 40 MVA 115 to 12.47-kV distribution transformers at the Vollmer Substation. The 40 MVA transformer has an estimated NEMA rating of 75 dB(A) for the transformer casing as a noise radiator. Each transformer will have cooling fans on the interior side that can add 7 to 10 dB(A) to the total noise level produced by the transformer. For this analysis, the fans were placed on the interior side of the transformer facing toward the center of the substation. This positioning will result in the fan noise being radiated across the center of the substation.

Acoustic modeling was completed that evaluated received sound levels at a receptor grid height of 1.5 meters (5 feet) above ground, the approximate height of an individual's ears. Results are displayed in Figures 1, 2, and 3 as operational broadband sound levels in color-coded isopleths.

The substation was located in the noise model as shown in Figure 1. The contour lines are lines of constant noise level from the new transformer alone operating with a loading of 20 MVA with the cooling fans off. The regulatory compliance line (25 feet out from the property line) is shown by the thick purple line. The model results indicate that the noise level from the transformers at all applicable locations (25 feet from the property line) would meet the residential limit of 50 dB(A). At the northern property line, the modeled noise level at 25 feet from the property line is 40 dB(A) at the location shown by the small yellow box. This location is the closest a residence can be placed next to the substation. All other locations at 25 feet from the property line are well below this noise level as shown in Figure 1.

The transformers were also modeled at a loading level of 32 MVA with the cooling fans on in first stage (low) cooling mode (Figure 2) and at an operating level of 40 MVA with the fans operating in the second stage (high) cooling mode (Figure 3). In all cases the maximum sound level where a new residence can be constructed as shown by the small yellow box is less than 50 db(A) the sound level acceptable to the PUC in a residential area. The area where the 50 dB(A) noise contour line is within the property line, thereby complying with the PUC-acceptable noise level for a residential zone as shown by Table 2.

Table 2:
Comparison of Maximum Noise Levels with allowed PUC Noise Levels

Transformer Operation Mode	Maximum Received Sound Level at 25 feet from Property Line (Small Yellow Box)	PUC Noise Compliance for Residential Zone (dBA)
20 MVA – Natural Cooling	40	**50**
32 MVA – Cooling Fans Low	48	
40 MVA – Cooling Fans High	48	

Noise Analysis Conclusions and Recommendations

Noise levels from the new Vollmer Substation are predicted by the Cadna/A® noise model to be less than 50 dB(A) at 25 feet from the property boundary of the substation for all operating conditions. The noise evaluation was conducted with a sophisticated model and the best information available. However, the results cannot be guaranteed given uncertainties inherent in the model algorithms, differences that typically occur between the noise source information used in the model and actual noise source levels that the new transformers will produce, and atmospheric and ground conditions that will vary from assumed values. Nevertheless, previous experience with the model algorithms has shown that there is a high degree of correlation between the predicted results and field measurements.

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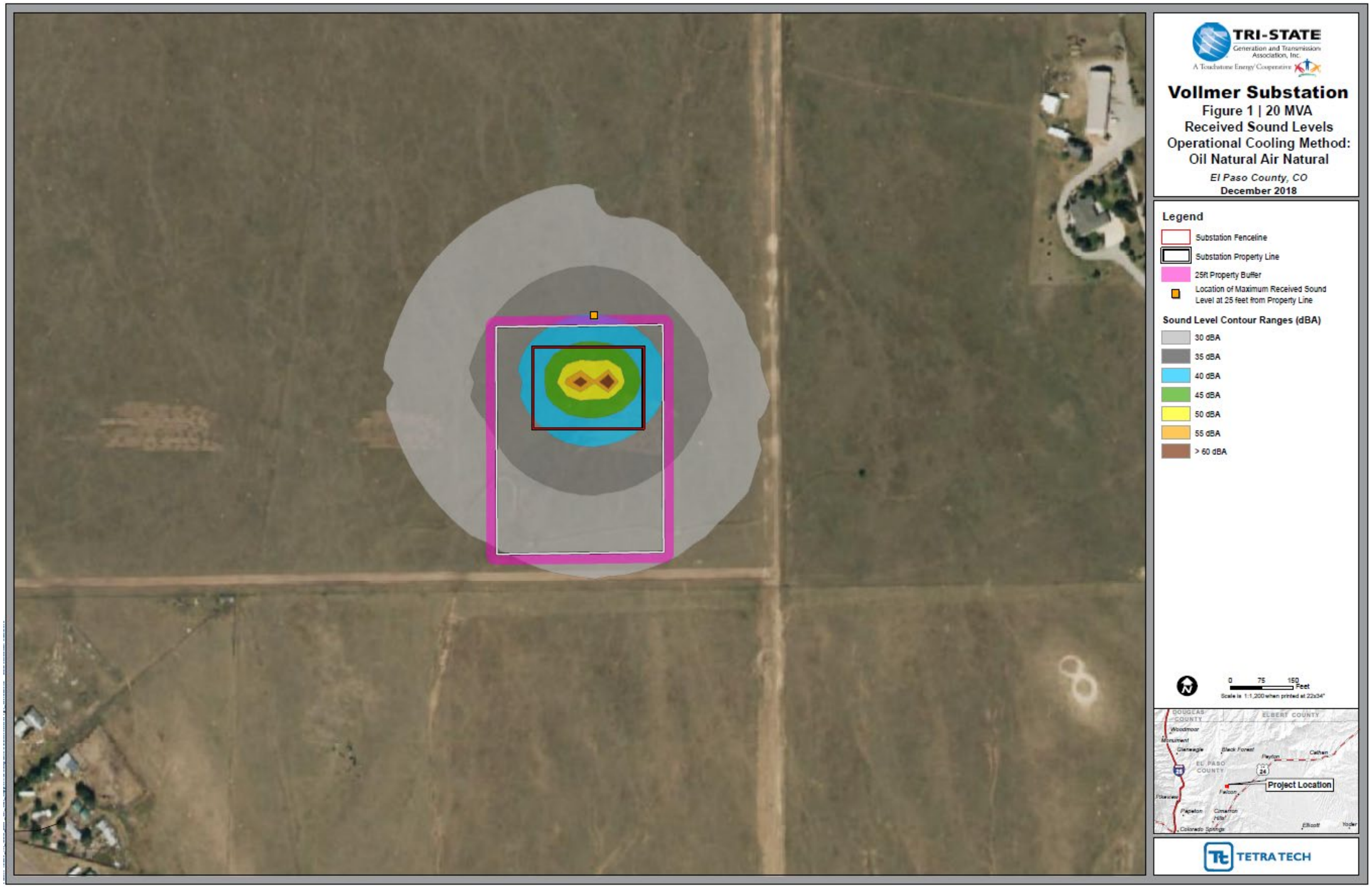


Figure 1: Received Sound Levels, 20 MVA Substation Operation Natural Cooling

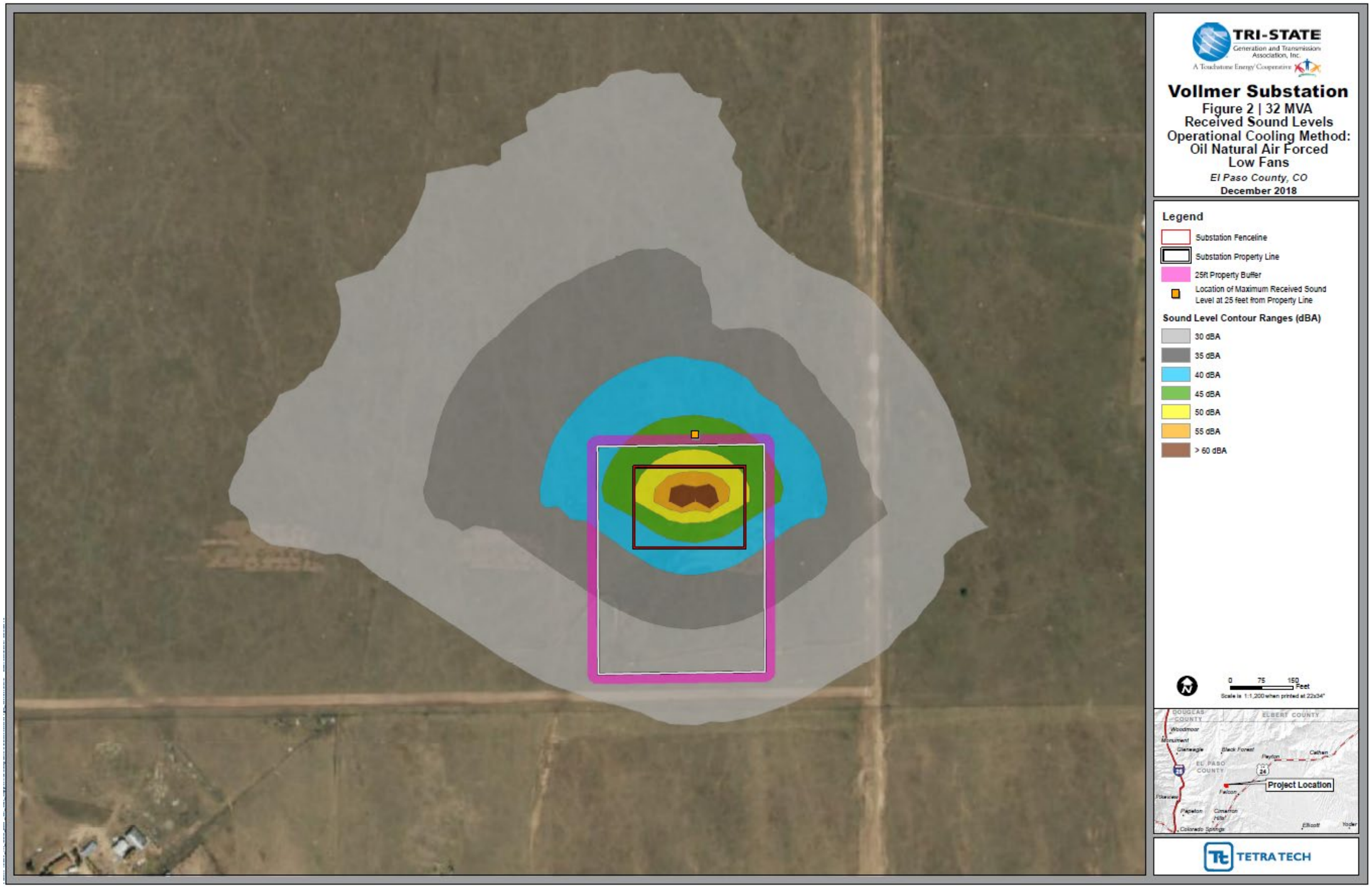


Figure 2: Received Sound Levels, 32 MVA Substation Operation 1st Stage Cooling

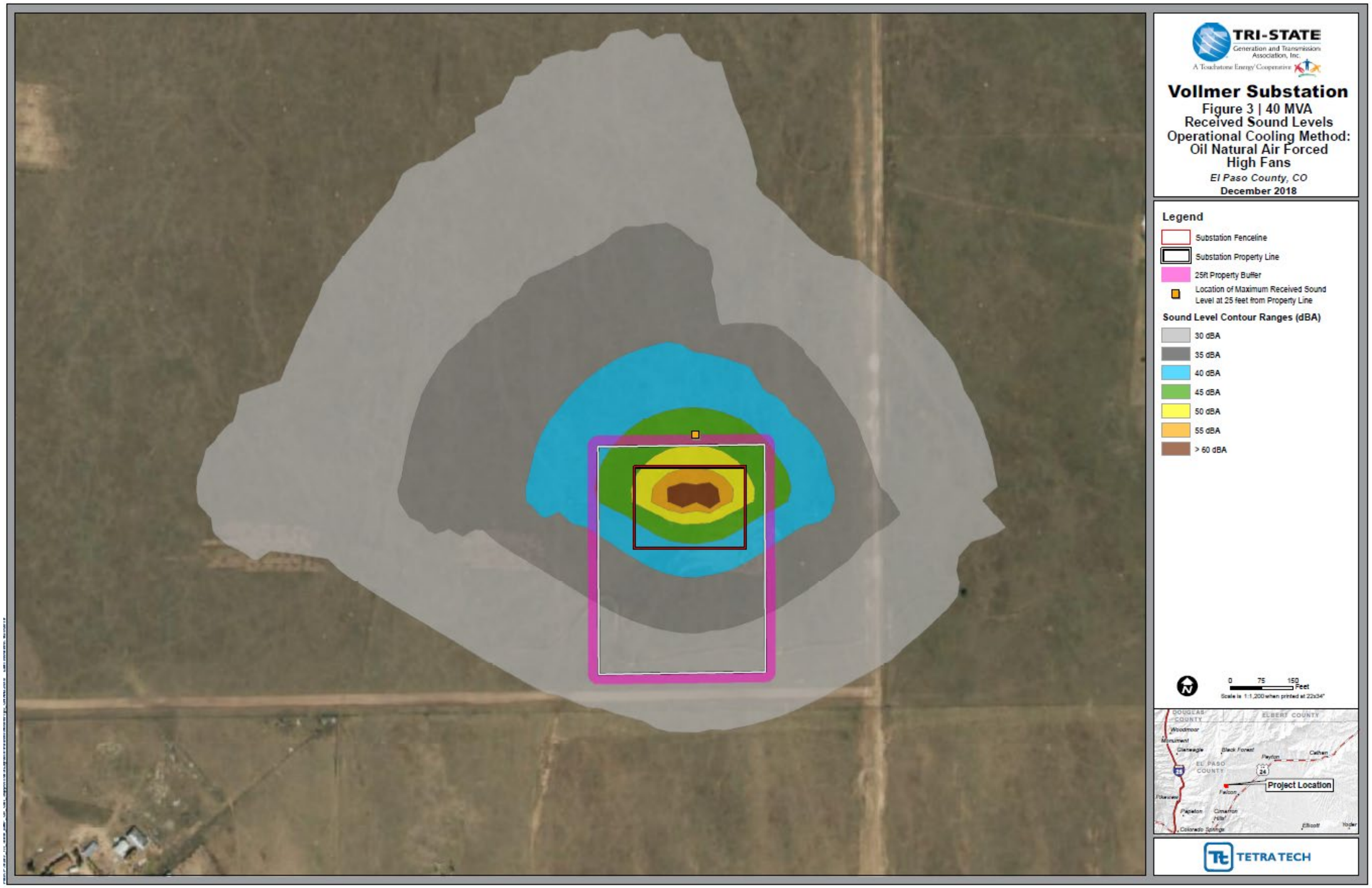


Figure 3: Received Sound Levels, 40 MVA Substation Operation 2nd Stage Cooling

Magnetic Field Analysis

Tri State also requested an analysis of the potential impact of magnetic fields from the new transformers and buss conductors within the Vollmer Substation to areas outside of the fenced substation. This analysis is required by PUC rule 3206(e). A three-dimensional (3D) magnetic field modeling analysis was conducted to estimate the levels of magnetic fields that will exist within and at the fence of the substation.

All electric utility wires and devices that carry electrical current generate magnetic fields. The earth itself generates steady-state magnetic fields. Magnetic fields are produced by the electrical load, or the amount of current flow, through the conductors measured in terms of amperage. The magnetic field strength is directly proportional to the amperage; i.e., increased power flow results in increased amperage that produces a stronger magnetic field.

The magnetic field is inversely proportional to the distance from the conductors, and the strength declines as the distance from the conductor increases. Magnetic fields are expressed in units of milligauss (mG). Unlike voltage, however, the amperage, and therefore the magnetic field around electric utility wires and devices, fluctuates hourly and daily as the amount of current flow varies. In a complex facility such as an electrical substation, the strength of the magnetic field at any point depends on the current flowing in nearby conductors, the geometry of the construction of the substation, the degree of reinforcement or cancelation from other conductors of similar or different electrical phases, and the distance from the conductors or cables.

The magnetic field analysis was conducted using the 3D-FIELDS program. The 3D-FIELDS program, written by the Southern California Edison Company, is designed to calculate and plot in three dimensions the magnetic fields produced by any wiring configuration such as those used in substations and other similar electrical facilities. The magnetic fields that will be generated by the proposed substation were calculated using the Grid mode in 3D-FIELDS at an elevation of one meter (approximately 3 feet) above 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 small percentage of the true value for the conditions modeled.

The 3D magnetic field analysis was conducted with the following assumptions. The 115-kV transmission line will have a power flow of 143 MVA into the substation. The power will pass through the 115-kV stepdown transformers and flow to the 12.47 switch cabinets and out of the substation on the primary distribution feeders.

The two transformers were modeled to be operating at 40 MVA power flow levels. The currents in each of the buss conductors were calculated to depict the magnetic fields that would be produced within the substation operating with these loads. The transformers, circuit breakers, and other items of discrete electrical equipment in the substation were not modeled for magnetic fields since they comprise point sources of magnetic fields that will have a very rapid “cube of the distance” decay. For example, if a magnetic field of 100 mG is predicted at 5 feet from a transformer, the field level becomes approximately one-eighth, or 12.5 mG at twice the distance (10 feet), and 1.6 mG at 20 feet.

The gridded magnetic field values from the buss and transmission line conductors computed by 3D-FIELDS were then plotted using the 3D graphing program Surfer, which is available from Golden Software. Surfer creates a 3D surface view of the magnetic field levels across the substation.

The magnetic fields that will be generated by the proposed substation were plotted as shown in Figure 4. The higher magnetic fields of the surface shown in the purple and pink colors are the locations where the magnetic field is the highest and the lowest levels are shown in green. The figure shows that the magnetic field strength decreases to background levels well within the new substation fence on the western and eastern sides of the new substation. The fields will be elevated in the north and south at the fence because the transmission line enters the new substation yard from the south and the distribution lines exit to the north. At the property line on the east and west sides, the magnetic fields from the substation itself will be less than 2 mG.

Those fields where the transmission line enters the new substation yard from the south are within the Tri State right of way. The magnetic fields will be elevated directly over the underground feeder lines that exit the substation toward the north. These distribution feeders will be located outside the substation in utility easements owned by MVEA. There are no PUC rules for maximum magnetic field levels that apply to these distribution feeder lines outside the substation.

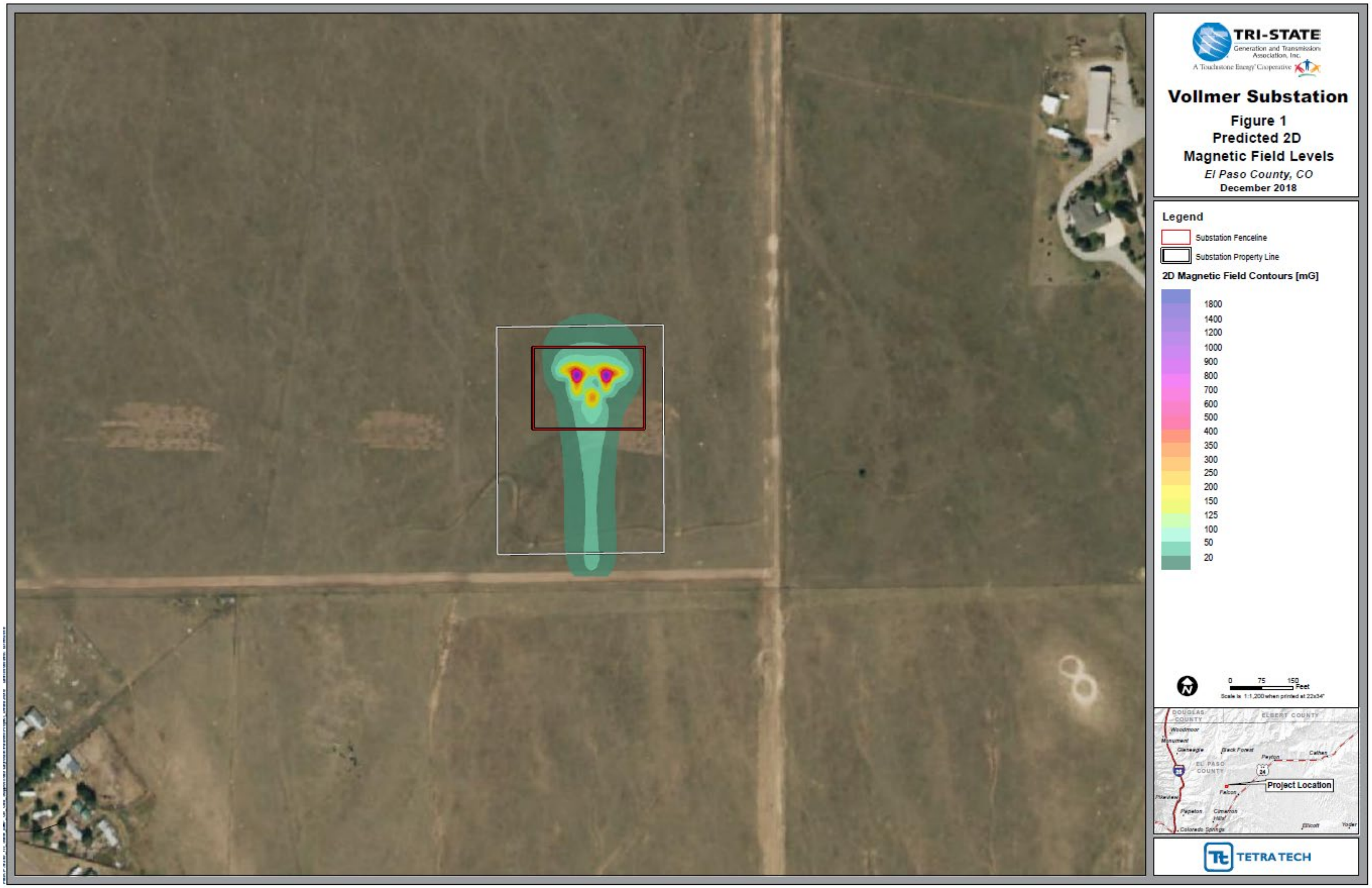


Figure 4: Predicted 2D Magnetic Field Levels

Magnetic Field and Noise Analysis of 115-kV Transmission Tie Line

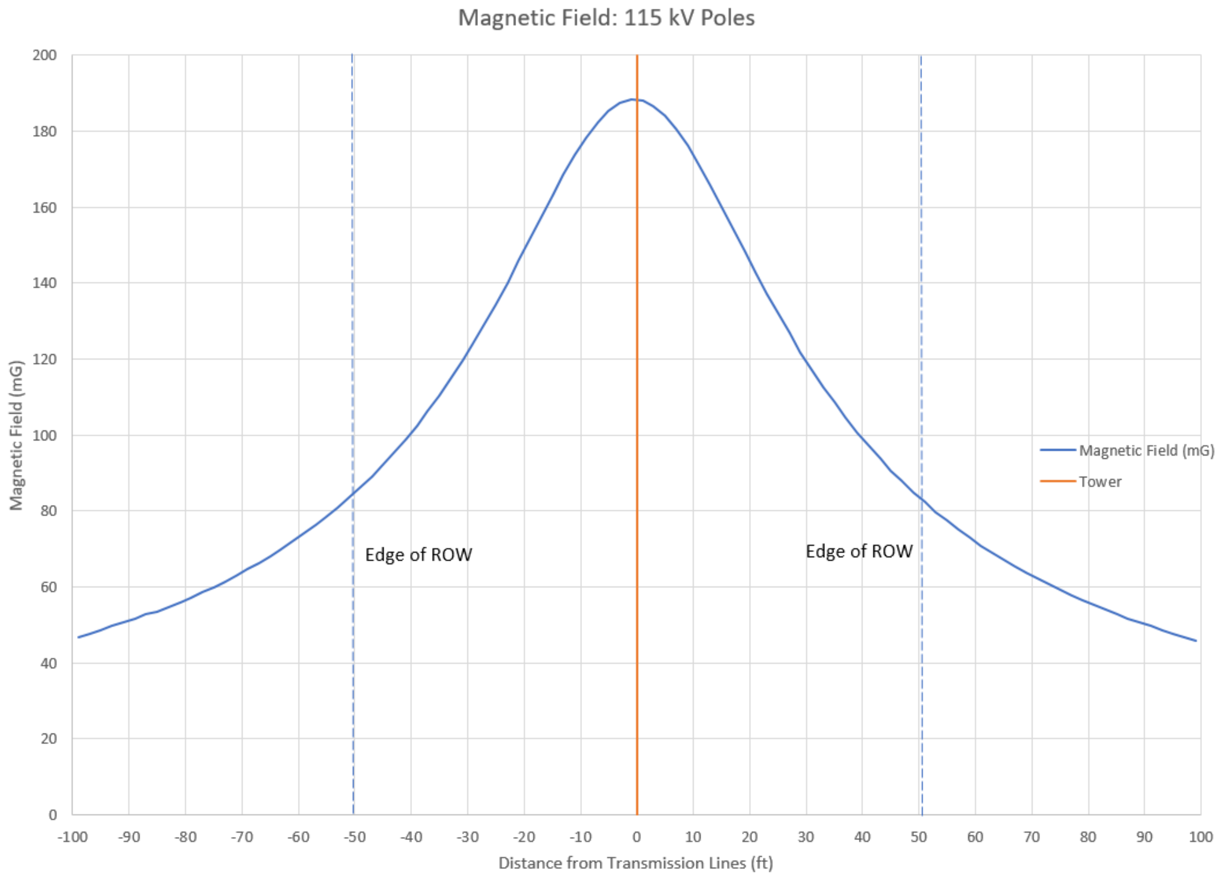
The Vollmer Substation will be connected to the Tri State-owned Black Squirrel to Fuller 115-kV transmission line located about 1.3 miles east of the substation. The 115-kV transmission line and the tie line are part of the Tri-State system. Magnetic field and corona audible noise modeling was performed on this proposed tie line (Vollmer-Vollmer tap 115-kV Transmission Line).

The tie line was modeled in an H-frame configuration. The modeling was done using the Corona 3 model from the Bonneville Power Administration (BPA) of the U.S. Department of Energy.

The magnetic fields that will be generated by the proposed 115-kV tie line to the substation were plotted as shown in Figure 5. The ROW for the 115-kV transmission lines has a corridor width of 100 feet with the transmission tie line centered within the ROW.

Figure 5 shows that the modeled magnetic field at the ROW boundaries of the tie line corridor shown as blue dashed lines is 85 mG.. These levels are well below the 150 mG allowed at the edge of the ROW in PUC rule 3206 (e).

Figure 5. Magnetic Fields from 115-kV Tie Lines



The BPA Corona 3 model was also used to calculate the corona induced audible noise from the 115-kV transmission tie line. 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 those from the Project 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, everything else being equal, lower corona than smaller conductors.

Irregularities (such as nicks and scrapes on the conductor surface or sharp edges on suspension hardware) concentrate the electric field at these locations, thereby increasing 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 (Reference 5). All other things being equal, audible noise at 600 meters elevation will be twice the audible noise at 300 meters. The Project was modeled with an elevation of 7,030 feet.

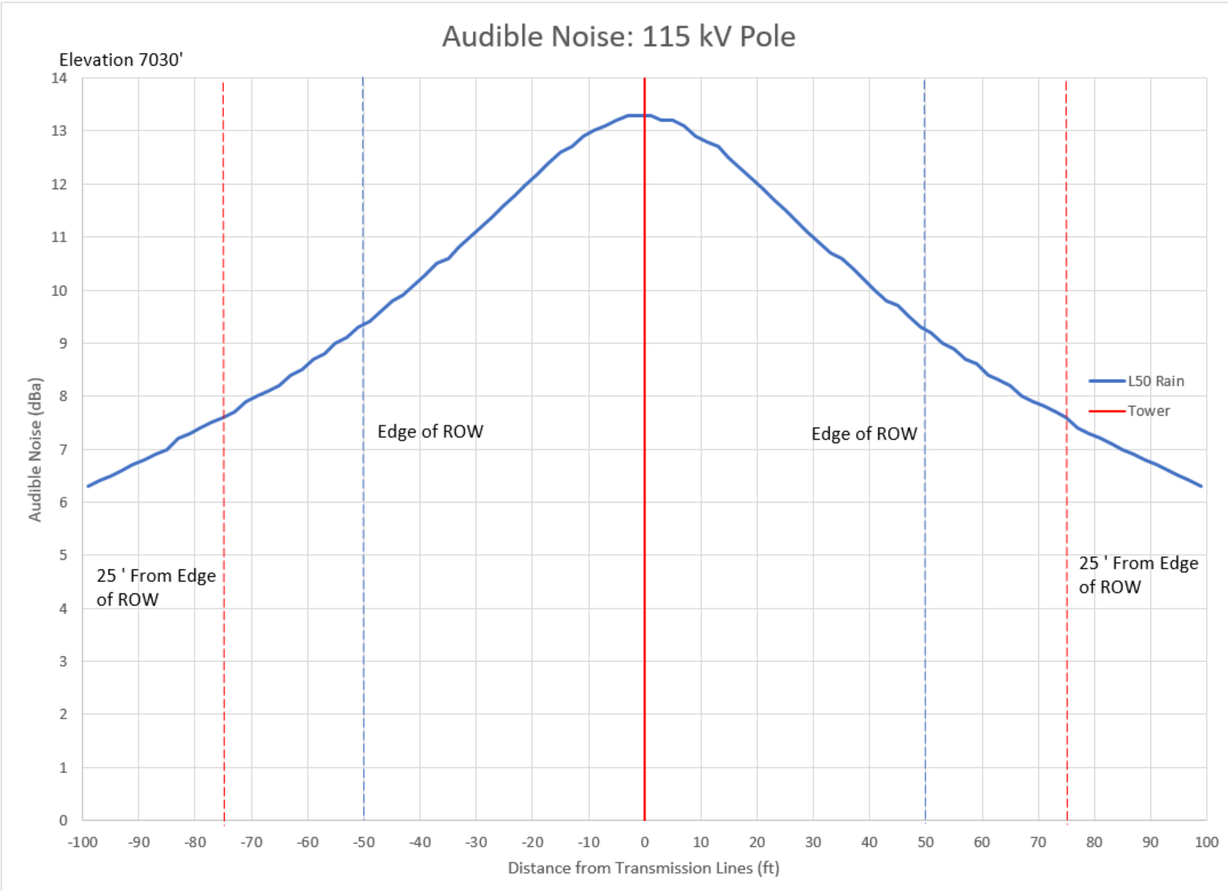
Raindrops, snow, fog, hoarfrost, and condensation accumulated on the conductor surface are also sources of surface irregularities that can increase corona. During fair weather, the number of these condensed water droplets or ice crystals is usually small and the corona effect is also small. However, during wet weather, the number of these sources increases (e.g., raindrops 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 raindrops 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 clamps that hold the conductor in place should have rounded rather than sharp edges and no protruding bolts with sharp edges will reduce corona. The conductors should be handled so that they have smooth surfaces without nicks or burrs or scrapes in the conductor strands.

The H frame structures modeled for magnetic fields were also used in modeling corona for the new tie line. The corona audible noise results are presented in Figure 6. The new 115-kV tie lines will be located on a 100-foot-wide ROW. The outer edges of the ROW are shown as vertical blue dashed lines in Figure 6. The audible noise levels in PUC rule 3206 (f) apply at 25 feet outside of the ROW. These lines are also shown as red vertical dashed lines.

Figure 6 presents the audible noise results for L_{50} rain and fair conditions. L_{50} is the dBA that may be exceeded 50 percent of the time within an hour. For the rain condition, the audible noise levels are 7.6 dBA at 25 feet from both sides of the ROW lines. For the fair condition, the audible noise level is 0 dBA across the ROW. All of these audible noise levels are well below the 50 dBA levels allowed in PUC rule 3206 (f).

Figure 6. Corona Audible Noise from 115-kV Tie Lines



Results and Conclusions

The noise model results indicate that the noise level from the transformers at all applicable locations (25 feet from the property line) would meet the residential limit of 50 dB(A). At the northern property line, the highest modeled noise level at 25 feet from the property line is 47.5 dB(A). All other locations at 25 feet from the property line are well below this noise level as shown in Figures 1, 2, and 3. These noise levels will comply with PUC rule 3206 (f).

Three-dimensional magnetic field levels from the new substation are essentially background levels (approximately 2 mG or less) at the western, and eastern substation fence. The locations where the transmission lines enter from the south and the distribution feeder lines exit the substation to the north will have elevated fields due to these transmission and distribution lines. The magnetic fields for the substation itself do not exceed the 150-mG magnetic field level per CPCN rule 3206(e) at the substation fence. The Vollmer substation, therefore, will comply with PUC rule 3606 (e).

The results of the magnetic field modeling for the transmission line plotted in Figure 5 show that at the ROW edges the magnetic field is approximately 85 mG. The results of the corona audible noise modeling plotted in Figure 6 show that 25 feet outside of both the left and right ROW edges, the audible noise is approximately 0 dBA in fair weather and 7.6 dBA in wet weather. The maximum noise that occurs within the ROW is 0 dBA in fair weather and 13.3 dBA in wet weather. These levels easily comply with PUC rules 3206 (e) and (f).

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