INTER-NOISE 2018
Impact of Noise Control Engineering
26-29 AUGUST
CHICAGO, ILLINOIS

Resolution of an Environmental Noise Problem Caused by a 345 KV Power Pole

David J. Parzych[a]
Power Acoustics, Inc.
12472 Lake Underhill Rd #302
Orlando, FL 32828

ABSTRACT

A remote long term sound monitoring and weather acquisition system was used to successfully solve an environmental noise problem related to a "singing" power pole.

Residents adjacent to a recently installed 345 KV power pole complained the pole would "sing" during gusty wind conditions. The intermittent nature of the noise, unpredictability of wind conditions and the pole's remote location created a conundrum for acoustical consultants trying to obtain the sound, frequency and wind data necessary to determine the cause.

The electric utility tried numerous corrective actions without a noticeable improvement. Scheduling power line outages needed to be made several weeks in advance and at a high cost. For safety, modifying active poles with high voltage power lines wasn't an option. Unfortunately, the trial and error approach was turning into a multi-year problem. To further complicate the issue, the noise was observed from only a few poles - even though hundreds of poles utilizing similar components and designs were installed. The problem was solved by collecting and analyzing the remote data over a several week period. The sound and wind data were correlated with analytical calculations and component sound tests. The offending poles were reviewed for similarities and differences with poles not generating tonal noise.

---

[a] email: dparzych@poweracoustics.com

1 INTRODUCTION

This paper discusses a case history related to solving an environmental tonal noise issue generated by a 345 KV power pole. Although the problem seems to be relatively straightforward, the pole's remote location, the noise's intermittency and the danger associated with getting close to an active 345 KV power pole caused unique challenges for acoustical engineers and consultants to overcome. Additional issues associated with acquiring the necessary data, developing ways to process large amounts of remote data and finally determining the cause and solution to the problem are addressed.

2 BACKGROUND

A resident living in a rural area adjacent to recently installed 345 KV power poles similar to the one shown in Figure 1 complained that a particular pole would "sing" during high wind or gusty wind conditions. Strangely, although many hundreds of similar power poles had been installed over an area that spanned over a hundred miles, no other residents living adjacent to poles had complained. It was first assumed that possibly all poles "sing" since the general construction of all poles was similar and maybe this complaint was from a particularly noise sensitive neighbor. But the resident also had exposure to other poles located within several hundred feet of his home that didn't sing. Utility personnel had witnessed the pole's sound which was intermittent in nature and often lasted only a second or two, then disappeared as wind conditions changed.

Fig. 1 – A 150 foot tall 345 KV power pole

Noise from other poles had not been documented, but there was discussion that possibly a utility worker had observed the sound from other poles while making routine inspections.

The utility hired a local acoustical consultant to determine the cause and location of the pole's noise by utilizing an acoustic camera system. But due to a combination of the pole's remote location, the unpredictability of wind conditions, the intermittent nature of the sound and the short duration of the sound when it occurred, the results from the acoustical camera were limited and not conclusive. At best the acoustical camera indicated the noise source was toward the tip of the pole’s arms, but changed location when different “pictures” were taken.

With little to go on, the utility decided to modify the pole during the next scheduled outage of the power transmission line. Modifications were to include plugging any visible gaps or holes and replacing the insulators. While other poles had the same gaps, holes and insulators in their design, it was conjectured that maybe this pole’s components were different or in some way defective.

The modifications were made which resulted in no improvement to the noise. They were back to square one.

Sketchy data was collected thereafter, including brief Fast Fourier Transform (FFT) data taken by the paper’s author, and a cell phone video taken by a utility engineer who had heard the tone while inspecting a different pole. The data indicated the problem was tonal, flute like in character, and occurred in the mid-frequency range.

The paper’s author, located about half the USA away from the power pole’s site, proposed obtaining weather and sound data using a long duration frequency based sound monitoring system. The measurement system would be set up to remotely monitor both the wind speed/direction as well as the sound pressure level spectrum for a period of a month or more to capture a broad range of wind/weather conditions. The data would be used for correlation with the various aerodynamic noise generating mechanisms associated with the power pole’s geometry that would then be evaluated and hopefully, a conceptual solution could be provided.

3 INSTRUMENTATION

The instrumentation necessary to capture the intermittent tonal sound would need to include:

1.) A remote sound monitoring system.

The sound monitoring system would be located near the property of the homeowner who identified the noise problem. The data would be sent to cloud based storage for off-site analysis. Since the pole’s tonal sound was not typically dominating the overall A-weighted ambient sound, the system would need to collect massive amounts of audio sound files for processing FFT analysis and real time 1/3 octave band data for providing a cursory view of the noise. Accounting for the possibility that only short duration tonal sound would occur, the system would need to capture the data in short 1 second durations. Continuous audio files were required to allow FFT analysis when potential tones were observed in the 1/3 octave band data.

While data transmission on a digital cellular network system is typically used in remote locations, the GSM signal was poor and the quantity of the processed data and audio files was large. It was determined that the only viable way to transmit the data would be through a WiFi/Ethernet broadband internet connection. DSL service was available in the area.

2.) An anemometer and weather station.

The anemometer and weather station would be located on a separate tall structure to provide temperature, wind speed and wind direction. The data from the anemometer would be transmitted in real time along with the sound data.

3.1 A B&K Sentinel Monitoring System Selected

The B&K Sentinel[1], a web-based subscription service that provides real-time environmental monitoring was selected for the application. The system is based on the B&K Type 1 (precision) Model 2250 sound analyzer. The Sentinel system is packaged in an all-weather outdoor waterproof package (Pelican Case) with an outdoor microphone and windscreen. The weather data (wind speed, direction, temperature, etc.) was obtained with a Vaisala Weather transmitter WTX520 that was provide by B&K with the system.

A temporary wooden pole was installed adjacent to the resident's property across the road from the offending 345 KV power pole. The B&K Sentinel sound monitoring system and Vaisala weather station were installed on the temporary pole. Shown in Figure 2 is the installation process including the microphone, the weather station and the packaged Sentinel instrumentation.

a. microphone *b. weather sensor* *c. B&K Sentinel*

Fig. 2 – Installation of the sound monitoring and weather instrumentation

3.2 Noise Data Collected

The system measured and transmitted the data via a DSL internet connection to cloud based storage so it could be accessed remotely. Data included time of measurement, in 1 second increments, A-weighted and 1/3 octave band sound data, wind speed, wind direction, temperature and humidity data, and contiguous 1-minute duration waveform audio samples.

3.3 Difficulty Analyzing Large Quantities of Data

After obtaining a single day of data consisting of 86,400 one-second 1/3 octave band samples, the first issue was how to process the enormous amount of data and make sense out of it. From the limited data collected prior to the installation of Sentinel data acquisition system, we knew the problem was tonal, had a flute like character, and occurred at a mid-frequency range. The available data showed the two different poles generated two different frequencies. What wasn't known was whether the frequency was wind speed and/or temperature dependent. Also, the tonal sound wasn't particularly loud. Trucks traveling on the rural road adjacent to the pole produced A-weighted sound levels that were typically 20-30 dB(A) higher than the tonal sound.

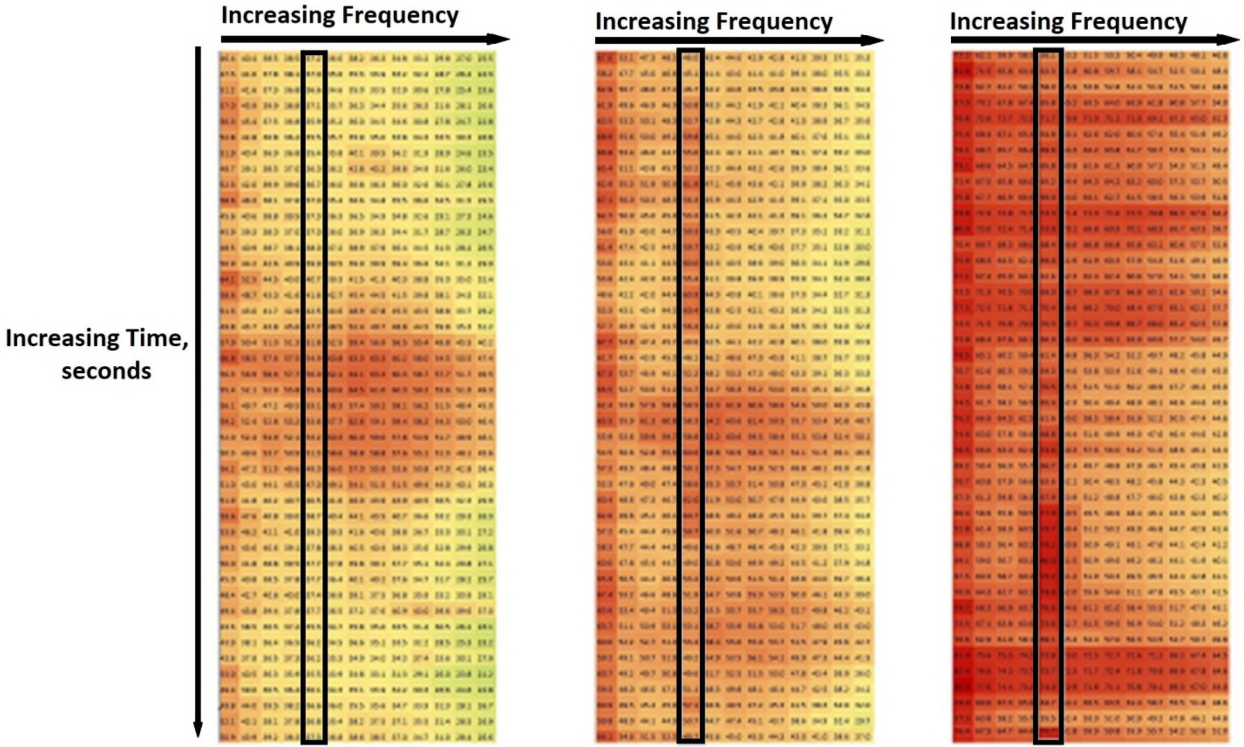
Remote sound level monitoring systems, like the B&K Sentinel are designed to report instances when simple preset sound level exceedances occur, such as when an A-weighted criterion is exceeded. They utilize simple functions that trigger audio recordings for sound identification and make it easy to perform additional analysis with the collected data. Unfortunately, a simple A-weighted trigger wouldn't suffice in our application. We had 86,400 records in a Microsoft Excel file. Each record contains thirty-two 1/3 octave bands ranging from 12.5 Hz to 20,000 Hz. And this was to going to occur every day for several weeks.

The best solution for visually analyzing the data was found to be conditionally formatting the Excel spreadsheet such that the 1/3 octave band values were color coded based on the cell's sound pressure level. An example of the conditional formatting data is shown in Figure 3 for three representative cases:

a) The typical sound from a passing vehicle with no tonal noise present,

b) Tonal noise is present during a day with gusty wind. Tonal sound comes and goes as the wind speed increases and slows,

c) Tonal noise is present during a day with sustained high velocity wind. Strong wind related noise and dynamic pressure are also observed.



a.) Normal Traffic Only

b.) Gusty Wind and Intermittent Tone

c.) Sustained Wind and Constant Tone

Fig. 3 – 1/3 Octave Band time histories using MS Excel conditional formatting

3.3 Dependence with Wind Speed and Direction

Observing the tone’s dependence on the wind was a key to understanding the problem. Dependence of the tonal noise with wind speed and direction was based on variability seen in the corresponding 1/3 octave band containing the tone. The sound level of the tone was determined by looking at the difference in the band’s level and average sound in the adjacent bands. The maximum tonal sound level is presented in Figures 4 and 5 relative to wind speed and direction respectively.

Through examination of proprietary FFT data not presented in this paper, distinct groups appeared:

1.) Several integer multiples (harmonics) of the fundamental frequency were present when the wind speed was low.

2.) A single tone occurred at twice the fundamental frequency when wind was blowing at a high sustained wind speed or during high speed intermittent gusts.

3.) The tone occurred consistently when the wind direction was primarily 20-50 degrees from parallel to the pole’s arms. The tone also occurred during variable direction gusty wind conditions so it is unknown if the data was influenced by a sudden change in wind direction. Clearly, the vast majority of tonal noise occurred when the wind direction was not perpendicular or parallel to the arms of the power pole.

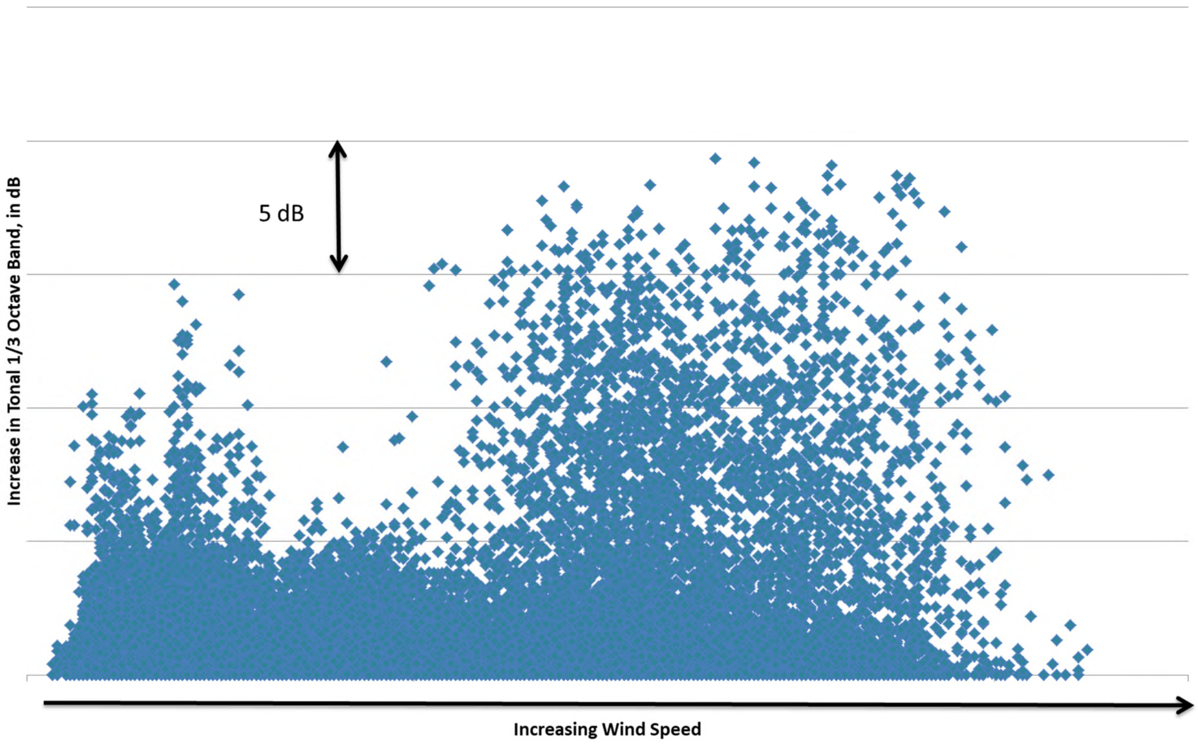


Fig. 4 – 1/3 Octave Band tonal dependence on wind speed

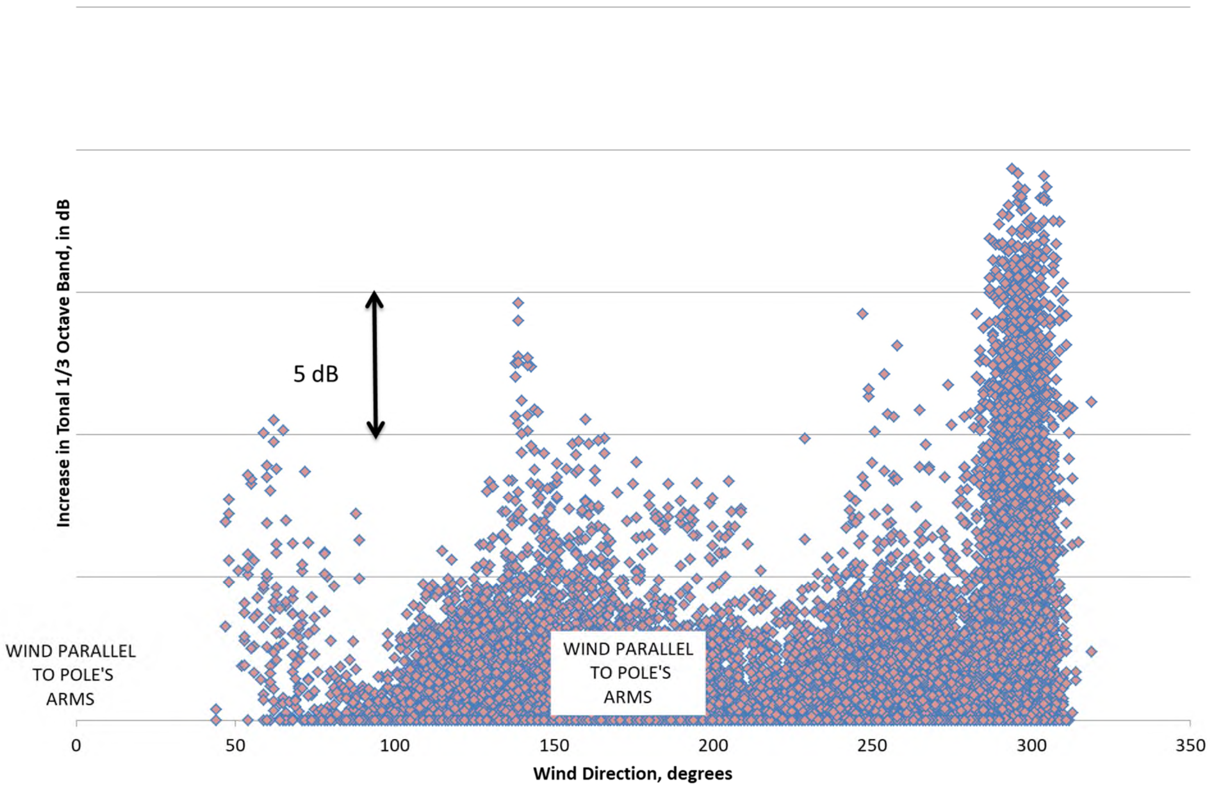


Fig. 5 – 1/3 Octave Band tonal dependence on wind direction

3.4 Analytical Evaluation

The analytical evaluation included evaluation of the pole's geometrical features for correlation with vortex shedding, open and closed end pipe sources, and Helmholtz resonator frequencies [2]. During low wind, the tone had several characteristics leaning toward an open-open end tube providing its flute-like characteristics[3]. During higher wind conditions, only the second harmonic of the fundamental frequency was observed. Dimensions and shapes of insulators, arms, power lines, holes, drop bracket structures, patrol signs and ladder clips were reviewed. Curiously, although the tone had characteristics of an open ended tube, its frequency didn't change with temperature and none of the pole's dimensional characteristics were that close to matching the frequency of the wind generated tone.

3.5 The Breakthrough

The confusing issue remaining was similar components were used on all poles, but all poles didn't generate tonal noise. So what made the "singing" poles different? Finally a breakthrough; the two poles that were observed to sing were on power poles where the alignment shifted to the opposite side of the road. The alignment change, as shown in Figure 6, proved to be the key to diagnosing the mechanism of the tonal noise.

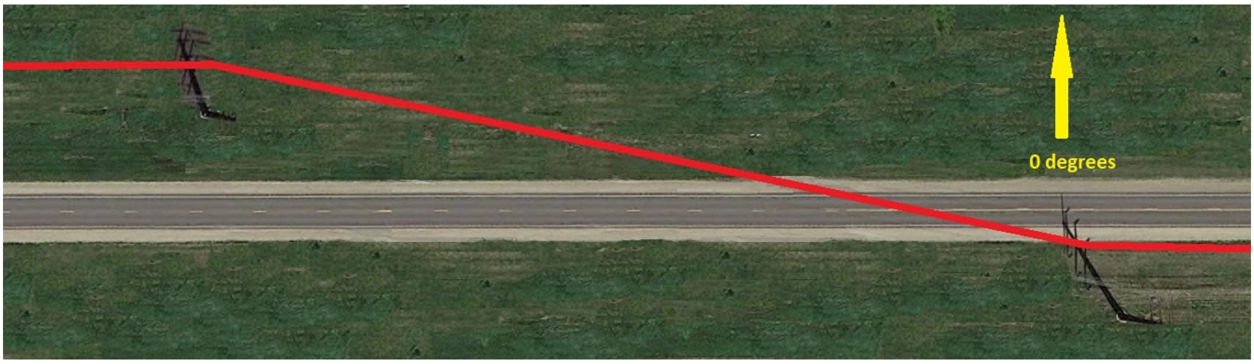
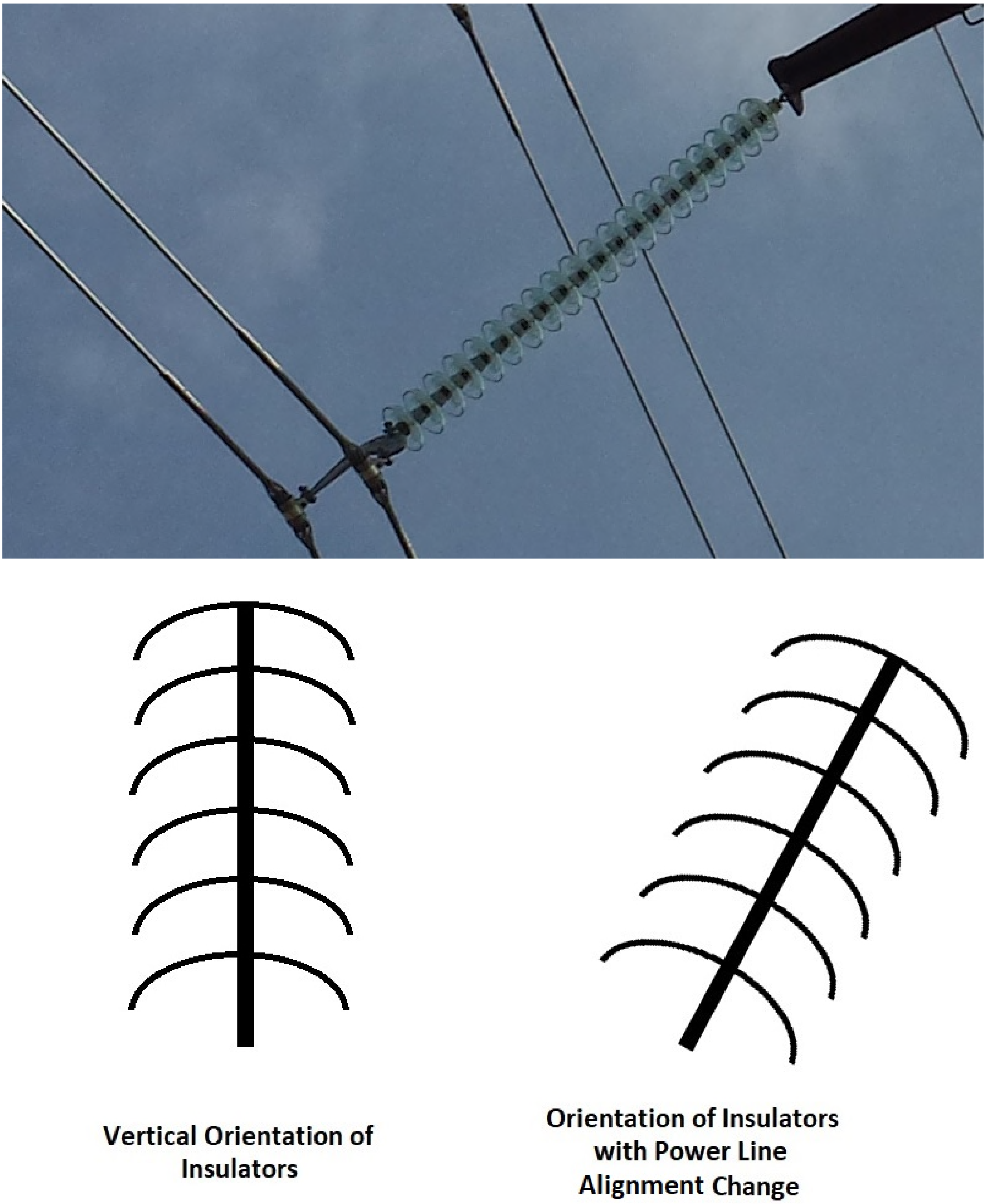


Fig. 6 – Power transmission line alignment direction change

When the power transmission line crossed to opposite sides of the road, the insulators, shown in Figure 7, were no longer hanging vertically, but slightly angled into the horizon and wind. Finally, there was a similarity with the poles observed to generate tones that made them unique in configuration compared to the majority of the other poles. Furthermore, the tonal noise only occurred when the wind was blowing into the concave surface or onto the convex surface of the insulators.



Vertical Orientation of Insulators

Orientation of Insulators with Power Line Alignment Change

Fig. 7 – Power transmission line insulator orientation

3.6 Resolution of the Problem

Discussion with the insulator manufacturer indicated that they were aware of conditions that could case these particular insulators to create tonal noise. The manufacturer recommended changing the insulator type to a different profile.

At the next scheduled power line outage, the insulators were changed and the tonal noise problem was cured.

4 CONCLUSIONS

While the vast majority of a utility's newly installed 345 KV power transmission lines do not result in noise when the insulators are suspended vertically, a flute-like tonal noise was generated when the insulator's concave or convex surfaces were slightly angled horizontally into the wind. The insulator's orientation is angled toward the horizon at locations where the power line's directional alignment changes.

Eliminating the tonal noise required changing the insulators on offending power poles to an alternate profile design.

5 REFERENCES

1. Brüel & Kjær Sound & Vibration Measurement A/S, Retrieved from http://noisesentinel.bksv.com/

2. M. S. Howe and H. D. Baumann "Noise of gas flows", Chap. 14 in *Noise and Vibration Control Engineering-Principles and Applications,* edited by Leo L. Beranek and Istvan L. Ver, Wiley, New York, (1992).

3. Donald E. Hall, *Musical Acoustics*, Wadsworth Publishing Company, Belmont, California, (1980).