Audible Noise Characters Analysis of 220kV Xiangtang Transmission Line

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Abstract. In order to know the corona audible noise characters of the 220kV transmission line and its influences on nearby residents' life, we measured the corona discharge UV-light, the environmental noise and sound energy of the transmission line respectively. The study results showed that the corona discharge occurred at the transmission line. The audible noise sound level on the roof was 46.2 dB(A) at night, that was slightly beyond the limit value of the first zone of Sound Environment Quality Standard. At night, the transmission line audible noise like ‘SiSi’ was so obvious that disturbs residents. The sound energy analysis results showed that the transmission line audible noise energy focused on the frequency range below 200Hz. The directivity study of sound intensity showed that the highest sound energy happened at 100 Hz in the direction from the transmission line to the top floor of the residents’ house, in which explains that the transmission line noise, slightly beyond the limit, is obvious.

1. Introduction

At present, with the continuous increase in power demand and the rapid development of the national power grid, the voltage levels of transmission lines, substations and other facilities have been correspondingly increased, in which long-distance and large-capacity high-voltage transmission lines have been put into use. The resulting circuit audible noise problems also attract more and more attentions. Some high-voltage lines inevitably pass through residential areas and often cause complaints from residents [1-3]. Wu. Xiong et al. found that under the same A gauge sound level, the audible noise of the transmission line is more annoying than traffic noise. When it is about 10 dB lower than ordinary public noise, the line audible noise shares the same sleep awakening probability as the public noise [4]. Yan. Weiming et al. conducted a human perception survey of noise in typical transmission and transformation facilities, and proposed a low frequency noise limit value for high-voltage transmission and transformation facilities [5]. Therefore, the line audible noise has become a factor that must be considered into the selection of wires and the design of the line structure, which is also the current research focus [6-7]. However, there is no relevant standard for audible noise of transmission lines in China at present, and there is no limit of lines below 500kV, [8]. Tan. Wen et al. studied the limits of audible noise on lines of various countries and found that AC transmission lines can be limited to 55 dB(A) and DC transmission lines can be restricted to 45 dB(A) in plain areas. At high altitudes, it can be limited by 45 to 50 dB(A) [9].
When high-voltage lines pass through rural areas, the audible noise is required to be no higher than 55 dB(A) during the day and 45 dB(A) during the night according to Sound Environmental Quality Standard at level 1\textsuperscript{[10]}. In addition, lots of researches had been done at home and abroad on the measurement and analysis of the line audible noise. In United States, Japan and other countries, corona cages and computer models are used to study statistical characteristics of audible noise\textsuperscript{[11]}. Lu. Yao et al. field tested the audible noise of DC transmission lines\textsuperscript{[12]}. Liu. Yuanqing et al. studied the spectral characteristics of audible noise on ultra-high voltage lines and found that the 8 kHz component of audible noise is relatively stable which can be used to predict A sound level\textsuperscript{[13]}. When Li. Xuebao et al. studied the characteristics of audible noise in DC single-point corona discharge, they found that there is a one-to-one relationship between audible noise pulse and corona current pulse\textsuperscript{[14]}. However, these studies focused on EHV and UHV transmission lines above 500kV. Because 220kV high-voltage transmission lines have low audible noise and are almost inaudible, there is few research\textsuperscript{[15]}. Since the 220kV Xiangtang line is about to be put into operation, the noise disturbance has been a problem. Therefore, the frequency, time and directional sound intensity of the line audible noise have been tested in this paper, in order to know the audible noise characteristics of Xiangtang transmission line.

2. Sound noise generation mechanism

When the electric field strength of the wire surface of the transmission line is higher than that of the corona starting field, corona discharge occurs in the air near the wire and is accompanied by repetitive pulse discharge. This broadband noise caused by chaotic pulses on the surface of the wire belongs to medium-high frequency noise, and the frequency range is usually concentrated at 400 Hz to 10 kHz. The burst pulse has a certain degree of randomness. It sounds like a broken sound, a "squeaking" sound, or a "sizzling" sound, which is clearly different from the general environmental noise. The audible noise generated by the actual corona discharge of the transmission line is generally a comprehensive effect of a series of random discharge points on the wire\textsuperscript{[16-17]}. The audible noise generated by corona in transmission lines is related to the structural design, construction and environmental factors.

3. Experimental instruments and test methods

3.1. Experiment description

The 220kV Xiangtang Electric Railway double-return line has a total length of 20.383 kilometers. It is an important supporting project for the Xiangyu electrified railway. The operating load of the Xiangtang Electric Railway III loop is 1.601 MW, the current is 4.04 A, and the voltage is 228.8 kV; The operating load of the Xiangtang Electric Railway IV loop is 1.602 MW, the current is 4.04 A, and the voltage is 229 kV. In this study, the environmental noise of the 28#-29# overhead line was tested on the spot. The test line (28#-29#) was located in Xiangtang town, Nanchang county, passing through the Xitian natural village, Jianxia village. The mechanical and physical properties of the wire used are shown in Table 1. Local residents reported that the transmission lines produced clear audible noise, which seriously affected their normal production and lives. There were four houses close to both sides of the line, of which the transmission line measured in the resident's home, the projection distance was 8m to the north of the line (shown Figure 1), has the largest audible noise value and is most seriously affected.

| Name               | Type            | Diameter (mm) | Cross section (mm\(^2\)) | Rated tensile strength (N) | Elasticity modulus (MPa) | Coefficient of linear expansion (1/\(1^\circ C\)) | Unit weight (kg/m) |
|--------------------|-----------------|---------------|--------------------------|---------------------------|--------------------------|-----------------------------------------------|---------------------|
| Conducting wire    | LGJ-240/40      | 21.7          | 277.74                   | 83760                     | 76000                    | 0.00000189                                    | 0.963               |
| Ground wire        | JLB35-100       | 13.0          | 100.88                   | 73540                     | 115300                   | 0.00000145                                    | 0.527               |

3.2. Introduction to test methods

According to the Method of Measurement of Overhead Transmittable Noise\textsuperscript{[16]}. It is required that the measurement position should be on the center of the span sharing almost the same tower height on both sides of the line and at a vertical projection of 15m to the positive pole of the outer wire of the AC line.
Considering that the residents’ horizontal projection distance from the transmission line is only 8 m, and the horizontal projection distance on the other side of the transmission line is less than 1 m, the measurement point cannot be arranged according to the method. After the field survey, we decided to set up three measuring points near the residents’ houses closest to the power lines, namely measure point 1 which is 21 m below the high-voltage line (8 m to the residents’ house), and measure point 2 which is at the top of the residents’ house, 17 m from the high-voltage line, and measure point 3 which is directly behind the residents’ house, as an environmental background, as shown in Figure 2. The instruments used in the tests were the daycor superB ultraviolet light tester, the LT7 Trupuse 200/200B range finder, the SW MC3642 four-channel acoustic analysis system, and the SI512 sound probe respectively. Among them, the distance between double probes of the sound intensity test is selected by 50 mm (the test frequency range is 63-1000 Hz). Test time is from 2 pm to 5 pm, 23 pm to 2 am on the next day.

3.3. Method for calculating audible noise in transmission lines
Since the measurement is at the same sampling time interval, a series of A sound level data sequences are obtained, and the equivalent continuous A sound level during the measurement period is calculated by the following expression[17].

\[ L_{Aeq} = 10 \log \left( \frac{1}{N} \sum_{i=1}^{N} 10^{L_{A,i}/10} \right) \]

(1)

N—the number of test data; \( L_{A,i} \)—the i-th A gauge sound pressure level, dB(A).

The total acoustic pressure level expression for a third of frequency range of the measurement point is:

\[ L_p = 10 \log \left( \sum_{f} 10^{L_{p,f}/10} \right) \]

(2)

\( L_p \)—sound pressure levels at different central frequencies, dB(A).

For sound intensity analysis, the expression of the sound intensity level is as follows:

\[ L_I = 10 \log \frac{I}{I_0} \]

(3)

\( L_I \)—sound intensity at different central frequencies, dB; \( I_0 \)—baseline sound strength, \( I_0 = 10^{-12} \) W/m².

4. Experimental results and analysis

4.1. Analysis of corona discharge
In this study, the corona discharge condition of the transmission line 28# -29# between the two towers of the Xiangtang line was analysed, using the Israeli daycor superB ultraviolet light tester. The analysis found that the corona discharge of the line is mainly concentrated on the line (shown Figure 3). There is no significant corona discharge of the cable fixture and insulator supported by the tower.
4.2. Environmental noise analysis

The SW MC3642 four-channel acoustic analysis system recorded the instantaneous total acoustic pressure level in the frequency range between 31.5 Hz to 16 kHz of the Xiangtang transmission line. The data is calculated to obtain equivalent continuous sound levels, sound level time variation curves and corresponding audible noise spectrogram, shown Table 2, Figure 3 and Figure 4, respectively.

| Measure point 1(courtyard) | Measure point 2(roof) | Measure point 3(background) | Standard |
|-----------------------------|------------------------|-----------------------------|----------|
| Daytime                     |                        |                             |          |
| 44.2                        | 49.3                   | 42.3                        | 55       |
| Nighttime                   |                        |                             |          |
| 45.5                        | 46.2                   | 40.2                        | 45       |

As can be seen from Table 2, the audible noise measured by residents on the roof and in the courtyard is higher than the background sound. The audible noise measured on the roof during the day is about 49 dB(A), which is about 5.1 dB(A) higher than the audible noise in the courtyard, and all meet the limit value standard of level 1 area in Sound Environmental Quality Standard. The audible noise measured on the roof and in the courtyard at night was close to 46 dB(A), slightly exceeding the limit of 45 dB(A) in the Sound Environmental Quality Standard in level 1 area at night.

Figure 4 shows that the time domain diagram during the day fluctuates greatly and is relatively stable at night. By comprehensive field environmental analysis, fluctuations of the sound level during the day are due to the influence of social noise (such as dog barking, vehicles) around the village; the sound level fluctuations at night are caused by the passing of distant trains.

From Figure 5(a), it can be seen that the sound levels measured by the three measurement points are relatively close in the low frequency range of less than 125 Hz; in the mid-frequency range from 125 Hz to 8 kHz, with the increase of frequency, the audible noise test on the roof is gradually distinguished from the background noise of the courtyard. From Figure 5(b), it can be seen that in the mid-low frequency range from 125 Hz to 500 Hz, the audible noise tested on the roof is 4.3 dB, which is higher than that of the courtyard; in the mid-high frequency range of 500 Hz to 8 kHz, the audible noise of the courtyard is higher than that on the roof, especially at about 4 kHz. The audible noise measured by the courtyard is 8.5 dB, which is higher than that on the roof, combined with environmental analysis. It's probably insects in the courtyard at night calling out loud and interfere in the high-frequency area.

From national standards, the environmental noise at this place was only slightly exceeded at night, but the actual residents reported that the noise was serious. At night, the "sizzling" sound of the transmission line could be clearly heard at the scene. Since it is not possible to clearly explain the disturbance phenomenon of the high voltage line from the common indicators of environmental noise testing, the research group carried out further research from the angle of acoustic energy.
4.3. Sound energy analysis

Due to the slightly excessive noise in the night environment and obvious audible noise on the transmission lines, this study carried out on-site simultaneous recordings of night audible noise at the measure points of the roof and courtyard, and obtained the time-frequency domain energy spectrogram of audible noise through Matlab numerical processing, shown Figure 6 below.

![Figure 6 Time-frequency energy spectrogram of audible noise of transmission lines](image)

From the energy spectrogram at the top of the building, it can be seen that the audible noise energy of the transmission line is relatively stable over time, and its energy distribution is mainly concentrated on the low-frequency parts below 200Hz. From the on-site point, the "sizzling" sound of the transmission line is heard more clearly at nighttime than at daytime. The reason is that the dew droplets formed or gathered on the wire at night, resulting in a large number of corona discharges randomly distributed along the wire. And produce burst sound.

From the energy spectrogram on the courtyard, it was found that the energy was concentrated in the range of 3800-4500Hz in addition to the above-mentioned low-frequency part. The reason for the analysis was due to the sound of insects in the courtyard grass.

Considering that the energy spectrogram in Figure 5 does not necessarily represent the acoustic energy value received by the household, we also used the pointing acoustic intensity test method to test the acoustic energy transmission of the transmission line noise to the top floor household direction at night. Sound intensity is directional, which refers to the sound energy per unit area, passing perpendicularly through the direction of sound wave propagation per unit area, w/cm²; the sound intensity level is used to represent the level of sound intensity in unit dB. This study uses SW pair sound intensity probe, and the distance between two probes is 50mm, the test frequency range is 63-1000Hz, the axis of the sound intensity probe is the same as the connection direction of the high-voltage transmission line and the top floor household room, and night sound intensity test results are analysed, shown Figure 6.

![Figure 7 Transmission line household direction night sound intensity spectrum curve](image)

From Figure 7, it can be seen that the direction of households on the transmission line at night is at a maximum of 100Hz, so the transmission line is transmitting the largest amount of acoustic energy in the direction of the household at a frequency of 100 Hz. Since the sound intensity is proportional to the square of the amplitude of the sound pressure or the velocity of the mass, when the sound energy transmitted to the human ear and the forced vibration of the tympanic membrane are large, the sound felt by the person is loud. Therefore, from the perspective of acoustic energy analysis, it can be explained that the transmission lines at night are slightly excessive, but the unique noise feels obvious.

5. Conclusion

The top of the residential building, near the 220kV transmission line, has the highest audible noise, and its diurnal acoustic pressure level is 49.3dB(A), which satisfies the limit value standard of level 1 area in Sound Environmental Quality Standard; it is 46.2dB(A) at night, which exceeds the corresponding
standard. At the test site, it was found that the unique noise of the transmission line was not obviously affected by the outside social noise during the day, but the "sizzling" sound of the transmission line was obviously heard at night due to the decrease of background noise and the influence of night dew. Although the night noise is only slightly excessive, residents nearby report serious interferences, this paper did further analysis in the acoustic energy perspective. The study found that the audible noise energy of the transmission line is mainly concentrated on the low-frequency part below 200Hz, and the night yard test is easily affected by the sound of insects, and its frequency is mainly concentrated on the range of 3800-4500Hz. Directional acoustic intensity tests in the direction of the household show that the transmission line is generating the largest amount of acoustic energy in the direction of the household at a frequency of 100Hz, which sounds horribly. Although the transmission line at night is slightly excessive, the unique noise is obvious. The further study will be the influence of different weather conditions to the audible noise of transmission lines.

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