Study on Noise Pollution of 220kV Substations in Liaoning Province

Songyu Wu¹, Xiang Li², Xiaoyan Qi², Chengjun Li¹ and Tianyuan Xu¹

¹Liaoning Dongke Electric Power Co., Ltd., Shenyang, 110179, China;
²Electric Power Research Institute, State Grid Liaoning Electric Power Co., Ltd.,
Shenyang, 110006, China

Author’s e-mail: 395364891@qq.com

Abstract: Environmental noise has become a common concern of the society, and there are more and more disputes over environmental noise. In this paper, the emission noise of 61 typical 220kV substations in Liaoning Province is tested and analyzed. A total of 610 measuring points are detected, and the level of the noise pollution is clarified. At the same time, the analysis and research on the spectral characteristics and attenuation rules of substations with sensitive points and environmental impacts are emphasized on the basis of actual measurement. The results show that the main noise pollution zone in the substations is in the middle and low frequency areas, and the staff in the substations need to do the key protection. Meanwhile, the vegetation area has a positive effect on the attenuation of the noise.

1. Introduction

The power transmission system in our country consists of two modes: AC and DC. As the national economy and electricity demand continue to climb, high-voltage transmission facilities are built more and more across the country, just like the blood vessels of the human body, interwoven in the motherland. The electric power continue to transport to any place where it needs, all of these “blood vessels” constitute the electricity transmission system of our country. High voltage substations are the relay stations of power transmission system, which is the main facility of it. On the one hand, with the acceleration of urbanization and the development of modern industry, the power load is increasing, also is the number of new and expanded substations. On the other hand, with the progress of the society, the improvement of environmental laws and regulations, and the continuous improvement of people’s environmental consciousness, the complaints of substations have also increased dramatically[1].

With the development of the city, the load density of power supply is increasing. The power supply radius of the substations is getting smaller and smaller. Part of the transformer substations in Liaoning Province are in the densely populated area, and the noise generated by the various electrical equipment in the substations will inevitably have an impact on the nearby residents and the environment. Based on the measured data of 220kV substations, this paper analyzes the current situation of noise emission and distribution law of 61 typical substations in Liaoning Province. In this paper, the distribution characteristics of noise pollution are found, which can provide scientific reference for the design of protection measures for substations, reasonable design of transmission, transformation engineering and the comprehensive control of noise pollution of substations.
2. Research objects and methods

2.1. Object of study
The transformer substations are selected according to the voltage level and the acoustic environment function area of the substations. The acoustic environment functional area of the substations is based on the “Standard of environmental noise of the People's Republic of China” (GB3096-2008). In this paper, 61 representative substations in Liaoning Province are selected as the research object. The substation voltage level is 220kV. The substation area covers the central area, general urban area and suburban area, and the coverage rate of the noise monitoring data of 220kV substations is 29%.

2.2. Detection methods and distribution
According to the requirements of “Discharge standard of environmental noise for industrial enterprises” (GB12348-2008) and “Measurement methods of audible noise for high voltage AC substations” (DL/T 1327-1327), acoustic environmental monitoring should be carried out without rain, snow and lightning, and the wind speed should be lower than 5m/s. The muffler should be covered with windshield when testing noise. Rain, snow, lightning or wind speed over 5m/s should be suspended. The test principles are as follows:

- Monitoring points should be evenly distributed around the station, and each side should not be less than 2 points. The difference between two adjacent noise measurements should not be greater than 3dB (A), if greater than 3dB (A) should be encrypted.
- The measuring points should be 1m outside the station, with a height of more than 1.2 m, and the distance from any reflection surface is not less than 1m. When the station boundary has a wall and surrounded by noise-sensitive buildings, the measuring points should be 1m outside the station, and 0.5m above the wall.
- The measuring frequency of each point is not less than 3 times and the time interval of each measurement is not greater than 5min. The 1min continuous A sound level dB (A) of the monitor of day and night was used as the evaluation basis of the noise.

According to the “Sound environmental quality standards” (GB3096-2008) of national standard of the People's Republic of China and “Power transformer-tenth part:Sound level measurement”(GB/T 1094.10-2003), the stationing are determined. There are a large number of 220kV substations, each site has 10 acoustic environmental test points around the station. Each monitoring point is selected at 1m outside the station, with a height of more than 1.2m, and the distance from any reflection surface is not less than 1m.

2.3. Test instrument
The main test instruments are table 1.

| Serial number | Equipment name            | Equipment model | Equipment serial number | Function                                      |
|---------------|---------------------------|-----------------|-------------------------|-----------------------------------------------|
| 1             | Thermometer               | 310             | 011203642               | Measure ambient temperature and humidity      |
| 2             | Empty box barometer       | DYM3            | 2824                    | Measure ambient atmospheric pressure          |
| 3             | Digital anemometer        | Testo435        | 41866                   | Measure the ambient wind speed                |
| 4             | Noise analyzer            | NL-42           | 031071                  | Measure the environmental noise and spectrum analysis |
3. Detection basis and evaluation criteria

3.1. Testing basis
The test results of noise measurement in substations are shown in table 2.

| Test content | Test basis                                                                 | Results assessment basis                                      |
|--------------|----------------------------------------------------------------------------|----------------------------------------------------------------|
| Station noise| GB 12348-2008 Standard for environmental noise discharge of industrial    | GB 12348-2008 Standard for environmental noise discharge of    |
|              | enterprises.                                                               | industrial enterprises.                                        |
|              | DL/T 1327-2014 Measurement method of living area noise in high voltage AC |                                                                     |
|              | substations.                                                               |                                                                     |

3.2. Evaluation standard
According to the description of the applicable regions in the standard of “Acoustic Environmental Quality Standard” (GB3096-2008), the substations which are involved in this paper covers the central area, the general urban area and the suburb area, etc. The specific values are shown in table 3.

| Serial number | Acoustic environment functional area category | Daytime | Nighttime |
|---------------|----------------------------------------------|---------|-----------|
| 0             | 0                                             | 50      | 40        |
| 1             | 1                                             | 55      | 45        |
| 2             | 2                                             | 60      | 50        |
| 3             | 3                                             | 65      | 55        |
| 4             | 4a                                            | 70      | 55        |
|               | 4b                                            | 70      | 60        |

4. Results and analysis
During the test, the atmospheric pressure is 100.1-100.3kPa, the ambient temperature is 18℃-25℃, the relative humidity is 42%-53%, the wind speed is 0.8-2.3m/s, meet the requirements of noise test and the normal operation of the substations to be measured.

4.1. Data collection and analysis of noise monitoring in substations
In Liaoning Province, 210 220kV substations were carried out, and 61 stations were monitored for noise monitoring, and the coverage rate of noise monitoring data of 220kV substations was 29%. According to the requirements of “Environmental noise discharge standard for industrial enterprises” and “Audible noise measurement methods for high voltage AC substations”, the 1min equivalent continuous A sound level measurement of day and night was carried out in 220kV substations. In order to more clearly reflect the noise level of 220kV individual substations and overall noise level of 61 220kV substations, the monitored data were analyzed statistically, as shown in Figure1-2.
In this paper, a total of 1220 data are collected at 220kV substations, with 610 daytime data and 610 for nighttime data. It can be seen from Fig. 1 that the noise monitoring values of the 220kV substations at daytime are mainly distributed below 55dB (A), accounting for 98.9% of the total measured points. The most distribution points are [0,45] dB (A), accounting for 44.7%. The maximum noise level at daytime is 68.6dB (A), where the substations are close to the busy sections of the city, the traffic is mixed and the background value is high. Therefore, the individual road survey is affected by the surrounding noise and noise monitoring results are more higher significantly. The minimum noise is 31.8 dB (A), the substations are far away from the road and is sparsely populated and less affected by ambient noise. The noise level distribution of 220kV substations can represent the noise level of 220kV substations.

It can be seen from Fig.2 that the noise monitoring values of the 220kV substations at night are mainly distributed between 30,45] dB (A), which accounts for 56.5%. The maximum noise value at nighttime station is 53.9dB (A), which is close to the highway and is located in the downtown area.
near the bustling commercial circle, which leads to the influence of the surrounding noise. The noise monitoring result is obviously high. The minimum noise value is 27.8 dB (A) at daytime, and the substations are far away from the road and is sparsely populated and less affected by ambient noise. The noise level distribution of 220kV substations can represent the noise level of 220kV substations at night.

Noise emission from the station is implemented “The noise standard of industrial enterprise factory” (GB12348-2008). The noise emission standard of the station boundary is related to the acoustic environment function area where the substations are located, as shown in table 3. In order to meet the demand of power supply, 220kV substations are widely distributed, although most of the substations are constructed in rural areas, suburban area, but still can't completely avoid the city center area, and part of the site construction in urban and rural areas next to the main road, so the acoustic environment functional areas of 220kV substations are more, most belong to Category 1 and Category 2, there is also a part of the site is located in the Category 4a. Can be seen from the figure 3, there are 41 substations’ boundary noise meet the standards of Category 1 of acoustic environmental function areas, 17 substations’ boundary noise meet the standards of Category 2, 2 substations’ boundary noise meet the standards of Category 3, 1 substation’s boundary noise meet the standards of Category 4.

![Figure 3. Distribution of acoustic environment function area of 220kV substations](image)

Generally, the acoustic environment function area of 220kV substations is most belongs to Category 1 and 2. After reviewing the EIA approval documents, the measured noise levels of 61 220kV substations are basically meet the relevant national standards. Individual road survey points are affected by the surrounding noise, the noise monitoring results are obviously high, but it is belongs to Category 4a sound environment functional area, so there is no beyond the national sound environmental standards.

4.2. Study on noise pollution distribution characteristics of typical substations

It can be seen from the results of 220kV substations involved in this article, with a few located in the city and the smaller (cannot effectively using distance attenuation of noise) sites have an effect on people’s lives around the outside, most of the station noise have a smaller effect on people’s daily life and work. However, the occupational health problems caused by the noise of substations can not be ignored[3]. Urban substations produces noise when it is running. Most of them do not belong to high decibel noise, but in most cases this low-frequency noise can cause chronic damage to the human body[4].
4.2.1. **Object of study**

The typical 220kV substations selected in this section are sites closer to the urban area. At the same time, in order to reduce the interference of the external noise to the results of this study, we consider to select the sites which far from the main traffic corridors and the enterprises with large noise.

We selected the 220kV outdoor substations whose connection mode is double bus with bypass wiring, and respectively connected with other power plant and substation system. The substations are located in the suburbs, covers a large area, sound waves through the long distance of the geometric divergence, can decay about 10~20dB (A); Second, with the increase in the distance, substation walls, the shelter of main building and absorption of grassland, can decay about 18~25dB(A). A simplified schematic of the substations is shown in Figure 4.

![Figure 4. Schematic diagram of 220kV substations](image)

4.2.2. **Test methods and principles**

Monitoring methods and principles of comprehensive reference to power industry standard of the People’s Republic of China DL/T1327-2014 “Measurement method of audible noise of high voltage AC substations”, DL/T1050-2007 “Guidelines for the electric power environmental protection and technical supervision”, DL/T 799.3-2010 “Technical specification for labor environment monitoring in power industry-Part 3: Monitoring of productive noise” and to monitor the actual situation.

The monitoring principles of the equipment area are as follows:

a. Equipment and safety requirements should be met.

b. The noise generated by the main noise source of the substations is measured in the distance of 1m. In order to understand the noise characteristics, we need to do the spectrum analysis. Frequency spectrum analysis is commonly used to measure the frequency of the center frequency including 63, 125, 250, 500, 1000, 2000, 4000 and 8000Hz. If necessary, a 1/3-frequency acoustic spectrum analysis measurement can be performed in the substation equipment area.

c. Measuring instruments should be greater 1m than the horizontal distance of equipment, from the ground height should be greater than 1.2m, from any of the reflective surface should not be less than 1m.

d. A representative site should be selected on the operator’s operation or inspection route.
4.2.3. Test equipment
Test instruments and functions are shown in table 1.

4.2.4. Measure the distribution point
The noise monitoring points of the substations are strictly based on the requirements of 3.2.2 and distribution characteristics. Due to the low voltage grade of 220kV substations, the main noise contribution source is the main transformer. Therefore, this section mainly discusses the noise monitoring results of the transformer of 220kV substations, as shown in FIG. 4, and the circular symbol is the measurement point of the transformer noise frequency band. The right side of the substations is the vegetation area, it provided favorable conditions to measure the transformer noise attenuation with distance, the arrow to the right (perpendicular to the wall to the 0 to 50 meters) marks points of measurement for the attenuation law of transformer noise.

4.2.5. Results and analysis
During the test, the ambient temperature is 17.8℃, the humidity is 46.5%, the wind speed is 1.17m/s, the atmospheric pressure is 99.7kPa, and the natural environment is suitable for noise monitoring. As the electric conductors in the substations are criss-cross, charged equipment and grounding structure varied, substation noise can not accurately reflect the noise level of a single device, can only reflect the noise level of the region.

4.2.5.1. The spectral characteristics of the main equipment of the 220kV substations
Through statistical analysis, it can be seen that the main noise source of typical 220kV substations is their transformer. The substations has two main transformers, measure the noise spectrum of phase A, phase B and phase C of each main transformer respectively, the spectrum distribution shown in Figure 5 and Figure 6 respectively.

![Figure 5. Spectrum distribution of 1# main transformer in 220kV substations](image)
Figure 6. Spectrum distribution of 2# main transformer in 220kV substations

It can be seen from Fig. 5 and Fig. 6 that the noise of the main transformer in the typical 220kV substations is high at the center frequency of 250Hz, 500Hz and 1000Hz, and the typical low frequency noise characteristic is presented. The six points we measured all present maximum value of the sound pressure level at the center frequency of 250Hz and 500Hz. 66.7 percent of the measuring points’ maximum value of the sound pressure level appears at the center frequency of 500Hz, and 33.3% of the measuring points’ maximum value of the sound pressure level appears at the center frequency of 250Hz, all are in the low frequency region. The main noise of the transformer is derived from the electromagnetic noise and mechanical noise during its operation. The electromagnetic noise is mainly caused by vibration of iron core due to magnetostriction, cause the iron core to vibrate periodically with the change of excitation current, its main contribution frequency band is the base frequency and its integer frequency. Mechanical noise is mainly caused by the noise of cooling fan. The cooling fan is mainly composed of high-frequency aerodynamic noise in 500Hz~4000Hz. It can be seen from the spectrum analysis that the transformer noise of the typical 220kV substations is the comprehensive result of the body noise and the cooling fan. The research shows that traditional noise reduction technology can reduce the noise of cooling fan effectively, but the noise reduction effect of transformer is not good[5]. At the same time, because the low-frequency noise have the characteristics of slow decay and strong penetrating, making the substations noise and corona noise superposition spread to the station, mostly in the form of low-frequency noise[6].

4.2.5.2. The law of transformer noise attenuation in 220kV substations

The right wall of the substations is the vegetation area, as shown in FIG. 4, in the direction of the east and vertical to the outside of the wall from 0 to 50 meters. The noise with the distance is shown in Figure 7.
Figure 7. Noise distribution of vegetation area around 220kV substations

The statistical results of Fig.7 can be intuitively seen that the noise attenuated with the increase of the distance from the substations. The vegetation area is close to the 220kV main transformer area of the substations, the maximum value is 0m outside the wall, and then decreases with the increase of the distance. The vegetation area is much higher than the measuring point, and the attenuation effect of the vegetation is better than the natural attenuation.

5. Conclusions and recommendations

1) Monitoring the station boundary noise of 61 220kV transformer substations in Liaoning Province, compared with the requirements of the EIA document on the station noise, the noise value of the 220kV substations monitored by this project basically meets the relevant national standards.

2) The noise of the main transformer in the typical 220kV substations is analyzed by the noise analyzer. The results show that the noise of the main transformer in the typical 220kV substations is high at the center frequency of 250Hz, 500Hz, 1000Hz, presents the typical features of low frequency noise, the staff in substations need to do a good job to reduce the impact of noise.

3) The noise attenuation effect of the typical 220kV substations is better. Therefore, the noise pollution control can be considered as the isolation belt of higher vegetation, which can effectively accelerate the attenuation of noise.

References

[1] Jingyou Lv, Yu Huang, Aiping Chi, Leixing Tao, Zhen Chen. (2011) Effects of noise in substations on environment and prevention measures. Power and energy, 32:162-164.

[2] Xiaopeng Fan, Li Li, Chengji Huang, Jiwen Liu, Min Chen, Qian Deng. (2014)Noise pollution analysis and control of 110kV substations. Control of noise and vibration, 34:120-124.

[3] Zhixiang Zhu, Zhi Lin, Jingkai Nie, Xin Chen, Yu Han, Fuyao Yang. (2011)Research on low-frequency noise absorption materials of substations (converter station) . East China power, 39:0357-0361.

[4] Ning Li, Dongmei Tian, Dapeng Shan, Chunyan Zang, Chao Zheng, Yajun Wei. (2015)Discussion on noise analysis and noise reduction of urban substations. High voltage electrical appliances, 51:139-144.
[5] Guoying Zhang, Hui Liu, Lianke Xie, Yuwei Zang, Xingang Ma, Yong Zhang. (2016) The noise spectrum analysis and control technology of the converter substations. China power, 49:165-173.

[6] Zuxia Huang. (2014) The application of the spectrum analysis in noise control engineering. Petroleum chemical safety and environmental protection technology, 32:50-53.