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THE RESEARCH ON THE NOISE CONTROL OPTIMIZATION SCHEME OF THE 110KV NEW GENERATION SMART SUB-STATION

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Decreasing the area is one of the advantages of the new generation smart substation, but the distance from the substation noise source to surrounding residents become closer simultaneously,so the noise control must be considered. The noise control optimization scheme was proposed, and substation acoustic field distribution before and after optimization were calculated based on SoundPlan software, the simulation results show that the maximum bounded noise decreased from 53.5 dB (A) to 49.0 dB (A) with the optimization measures. The measured results showed that the simulation model was accuracy and the noise control optimization scheme was efficient.
Keywords: new generation, smart substation, noise

1. Introduction

New generation smart substation has lots of advantages, such as reasonable structure, highly integrated system, advanced technology and equipment, economic, energy saving and environmental protection, regulation and control integration, what's more, the floor space and construction area was remarkably reduced compared to traditional substation, which saved the project investment and shorten the construction cycle[1-3]. However, the noise source is closer to the wall and surrounding residents, which put forward more stringent requirements on noise control technology for new generation smart substations[4-6]. Noise control optimization scheme was proposed combined with an 110kV new generation smart substation in Hunan based on the characteristics of noise source and simulation analysis in this study, and the proposed scheme was carried out a demonstration application, which achieved good results.

2. Characteristic of noise sources

2.1 Main noise source of 110kV new generation smart substation

As a demonstration project of new generation smart substation expansion, the project scale of an 110kV substation in Hunan was given in Table 1. Major noise source in substation include transformers and ventilation fans.

Table 1 The project scale of an 110kV substation in Hunan

Project name	Final scale	Current scale
Main transformer	2×63MVA	1×63MVA
110kVoutgoing	2loop	2loop
10kVoutgoing	32 loop	16 loop
Capacitive reactive power compensation	4×6Mvar	2×6Mvar
Grounding transformer	2×700kVA	1×700kVA
The land expropriation of this project based on final scale, and constructing by stages.		

2.2 Characteristics of major noise source

2.2.1 Main transformer noise

Transformer noise is caused by the vibration of power transformer body(iron and winding) and cooling devices(cooling fan and oil pump)[7-9].Main vibration sources of transformer body include periodic vibration of iron core caused by magnetostriction of silicon steel sheet, the vibration of iron core caused by electromagnetic attraction which due to leakage flux between the silicon-steel sheet and lamination, the vibration caused by inter-turn electrodynamic force that was generated by load current in windings and the vibration of tank wall caused by leakage flux. Thereinto, the vibration caused by magnetostriction of silicon steel sheet is the most important source. The fundamental frequency of transformer electromagnetic noise is two times as much as power supply frequency, for a 50Hz power transformer, its fundamental frequency of electromagnetic noise is 100 Hz.In addition to the fundamental frequency, there are higherharmonic noise components, and that the larger the power transformer, the lowest the maximum harmonic frequency.

The level of electromagnetic noise of transformer is related to transformer power, the greater the power, the higher the noise. Under the same power condition, the transformer noise is proportional to the magnetic flux density of the transformer core. Fig.1 and Fig.2 showed the typical noise time domain signal and the noise spectrum distribution of an 110kV transformer, respectively. It can be seen from the Figure thatthe noise frequency of transformer is mainly concentrated on 100 Hz and a series of harmonic frequency due to the periodic characteristics of magnetostriction and inter-turn electromagnetic force.The whole spectrum of transformer noise is mainly distributed in the range of 1 kHz, and the energy is relatively lowwhen the noise is above 600Hz band.

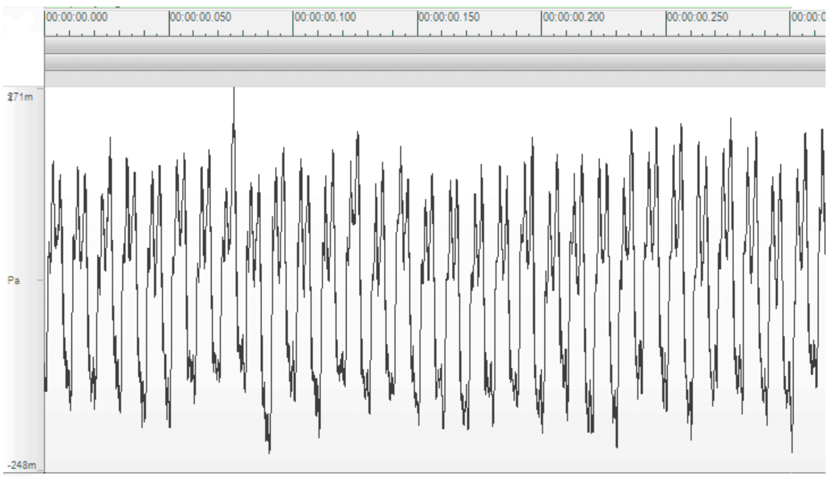


Fig.1 The typical noise time domain signal of a 110kV transformer

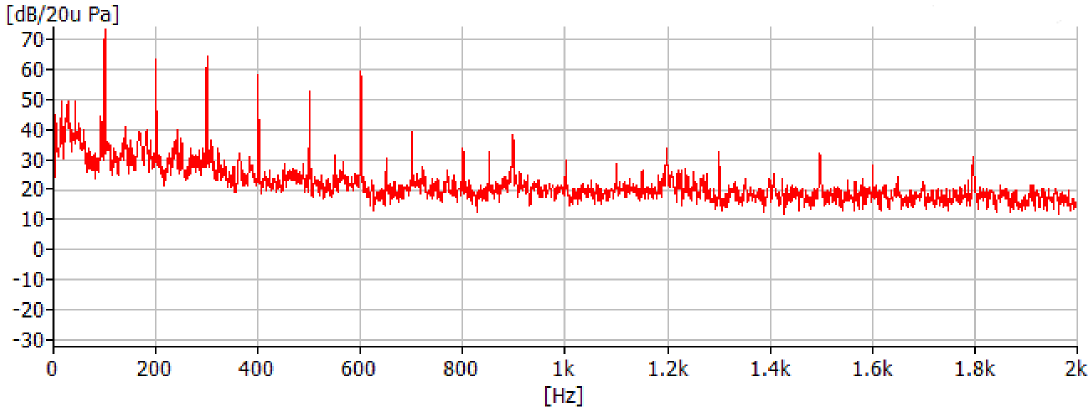


Fig.2 The typical noise spectrum distribution of a 110kV transformer

2.2.2 *Ventilation fan noise*

As for the reason of fan noise, three aspects are concluded.Firstly, the noise produced by aerodynamics. Secondly, the noise generated by mechanical vibration. Lastly, the noise produced by the interaction of the abovementioned aspects[10-12].

Noise generated by High speed air flow, unsteady airflow and the interaction of air and objects are called aerodynamic noise. According to the producing mechanism and characteristics of the aerodynamic noise, the aerodynamic noise can be divided into jet noise, vortex noise, rotating noise, periodic exhaust noise and combustion noise. Generally speaking, the noise of fan can be attributed to rotating noise.

The harmonic frequency of rotating noise can be expressed by the following formula:

$$f_i = \frac{n\tau i}{60} \quad (i=1,2,3\cdots) \tag{1}$$

In the formula, n represents the rotating speed of blade, and τ represents the number of blade.

The relative intensity of each harmonic components of rotating noise depends on the shape of the pressure pulse and the width of the blade, and the more intense the pressure pulse, the smaller the difference of the relative intensity between each harmonic components. The typical time domain signal and spectrum distribution of an axial flow fan noise are shown in Fig.3 and Fig.4, respectively. It can be seen from the two figures that the signal of fan noise is stable and the spectrum distribution is wide.

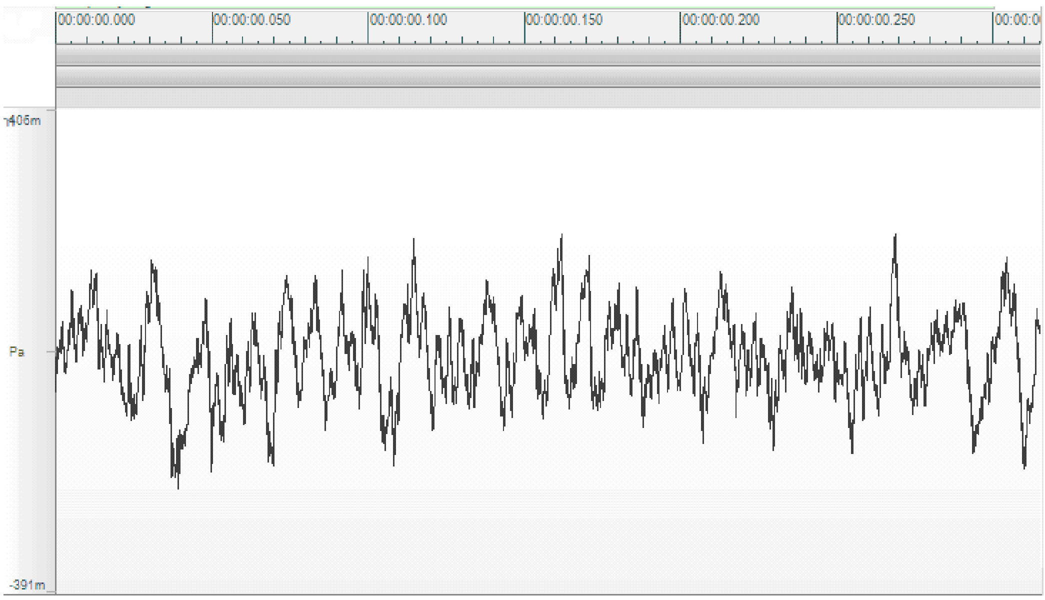


Fig.3 The typical noise time domain signal of an axial flow fan

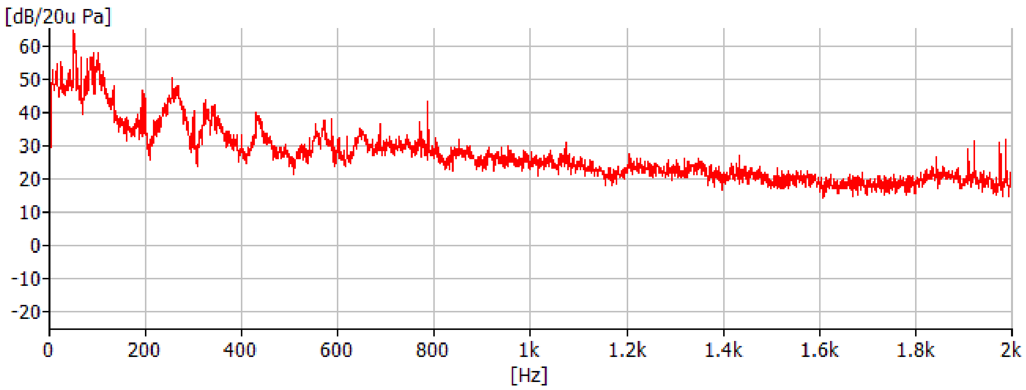


Fig.4 The typical noise spectrum distribution of an axial flow fan

3. Optimization measures

3.1 Optimal substation location

It is necessary to avoid locating the substation on 0 and 1 class noise environment functional areas. The substation was located on 2 class environment functional areas.

3.2 Optimization of substation design

For the substation, whole-indoor style was adopted. At the same time, body and radiator split type transformer was used in substation, the main transformer was located indoor and the radiator was arranged outdoor, effectively reducing the noise of main transformer leakage.

The ventilation pattern that combining natural ventilation with mechanical ventilation was adopted in the substation.

The wall of main transformer room should be built and leave only a small access door after the equipments were arranged in its place, thus making the noise closed in the confined space, meanwhile, reducing doors and windows of the grounding and capacitor room so as to reduce noise pollution to the outside environment.

3.3 Selection of low noise device

As for devices, mainly including main transformer, ground transformer, capacitor, low noise devices should be selected.

In addition to the cable interlayer, 10kV high pressure room and GIS room, which adopt low noise axial flow fan and use mechanical ventilation, the rest of the rooms should use non powered roof fan, which allowing natural ventilation and will not make noise.

3.4 Noise reduction measures

Sound proof door was used for both main transformer room and capacitor room, in this way, the sound transmission loss can be improved by 5~10dB(A).As is well, silencing shutter was used for air intake, which make the sound transmission loss improved by 2~3dB(A).

4. Simulation analysis

4.1 Establishing a simulation model based on SoundPlan software

Geometric acoustic simulation method includes ray-tracing algorithm and sector algorithm. In general, sector algorithm is more accurate, for it can override all areas around acceptance point. However, the ray-tracing algorithm would ignore the parts between rays. As a result, the sector algorithm model is employed for sound field computation in SoundPlan. In real environment, the sound source can be simplified as point source, line source, area source, or volume source, which is surrounded by several area sources, according to the size of sound source and the distance from the related region.

According to the noise superposition formula, the noise contribution of all sound sources to a certain point can be calculated by the following formula:

$$L_{i,sum} = 10 \times \log\left(\sum 10^{L_i/10}\right) \quad (2)$$

The contribution to a single sound source can be calculated by the following formula:

$$L_i = L_w - C_1 - C_2 ... C_n \quad (3)$$

Among them, L_w represents acoustical power of a single sound source, $C_1 ... C_n$ represent correction coefficient of different propagation mode, including direct sound field, air absorption, diffraction sound field, surface influence and reflection sound field.

Sound field distribution of a 110kV new generation smart substation was simulated by using SoundPlan software, as shown in Fig.5, the transformer was simplified as a volume sound source that consisting of 5 area sound sources, and the fan was simplified as a point sound source.

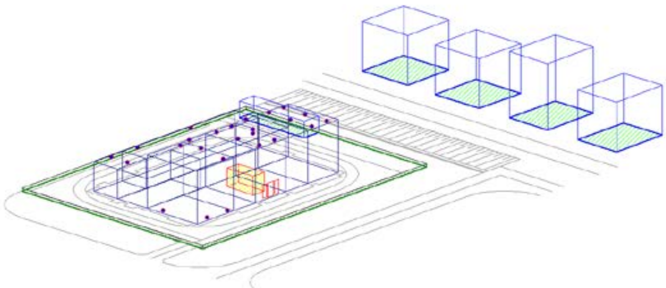
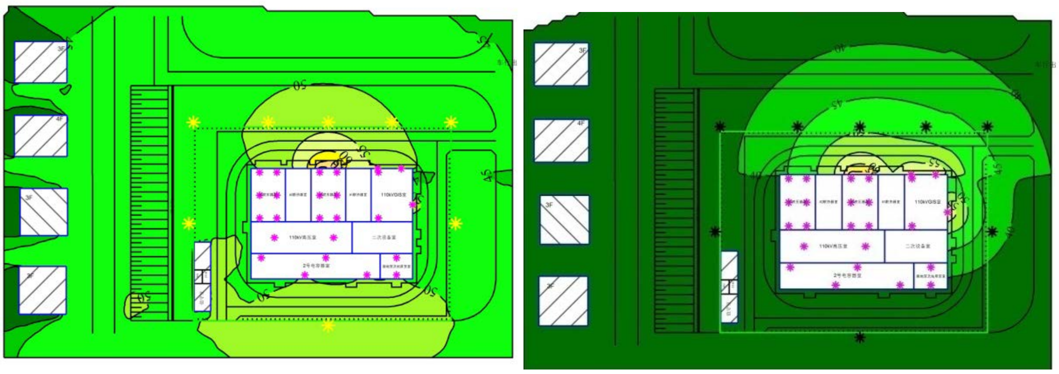


Fig.5 The noise simulation model diagram of the new generation smart substation

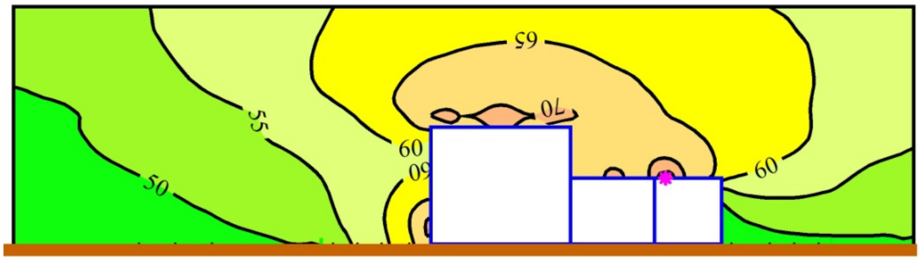
4.2 Sound field distributionof substation before and after optimization

The sound field distribution of new generation smart substation before and after the noise control optimization was calculated by using SoundPlan software, respectively, the result were shown in Fig.6 to Fig.8.It can be seen from Fig.6 that the greatest influence on north station boundary was the noise of main transformerand the greatest impact on south station boundary was the noise generated by fanbefore the noise control was optimized, besides, the noise of station boundary can meet the emission standard absolutely though optimization measures of noise control. As shown in Fig.7 and Fig.8, the noise of west sensitive spot caused by fan exceed the standard before the noise control was optimized, nevertheless, the noise of west sensitive spot can meet the environmental quality standards by optimizing the noise control measures.

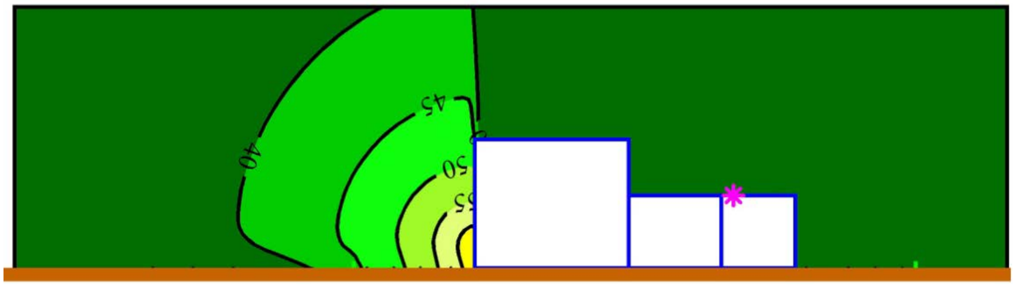


(a) Before optimization (b) After optimization

Fig.6 The sound field plan of the new generation smart substation (h=2.5m)

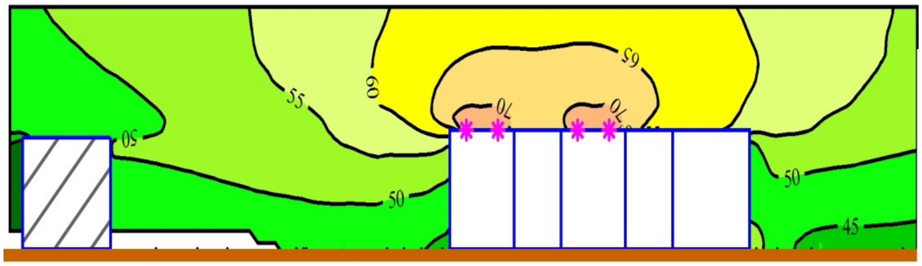


(a) Before optimization

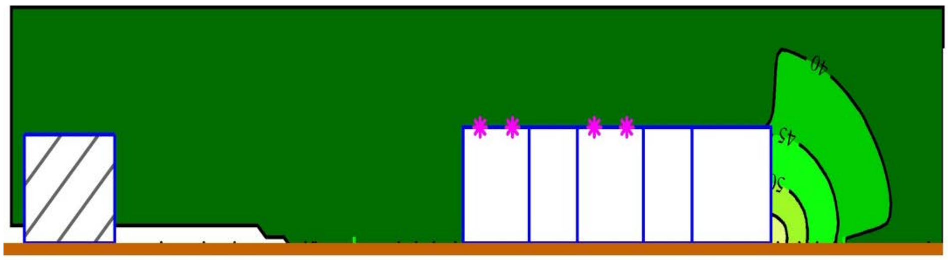


(b) After optimization

Fig.7 The sound field section of the new generation smart substation(north-south)



(a) Before optimization



(b) After optimization

Fig.8 The sound field section of the new generation smart substation (east-west)

5. Application verification

The boundary noise of new generation smart substation in operation was monitored, the arrangement of monitoring points were shown in Fig.9 and the monitoring results were given in Table 2. It can be concluded from Table 2 that good effects were obtained by carrying out the optimization scheme of noise control technology, and the boundary noise emission of this substation can fully meet the requirements of the standard. At the same time, the difference between theoretical and measured value is within 2dB (A), and the accuracy of the simulation model was verified.

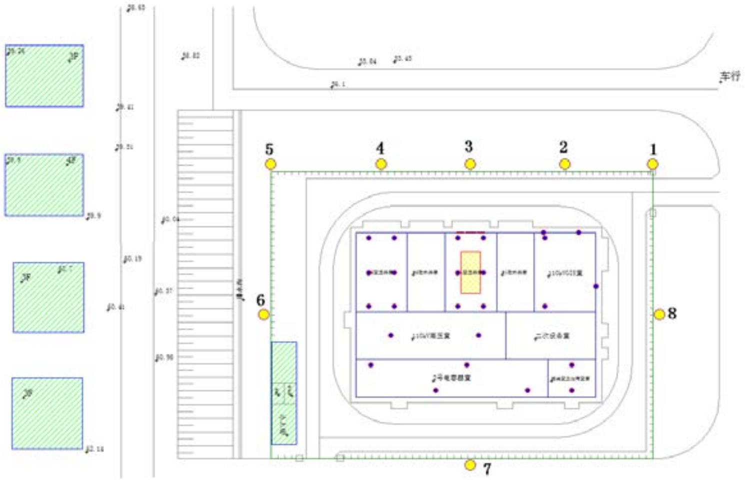


Fig.8 The sound field section of the new generation smart substation(east-west)

Table 2 The monitoring results of boundary noise of the new generation smart substation

Monitoring points	Contribution value of substation boundary noise dB(A)		
	Before optimization	After optimization	Measured value
1	47.3	43.7	44.9
2	50.4	47.5	48.5
3	53.5	49.0	49.1
4	51.0	44.3	48.4
5	48.4	40.4	47.9
6	47.2	42.7	44.4
7	52.6	38.2	40.1
8	49.3	40.2	41.5

6. Conclusions

Combining with the construction of an 110kV new generation smart substation in Hunan, various optimization schemes of noise control technology were put forward in this study, mainly including selecting optimal substation site, optimizing the design scheme, choosing low noise equipments and taking steps to reducing noise. What's more, the sound field distribution of new generation smart substation before and after the noise control optimization was simulated based on SoundPlan software, both the results of simulation and field test verified the excellent effects of optimization scheme of noise control technology.

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