Noise Source Identification for a ±800kV Converter Station Based on Beam-forming Acoustic Imaging Technology

Tao Huang¹, *, Xingyao Wang², Kai She², Wei Cai² and Cao Hao¹

¹State Grid Hunan Electric Power Corporation Research Institute, Changsha, China
²State Grid Loudi Power Supply Company, Loudi, China

*Corresponding author: huangt7@hn.sgcc.com.cn

Abstract. In this paper, a beam-forming acoustic imaging technology is applied to identify the spatial position and frequency characteristics of the main noise source on the key position of a ±800kV DC converter station. The test results show that the main noise sources of the AC filter field are the reactor group and the capacitor group, the noise of the reactor group has obvious peak value at 600Hz, and the noise of the capacitor group has obvious peak value at 100Hz. The main noise of DC filter field is from the reactor. The main noise source in the converter transformer area is the cooling fan array arranged outside the transformer. The maximum noise of the water cooling system is generated by the spray water on the bottom water pan of the cooling tower.

1. Introduction

In recent years, with the rapid development of our country's economy, the contradiction between energy demand and supply imbalance among different regions has become prominent. In order to solve this contradiction, the UHV DC transmission system has developed rapidly in my country by virtue of its advantages in long-distance transmission, cross-regional networking and flexible dispatching. At present, many domestic ±800kV UHV DC transmission lines have been built and put into operation [1-3]. UHV converter station is the place where AC and DC exchange is completed in the DC transmission system. In the existing DC transmission projects, the problem of noise pollution from converter stations is more prominent, and it has become the focus of complaints from surrounding residents [4-6].

The cause of noise in the converter station is mainly due to the large amount of harmonic current in the DC transmission system. When the harmonic current flows through the filter system, it will generate a lot of noise on capacitors, reactors, transformers and other equipment, and the filter system occupies most of the space of the converter station, and the noise generated by it will have a huge impact on the environment of the converter station plant boundary. In addition to the main equipment such as capacitors, reactors, transformers, etc., which will generate large noises, the supporting cooling equipment, such as the converter heat dissipation system, valve cooling system, and external cooling water system of the converter also contributes a lot to the noise of the converter station.

This paper takes a ±800kV DC receiving end converter station as the research object, and uses beam-forming based acoustic imaging measurement technology to conduct field tests on the audible noise at key locations of the entire DC converter station and obtain the spatial location and frequency characteristics of the main noise sources. Through the acoustic imaging measurement and analysis of the current situation and characteristics of noise pollution in the main equipment area of the converter station, it
can lay a foundation for the further development of noise environmental assessment of converter stations, noise control optimization in the planning and design of new converter stations, and noise pollution control of converter stations in operation. Therefore, the work of this article has certain guiding significance for the practice of HVDC transmission engineering.

2. Overview of Converter Station
The construction scale of the ±800kV converter station is 2 times of ±800kV DC incoming lines and 7 times of ±500kV AC outgoing lines. The layout of the station is mainly composed of several functional areas such as commutation area, DC field, AC field, camera and other auxiliary systems. The specific layout is shown in Fig. 1. The main equipment in the station includes 2 sets of 500kV station transformers, 2 sets of 35kV station transformers, 10 sets of AC filters, 9 sets of parallel capacitor banks, 2 sets of low impedance, 12 sets of high-end converter transformers, 12 sets of low-end converter transformers, 2 groups of DC filters, 4 groups of smoothing reactors, etc.

The converter station is equipped with 4 valve halls, and each valve hall is equipped with an independent closed loop valve cooling system. A set of valve cooling system includes: valve internal cooling system, valve external cooling system (including closed cooling tower, spray pump group, external cooling water treatment system).

Figure 1. HVDC layout drawing and measurement point distribution.

In order to adjust the dynamic reactive power compensation of the UHV DC transmission system, the converter station is also equipped with two 300Mvar dual internal water cooling cameras, and an external cooling water system is installed to cool the internal cold water of the converter.

Most of the above-mentioned equipment is arranged inside and outside the station, of which 24 converter transformers and the main body of the adjusting device adopt Box-in arrangement.

3. Testing method
In this paper, the B&K 3660-C-000 noise source identification system is used, and beam-forming acoustic imaging technology is used to locate and identify noise sources in converter stations.

Beam-forming technology (BF) is a noise source identification technology based on microphone array measurement. The basic principle is to arrange a set of microphones in different positions in space in a certain way to form a microphone array to receive sound signals, and after appropriate delay and sum processing, to extract information such as sound source location and sound source intensity, that is,
the number, direction, and amplitude of acoustic radiation sources. BF was first used in radar, sonar, wireless communication and other fields. It is a medium and long-distance sound source localization technology based on acoustic array measurement methods, suitable for long-distance measurement of steady-state sound sources, with fast test speed and better resolution for sound source identification.

The basic theoretical analysis of beam-forming technology is as follows. As shown in Fig. 2, assuming a plane wave sound source is incident on the array, the beam-forming output formula is as follows.

\[
\begin{align*}
B(\vec{k}, w) &= P_0 W(\vec{K}) \\
W(\vec{K}) &= \frac{1}{M} \sum_{m=1}^{M} e^{i(k-\vec{k}_0)\vec{r}_m}
\end{align*}
\]

where \( B(\vec{k}, w) \) is the output when the focusing direction is \( \vec{k} \), \( P_0 \) is the wave number vector of the plane wave's actual occurrence direction, \( \vec{K} \) is the difference between \( \vec{k} \) and \( \vec{k}_0 \), \( \vec{r}_m \) is the position vector of the \( m \)th microphone, \( W(\vec{K}) \) is the array pattern of the microphone array, and is an important parameter that reflects the performance of the microphone array. When the focusing direction \( \vec{k} \) is consistent with the plane wave propagation direction \( \vec{k}_0 \), the array mode takes the maximum value, which is the 'main lobe', otherwise the result is attenuated, which is called the 'side-lobe', as shown in Fig. 2. Side-lobes overlap each other to form a 'ghost', which affects the accuracy and accuracy of beam-forming sound source recognition.

![Figure 2. Principle of beam-forming.](image)

The main test areas of this paper include AC filter field, DC filter field, converter transformer, 500kV station transformer, valve cooling system and external cooling water system of the adjusting camera. The acoustic imaging measurement point layout is shown in Fig. 1. The main body of the BF test device is a 30-channel acoustic holographic array with a diameter of 4m, composed of 5 test arms, and six 1/4-inch high-precision microphone probes are arranged on each test arm. The acquisition device uses B&K's LAN-XI acquisition instrument, and the terminal display and data processing are completed by a computer, as shown in Fig. 3.
4. Test results and analysis

4.1. AC filter field

The AC filter field is composed of a filter reactor bank and a filter capacitor bank. The reactor adopts a dry-type air-core reactor, and the reactor coil generates periodic magnetic vibration under the action of an alternating electromagnetic field, which leads to noise. Figure 4 shows the acoustic imaging diagram of the AC filter field filter reactor bank, and Figure 5 shows the acoustic imaging diagram of the filter capacitor bank. It can be seen from the test results that the noise source in the area of the filter reactor group is mainly the dry-type air-core reactor itself, and its noise has a significant peak in the range of 562~708Hz. The sound source of the filter capacitor bank is mainly the capacitor unit, and there may also be vibration and noise caused by the improper installation of other supporting components. In addition to the frequency peak in the range of 89~112Hz, there is also a peak in the range of 562~708Hz similar to the reactor test result.
Figure 4. (a) (b) Acoustic imaging test results of reactor banks in AC filter field.

Figure 5. (a) (b) Acoustic imaging test results of capacitor banks in AC filter field.

4.2. DC filter field
The reactor in the DC filter field is the main noise source in this area. The reactor uses a dry type air-core reactor, and the reactor coil is composed of one or more sealed coil layers. The fundamental
frequency and harmonic frequency noise caused by the current interaction between the coil and the coil magnetic field is the main reason for the noise of the smoothing reactor. The smoothing reactor is arranged in the air at a distance of about 5~7m from the ground, and it is difficult to shield it from noise, and because the capacity is generally large, its noise will cause great interference to the boundary of the converter station.

Figure 6 shows the results of the acoustic imaging test in the DC field. It can be seen that there is noise interference between the two smoothing reactors tested, and the noise source location point is between the two reactors.

4.3. Converter transformer

Figure 7 shows the results of the acoustic imaging test of the converter transformer area. The main noise of the converter transformer is mostly separated by the wall, acoustic imaging measurements show that the main noise source in this area is the fan array of the converter cooling system arranged outside the converter. It can also be seen from the figure that the fan array noise is dominated by low-frequency noise, concentrated in the frequency band below 200 Hz.
4.4. Water cooling system
The water cooling system is a water circulation system. The main noise sources of water cooling towers are as follows: the rotation of the fan blades causes the turbulence of the air flow and the noise generated by the vortex; the noise generated by the spray water hitting the radiator coil and the bottom water pan under the action of gravity and the operation of the spray pump and piping cause the tower body to vibrate and generate radiation noise.

Figure 8 shows the sound image test results of the cold water cooling tower. It can be clearly seen from the figure that the biggest noise of the cooling tower comes from the noise generated by the spray water hitting the bottom water pan, and the noise is rich in frequency components below 1000 Hz.
5. Conclusion

In this paper, the acoustic imaging measurement technology based on beam-forming is used to conduct on-site acoustic imaging tests for the audible noise at the key locations of the entire station at a ±800kV DC receiving end converter station and obtain the spatial location and frequency characteristics of the main noise sources. The main conclusions are as follows:

1) The noise source in the area of the AC filter reactor group is mainly the dry-type air-core reactor, and its noise has a relatively obvious peak in the range of 562~708Hz. The sound source of the filter capacitor bank is mainly the capacitor unit.
2) The main noise of the DC filter field comes from the reactor, and there are obvious noise components caused by higher harmonics.
3) The main noise source in converter transformer area is the fan array of the converter cooling system arranged outside the converter.
4) The maximum noise of the external water cooling system is generated by the spray water hitting the bottom water pan. The noise is rich in frequency components below 1000Hz.

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