Anomalous Noise Measurement and Analysis of the Valve Hall in ±800kV UHV Converter Station

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Abstract. In order to control the anomalous noise of the pole-I valve hall in a ±800kV UHV converter station, the background noise of the valve hall and the noise of each valve group in the valve tower are measured, respectively. The sound pressure level differences of the valve groups are compared. The anomalous noise locates in the short-circuit pipe of cooling water in the valve tower. Frequency spectrum analysis shows that the abnormal noise is related with the flow of cooling water. The two-dimensional finite element model is established to analyze the influence of chamfer angle and pipe length on the flow velocity of cooling water. The result shows that the abnormal noise is only related with the chamfer angle of the short-circuit pipe with constant flow velocity. The abnormal noise is successfully controlled by structure improvement of the short-circuit pipe and the potential risk to the valve group is avoided, which will give technique support to the operation and maintenance of the valve hall in UHV converter stations.

1. Introduction

UHV DC transmission projects can meet the needs of long-distance and large-scale transmission of electrical energy, and greatly improve the economy and flexibility of electrical energy transmission [1]. In recent years, UHV transmission technology has developed rapidly and matured in China, and the noise problem generated by UHV DC transmission projects has become increasingly prominent. Abnormal noise not only easily leads to excessive noise at the boundary of the converter station and causes environmental protection disputes, but also easily induces potential equipment defects and affects the safety and stable operation of the equipment. Therefore, sufficient attention should be paid to the abnormal noise of equipment in the converter station.

At present, there are many domestic research reports related to the valve hall of converter stations, mainly focused on the structural design of the valve hall, electromagnetic interference, electric field calculation, electrical equipment layout, and noise measurement and control [2-12]. The literatures [10] analyzes and studies the noise control schemes in various areas of UHV converter stations, and proposes noise control measures for UHV DC converter stations. The literature [11] discusses the noise distribution of converter stations. The literature [12] introduces the noise characteristics of converter stations and their control measures. However, there are relatively few research results on the detection and analysis of abnormal noise in the valve hall of converter stations.
In this paper, the abnormal noise of the extremely low-end valve hall of a ±800kV UHV converter station is detected, the location of the abnormal noise is determined, the fluid field finite element calculation model is used to analyze the cause of the abnormal noise, and the effect of abnormal noise treatment is tested and compared. Evaluation, so as to provide reference for the investigation and treatment of abnormal noise in the valve hall of the UHV converter station.

2. Arrangement of noise measuring points in valve hall

The valve hall of the converter station contains 6 valve towers, each of which is mainly composed of 8 valve groups, water cooling systems and shielding covers. The water cooling system is composed of main water pipes, branch water pipes and short connection pipes. The main cooling water pipe of the valve tower adopts a double-pipe spiral design with an inner diameter of 81mm and is divided into an inlet pipe and an outlet pipe. When the main water pipe passes through each layer of valve components, the cooling water is introduced into the valve block from the branch water pipe with an inner diameter of 16mm, absorbs the heat of the valve block, and returns to the outlet pipe to realize the cooling cycle of the valve block. The valve tower structure and the arrangement of noise measurement points are shown in Fig. 1.

![Figure 1. Schematic diagram of the valve tower and noise measurement points.](image)

In order to improve the water circulation at the end of the main water pipe and prevent the "dead water" at the end of the water pipe from causing deterioration of water quality and residual air at the end of the water pipe, a 16mm inner diameter short joint pipe is generally used to connect the inlet and outlet pipes to connect the end of the main inlet pipe and the end of the main outlet pipe. Since the short connection pipe is connected in parallel with the branch water pipe, in order to ensure that the cooling water entering the valve group can maintain a certain pressure and flow rate, a cut-off pipe with a length of about 4 cm is usually welded in the middle of the short connection pipe to clamp the cooling water flow rate in the short connection pipe, as shown in Fig. 2. The short-circuit tube is located at the noise...
8# measuring point in Fig. 1. Furthermore, the inner diameter of the intercepting pipe is 4mm. In order to reduce the vortex effect of the water flow, a chamfered design is adopted inside.

During the low-end commissioning of the converter station, the valve towers in the extremely low-end valve hall of the ±800kV converter station had large and sharp abnormal noises. In order to locate the location of abnormal noise, it is necessary to perform a local noise test on each valve group in the valve tower. The location of the noise measurement point is shown in Fig. 1. During the specific test, the measuring point is located 0.3m in front of each shielding cover, and the B&K 2270 handheld sound level meter is used to measure the sound pressure level (SPL) of each measuring point and record the wave. The test time is 10s and the sampling frequency is 48 kHz.

**Figure 2.** Schematic diagram of the short-circuit pipe.

### 3. Valve hall noise test and analysis

As the valve hall was transferred to the overhaul state during the test, the electrical equipment has been out of operation. In addition, the gate of the valve hall was closed during the test, and the noise of the water pump outside the hall had a small effect on the noise in the hall and was negligible. Therefore, the noise sources in the valve hall are mainly water cooling systems and ventilation fans. When the water cooling system is shut down, the background noise in the valve hall is 63.4 dB (A), and the frequency spectrum is shown in Fig. 3. It can be seen that the fan operating noise frequency is 466 Hz. After the water cooling system is running, the test results of the sound pressure level of each valve tower in the very low-end valve hall are shown in Table 1 and Table 2.

**Figure 3.** Frequency spectrum of background noise.
Table 1. Sound pressure levels of the valve hall.

| valve tower | measuring point | SPL/dB(A) | valve tower | measuring point | SPL/dB(A) |
|-------------|-----------------|-----------|-------------|-----------------|-----------|
| Y/D A       | 1#              | 67.9      | Y/Y A       | 1#              | 66.8      |
|             | 2#              | 69.2      |             | 2#              | 66.1      |
|             | 3#              | 67.4      |             | 3#              | 67.6      |
|             | 4#              | 69.0      |             | 4#              | 66.0      |
|             | 5#              | 67.8      |             | 5#              | 67.4      |
|             | 6#              | 69.7      |             | 6#              | 66.3      |
|             | 7#              | 68.1      |             | 7#              | 66.7      |
|             | 8#              | 71.2      |             | 8#              | 67.2      |
|             | 1#              | 68.8      |             | 1#              | 66.7      |
|             | 2#              | 70.5      |             | 2#              | 66.8      |
|             | 3#              | 69.8      |             | 3#              | 66.9      |
| Y/D B       | 4#              | 70.3      | Y/Y B       | 4#              | 65.9      |
|             | 5#              | 69.9      |             | 5#              | 66.5      |
|             | 6#              | 72.7      |             | 6#              | 66.4      |
|             | 7#              | 69.6      |             | 7#              | 67.2      |
|             | 8#              | **80.0**  |             | 8#              | 67.7      |
|             | 1#              | 73.2      |             | 1#              | 68.6      |
|             | 2#              | 72.0      |             | 2#              | 67.4      |
|             | 3#              | 71.4      |             | 3#              | 68.5      |
| Y/D C       | 4#              | 73.5      | Y/Y C       | 4#              | 69.0      |
|             | 5#              | 72.8      |             | 5#              | 69.4      |
|             | 6#              | 76.0      |             | 6#              | 70.4      |
|             | 7#              | 74.0      |             | 7#              | 70.9      |
|             | **84.6**        |           |             | 8#              | 78.0      |

It can be seen from the table that the maximum noise position of each valve tower is at the short connection pipe (measurement point 8). Among them, the noise level is the highest at the measuring point near the valve hall ventilation fan and the valve hall entrance. The maximum noise at measuring point 8# of the pole I valve tower Y/D C is 84.6 dB(A). Regardless of the 8# measurement point, the noise level of the pole I valve tower measurement point 1#–7# is in the range of 65.9–76.0 dB (A). The 8# measuring point of pole I valve tower Y/D C exceeds the normal level by about 8.6 dB(A).

Figure 4 shows the comparison of the sound pressure spectrum between the 8# measuring point of the pole I valve tower Y/D C and the 8# measuring point of the innermost valve tower Y/Y A. It can be seen that the maximum value of the noise spectrum at the two measurement points is at 1496Hz, which is consistent with the rotation speed of the valve hall cooling water centrifugal pump 1493 r/min. It can be judged that the abnormal noise at the intercepting pipe is mainly caused by the flow of cooling water.

Figure 4. Spectral comparison of 8# measurement point of valve tower Y/D C and Y/Y A.
4. Analysis of the fluid filed in the closure pipe

4.1. Solution region and mesh grid

The solution domain of the interception pipe is shown in Fig. 5(a). Only the fluid area is modeled. In order to strengthen the convergence of the numerical calculation process, a locally refined mapping meshing method is used to determine the chamfer and the position close to the interception pipe wall. The grid is refined. As shown in Fig. 5(b), the model is divided into 28800 grids using Fluid141 elements.

![Figure 5. Solution region and mesh grid.](image)

4.2. Governing equations and boundary conditions

Due to the short length of the model and no cavity in the pipe, the influence of gravity on the flow of cooling water is ignored. Assuming that the cooling water is an incompressible fluid and its thermal effect is not considered, the model governing equation under steady-state conditions is as follows [13].

(1) Continuity equation

\[ \nabla \cdot (\rho V) = 0 \]  \hspace{1cm} (1)

(2) Momentum conservation equation

\[ \nabla \cdot (\rho V V_x) = \nabla \cdot (\mu \nabla V_x) - \frac{\partial p}{\partial x} \]  \hspace{1cm} (2)

\[ \nabla \cdot (\rho V V_y) = \nabla \cdot (\mu \nabla V_y) - \frac{\partial p}{\partial y} \]  \hspace{1cm} (3)

where \( \rho \) is the density, \( x, y \) are the rectangular coordinates in space, \( V_x, V_y \) and \( V_z \) represent the components of the velocity vector \( V \) on the x-axis, y-axis and z-axis, respectively, \( \mu \) is the cooling hydrodynamic viscosity, \( p \) is the pressure.

The model boundary conditions include velocity boundary conditions and pressure boundary conditions. In the solution domain, the flow velocity boundary conditions shown in (4) and (5) are, respectively, applied to the inlet and wall of the intercepting pipe.

\[ V_x = v, \quad V_y = 0 \]  \hspace{1cm} (4)

\[ V_x = 0, \quad V_y = 0 \]  \hspace{1cm} (5)

Where \( v \) is the known cooling water flow rate, which is generally within the range of 1~3 m/s according to the valve tower cooling water flow rate.

The boundary condition at the outlet of the interceptor is

\[ p = 0 \]  \hspace{1cm} (6)
4.3. Flow field distribution results and analysis
When the length of the intercepting pipe is 2 cm and the cooling water flow rate is 1 m/s, the results of the cooling water velocity distribution of the intercepting pipes with different chamfers are shown in Fig. 6. It can be seen that with the decrease of the chamfer angle the flow rate of the cooling water at the inlet gradually decreases, and the flow velocity distribution at the inlet and outlet of the pipeline gradually tends to be uniform. Since the cooling water flow noise is related to the flow velocity distribution, reducing the chamfer angle is beneficial to reduce the noise level of the intercepting pipe.

Increase the length of the intercepting pipe to 6cm, and the cooling water velocity distribution results are shown in Fig. 7. Comparing Fig. 6(c) with Fig. 7, it can be seen that under the condition of the same chamfer angle of the interceptor tube, increasing the length of the interceptor tube does not change the flow velocity distribution of the cooling water at the inlet and outlet.

![Figure 6](image1)

![Figure 7](image2)

Figure 6. (a) (b) (c) Velocity distributions with different chamfers.

Figure 7. Velocity distributions with long pipe.

5. Abnormal noise treatment of intercepting pipe
According to the results of on-site noise detection and flow field simulation calculation, it is judged that the intercepting pipe has a design defect of excessive chamfering, and the analysis result is consistent
with the actual situation. By improving the design of the intercepting pipe and replacing the short-circuit pipe on site, the problem of abnormal noise in the valve hall was successfully solved and potential hidden dangers were eliminated. Take the valve tower Y/D C and Y/D B with higher noise level as examples. After replacing the short-circuit pipe, the valve hall noise test results are shown in Table 2. It can be seen from the comparison of Table 1 and Table 2 that under the same operation mode, after replacing the short-circuit tube, the noise level of the valve tower Y/DC 8# measuring point is reduced from 84.6 dB(A) to 67.2 dB(A). The noise level of 8# measuring point of tower Y/DB is reduced from 80.0 dB (A) to 65.7 dB (A), and the noise of each valve group in the valve tower is relatively uniform and is at a normal level. Before and after the replacement of the short-circuit tube, the noise spectrum analysis of Y/D C valve tower 8# showed that the amplitude of the 1496Hz frequency component in the abnormal noise was greatly reduced, as shown in Fig. 8.

Table 2. Sound pressure levels of the valve hall.

| valve tower | measuring point | SPL/dB(A) | valve tower | measuring point | SPL/dB(A) |
|-------------|----------------|----------|-------------|----------------|----------|
| Y/D C       | 1#             | 63.6     | Y/D B       | 1#             | 63.1     |
|             | 2#             | 65.4     |             | 2#             | 63.6     |
|             | 3#             | 63.6     |             | 3#             | 63.0     |
|             | 4#             | 64.7     |             | 4#             | 63.8     |
|             | 5#             | 63.6     |             | 5#             | 63.0     |
|             | 6#             | 64.9     |             | 6#             | 63.7     |
|             | 7#             | 63.5     |             | 7#             | 63.5     |
|             | 8#             | 67.2     |             | 8#             | 65.7     |

Figure 8. Spectral comparison of 8# measurement point of valve tower Y/D C before and after short-circuit pipe substitution.

6. Conclusion
This paper detects and analyzes the abnormal noise in the valve hall of the ±800kV UHV converter station. It is found that the abnormal noise is located at the end of the valve tower cooling water main pipe, and the abnormal noise is related to the cooling water flow. The calculation results of the two-dimensional finite element flow velocity distribution of the cooling water in the interception pipe show that the abnormal noise in the valve hall is caused by the excessive chamfer of the interception pipe and has nothing to do with the length of the interception pipe. By improving the design of the intercepting pipe and replacing the short connection pipe with design defects on site, the abnormal noise of the valve hall was solved, and technical support was provided for the operation and maintenance of the valve hall of the UHV converter station.

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