Computer Simulation Analysis and Control of Vibration and Noise in UHVDC Converter Station

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Abstract. In recent years, the progress speed of UHVDC converter station power grid is obvious. Although China's power grid research started relatively late, we still made a lot of achievements. However, in the process of research, experts found that the noise in the living room of UHV DC converter station is very serious to people[1]. At present, the harm of audible noise has become an urgent problem. It is related to the maintenance of physical and mental health and the improvement of work efficiency of nearby residents and station staff. More seriously, it may affect the safety of the use of the grid. According to the research of scholars, the vibration of capacitor is the main reason of noise. In this paper, through the computer simulation analysis of UHV converter station vibration and noise, the final conclusion is obtained.

Keywords: UHV, Vibration, Noise, Simulation

1. Introduction

The development of UHV power grid can help to adjust the distribution of resources and control the development of economy. It is very important to save electricity, reduce network loss and improve transmission capacity. Due to the large power transmission capacity and good regulation function, the renovation and progress of DC converter station are strongly supported by the state. With the passage of time, the noise pollution of DC converter station has been widely concerned[2]. Experts believe that the noise control of converter station has a profound impact on the investment of land resources, the reduction of demolition and the control of power grid security.

With the continuous updating of China's electric power industry and urban power grid, there is no doubt that the converter station of high-voltage DC transmission will be built in the controllable range of the city. According to the tests conducted by researchers from the Chinese Academy of Electric Power Sciences, they found that the noise around the capacitor device is very high. Up to 89.7 dB. In
some converter stations with high power consumption, the noise level of capacitor can even reach 105 dB. After comparing the noise level of capacitor with the noise standard of environmental control in China, we can find that the noise level of capacitor in UHV DC converter station has far exceeded the environmental noise standard. This kind of noise will cause serious harm to human and animal health.

2. Analysis of vibration mechanism of UHVDC Converter Station

2.1. Vibration related equipment

We can find that the value of capacitor in DC converter station is very high. If there is no capacitor technology support. The power transmission of converter station will not be very smooth. Therefore, we can think that the lack of capacitors can limit the efficiency and even the working state of DC converter station. In the process of using capacitors in DC converter station, the most commonly used capacitors are divided into two types. The first is a common capacitor. The second is filter capacitor. The structure of the two types of capacitors is similar.

2.2. Analysis of capacitor structure

Generally speaking, the composition structure of the capacitor includes the capacitor unit, shell, electrolyte lead and insulating bushing. In general, the unit of the capacitor is made of polypropylene film. The shell of the capacitor will be filled with insulating oil. The oil can completely seal the housing. The bushing will be used to lead out the electrodes for the connection. In this case, the electric field forces acting on the top and bottom plates of the capacitor cannot be mutually inefficient. However, the electric field forces of the remaining intermediate plates can be offset by each other. This is also the main reason for the capacitor vibration (see Figure 1).

![Figure 1. UHVDC power exchange](image)

3. Analysis of vibration and noise principle of capacitor

Because the structure of the capacitor device is flat, the upper and lower plates are parallel during its operation. According to the physics related formula, we can draw the corresponding conclusion.

3.1. Energy distribution between two plates

According to the relevant theory of physical electricity, we need to use the relevant theoretical
knowledge of dielectric constant, alternating current and plate electric quantity. The attraction between the two plates is as follows:

\[ f = \frac{dW}{dy} \]  

(1)

In this equation, \( W \) is the electric field energy in the capacitor. \( C \) is the capacitance of the parallel plate capacitor. \( F \) is the attraction between the plates.

\[ W = \frac{1}{2} C u^2(t) \]  

(2)

According to the above formula, we can get:

\[ F(t) = \left(-\varepsilon A / 2 d^2\right) u^2(t) \]  

(3)

3.2. Voltage control of UHVDC Converter Station

In the actual working process of converter station, capacitors can be used for filtering and reactive power compensation. According to the knowledge of mathematical function, we can think that the basic form of voltage placed at both ends of capacitor is not a single sine function. According to the relevant mathematical conversion, we can draw the following conclusions:

\[ F(t) = K \left(U_0(t) + U_0(t)\right)^2 \]  

(4)

3.3. The generating principle of vibration and noise in UHVDC Converter Station

According to the above analysis, we can find that the original capacitor can produce corresponding static force. In addition, it can produce harmonic forces of four frequencies. The direction of their force is perpendicular to the direction of the bottom of the capacitor\(^3\). Therefore, the bottom and top of the capacitor are the most significant parts of the vibration frequency. This will cause the noise of capacitor to have obvious directivity.

4. Comprehensive simulation analysis of vibration and noise of UHVDC Converter Station

According to the analysis of the above mechanism, we can find that the number of the original capacitor is relatively large. It is impossible to conduct data statistics through direct calculation. In addition, the inside of the capacitor includes electromagnetic field and sound field. This kind of problem belongs to the pluralistic coupling problem in physics. Therefore, we need to carry out comprehensive simulation analysis of vibration and noise (see Table 1).

| Parts            | Density | Elastic  | Poisson's ratio |
|------------------|---------|----------|-----------------|
| Housing          | 6.301   | 2.1E9    | 0.15            |
| Capacitor element| 775     | 2.1E8    | 0.21            |

Table 1. Investigation on the properties of capacitor model materials
4.1. Establishment of simulation model of capacitor vibration in converter station

In order to build the vibration model, we must understand the material properties of the model. Theoretically, the finite element model of capacitor vibration should be composed of shell, component and insulator. We can set the basic situation of capacitor operation. The basic frequency is 50 Hz. The voltage is 15 volts. The harmonic frequency is 550 Hz. According to the transient response analysis of computer simulation technology, we can get the velocity of the joint between the shell and the porcelain column. According to the above data, we can get the velocity nephogram of the capacitor surface. From this we can get the maximum value of vibration.

4.2. Conclusion of the experiment

According to the experimental results, we can find that the vibration of capacitor is closely related to the noise of converter station. Moreover, the unbalanced distribution of the electromagnetic force between the two plates will lead to the increase of the noise effect.

5. Analysis of noise source of UHVDC Converter Station

The vibration of capacitor can be considered as the main source of noise in converter station. However, there are still many components that will produce corresponding noise\[4]. Although their noise impact is relatively small, we still need to pay attention to them. According to the research of experts, the noise sources in DC converter station include capacitors, transformers, reactors and filters.

5.1. Influence of converter transformer noise

The noise of converter transformer includes electromagnetic noise, cooling fan noise and transformer vibration structure noise. Among them, the influence of the noise of the transformer fan is the biggest. It is mainly composed of dynamic noise of air and mechanical noise of body shell. The speed of the fan of the transformer is very high. Its noise is mainly concentrated in high frequency.

5.2. Noise of smoothing reactor

The noise of reactor is caused by the interaction of DC current and harmonic current\[5]. In special cases, the interaction between the coil and the current generated by the coil's magnetic field will also cause the coil to vibrate. This is also the reason for the noise of air core reactor.

5.3. Noise of filter

There are many filter devices in DC converter station. These devices are mainly composed of reactors and capacitors. In short, the essence of filter noise is the integration of capacitor noise and reactor noise.

6. Noise control measures of UHVDC Converter Station

6.1. Noise reduction at sound source
For this form of noise reduction, we can divide it into three parts. Reduce the noise of converter transformer, smoothing reactor and capacitor. We can reduce the magnetic density of the iron core and use the high magnetic conductivity material with small expansion rate to reduce the noise of the transformer. We can adjust the structure size and increase the series number of capacitors to reduce the noise of reactor and capacitor respectively.

6.2. Noise reduction in the process of noise propagation

This noise reduction measure is more intuitive. We can set up some noise shielding devices around the DC converter station. Another way is that we can strengthen the form of noise pollution control in residential areas.

6.3. Noise reduction measures at the receiving point of noise

This noise reduction standard is mainly used as a theoretical study of noise reduction for staff. Workers can bring a protective headset to work in high noise space[6].

6.4. Post processing of noise reduction based on computer

We can use computer software to calculate noise. It can be used to calculate the distribution characteristics of noise in the area without noise reduction. According to the distribution of noise, we can shield the noise.

7. Conclusion

In order to help the development of China's power grid as soon as possible, we need to use computer technology to optimize the power grid technology. The vibration and noise control of UHV DC converter station is a problem we must solve. We want to minimize the residents and work resentment noise disturbance. We should ensure the safe operation of the converter station.

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