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RESEARCH ARTICLE

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Electromagnetic interference and shielding of valve hall in HVDC converter station

Abstract The electromagnetic interference (EMI) from the valve hall as an important consideration in the design of high voltage direct current (HVDC) converter stations is analyzed by electromagnetic field numerical method and measurements. By using moment method, the EMI filed strength level as well as radio interference level (RIL) of the valve hall during the normal operation are computed after an antenna model is built for the valve tower. According to the character of EMI obtained, the practical shielding measures for valve hall are discussed to satisfy the relative standards. The test results for the ±500 kV converter station show that both the numerical method and shielding technique used in this paper are practical.

Keywords electromagnetic interference (EMI), valve hall, high voltage direct current (HVDC), converter station, shielding

1 Introduction

For the wide use of high voltage direct current (HVDC) projects, the electromagnetic interference (EMI) of HVDC converter station has been paid more attention [1–3] recently. Especially for China, which has the largest quantity of HVDC projects in the world and is building the first extra high voltage direct current (EHVDC) (±800 kV) projects in the world, the research of EMI of HVDC projects is significant. The EMI induced by the operations in the converter station including the steady and transient interference may affect the safety of the equipments in the converter station. In addition, the electromagnetic environment around the converter station may become rigorous for radio signal. References [4,5] studied the electromagnetic environment of HVDC converter station by measurement, and Ref. [6] used numerical method to analyze the radio frequency noise induced by converter station. However, most of the researches in the past did not refer to ±500 kV converter stations or EHVDC converter stations, which are being built in China. Furthermore, the effects of EMI and the measures to control EMI to an acceptable level have not been studied thoroughly.

In this paper, the mechanism of radiated interference from the valve hall is analyzed firstly, and the relative standards [7,8] about EMI that must be obeyed are discussed. Due to the complexity of the valve tower, the moment method [9] is used to compute the radiated EMI of ±500 kV converter station after a complicated antenna model is built. Based on the computed results, the character of EMI level is analyzed and proved that shielding measures must be used with the valve hall to restrain the EMI to a specific level according to the standards. Then the practical shielding measures are discussed. The test results obtained by IEEE standard method [10] proved that both the numerical method and the shielding measures are valid.

2 EMI of valve hall

2.1 Mechanism of radiated interference from valve hall

Electromagnetic interference from HVDC converter stations might be generated over a wide band of frequencies by several situations as follows:

1) Voltage break-downs in the converter valves during the firing processes and the consequent current impulses in the valves, the converter circuits, alternating current (AC), and direct current (DC) lines connected to the valves.

2) Corona discharges in the air around the surfaces of HVDC conductors.

3) Switching operation in AC and DC yard.

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In general, EMI noise from the valve hall includes 1) and 2) listed above, while 1) is the main EMI source because the corona discharges can be held to acceptable levels by proper electrical design of the bus bars and the hardware of the stations. So the studies of EMI from valve hall in this paper mainly focus on 1).

Figure 1 shows the approximate time dependent valve voltage and its spectrum for a typical operation mode in a ±500 kV converter station with normal power. We can see some high frequency components in this transient process. It means the EMI contains some high frequencies.

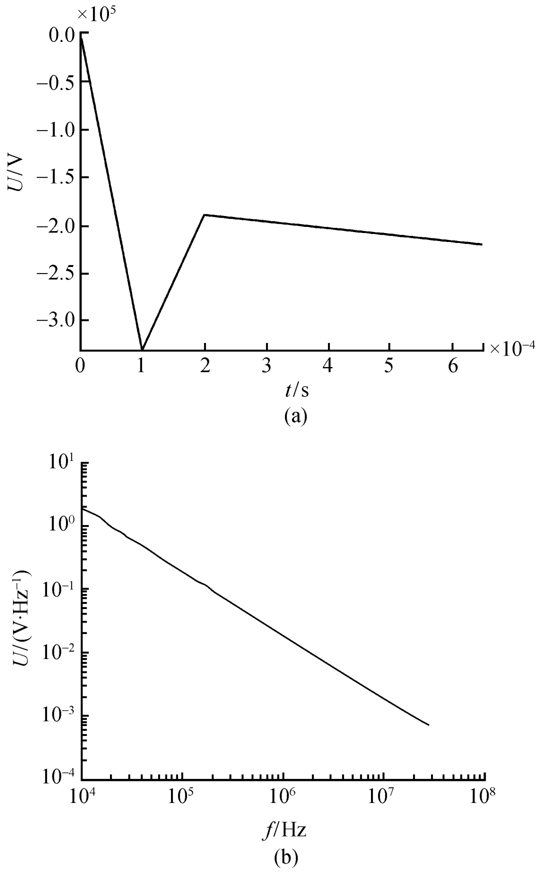

Fig. 1 Time dependent valve voltage and its spectrum. (a) Time dependent valve voltage; (b) amplitude of valve voltage

There are two kinds of effects due to the EMI from valve hall. One is that the electromagnetic field strength level may exceed the immunity of the equipments used in converter station such as the secondary equipments in the control room. In this aspect, the standard that can be referenced is IEC 61000-6-2, which prescribes that the generic standard of immunity for industrial environment is 10 V/m. The other effect is that EMI may affect the radio signal propagation around converter station. The relative standards (ITU-T K.60) prescribe that the radio interference level (RIL) in the range of 1 to 30 MHz should not exceed the value (E) determined by

$$E = 52 - 8.8\lg f \ \mathrm{dB \cdot \mu V/m}. \tag{1}$$

Equation (1) indicates that the value of electric field E decreases from 52 dB·μV/m at 1 MHz to about 39 dB·μV/m at 30 MHz.

The location must be considered for RIL in the standard, as shown in Fig. 2. These locations include the circle area around the converter station with the radius 450 m and also the area near the power line with the distance to converter station that is far to 5 km.

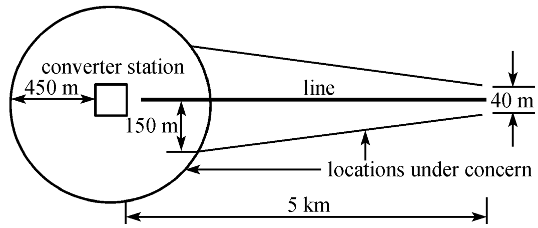

Fig. 2 Locations under concern for RIL

2.2 Numerical method for analysis of EMI

Considering the complexity of the metal structures in valve hall, the electromagnetic field numerical method must be used to analyze its EMI problem accurately. Here we use moment method to compute the EMI level of valve hall. We built an antenna model for valve tower as shown in Fig. 3. In this model, the metal structures are treated as wire model for the conductor wires and patch model for the frames of the valve tower in the valve hall. The thyristors and reactors are treated as lumped elements as the block in Fig. 3, in which the impedances of these elements are frequency dependent, and the values are obtained by measurements. The valve voltage is considered as the excitation added on the antenna system at the position where the valves are placed. Then the EMI levels from the valve hall at different frequency for a typical operation mode are computed.

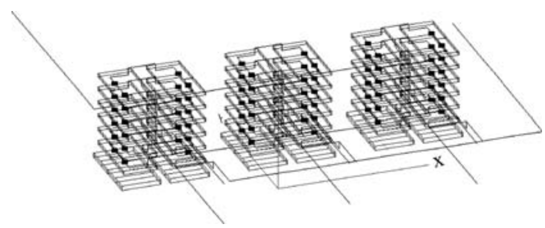

Fig. 3 Model of valve tower for computation

2.3 EMI level of valve hall

Both electric field intensity level and RIL are analyzed with the wall of valve hall and are not considered in our computation firstly. The layout of a valve hall in a

±500 kV converter station is shown in Fig. 4. Figure 5 shows the electric field intensity level at the edge of valve hall at different sides. At most of the frequencies, the electric field intensity components of z direction (E_z) are higher than the components of x direction (E_x) and y direction (E_y). The electric field intensity level decreases with the increase in frequency, and it is higher than 10 V/m when the frequency is lower than 100 kHz, and it exceeds 100 V/m at some frequencies.

Figure 6 shows the electric field components of z direction at different locations along the x axis and y axis, respectively. The electric field intensity level is higher than 10 V/m only in the area which is not far from the valve hall, and it decreases remarkably when the distance to the valve hall is far.

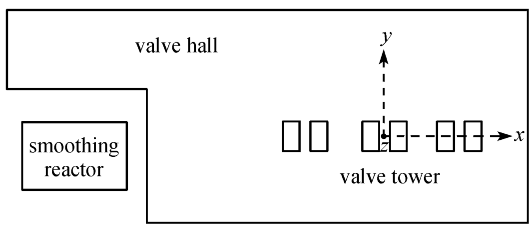

Fig. 4 Layout of valve hall

Figures 7(a)–7(h) show the RIL at the locations under concern as shown in Fig. 3. They are the directional diagrams of RIL for 1 MHz and 20 MHz when the distance to the valve hall is 450 m, 1 km, 3 km, and 5 km, respectively. We can see that when the frequency is 1 MHz, RIL is about 30 dB·μV/m which does not exceed the standard limitation. Whereas when the frequency is 20 MHz, RIL is about 60 dB·μV/m, and it exceeds 40 dB·μV/m remarkably at the distance of 450 m. This phenomenon illuminates that with the increase in frequency, the radiated effect due to the valve tower becomes more obvious; thus, RIL at higher frequency is stronger than that at lower frequency. RILs at other locations all have this phenomenon, and with the increases in distance, RILs at the same frequency decrease. But even when RIL attenuates from 60 to 40 dB·μV/m at 20 MHz, it is still higher than the limitation determined by Eq. (1) at the far area.

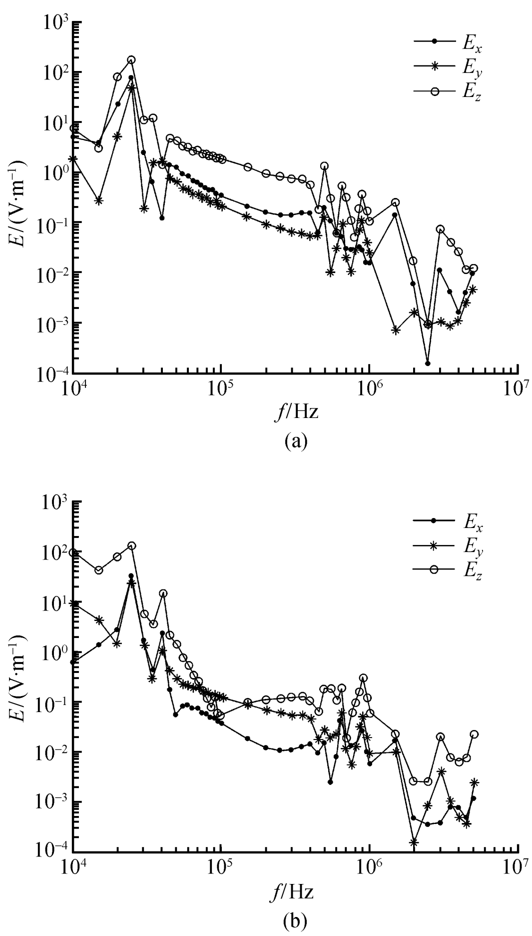

Fig. 5 Electric field intensity level at the edge of valve hall. (a) x direction; (b) y direction

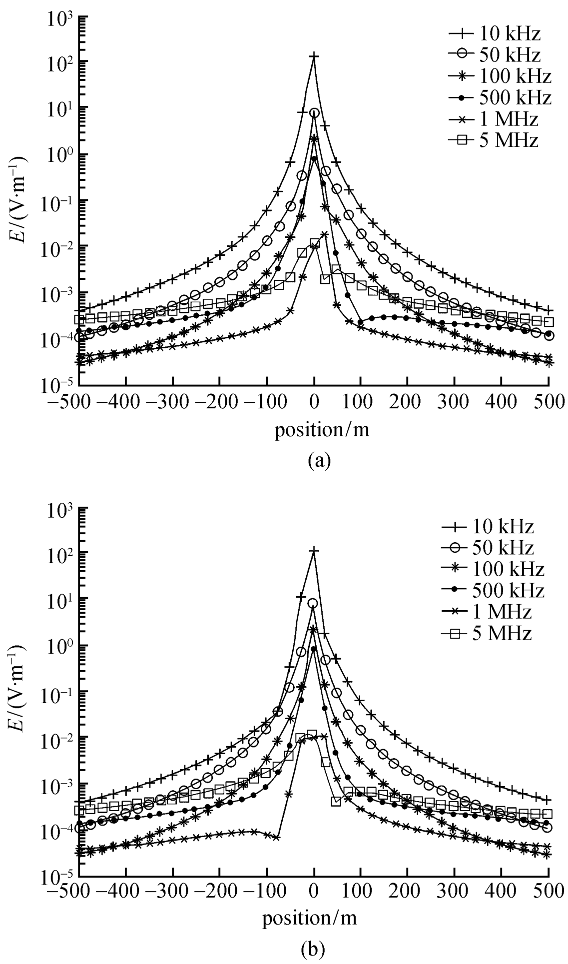

Fig. 6 Electric field intensity level. (a) x axis; (b) y axis

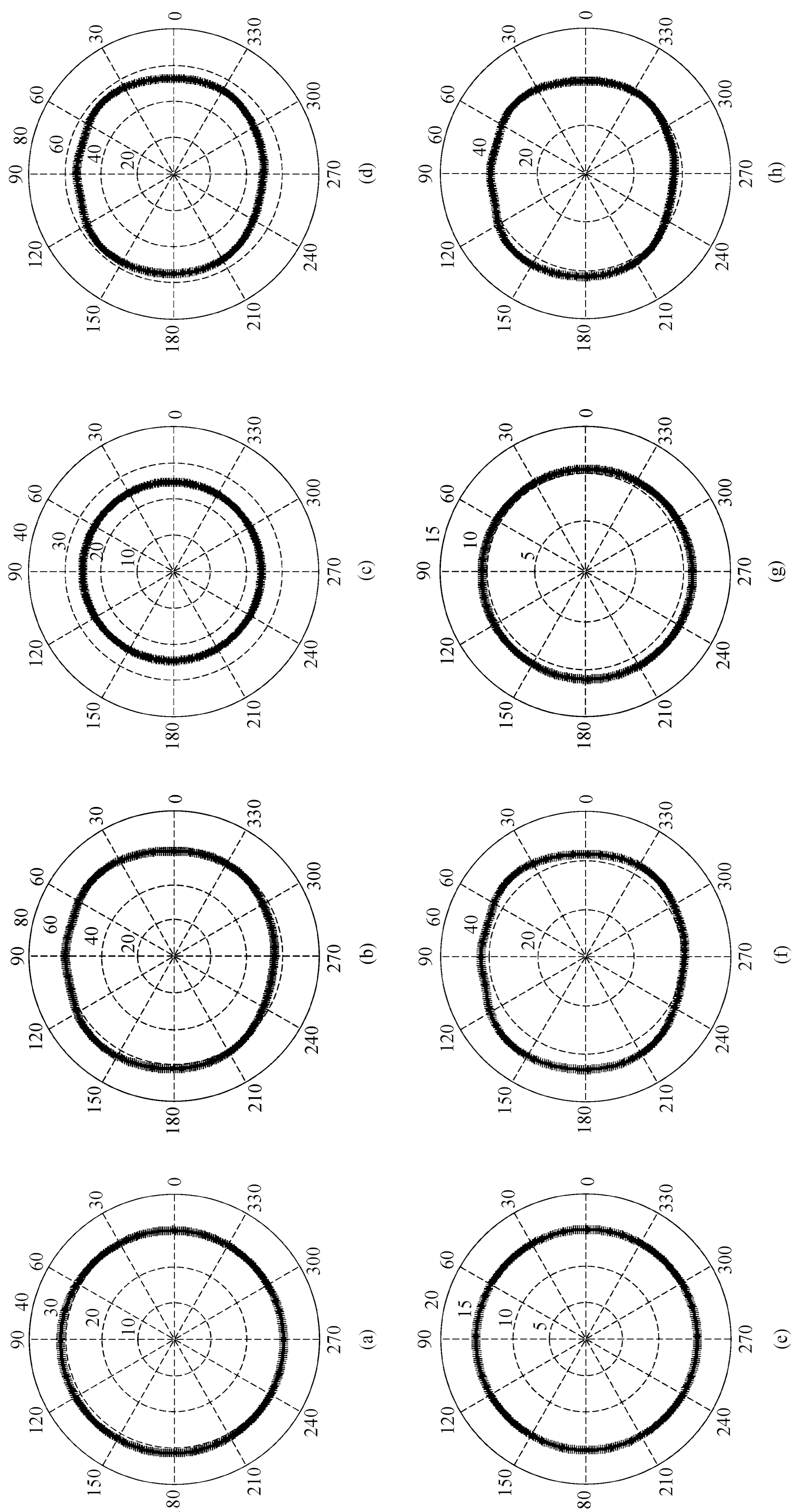

Fig. 7 RIL at different distance. (a) Distance is 450 m, $f = 1$ MHz; (b) distance is 450 m, $f = 20$ MHz; (c) distance is 1 km, $f = 1$ MHz; (d) distance is 1 km, $f = 20$ MHz; (e) distance is 3 km, $f = 1$ MHz; (f) distance is 3 km, $f = 20$ MHz; (g) distance is 5 km, $f = 1$ MHz; (h) distance is 5 km, $f = 20$ MHz

3 Shielding measures

3.1 Shielding effectiveness of valve hall

Based on the computation results above, we can see that the electromagnetic field strength levels are higher than the limitation at some positions around the valve hall if the wall of valve hall is not considered. The generic instrumentation is likely to be disturbed when it is not designed specifically for installations with such high field strength levels. Hence, some measures have to be carried out for the safety of the instrumentation and control equipment around the valve hall. Furthermore, the RILs also need to reduce by some measures.

There are basically two possibilities for equipment to cope with the occurrence of electromagnetic field strengths with high levels:

1) The equipment itself is designed with its immunity satisfied with high field strength levels.

2) The immunity of the equipment is designed the same as those used in a generic industrial environment, and, at the same time, the valve hall and control room will be shielded in order to make the field strength levels not higher than those typical for industrial environments.

The first approach cannot be considered as a practical one in the current situation because this would mean that all items of equipment have to be specifically designed for the special application. Considering the practical way to reduce the RIL is to shield the valve hall by some measures, more suitable is the second approach. In this way, the equipment can be used which is specified for a typical electromagnetic environment, and RIL is also reduced at the same time.

The required shielding effectiveness (SE) of valve hall can be derived by

$$SE = 20\lg(E_S/E_I)\ \text{dB}, \quad (2)$$

where E_S are the occurring field intensity levels needed to shield, and E_I are the existing immunity levels required in the relative standards. For example, when the field strength level E_S at the edge of valve hall is about 200 V/m at 30 kHz, according to the immunity level E_I for equipments of 10 V/m, the required minimum SE shall be at least 26 dB. Considering the immunity levels of the equipment, RIL, and the additional margin, the SE of the valve hall should not be less than 40 dB.

To obtain such high SE, proper measures must be used. A basic method of shielding is using solid metallic sheets at the walls, e.g., by adding a cladding at the walls. The cladding consists of steel sheets providing an SE of more than 60 dB and can, therefore, be considered as sufficient in the present situation in theory. However, in practice, the achievable actual shielding effectiveness of the entire shielding structure made of panels with such cladding depends more on the mounting arrangements of the cladding than on the cladding sheets themselves. The panels for the wall and roof of the valve hall shall be connected together with self-tapping rustproof screws at intervals of regular distances which can provide low impedance electrical contact. The interval of the distances is the most crucial factor in maintaining a sufficient SE, and about a 35 cm distance between electrical contacts can provide the SE, which should be at least 40 dB. Wire meshes could be used in case of roofs or windows to ensure light openings and also provide shielding. The required SE of 40 dB requests that the wire mesh size should not be larger than 3 cm with the wire diameter about 3 mm. The doors shall be metal doors, and their shielding efficiency shall have a comparable shielding effectiveness as applicable to the walls. The doors shall be contacted to the shielding structures of the walls via a metallic door frame, and the contacting arrangements should be the same as those used with the cladding mentioned above. In addition, there should be a grounding grid in the bottom floor of valve hall. This grid shall be connected to the shielding structure of the walls and connected to the grounding grid of the converter station.

3.2 EMI level after shielding

Here we represent some test results and compare them with the results computed after the real SE of the wall is considered. A typical ±500 kV valve hall is built with the shielding measures mentioned above. Its SE measured based on the IEEE standard is not lower than 40 dB. At the edge of a similar valve hall, the electric field intensity levels tested are 100–200 mV/m at the range of low frequency. Considering the real SE of wall is about 40 dB at this range of frequency, the field intensities at these positions should be about 10–20 V/m without shielding, which are accordant with the results computed by moment method and also without considering the wall of valve hall. So our computational method is proved to be accurate, and the shielding measures used for the wall are proved to be practical.

4 Conclusion

The EMI field intensity level and radio interference level from valve hall of the ±500 kV converter station are analyzed. The necessary shielding measures for the valve hall are discussed based on the results computed and the relative standards. The test results for a converter station proved that the computational method and the shielding measures used are accurate and practical.

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