Study on Electromagnetic Radiation of the valve tower in HVDC Converter Station

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Abstract — Based on the direct frequency calculation method, this paper makes some study on the converter valve module impedance parameters in frequency domain calculation method. Then do simulation based on the impedance parameters obtained by one method above-mentioned using the simulation software which is based on moment method, the simulation build a HVDC and UHVDC valve tower electromagnetic radiation model, the model considers the valve shield module, metal beams and other antenna structures, more accurately reflects the actual structure of the valve tower. The article also carried out HVDC valve tower 10:1 scale model test, the test verified the correctness of the simulation.

I. INTRODUCTION

Electromagnetic Compatibility problem of HVDC converter station is an important part in HVDC and UHVDC project's design, construction and work. During the operation of the HVDC converter station, the converter valves will produce radiated interference noise during the ignition and extinction processes of the thyristors. The rapid changes in the voltage between anode and cathode of the thyristors at these moments result in transient interference voltages and currents, which initiate the electromagnetic radiation with high frequency and wide spectrum inside valve hall. The converter valve tower can be seen as large antenna array, the structure is time-varied along with the conducted valve arm change. Take the 12 pulse converter valve for example, in a power frequency cycle, there are 12 times commutation, during each commutation, there are two valve arms to be conducted at the same time, when the two valve arms act as antenna excited by the transient voltage. This paper will study the radiation model of the converter valve, and simulate with the software based on moment method. The article also carried out three-phase valve tower 10:1 scaled model test, then this paper compare the simulation and test result with the measurement data in a ±800kV converter station to verify the correctness of the simulation.

II. METHOD OF COMPUTE THE ELECTROMAGNETIC RADIATION OF VALVE TOWER

The space electromagnetic field calculation formulas are shown as follows, which is the basis of the direct frequency domain calculation method.

$$B_{\varphi}\left(r,\varphi,z,t\right)=\frac{\mu_0}{4\pi}\left\{\int_0^H\left[\frac{r}{R_0^{\,3}}I(z',\omega)\left(1+jkR_0\right)e^{-jkR_0}\right]dz'+\int_0^H\left[\frac{r}{R_1^{\,3}}I(z',\omega)\left(1+jkR_1\right)e^{-jkR_1}\right]dz'\right\} \quad (1)$$

$$\begin{aligned}E_r\left(r,\varphi,z,t\right)=\frac{1}{4\pi\varepsilon_0}&\left\{\int_0^H\left[\begin{array}{l}\frac{3r(z-z')}{R_0^{\,5}}\frac{1}{j\omega}I\left(z',j\omega\right)e^{-j\omega R_0/c}+\frac{3r(z-z')}{cR_0^{\,4}}I\left(z',j\omega\right)e^{-j\omega R_0/c}\\+\frac{r(z-z')}{c^2R_0^{\,3}}j\omega I\left(z',j\omega\right)e^{-j\omega R_0/c}\end{array}\right]dz'\right.\\&\left.+\int_0^H\left[\begin{array}{l}\frac{3r(z+z')}{R_1^{\,5}}\frac{1}{j\omega}I\left(z',j\omega\right)e^{-j\omega R_1/c}+\frac{3r(z+z')}{cR_1^{\,4}}I\left(z',j\omega\right)e^{-j\omega R_1/c}\\+\frac{r(z+z')}{c^2R_1^{\,3}}j\omega I\left(z',j\omega\right)e^{-j\omega R_1/c}\end{array}\right]dz'\right\}\end{aligned} \quad (2)$$

$$\begin{aligned}E_z\left(r,\varphi,z,t\right)=\frac{1}{4\pi\varepsilon_0}&\left\{\int_0^H\left[\begin{array}{l}\frac{2(z-z')^2-r^2}{R_0^{\,5}}\frac{1}{j\omega}I\left(z',j\omega\right)e^{-j\omega R_0/c}+\frac{2(z-z')^2-r^2}{cR_0^{\,4}}I\left(z',j\omega\right)e^{-j\omega R_0/c}\\-\frac{r^2}{c^2R_0^{\,3}}j\omega I\left(z',j\omega\right)e^{-j\omega R_0/c}\end{array}\right]dz'\right.\\&\left.+\int_0^H\left[\begin{array}{l}\frac{2(z+z')^2-r^2}{R_1^{\,5}}\frac{1}{j\omega}I\left(z',j\omega\right)e^{-j\omega R_1/c}+\frac{2(z+z')^2-r^2}{cR_1^{\,4}}I\left(z',j\omega\right)e^{-j\omega R_1/c}\\-\frac{r^2}{c^2R_1^{\,3}}j\omega I\left(z',j\omega\right)e^{-j\omega R_1/c}\end{array}\right]dz'\right\}\end{aligned} \quad (3)$$

The direct frequency domain calculation method need first getting the impedance parameters of the valve components $Z_k(f)$,the electrical connection of the main components of a valve is presented in Fig.1. Then calculated the voltage value of every valve arm in time-domain $u_L(t)$, which can be transformed into frequency domain by FFT. One valve arm voltage value of some UHVDC converter station is shown in Fig.2. Finally, add the impedance in every valve arm according to frequency and conduction state, add the corresponding voltage $U_L(f)$ as excitation, then the modeling is complete, we can simulate with the software and get the space radiation electromagnetic fields at each frequency point.

There are three kind of method to get the valve arm impedance parameters .The first method is to use the impedance analyzer, another is calculating with the Fast Fourier Transform(FFT) method, the third is calculating with Short Time Fourier Transform(STFT) or Wavelet Transform method.

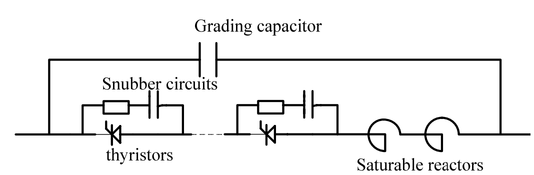

Fig 1.Valve components used in HVDC system

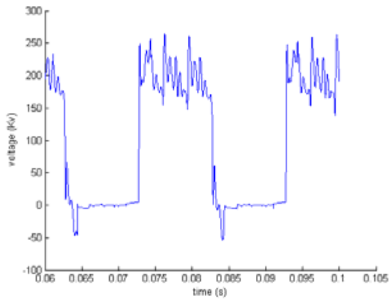

Fig.2. Valve arm voltage in a UHVDC converter station

III. MODELING AND SIMULATION

The structure of the valve tower is different in HVDC converter station and UHVDC converter station. Fig.3 and Fig.5 respectively show the structure of the UHVDC valve tower and the HVDC valve tower. Then the simulation model is completed as shown in Fig.4 and Fig.6 according to the structure.

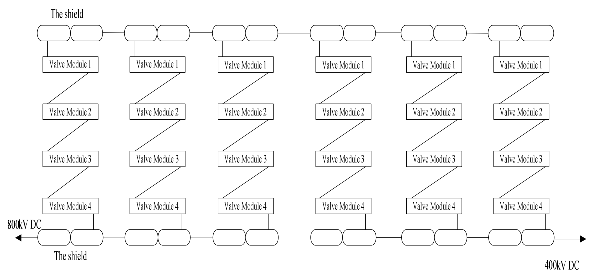

Fig.3. UHVDC High voltage valve tower structure

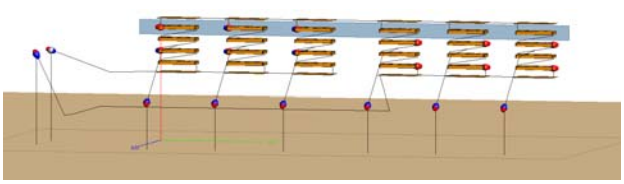
Fig.4 UHVDC valve tower model

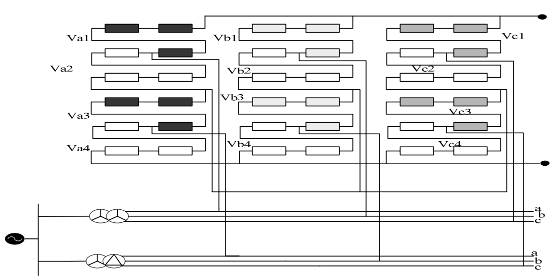

Fig.5. HVDC valve tower structure

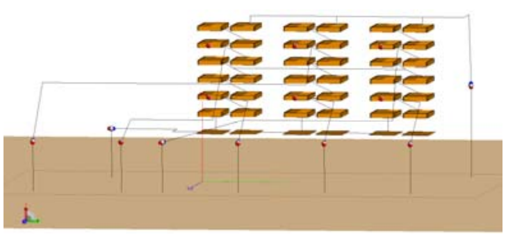
Fig.6. HVDC valve tower model

IV. SCALED MODEL TEST

To verify the correctness of simulation, the scaled model test was carried out with the 10:1 scaled model of the HVDC valve tower, the signal generator, antenna and receiver. The signal generator generated certain frequency and voltage signal, which was then added to the scaled model, the loop antenna placed 1 meter distance in front of the tower which simulate the field strength actually 10 meter distance in front of the tower location. The receiver connected to the antenna and read the radiation value. Fig.7 is the photo of test.


Fig.7. photo of test

V. CONCLUSION

This paper gives three kinds of method to get the impedance parameters of the valve module in the direct frequency domain calculation method. Base on the impedance parameters obtained with one method, the paper model and simulate the valve tower in HVDC and UHVDC converter station, the 10:1 scaled model test verified the correctness of the simulation.

VI. ACKNOWLEDGEMENT

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VII. REFERENCES

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