Electromagnetic Interference Prediction of ±800kV UHVDC Converter Station

Haifeng Sun, Xiang Cui

Electrical Engineering Department, North China Electric Power University, Baoding, 071003, China, haif_sun@126.com

During the processes of firing and turning-off of the valves in HVDC converter station, electromagnetic disturbance (EMD) is generated and conducted through the wall bushings, along the buses in the AC and DC yard, and to the overhead lines. The adjacent equipments could be interfered by the disturbance, which could cause the equipments work badly. The frequency of the EMD varies from kHz to MHz, hence it is necessary to build a wideband model of the converter system to predict the characteristics of the electromagnetic interference (EMI) source. Methods of modeling the equipments in HVDC converter stations are presented in this paper, and the equivalent circuits are established in accordance with components in the wideband model built in this paper. The components include thyristor valves, converter transformer, smoothing reactor, filters and so on. Different methods are provided to calculate the stray capacitances and inductance of the valves. Finally, the whole wideband model of the converter system is simulated by PSCAD/EMTDC. Based on the model presented in the paper, the characteristics of EMI under the condition of normal operations are calculated. Method of Images is used to carry out the radiated electromagnetic field around the converter station. In the end, the proposed method is verified by comparison with the data measured.

Index Terms— **HVDC, Electromagnetic interference, Converter station, Thyristor valves, Wideband modeling.**

I. Introduction

Conducted electromagnetic disturbance (EMD) in HVDC converter stations is generated during the processes of firing and turning-off of the thyristors in the converter valves. The voltage across converter valves and the current through them collapse or rise rapidly during the periodic processes. The interference is produced and conducted through the bushing, along the buses connected with the valve hall, and hence to the AC and DC switchyards. Radio noise is radiated from the valves to the switchyard and transmission lines. The location of HVDC converter station might be in an electromagnetically sensitive environment and the disturbance caused by HVDC converter stations could interfere with the operation of various computer, control-systems and communication facilities, etc.

In order to calculate and predict the EMI in HVDC converter stations, many methods and techniques were developed during 1970s to 1990s. In [1]-[3], method based on impedance measurements (frequency ranges from 0.1 MHz to 5 MHz) was developed to model main equipments in HVDC converter stations. Method of moment in [4] is used to calculate the electromagnetic field in HVDC converter stations, but the radiated source is difficult to determine by this method. Only accurate equivalent circuit model can figure out the accurate radiated source.

II. Wideband Modeling of Converter valve

A. Equivalent Circuit of Valve Components

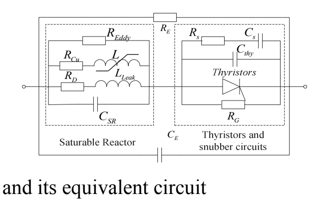


Fig.1 Valve section and its equivalent circuit

The equivalent circuit of the typical valve module consists of two valve sections in series connection. The model of valve section can be represented by the equivalent circuit shown in Fig.1. R_G is the grading resistance, which is part of thyristor voltage monitoring PCB. R_S and C_S are the resistance and capacitance of snubber circuit respectively. C_E is the compensating capacitor.

B. Stray Capacitances Extraction

The stray capacitances of the heat sinks include the capacitances between the heat sinks and the ground capacitances, as shown in Fig.2. The finite element method can be used to calculate these parameters.

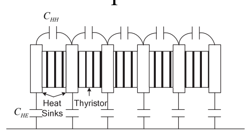


Fig.2 Stray capacitances distribution of the heat sinks

The distribution of the capacitances of one phase of the valve used in HVDC converter station is demonstrated in Fig.3.

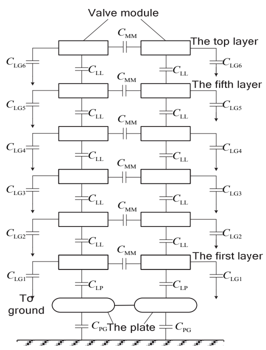


Fig. 3. Stray parameters distribution of valve tower

C. Wideband Model of Valve Tower

The equivalent circuit of the valve components mentioned above is established according to the electrical connections with a certain sequence. By adding the stray capacitances and stray inductances, wideband model of the valve section is established as shown in Fig.1. Considering of the parasitic parameters of valve layers, wideband model of the converter system is shown as Fig.4.

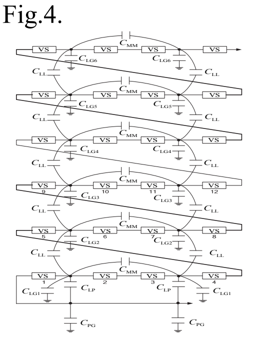


Fig.4 Wideband modeling of the converter system

III. Wideband Models of the Key Equipments

A. Converter Transformer

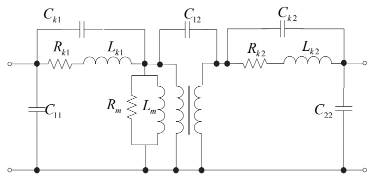


Fig.5 Wideband model of the converter transformer

The parameters of the wideband model are defined as follows[5]. L_{k1} and L_{k2} are leakage inductances, R_{k1} and R_{k2} are resistances related to winding losses, and C_{11} and C_{22} are capacitances of the windings, C_{12} is capacitance between primary and secondary windings, L_m is the magnetizing inductance, R_m is the resistance due to core losses, C_{k1} and C_{k2} are the capacitances paralleled with L_{k1}, R_{k1}, L_{k2}, and R_{k2}, which are called leakage capacitances.

B. Smoothing Reactor

The DC smoothing reactor is represented by inductance L_m, ohmic losses resistance R_m and stray capacitances, as shown in Fig.6. The stray capacitance between windings is represented by C_{12}, and the stray capacitances between coils and the ground are represented by C_g. In this paper, all the parameters of the smoothing reactor are obtained from the specifications provided by the manufacturer.

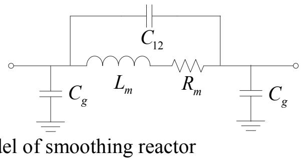


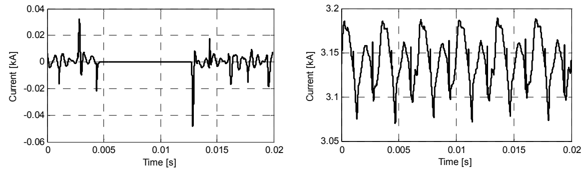
Fig. 6. Wideband model of smoothing reactor

C. Other Equipments

The other equipments in the HVDC converter stations are similar with the equipments in HVAC power stations, such as tubular bus, surge arrester, current and voltage transformer, CVT, circuit breakers, etc.

IV. Conducted EMI of the Converter System

Using PSCAD/EMTDC, a HVDC converter station of 12-pulse ±800kV 3000MW in China is simulated by the wideband equivalent circuits mentioned above. Current waveforms of RC snubbers and bus are simulated as shown in Fig.7.

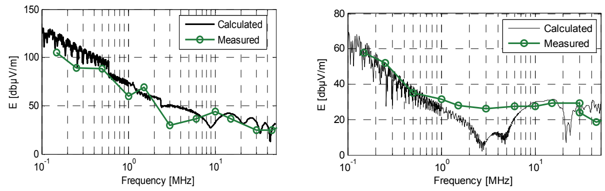


(a) snubber current (b) bus current

Fig.7 Current waveforms of RC snubbers in converter and bus

V. Radiated EMI of the Converter System

Based on the conducted currents simulated by the wideband circuit model, method of images is used to calculate the radio interference level at the location of 20m and 200m away from the major equipment in the converter station. The radiated radio interference level at the same point is also measured. The comparison between measured and calculated results is shown in Fig. 8. Considering of the actual complexity of the circumstances, the calculation results are acceptable.



(a) 20m (b) 200m

Fig.8. Comparison between calculated and measured electric field strength around the converter station

VI. Conclusion

In order to predict the EMI in HVDC converter stations, a wideband model of the converter systems is established in this paper. The wideband model and equivalent circuit built in this paper could be used to guide the shielding design of HVDC and UHVDC converter stations.

Acknowledgement

This research was supported in part by National Natural Science Foundation of China (Grant No. 51207054), and Fundamental Research Funds for the Central Universities (Grant No. 13MS75).

References

[1] Annestrand S A, "Radio interference from HVDC converter stations", IEEE Transactions on Power Apparatus and Systems, PAS-91(3): 874 – 882, 1972.

[2] Ross Caldecott, Yilu Liu, Stephen A S, et al, "Measurement of the frequency dependent impedance of major station equipment", IEEE Transactions on Power Delivery, 5(1): 474-480, 1990.

[3] D.G. Kasten, R. Caldecott, S.A. Sebo and Y. Liu. A Computer Program for HVDC Converter Station RF Noise Calculations. IEEE Transactions on Power Delivery, 1994, 9(2): 750~756.

[4] Murata Y, Tanabe S, Ukawa Y, et al, "3D-MoM analysis of radio frequency noise radiation from HVDC converter station", Proceedings of IEEE International Symposium on Electromagnetic Compatibility, Seattle, 1999.

[5] Yu Zhanqing, He Jinliang and Zeng Rong, el al. Simulation Analysis on Conducted EMD Caused by Valves in ±800 kV UHVDC Converter Station. IEEE Transactions on Electromagnetic Compatibility, 2009, 51(2): 236~244