Calculation of Electromagnetic Radiation of VSC-HVDC Converter System

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Due to the wide application of new technologies such as wind power, photovoltaic power, distributed generation, and smart grid, voltage source converter (VSC)-based HVDC systems has obvious advantages over traditional ones. This paper presents a novel method of analyzing the radiated electromagnetic disturbance (EMD) of VSC-HVDC converter system considering its own structure together with operational states. The method is based on the experimental platform of VSC-HVDC converter system, located in the new energy laboratory of North China Electric Power University (NCEPU). The mechanism of radiated EMD generated by converter valve is described and simulation model of system operation is developed using PSCAD / EMTDC. Antenna model of VSC-HVDC converter system is built based on antenna theory. By applying electric dipole theory and Rao-Wilton-Glisson (RWG) edge method, the radiated EMD produced by three-phase two-level converter is calculated by FEKO, which is a kind of method of moments (MOM) simulation software. Finally, the proposed method is verified by the comparison between calculated and measured data.

***Index Terms*— Antenna model, Electromagnetic radiation, IGBT, Method of moments, Source of disturbance.**

I. INTRODUCTION

Aiming at analyzing EMC in traditional HVDC transmission system, some researches have been carried out [1]-[2], but few of them touch the field of VSC-HVDC, which uses new electronics switch devices such as IGBT[3]-[5]. Due to the high-frequency operation of IGBT, voltage between anode and cathode changes sharply and produces interference voltage and current which would conduct to outside equipments. These voltage and current would produce damped oscillation and radiate into nearby space. Sometimes they could transmit along high voltage transmission lines. The noise is much larger than traditional valve produced, the frequency ups to tens of megahertz [6].

The operational states of the converter system controlled by PWM are studied in this paper. The amplitude-frequency characteristics of bridge voltage is simulated by PSCAD/ EMTDC when the system operates steadily. By analyzing the propagate path of EMD and taking arm voltage as radiated disturbance sources, the antenna model of VSC-HVDC converter system is developed. Electromagnetic radiation of the antenna model of VSC-HVDC converter system is then calculated by FEKO.

II. ANTENNA MODEL OF VSC-HVDC CONVERTER SYSTEM

A. Analysis of operational state

Topological structure of three-phase two-level voltage source converter is shown in Fig. 1. There are three bridge arms, each leg consists of two devices, including a controlled turned off device VTi and its respective anti-parallel diode VDi . The converter has six output states as shown in Table I.(In this paper, '1' indicates that the IGBT of upper arm is conducting and the lower arm IGBT is off.)

TABLE I
SIX OUTPUT STATES OF THE THREE-PHASE TWO-LEVEL VSC

Condition	I	II	III	IV	V	VI
Mark	[101]	[100]	[110]	[010]	[011]	[001]

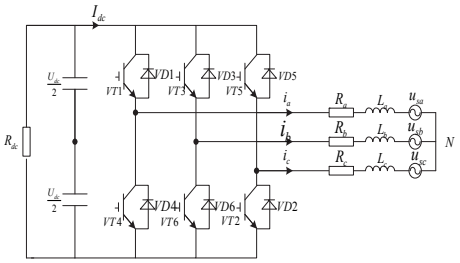
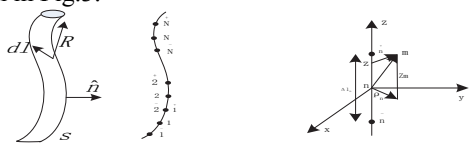


Fig.1 Topological structure of VSC-HVDC converter

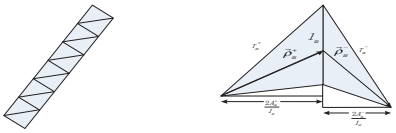
B. Antenna modeling methods

Due to the existence of the metal structures in converter system, such as AC-DC bus and metal cabinet, the converter valve shows different impedance characteristics under different conditions and frequencies. The complex problems of electromagnetic field could be solved by electromagnetic numerical methods. The method of moments has advantages in solving electrically large electromagnetic problems, which is more accurate and faster than other methods. This paper studies the radiated EMI of converter system using MOM. Radiation sources (i.e., high-frequency conducting current) are simulated by discrete electrical dipole after discretization. The principle of calculating radiated EMD about wire antenna is shown in Fig.2. Ideal mental surface is used to simulate the chassis shells of converter system as it is the main reflection surface. The radiation field and the surface current of each small dipole are calculated by RWG edge element method. The surface current and the radiation field of the whole antenna is the result of the interaction of all dipoles. Calculation principle of radiated EMD about surface antenna is shown in Fig.3.



(a) wires and subparagraph (b) Nth antenna electromagnetic radiation calculation principles

Fig2. Calculation principles of wire antenna electromagnetic radiation



(a) Antenna after Triangulation (b) RWG edge element

Fig3. Calculation principles of surface antenna electromagnetic radiation

III. SOURCES OF DISTURBANCE AND SIMULATION

Based on the experimental platform of VSC-HVDC converter system, located in the new energy laboratory of NCEPU, this paper builds a simulation system of operational state of three-phase two-level converter with PSCAD / EMTDC. The system consists of several parts listed as follows: IGBT convert valve, convert transformer, convert reactor, AC filter, DC capacitor and DC filter. Sources of disturbance are obtained by simulation as shown in Fig.4. High-frequency current produced by IGBT would conduct to outside equipments. These disturbances would produce damped oscillation and radiate into nearby space or transmit along transmission lines. Electromagnetic radiation noise are generated mainly by the converter valves, circuit devices and connecting line between converter and AC filter, AC and DC bus and the connecting line. The propagation path of the EMI from the converter system is shown in Fig.5.

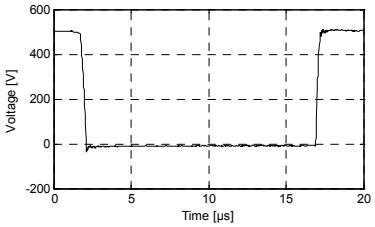


Fig.4 Bridge voltage waveform in time-domain

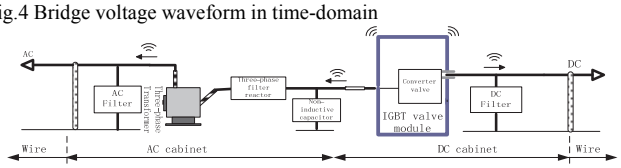


Fig.5 Propagation path of EMI in converter system

IV. SIMULATION OF ANTENNA MODEL AND VERIFICATION

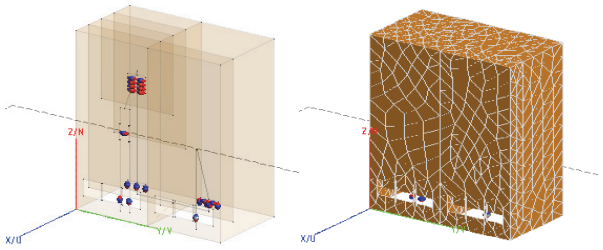


Fig.6 Antenna model of converter system and RWG edge elements

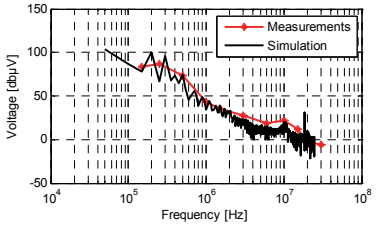


Fig.7 Comparison of calculated and measured

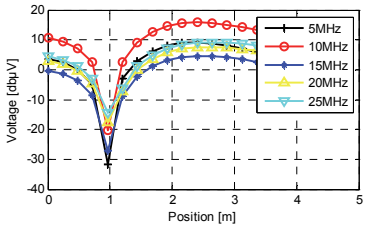


Fig.8 Electric field distribution of 2m

FEKO is a comprehensive electromagnetic simulation software tool for the electromagnetic field analysis of 3D structures, whose core algorithm is MOM. An antenna model of converter system is established based on experimental platform by FEKO as shown in Fig.6. Taking the first operating condition Ⅰ as example, VT1, VT5 and VT6 are conducting. As Ⅱ described, high-frequency conduct current produced are simulated by discrete electrical dipoles after discretization, with adding disturbance sources to the conducted arms. RWG edge elements of the antenna model are also shown in Fig.6. The electric field at the same point of front of the system is calculated and measured. The comparison between measured and calculated data is shown in Fig. 7. Considering of the complexity of the circumstances, the results are acceptable. The distribution of electric field of 2m in front of experimental platform is shown in Fig.8.

V. CONCLUSION

This paper presents a novel method to analyze the radiated EMD of the converter system of VSC-HVDC. By analyzing the operate states, the simulation system of sources of disturbance is built by PSCAD/EMTDC. Sources of disturbance can be caught from simulation. With antenna theory, antenna model of the converter system of VSC-HVDC is developed and the EMI in the near field is calculated. At last, the comparison between measured and calculated results prove the correctness of the proposed method.

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