Research on Conducted Electromagnetic Interference Mechanism based on High Power Transformer Cabinet

Lingxiang Deng[1], Yongan Wang[2], Xudong Zhao[3] and Shijin li[4]

[1] Nanjing Normal University

Received: 13 December 2018 Accepted: 2 January 2019 Published: 15 January 2019

Abstract

The problem of conducted electromagnetic interference generated by high-power transformer cabinets is analyzed. Firstly, the equivalent model of the high-frequency circuit of conduction noise is established. The calculation method of noise current and voltage is described. Then the joint mode and differential mode conduction noise are analyzed. I am modeling as a theoretical basis for subsequent conduction noise extraction and separation. The method of suppressing conducted noise is studied, and the suppression effect of the filter on the noise of the AC output of the high-power transformer cabinet is analyzed, which provides a theoretical basis for the actual engineering rectification.

Index terms— high-power transformer cabinet, conducted electromagnetic interference noise,

1 Introduction

ith the increasing use of high-power transformer cabinets, there is a more complex electromagnetic compatibility problem. The power density continues to increase, and the electromagnetic environment inside the system is more complicated. A large number of electromagnetic interferences will bring a series of problems, such as equipment malfunction, motor rotor heating, communication system collapse, transformer life reduction, etc. The question poses a threat to the reliability of itself and other surrounding equipment, and also exacerbates the electromagnetic environment pollution problem and high-frequency impact [1][2][3][4][5]. Therefore, it is extremely urgent to study the modeling problem of conducted electromagnetic interference for high-power transformer cabinets and the method of conducting EMI noise suppression.

The schematic diagram of the high-power transformer cabinet system is shown in Figure **??**.

The transmission path of the electromagnetic emission can be seen by the arrow in the figure **??** Generally, the high-frequency noise generated by the high-power inverter is transmitted through the cable, with common-mode and difference. The form of the mode is propagated out [6][7][8][9][10]. This paper will analyze the conduction noise model and the conducted noise suppression method of a certain type of high-power transformer cabinet. **??** shows the high-frequency equivalent circuit diagram of the conducted noise. The block diagram illustrates that the common mode noise source and the differential mode noise source are separate parts. Assuming that ICM is a common mode current, IDM is a differential mode current, and in and Ip are the noise currents flowing through the live and neutral lines, respectively, then.

2 Power

= + p CM DM I I I (1) = ? n CM DM I I I (2)

Those equations give the relationship between ICM and power line current.= / 2 ()+ CM p n I I I (3) = 2 + = g p n CM I I I I (4)

Assume that VN and VP are respectively zero line and live line conducting noise voltage, and the common-mode voltage is defined as50 50 50 2 2 × ?+ × ? + = × ? = = p N p N CM CM I I V V V I (5)

It can be seen from equations (**??**) and (**??**) that the voltage value across the resistor is the commonmode voltage, and the common-mode current value is equal to the current noise value of the live line plus the noise current value of the neutral line.= + CM p n I I I (**6**)

Comparing equations (**??**) with (6), it can be obtained that the values of ICM and Ig are equal. The common-mode current is not equal to the live and neutral currents in all cases. The ICM forms a loop with the parasitic capacitance in the circuit to generate current. Equation (7) shows the current pulse size ic caused by the rapid change of the parasitic capacitance Cp.= c c p dV i C dt (7)

When the load connection-mode is Y-type connection, the common-mode voltage refers to the voltage of the neutral points to the zero potential point. Set the voltage midpoint O point to the reference ground, and divide the DC side voltage into two parts, one part is Vdc/2, and the other part is -Vdc/2, then the DV/dt condition can be directly observed, and it can be clear Indicates the common-mode voltage. The schematic diagram of the three-phase inverter circuit is shown in Figure **??**. The common-mode current in the circuit includes the live-ground, neutral, and ground lines, and the values are the same, and the directions are the same. Assume that the line impedance stabilization network is the same for the live and neutral lines, and then connect the impedance to the ground in the circuit, and its value is 50?. From the above study of the common-mode current, it can be seen from Fig. **??** that the relationship between the ground current Ig and the common-mode current ICM is as follows:

As shown in Figure **??**, with zero point zero reference point, there are? ? = + ? ? ? ? = + ? ? ? ? = + ? ? a a cm m a m b b cm m b m c c cm m c m di V V R i L dt di V V R i L dt di V V R i L dt (8)

In the above formula, Va, Vb, and Vc are the phase voltages of each phase; ia, ib, and ic are the current outputs of each phase; and Vcm refers to the common-mode noise voltage. deformation of equation (8).( ) 3 ( ) + + + + ? = + + + a b c a b c cm m a b c m d i i i V V V V R i i i L dt (9)

According to Kirchhoff's current law KCL, ia+ib+ic=0, the simplified common-mode noise voltage is obtained by (9).3 + + = a b c cm V V V V (10)

Similarly, the common-mode noise value of a single-phase inverter can be obtained.2 + = a b cm V V V (**11**)

It can be seen that the common-mode noise of the inverter can be represented by the line voltage, and the common-mode voltage noise must exist in the inverter system, but the common-mode current noise interference is not reflected, only when the current flows through the parasitic capacitance. In the ground, then the common-mode current noise interference is generated by the loop. Also, if the circuit is symmetrical, the common-mode current flowing through the neutral line and flowing through the live line is the same, and the value flowing through the ground line is twice the common-mode current.

3 b) Analysis of differential mode EMI noise

The relationship between the differential mode current IDM and the power supply current can be obtained by the equations (**??**) and (2). The differential mode current IDM flowing through the live line and flowing through the neutral line is large and reverse. Based on the definition of the differential mode current IDM in the above equation, the differential mode voltage is defined as50 50 50 2 2 p N p N DM DM i i V V V i × ?? × ? ? = × ? = = (13)

Modulate the pulse width of the PWM, so that the inverter produces the sine wave we need, and also accumulates many high-order harmonics. The function of the filter is to weaken the harmonics. Different filters have different filter bands due to the difference in parameters. The upper limit of the frequency of the insulated gate bipolar transistor is very high, about 10khz to 20khz, the LC filter cannot be completely filtered out, which makes some high-frequency harmonics still exist, which acts on the output side of the circuit to generate differential mode noise.

Due to the existence of distributed capacitance, inductive load, and inductance, the differential mode EMI noise of high-frequency oscillation will inevitably occur in the breaking of the switching tube. If it is not suppressed, it will affect the DC power supply measurement and the load side, making the abnormal load jobs.

4 III. Application of Filter in Suppressing

Conducted Noise of High Power Transformer Cabinet

Two important characteristics based on the filter: common-mode rejection ratio and differential mode rejection ratio. There is also a feature that the differential mode insertion loss is small in the common mode filter, and the common-mode insertion loss is small in the differential mode filter. Therefore, in the design circuit, it is necessary to give priority to the parameters of the filter to enable it to exert the best noise suppression capability and highlight the commonmode rejection ratio.

In this paper, the simulation model of the common-mode filter of the inverter circuit shown in the following figure is used. The noise source impedance Zs can be replaced by the parallel connection of the current source Iscm and the high impedance Zp. According to practical experience, it is known that Rs = 0.15 ?, Lp = 15 NH, RL = 10 m?, Cp = 5 pF, and Zp = 10 k?. In Figure **??** and Figure 7, we built the filter and set the parameters in the Simulink simulation software to extract the voltage at the input. As can be seen from the figure, compared with the previous circuit, the addition of the filter makes the conduction noise greatly reduced. The result of this simulation proves that the filter can reduce the conduction noise in the high-power transformer cabinet circuit, and It has practical significance.

5 Conclusion

This paper mainly studies the mechanism of conducted noise and models, separates and suppresses noise. In the first step, based on the highfrequency equivalent circuit topology, the conduction noise current and voltage were successfully extracted, and the generation mechanism of the common-mode conduction noise was summarized. In the second step, a noise conduction equivalent circuit model based on this mechanism is built-in Simulink. The above work provides a theoretical basis for the following discussion to discuss the extraction and separation of conducted noise. In the third step, simulation experiments show that adding a filter to the simulation circuit can greatly reduce the conduction noise at the AC output, which provides a theoretical basis for our future practical application.

Global Journal of Researches in Engineering ( ) Volume XIX Issue V Version I [1]

[Tech ()] , Virginia Tech . 2001.

[IEEE Transactions on Electromagnetic Compatibility ()] , *IEEE Transactions on Electromagnetic Compatibility* 2009. 51 (2) p. .

[Transactions of China Electro technical Society ()] , *Transactions of China Electro technical Society* 2010. 25 (10) p. .

[Proceedings of the CSEE ()] , *Proceedings of the CSEE* 2013. 33 (15) p. .

[Yuan and Qian ()] 'Analysis of Power MOSFET Modeling for Conducted'. Yisheng Yuan , Guangliang Qian . *Journal of Zhejiang University (Engineering Science)* 2003. 37 (2) p. .

[Manzi et al.] *Coexistence Between Ultra-wideband Radio and Narrow-band Wireless LAN Communication Systems-part II: EMI evaluation*, G Manzi , P Feliziani , Beeckman .

[Qian and Cheng] *Electromagnetic Interference Design and Interference Suppression Technology for Power Electronic Systems*, Guangming Qian , Weiji Cheng .

[Qian et al. ()] 'EMC Design of High Power Converters'. Guangliang Qian , Zhengyu Lu , Xiangning He . *Proceedings of the 14th National Conference on Power Technology*, (the 14th National Conference on Power Technology) 2001. p. .

[IEEE, Transactions on Power Electronics ()] *IEEE, Transactions on Power Electronics*, 2010. 25 p. .

[Mukherjee et al.] *Impact of a Frequency Modulated Pulsewidth Modulation Switching Converter on the Input Power System Quality*, R Mukherjee , Patra , Banerjee .

[He et al. ()] 'Internal stray electromagnetic coupling of power line EMI filter and its effect'. Junping He , Wei Chen , Jianguo Jiang . *Transactions of China Electrotechnical Society* 2006. 21 (10) p. .

[Yan et al.] *Mechanism analysis and suppression of radiated EMI noise in complex electronic systems*, Wei Yan , Yang Zhao , Enrong Wang .

[Sarikhani et al. ()] 'Optimum Equivalent Models of Multi-source Systems for the Study of Electromagnetic Signatures and Radiated Emissions From Electric Drives'. A Sarikhani , M Barzegaran , O A Mohammed . *IEEE Transactions on Magnetics Mag* 2012. 48 (2) p. .

[He et al. ()] 'Research on Common Mode Conducted Interference Model of Switching Power Supply'. Junping He , Wei Chen , Jianguo Jiang . *Proceedings of the CSEE*, (the CSEE) 2005. 25 p. .

[Zhou] *Research on common mode EMI analysis and active suppression technology for single-phase inverter*, Yunbin Zhou .

[Peng and Tang ()] 'Research on Electromagnetic Compatibility of Transmission System'. Yanbo Peng , Yongqi Tang . *Electric Drive*, 2007. 16 p. .

[Li et al. ()] 'Research on Feature Extraction Method of Ship Radiated Noise Based on'. Yuxing Li , Yaan Li , Xiao Chen . *Journal of Vibration and Shock* 2017. 36 (5) p. .

[Zhao et al.] *Research on Mechanism Diagnosis and Characteristic Estimation Method of Circuit Radiation Interference*, Yang Zhao , Wei Yan , Bo Zhao .

[Hertz] *Thermal and EMI Modeling and Analysis of a Boost PFC Circuit Designed Using a Genetic-Based Optimization*, E Hertz .