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

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

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**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.

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## I. INTRODUCTION

With 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 [1-5]. 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 1.

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 [6-10]. This paper will analyze the conduction noise model and the conducted noise suppression method of a certain type of high-power transformer cabinet.

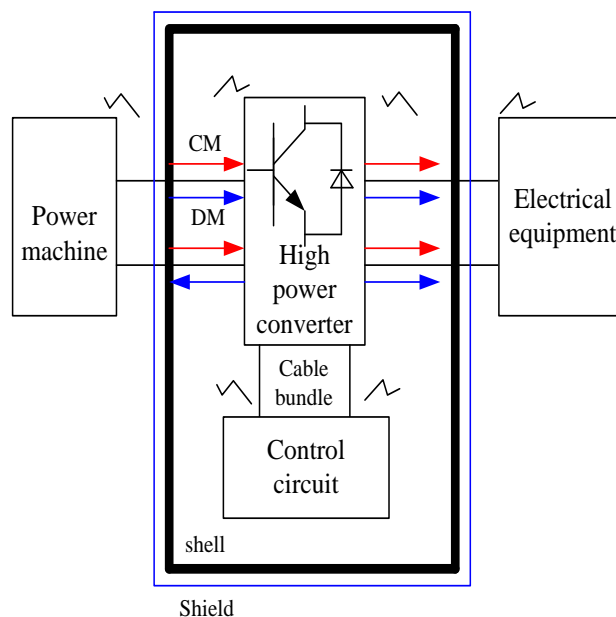


Fig. 1: Transmission control system electromagnetic transmission path

The conducted electromagnetic interference problem seriously affects the working state of the load and reduces its use efficiency. It also causes a harmful shadow on the working state of the inverter power supply. Therefore, it is necessary to analyze and suppress the conducted noise of the inverter circuit [11-14].

## II. ANALYSIS OF CONDUCTED EMI NOISE IN HIGH POWER TRANSFORMER CABINET

### a) Analysis of common mode EMI noise

For the conducted EMI mechanism of the inverter, in our electromagnetic compatibility laboratory, an artificial power network and a receiving device are used to extract the conducted noise of the equipment under test.

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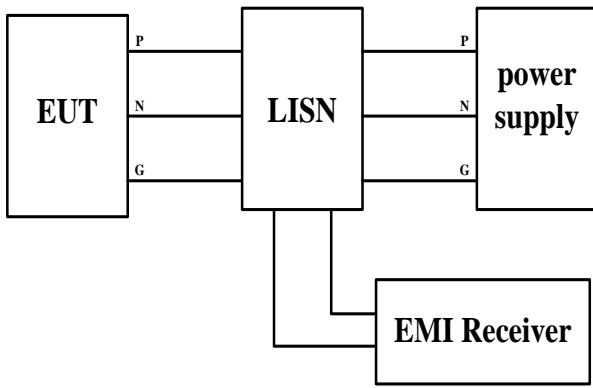


Fig. 2: Conducted noise test schematic

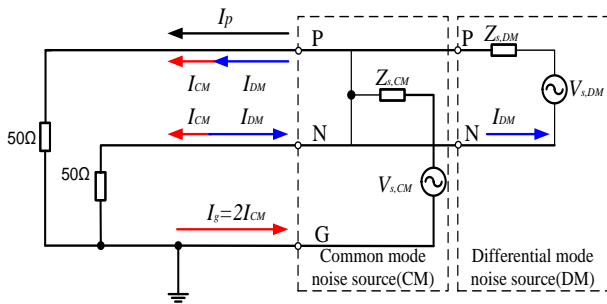


Fig. 3: Conducted noise high frequency equivalent circuit model

Figure 2 is a schematic diagram of the conducted noise test. In this figure, the G point of the P point and the N point represent the fire line, the neutral line/the neutral line, and the ground line. Figure 3 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  $I_{CM}$  is a common mode current,  $I_{DM}$  is a differential mode current, and  $I_p$  and  $I_n$  are the noise currents flowing through the live and neutral lines, respectively, then.

$$I_p = I_{CM} + I_{DM} \quad (1)$$

$$I_n = I_{CM} - I_{DM} \quad (2)$$

Those equations give the relationship between  $I_{CM}$  and power line current.

$$I_{CM} = (I_p + I_n) / 2 \quad (3)$$

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  $50\Omega$ . From the above study of the common-mode current, it can be seen from Fig. 4 that the relationship between the ground current  $I_g$  and the common-mode current  $I_{CM}$  is as follows:

$$I_g = I_p + I_n = 2I_{CM} \quad (4)$$

Assume that  $V_N$  and  $V_P$  are respectively zero line and live line conducting noise voltage, and the common-mode voltage is defined as

$$V_{CM} = I_{CM} \times 50\Omega = \frac{I_p \times 50\Omega + I_n \times 50\Omega}{2} = \frac{V_p + V_n}{2} \quad (5)$$

It can be seen from equations (4) and (5) that the voltage value across the resistor is the common-mode 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.

$$I_{CM} = I_p + I_n \quad (6)$$

Comparing equations (4) with (6), it can be obtained that the values of  $I_{CM}$  and  $I_g$  are equal. The common-mode current is not equal to the live and neutral currents in all cases. The  $I_{CM}$  forms a loop with the parasitic capacitance in the circuit to generate current. Equation (7) shows the current pulse size  $i_c$  caused by the rapid change of the parasitic capacitance  $C_p$ .

$$i_c = C_p \frac{dV_c}{dt} \quad (7)$$

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  $V_{dc}/2$ , and the other part is  $-V_{dc}/2$ , 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 5.

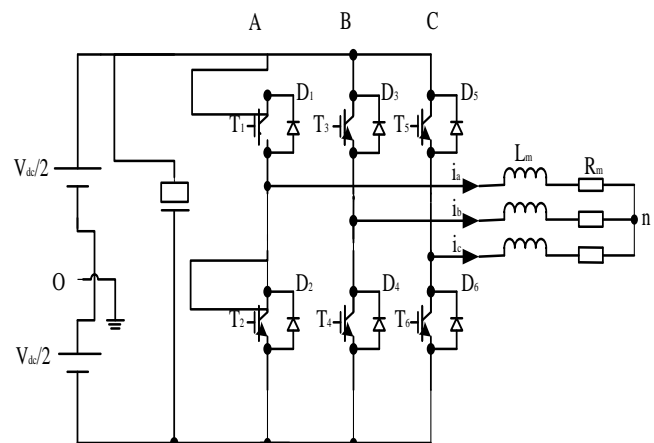


Fig. 4: Three-phase inverter circuit diagram

As shown in Figure 4, with zero point zero reference point, there are

$$\begin{cases} V_a - V_{cm} = R_m i_a + L_m \frac{di_a}{dt} \\ V_b - V_{cm} = R_m i_b + L_m \frac{di_b}{dt} \\ V_c - V_{cm} = R_m i_c + L_m \frac{di_c}{dt} \end{cases} \quad (8)$$

In the above formula,  $V_a$ ,  $V_b$ , and  $V_c$  are the phase voltages of each phase;  $i_a$ ,  $i_b$ , and  $i_c$  are the current outputs of each phase; and  $V_{cm}$  refers to the common-mode noise voltage. deformation of equation (8).

$$V_a + V_b + V_c - 3V_{cm} = R_m(i_a + i_b + i_c) + L_m \frac{d(i_a + i_b + i_c)}{dt} \quad (9)$$

According to Kirchoff's current law KCL,  $i_a + i_b + i_c = 0$ , the simplified common-mode noise voltage is obtained by (9).

$$V_{cm} = \frac{V_a + V_b + V_c}{3} \quad (10)$$

Similarly, the common-mode noise value of a single-phase inverter can be obtained.

$$V_{cm} = \frac{V_a + V_b}{2} \quad (11)$$

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.

b) Analysis of differential mode EMI noise

The relationship between the differential mode current  $I_{DM}$  and the power supply current can be obtained by the equations (1) and (2).

$$I_{DM} = (I_p - I_n) / 2 \quad (12)$$

The differential mode current  $I_{DM}$  flowing through the live line and flowing through the neutral line is large and reverse. Based on the definition of the differential mode current  $I_{DM}$  in the above equation, the differential mode voltage is defined as

$$V_{DM} = i_{DM} \times 50\Omega = \frac{i_p \times 50\Omega - i_n \times 50\Omega}{2} = \frac{V_p - V_n}{2} \quad (13)$$

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.

### 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 common-mode 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  $Z_s$  can be replaced by the parallel connection of the current source  $I_{scm}$  and the high impedance  $Z_p$ . According to practical experience, it is known that  $R_s = 0.15\Omega$ ,  $L_p = 15\text{ NH}$ ,  $R_L = 10\text{ m}\Omega$ ,  $C_p = 5\text{ pF}$ , and  $Z_p = 10\text{ k}\Omega$ .

$$I(Z_{LISN}/2) = (Z_{2C_y}/Z_p) I_{scm} / (Z_{L_c} + Z_{LISN}/2 + Z_{2C_y}/Z_p) \quad (14)$$

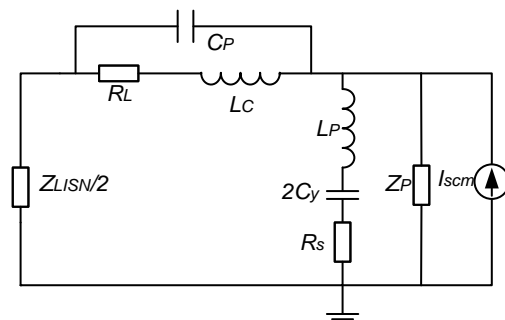


Fig. 5: Common mode filter circuit model

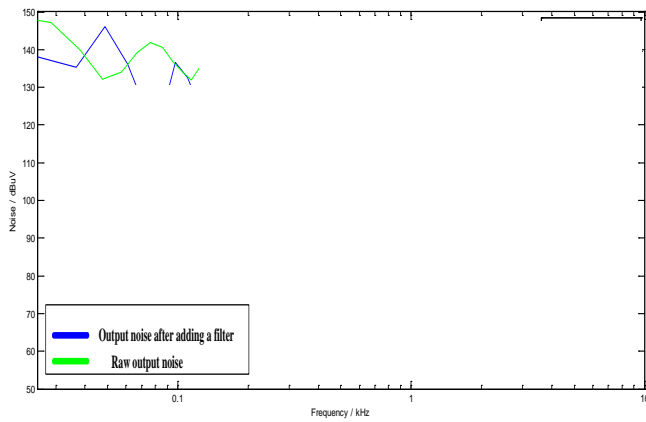


Fig. 6: The effect of the output filter added on CE101

In Figure 6 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.

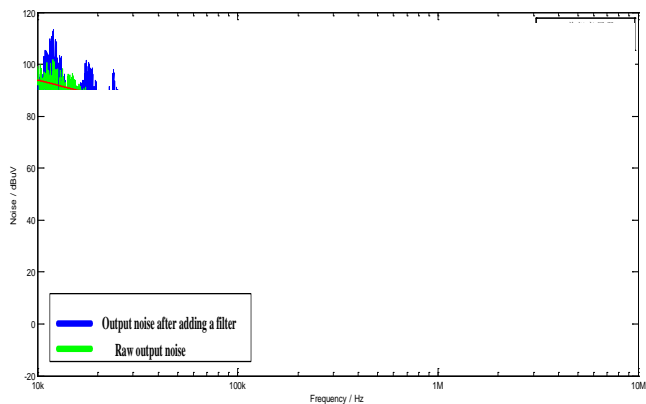


Fig. 7: The effect of the output filter added on CE102

#### IV. CONCLUSION

This paper mainly studies the mechanism of conducted noise and models, separates and suppresses noise. In the first step, based on the high-frequency 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.

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