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Research on Power Electronic Transformer Based on Phase Shift Converter

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Abstract. *Traditional transformers have been widely used in power systems due to their outstanding stability and high working efficiency. However, the weight and volume of traditional transformers are large. In recent years, the shortcomings in dealing with power quality problems have gradually emerged. In addition, the performance of power electronic devices is gradually improving, power electronics technology is rapidly developing, and the application range in power systems is also increasing. Therefore, whether power electronic technology can be applied to the field of transformers to improve the problems of conventional transformers becomes With the research hotspot, the concept of power electronic transformers came into being. The high-frequency DC link in power electronic transformers is a key part to improve its working efficiency and reduce the volume of the device. This paper adopts a phase-shifted full-bridge DC converter that can realize zero-voltage switching (ZVS), which is verified by simulation experiments. The achievability in power electronic transformers and the role of power electronic transformers in improving power quality.*

Keywords: *transformer; converter; power quality*

1. Introduction

With the increasing application of power electronics technology in power systems, a power electronic device used for transformer network transformation has gradually attracted the attention of researchers. Because its basic functions are consistent with traditional transformers, energy is realized. The transfer and voltage level transformations are therefore referred to as power electronic transformers (PET). For power electronic transformers with DC link, the DC link is an important part affecting the working efficiency and weight. One of the goals of the power electronic transformer is to reduce the weight of the transformer. The most effective way is to improve the DC link switching device. The operating frequency, and the increase of the switching frequency, will inevitably lead to an increase in the loss caused by the switching device, thereby reducing the operating efficiency of the power electronic transformer. The phase-shifted full-bridge DC converter can realize

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zero-voltage switching (ZVS) by using the junction capacitance of the switching device and the resonant inductance in the circuit, and reducing the loss of the switching device in the high-frequency state, thereby improving the weight and volume of the device while improving the goal of work efficiency.

2. Topology and working principle

The topology of the power electronic transformer is shown in Figure 1. Its working principle is to convert the input high-voltage alternating current into high-voltage direct current in the rectification section, and then to form a high-frequency alternating square wave through the phase-shifted full-bridge, using high-frequency The transformer is coupled to the secondary side, and then the full-wave rectification is used to reduce the low voltage of the direct current. Finally, the inverter link is used to change the required power frequency alternating current.

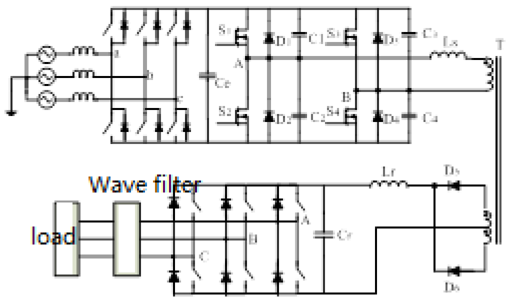

Figure 1. Power electronic transformer based on zero-voltage phase-shifted full-bridge converter

2.1. Rectification link

The two-level form is utilized in the rectification section. The main functions are: (1) supplying the DC input voltage to the phase-shifted full-bridge transformer; (2) ensuring that the phase of the current and voltage on the grid side are the same, thereby achieving power factor Correction function. On the basis of the above two points, the control strategy of the rectification link is shown in Figure 2. It can be seen from the figure that the control system is in the double closed loop condition, the control loop of the DC voltage is in the outer loop, and the control loop of the alternating current is in the inner loop. And through direct current control, compared with the control of indirect current, can significantly improve the dynamic response speed of the system.

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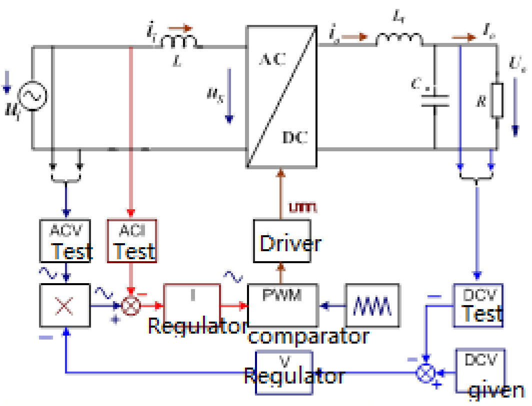

Figure 2. Control strategy of the rectifier link

2.2.Inverter link

The output part of the power electronic transformer is in the inverter link, and the output part is used to invert the DC voltage outputted in the DC link to the required constant frequency and constant voltage AC power. When the grid side voltage fluctuation or load changes suddenly, the output can be ensured. The voltage remains the same and the output voltage is guaranteed to meet the national power quality standards. The load in the power distribution system is mostly passive. Therefore, in the control mode, the constant voltage control based on the instantaneous value feedback under the d and q coordinate axes is used to separate the d and q components of the three-phase load voltage with their respective references. The deviation amount after the value comparison is sent to the PI regulator to obtain the sum, and then the trigger signal of the switch tube is obtained by SVPWM, and the control strategy thereof is as shown in Fig3.

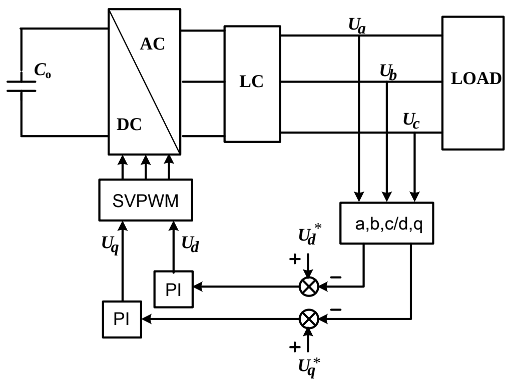

Figure 3. Inverter Link Control Strategy

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3. Phase shift full bridge to achieve zero voltage switching conditions

Due to the presence of the junction capacitance of the switching device, the voltage across the device cannot be abruptly changed, so zero voltage shutdown can be achieved. To achieve zero voltage turn-on, sufficient energy must be removed to remove the charge on the junction capacitance of the switch to be turned on. And the junction capacitor of the switch to be turned off is charged to the same bridge arm. Without considering the parasitic capacitance of the primary winding and the nonlinearity of the MOSFET junction capacitance, the zero-voltage switching of the super-forearm needs to satisfy equations (1) and (2), and the lag arm needs to satisfy equations (3) and (4). The middle L_s is the resonant inductor, which L_f is the filter inductor, which I is the primary current, which U_{in} is the DC input voltage, which n is the high-frequency transformer ratio, which C_{lead} is the value of the forearm capacitor, which C_{lag} is the value of the hysteresis arm, which T_{dead} is the dead time.

$$\frac{1}{2}(L_s + n^2 L_f) I^2 > C_{lead} U_{in}^2 \tag{1}$$

$$T_{dead} \geq U_{in}(C_1 + C_3) / I_P = 2C_{lead} U_{in} / I_P \tag{2}$$

$$\frac{1}{2} L_s I^2 > C_{lag} U_{in}^2 \tag{3}$$

$$T_{dead} \leq \frac{\pi}{2}\sqrt{L_s(C_2 + C_4)} = \frac{\pi}{2}\sqrt{2L_s C_{lag}} \tag{4}$$

4. Simulation research

In order to verify the feasibility of the proposed method and the function of power electronic transformer, the simulation research is carried out by using Matlab software and establishing model in Simulink environment. The simulation research is based on 10kV/0.38kV power distribution system. The specific simulation parameters are: input Inductance is 10mH, DC stabilized capacitor is 100uF, resonant inductor is 40uH, parallel junction capacitance is 10nF, output filter inductor is 1mH, filter capacitor is 33uF, DC link switching frequency is 100kHz, load active power is 40kW, reactive The power is 10kvar.

Figure 4 shows the waveform of the current and voltage on the grid side. It can be seen from Fig. 4 that the voltage and current on the grid side are both sinusoidal in phase, which shows that the rectification link can achieve the goal of unity power factor control.

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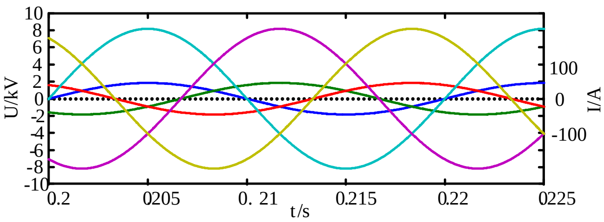

Figure 4. Grid side current and voltage

From Fig. 5 and Fig. 6, it can be seen that the voltage state of the PET output when the grid side voltage changes. It can be seen from Fig. 5 that a voltage drop of 15% and a voltage rise of 15% occur respectively between the grid side voltages of 0.4 s to 0.5 s. Fourier analysis of the output voltage shows that the THD of the output voltage is very small, and the amplitude of the voltage has a small change of less than 1%, which fully demonstrates that PET can withstand voltage fluctuations well.

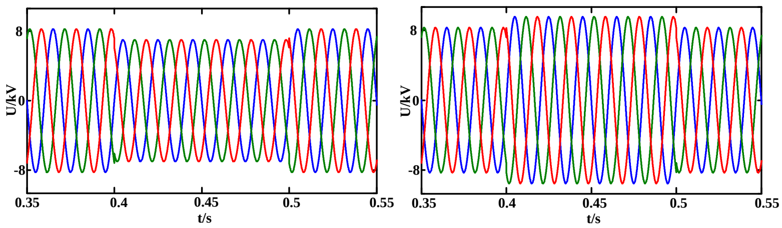

Figure 5. Grid side voltage fluctuations

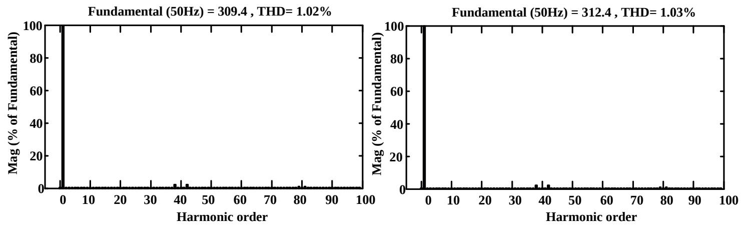

Figure 6. Fourier analysis of the output voltage

Fig. 7 is a voltage simulation diagram when the grid side voltage has a harmonic. It can be seen from the figure that 5 times of 20% harmonics and 7 times of 15% harmonics are injected into the grid between 0.35s and 0.45s. The simulation results fully indicate that the output voltage is not affected by the harmonics on the grid

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side. 1.02% THD indicates that PET can suppress the diffusion of harmonics very well.

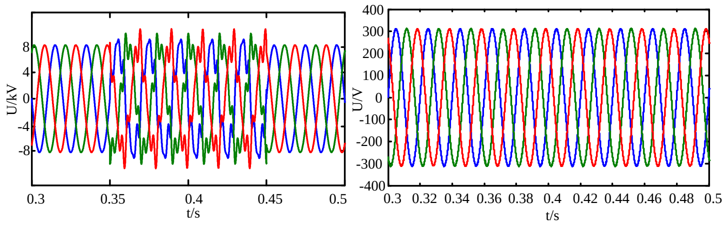

Figure 7. Output voltage of the grid side voltage containing harmonics

Figure 8 shows the simulation results of the output voltage when the voltage on the grid side flickers. A frequency drop of 10 Hz occurs in the grid side voltage between 0.4s and 0.5s, and the output voltage maintains the original frequency, which proves that PET has the function of coping with the voltage fluctuation on the grid side.

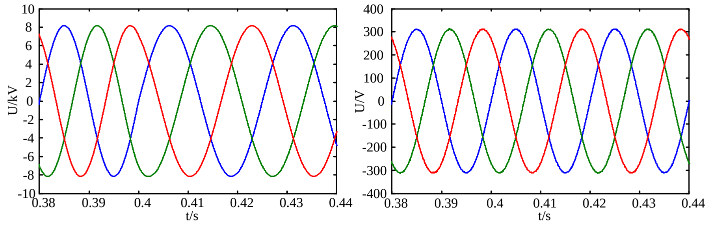

Figure 8. Output voltage when the grid side voltage frequency flickers

5. Conclusion

By introducing soft switching technology, the power electronic transformer based on the shifting converter works well in the high frequency state, which plays an important role in reducing the volume of the transformer, reducing the weight of the transformer and improving the efficiency of the transformer. By applying closed-loop control to the DC link, the load capacity of the power electronic transformer is stronger. In addition, on the basis of the basic functions of power transmission and voltage conversion, the power electronic transformer also has a good response to sudden changes in power load, system frequency flicker, grid voltage fluctuations, etc., and provides high power load. The quality of electric energy has a good regulation effect on the quality of electric energy.

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