Design of Active Power Filter for Low Voltage and High Current Switching Power Supply

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Abstract—**Switching power supply of low voltage and high current based on power electronic technology is widely applied in some industry fields, especially in electroplating, welding and heating. Harmonics in high-power switching supply pollute power system heavily, which must be suppressed effectively. On basis of analyzing harmonic current of switching supply that the output technical specification is 60V/500A, this paper designs active power filter for switching power supply with high power and frequency, which adopts i_p-i_q current detecting method and hysteresis current control method. Based on simulation platform of Matlab/Simulink, the filtering effect is simulated and analyzed. Simulation results demonstrate the active power filter has expected performance, which can not inhibit harmonic current instantaneously, but also compensate reactive power. The designed active power filter can effectively improve the power quality.**

Keywords-low voltage and high current; switching power supply; active power filter; harmonic current; hysteresis current control.

I. INTRODUCTION

With the development of power electronic technology, low voltage and high current switching power supply has been applied widely in production and life. But harmonic pollution becomes severe increasingly in switching power supply. Generally, there are two methods to eliminate harmonics, which are mainly passive power filter and active power filter. The former is relatively low cost, but filtering effect is far from desirability[1, 2]. By contrast, the latter can suppress the harmonics instantly and compensate reactive power, and it becomes an effective approach to inhibit harmonics[3, 4]. Thus, this paper employs active power filter to suppress harmonic current of low voltage and high current switching power supply.

This paper proposes the design and performance analysis of active power filter for 60V/500A switching power supply.

II. HARMONICS ANALYSIS OF SWITCHING POWER SUPPLY

A. Basic structure and Technical specification of the low voltage and high current power supply

The low voltage and high current power supply mainly consists of three components: "input rectifier filter circuit", "high frequency inverter circuit" and "output rectifier filter circuit". Through the conversion of AC~DC~AC~DC, the needed DC voltage can be obtained. Structure diagram of the low voltage and high current power supply is shown in Figure1.

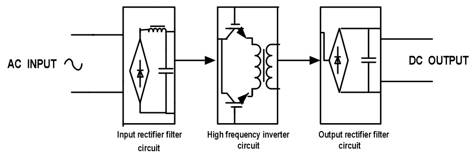

Figure 1. Structure diagram of the low voltage and high current power supply

Technical specification of the low voltage and high current power supply:

1) Input Voltage: AC 380±10%V;

2) Power grid Frequency: 50Hz;

3) Output Standard Voltage: 60VDC;

4) Output Standard Current: 500A;

5) Output Voltage Range: 55~65VDC;

6) Output Maximum Current: 540A;

7) IGBT Operating Frequency: 20kHz;

B. Harmonics in the low voltage and high current power supply

In the presence of full-load, the voltage and current of the low voltage and high current power supply can be detected by using the HIOKI 3196 Power Quality Analyzer, and is concretely shown in Figure2.

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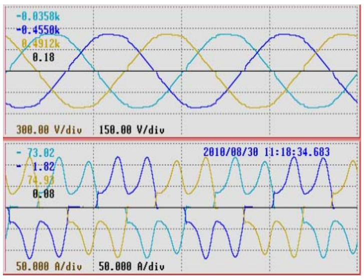

Figure 2. Waveform of three-phase voltage and current

As can be seen from Figure2, the distortion of three-phase voltage waveform is not obvious, THD_U=2.62%<5%, confirming to GB's limits, while the distortion of three-phase current waveform is quite serious. The histogram of A-phase harmonic current is the middle section in Figure3, which shows that 5th harmonics is nearly 25A, 7th harmonics can reach to 12.5A. Individual harmonic current value is detailedly shown in TABLE Ⅰ.

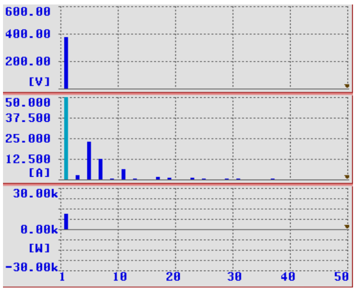

Figure 3. A- phase harmonic voltage, current and power histogram

MEASUREMENT VALUE, SIMULATION VALUE AND GB'S LIMITS OF A-PHASE HARMONIC CURRENT

Harmonic order	**conversion value of GB's limits /A**	**Harmonic current measurement value /A**	**Harmonic current simulation value /A**
1	/	53.53	56.57
3	3.72	2.35	4.24
5	3.72	23.02	23.16
7	2.64	12.65	15.55
11	1.68	6.57	7.1
13	1.44	0.43	4.8
THD_I/%	/	51.12	52.13

Table footnote: standard voltage is 0.38kV, and standard short circuit capacity is 600KVA; GB's limits converted value is calculated according to GB/T1459-1993 "harmonic power quality utility grid"[5].

Total Harmonic Distortion of A-phase harmonic current is shown in TABLE Ⅰ, THD_I=51.12%. 5th, 7th and 11th harmonic current all have exceed GB's limits, and must be restrained.

III. DESIGN OF ACTIVE POWER FILTER

A. *System configuration of Active Power Filter*

System configuration of Active Power Filter is shown in Figure4, and its operating principle is as follow: firstly, detect the voltage and current of compensated object; secondly, calculate the instruction signal of the needed compensated current via the operation circuit of instruction current; thirdly, amplify the instruction signal via generation circuit of compensating current, and get the needed compensating current; finally, the obtained compensating current eliminates the harmonic component in load current to attain the expected grid-side current[5].

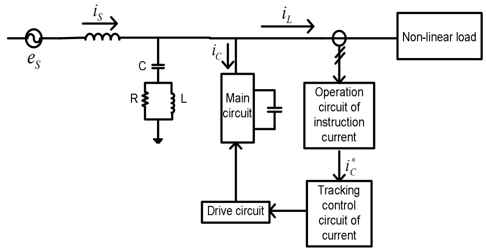

Figure 4. System configuration of Active Power Filter

B. *Design of Instruction Current's Generation Circuit*

On the basis of instantaneous reactive power theory, there are two methods to detect the harmonic current. They are p-q and i_p-i_q detecting methods respectively[6, 7]. When power grid voltage appears distortion, i_p-i_q detecting method will be more precise. So it is used extensively. The principle diagram of i_p-i_q detecting method is shown in Figure5[8].

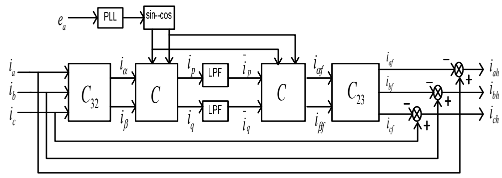

Figure 5. Principle diagram of i_p-i_q detecting method

The expressions of C32 and in the fig2-2 are following.

$$C_{32} = \sqrt{2/3}\begin{bmatrix} 1 & -0.5 & 0.5 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix};$$

$$C = \begin{bmatrix} \sin\omega t & -\cos\omega t \\ -\cos\omega t & -\sin\omega t \end{bmatrix}.$$

i_p-i_q detecting method mainly applies Phase Locked Loop(PLL), sine and cosine signal generator to obtain the sine and cosine signal with the same phase as grid-side A-phase voltage. Calculate the value of i_p and i_q according to definition, attain the DC components of i_p and i_q via the Low-Pass Filter(LPF), get i_{af}、i_{bf} and i_{cf} through reversed transformation of the DC components, and then ultimately calculate the instruction current signal i_{ah}, i_{bh} and i_{ch} .