Research and Design of Aviation Active Power Filter Based on DSP

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Abstract. As the application of power electronic devices in aviation power system become more and more widely, the harmonic and reactive power problems are becoming more and more serious. Active power filter has become an important research direction of power electronics technology. In this paper, the harmonic harm and harmonic suppression methods are briefly described. Then the software and hardware of APF are designed. Finally, the system is simulated by Simulink, which proves the rapidity and accuracy of harmonic and reactive current detection and compensation.

1. Introduction
With the development of power electronic technology, various power electronic devices are widely used in aviation power system. Harmonic and reactive power problems are becoming more and more serious, which pose a great threat to the safe and stable operation of aviation power system. Active power filter (APF) has become an important research topic of power electronics technology in aviation power supply[1].

2. Harmonic harm and suppression method
The increasing nonlinear load is the main harmonic pollution source of aviation power system. Harmonics may cause voltage resonance in the aircraft power system and cause over-voltage on the line. Harmonics can also make the voltage waveform peak, so as to accelerate the aging of cable insulation and shorten the service life of cable[2].

To solve the problem of harmonic pollution in power electronic devices and other harmonic sources, two methods are mainly used[3]. One is to reform the power electronic device itself, such as...
using multiple technology, PWM rectification technology and power factor correction technology. The other is to install harmonic compensation device to compensate harmonic, which is applicable to all kinds of harmonic sources. Harmonic compensation device can be divided into passive filter and active power filter.

Passive filter is a device composed of capacitor, reactor and resistor. Passive filter has the advantages of simple structure, low equipment investment and low operating cost. However, this kind of filter is easy to be affected by grid impedance and operation state, and it is easy to have parallel resonance with the system. Harmonics may overload or even burn out LC filter[4].

Active power filter (APF) can track and compensate the harmonics with varying frequency and amplitude, and the compensation characteristics are not affected by grid impedance. The classification of active power filter is shown in Figure 1.

3. Hardware design of APF system
Digital signal processor (DSP) has been developed for more than 20 years. The high-speed computing ability of DSP makes many complex control algorithms and functions realized. At the same time, the real-time processing ability and the peripheral functions of the controller are integrated into one, which is also well applied in the control field. With the wide application of high speed DSP, it has become a trend to control active power filter with DSP.

3.1. DSP hardware circuit
DSP hardware circuit mainly includes signal acquisition circuit, current signal conditioning circuit and clock circuit. The main circuit of DSP system is shown in Figure 2.
3.1.1 Current signal acquisition circuit
The current signal acquisition circuit mainly completes the power supply current signal acquisition work in the power grid. The circuit structure is shown in Figure 3.

The current signal is converted from current transformer to weak voltage signal. After conditioning circuit, the signal meets the input signal requirements of A/D conversion circuit. The internal A/D conversion module of TMS320F2812 requires that the voltage range of input signal is 0-3V. When the sampling start signal comes, it can start to sample the current signal[5].

3.1.2 Signal conditioning circuit
The load current and compensation current signal transformed by Hall current sensor is still an alternating signal. The A/D in DSP2812 is unipolar (0~3.3V). In order to measure the signal current safely, correctly and reliably, it is necessary to transform the signal from bipolar to monopolar by operational amplifier circuit, and then it can be directly introduced into DSP. Otherwise, it will cause operation error and even burn the DSP. The implementation circuit is shown in Figure 4.
3.2. Main circuit design

The project adopts shunt active power filter. Its typical circuit structure is three-phase voltage type PWM converter circuit, as shown in Figure 5.

![Main circuit of active power filter.](image)

We assume that the grid voltage is symmetrical, from which we can derive the differential equation of the main circuit[6].

\[
L_a \frac{di_{a}}{dt} = e_a + K_a U_d
\]  
(1)

\[
L_b \frac{di_{b}}{dt} = e_b + K_b U_d
\]  
(2)

\[
L_c \frac{di_{c}}{dt} = e_c + K_c U_d
\]  
(3)

\(K_a U_d, K_b U_d\) and \(K_c U_d\) are the voltage between the neutral point of each bridge arm of the main circuit and the neutral point of the power supply. \(K_a, K_b\) and \(K_c\) are switching coefficients. The corresponding relationship between the working mode of the main circuit and the switching coefficient is shown in Table 1.
Table 1. Working mode and switching coefficient of main circuit.

| Serial number | Working mode   | Switching coefficient |
|---------------|----------------|-----------------------|
|               | S1  S3 S5 S2  S4 S6 | K_a K_b K_c          |
| 1             | opening        | opening opening       | -2/3 1/3 1/3 |
| 2             | opening        | opening opening       | 1/3 -2/3 1/3 |
| 3             | opening        | opening opening       | 1/3 -1/3 2/3 |
| 4             | opening        | opening opening       | 1/3 1/3 -2/3 |
| 5             | opening        | opening opening       | -1/3 2/3 -1/3 |
| 6             | opening        | opening opening       | 2/3 -1/3 -1/3 |

In the design of the main circuit, DC side capacitance, AC side inductance and power devices are the key contents.

4. Software design of APF system
The software program adopts modular and structured design idea. The main consideration is that it is convenient to transplant and modify, and the function module is easy to expand the program. The main program flow of the system is shown in Figure 6.

![Software design of APF system diagram](image-url)
5. System simulation
The system simulation results are shown in Fig. 7 and Fig. 8.

![Figure 7. Fundamental current.](image7.png)

![Figure 8. Sum of harmonic current and reactive current.](image8.png)

6. Conclusion
This paper focuses on the harmonic and reactive current detection method, PWM control strategy, system structure, filtering principle, software and hardware implementation of the aviation active power filter based on DSP chip. Through the Simulink simulation module, the simulation model is established and the simulation is carried out. These studies lay a theoretical and practical foundation for the development of active power filter.

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