AN ACTIVE POWER FILTER BASED ON WAVELET ANALYSIS

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Abstract

As modern accelerators demand greater stability to magnet power supply, it becomes more and more important to decrease the fluctuation and harmonic contents in the voltage. Active p ower filter (APF) is an effective method to improve the performance of voltage. To decrease the harmonic in the voltage, the APF circuit generates a harmonic voltage, which is added to the output of power supply, to countervail its harmonic. In this paper, a novel APF which is based on wavelet transform is mentioned. Digital control technology is used to this APF, which makes it easily to change its working state. Discrete wavelet transform is used to analyze the harmonic components in the voltage, and APF works according the result. At end of this paper, a simulation result is given to prove the effect of APF.

ACTIVE POWER FILTER

APF can work in DC situation or AC situation. Figure 1 shows a schematic diagram of APF circuit, which is used in AC power supply. In this circuit, the controller samples the voltage value from the load side, then the data are analyzed to get the amplitude and phase information of the harmonic. According to the analyzed result, the APF circuit produces harmonic voltage which will be added to output voltage of the power supply to decrease the harmonic. Similarly, in DC situation, APF generates a voltage to decrease ripples and harmonic waves in the voltage from power.

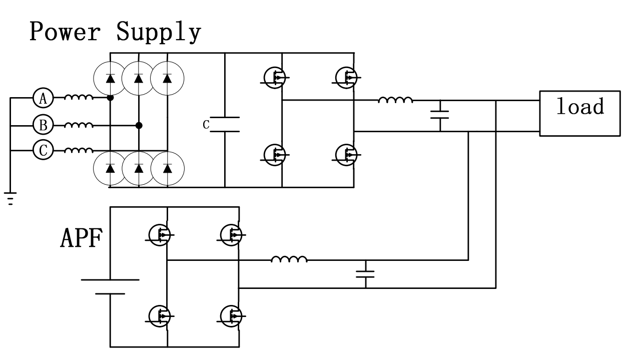

Figure 1: Single-phase APF used in AC power supply.

Figure 2 shows the control diagram of an APF. For AC situation, the signals analyzing part makes a distinction between fundamental wave and harmonics. The APF generate a voltage to offset the harmonics without influence the fundamental wave. While for DC situation, we focus on all the ripples and harmonics of the voltage. Digital processing makes it conveniently to change its working state. As there is no essential difference between AC and DC application, that the analysis in this paper is suitable for either situation.

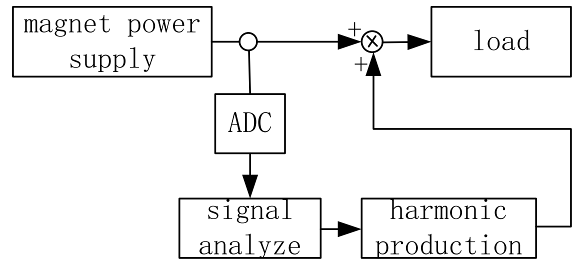

Figure 2: Control loop of APF.

HARMONIC ANALYSIS

A big problem in APF technology is how to get the harmonic information from sampled signal. Fast Fourier Transform (FFT) is the most widely method used at present.

FFT

FFT is the method used most widely in digital signal processing. However, its intrinsic shortage of bad time-resolution limits its application, which means that the transients and notching cannot be analyzed by FFT.

Wavelet Transform

Wavelet transform (WT) provides a new way to analysis the digital signal. The mathematical background can be found in [1-4], a brief summary is given in this paper. Let φ(t) and ψ(t) be the scaling function and the corresponding mother wavelet function in formula (1) , then the voltage signal f(t) can be analyzed as follow:

$$f(t)=\sum_{k} x_j(k)\varphi_{J,k}(t)+\sum_{j=1}^{J}\sum_{k} d_j(k)\psi_{j,k}(t) \qquad (1)$$

Where $\varphi_{J,k}(t)$is the scaling and shifting of φ(t),and $\psi_{j,k}(t)$ is the scaling and shifting of ψ(t) , x_j and d_j are the detail parts and the approaching parts of the analysis result .

Discrete wavelet transform (DWT) makes it possible to realize WT in digital processing. It divides the original signal into separated frequency bands, so it is possible to analyze higher frequency components for each band independently. The input at each stage is always split into two bands, and then the higher band becomes one of the outputs, while the lower band is further split into two bands. This procedure is continued till a desired resolution is achieved, from which the recursion formulas of decomposing coefficient are shown as follows:

$$x_{j+1}(k)=\sum\nolimits_{m} h_0(m-2k)x_j(m) \qquad (2)$$

$$d_{j+1}(k)=\sum\nolimits_{m} h_1(m-2k)x_j(m) \qquad (3)$$

Where $h_0(k)$ refers to unit sampling response of low-pass digital filter, and $h_1(k)$ refers to unit sampling response of high-pass digital filter. The analyzing process can be shown in Figure3.

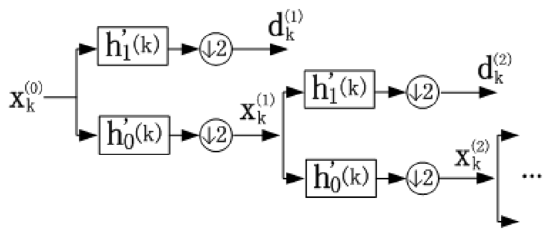

Figure 3: Process of discrete wavelet transform.

Then the APF circuit is controlled to work according the results in formula (2) and (3), making compensation for the ripple and harmonic of voltage across the load.

SIMULATION

The simulation of the proposed DWT based APF is carried out using MATLAB, in which the control part is programmed in S-function. Figure 4 shows the primary voltage signal.

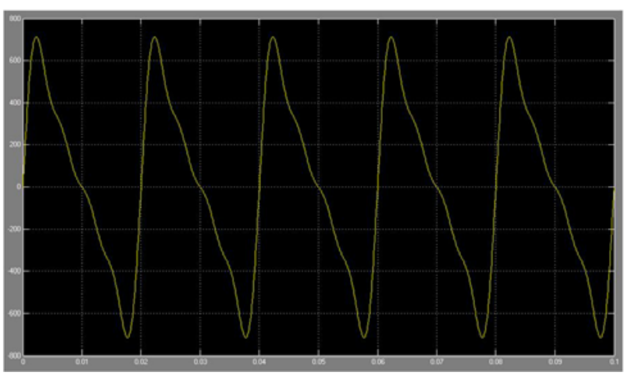

Figure 4: Wave of primary voltage.

Analyze the voltage signal using db5 wavelet, then the result is shown in Figure 5.

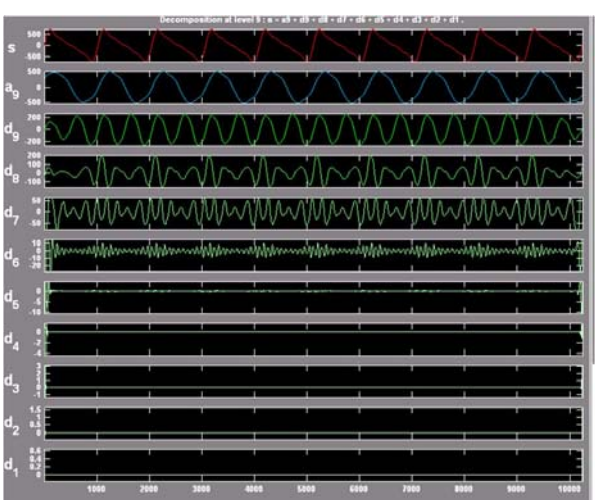

Figure 5: Result wave of DWT.

Make the APF circuit to generate harmonic according this result, and output this harmonic voltage to the magnet, then the final voltage across the magnet is shown in Figure 6.

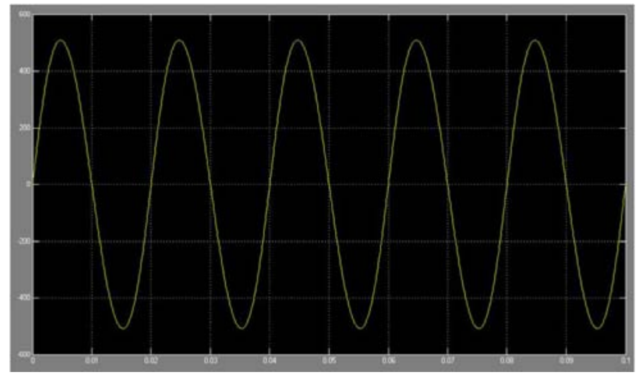

Figure 6: Wave of final voltage.

CONCLUSION

With APF we can improve the power supply's performance. From simulation results above, it can be seen that WT has excellent localization in both time and frequency domains, with the result of DWT, the APF circuit can countervail the harmonics in voltage.

However, the capability of APF depends on the result of signal analyzing, and bad analyzing result may even make the current worse. As a result, we have to attach much importance to the study of digital signal analyzing. In addition, the capabilities of the digital signal processing chips have great influence to the APF [3].

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