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Research and Analysis of PI Control Strategy Based on Neural Network in Power Grid

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ABSTRACT

With the rapid development of power electronic technology, the nonlinear loads in power system increased bring the serious harmonic contamination. Currently active power filter (APF) is an effective method to deal with the harmonic pollution in power grid. In this paper, a detection method based on adaptive neural network is proposed through the principle study of APF system and the equivalent circuit model of three-phase nonlinear load establishment by the detection of harmonic current and reactive current. The proposed method uses neural network to approximate the nonlinear loads in the model according to the size of the harmonic error, the proportion integration (PI) controller is combined to the online real-time adaptive feedback. And the steady accuracy of the device is ensured by using the zero steady-state error of the repeated cycle control, so as to meet the requirements of the optimality. At last the fundamental active current in the power system is obtained by the simulations, the detection of the harmonic current is realized and compensated for each other, which confirm the effectiveness of the proposed method.

Keywords: Neural network, Harmonic wave, PI control, Active power filter.

1. INTRODUCTION

In the process of the development of science technology and the progress of the society, all kinds of high-tech products and derivatives are emerging. In the electric power due to the geographical structure and resource distribution of our country, the geographical structure of the power grid is determined. Especially in the poor environment the long distance of the power transmission and distribution, the operation efficiency of the power grid is poor, the additional loss of power supply and equipment makes the temperature of the device high, which reduces the utilization rate of equipment and economic benefits in the transmission of the power. Because of the instability of the common three-phase AC sinusoidal voltage, especially a large number of non-sinusoidal current (voltage) signals generated by AC power cause the effective use of the power and a series of harmonic interference, etc. Active power filter (APF) can suppress some harmonics and improve the stability and quality of the power. Based on the principle the mathematical model of three-phase parallel APF is established. At the same time, the harmonic current detection with multiple adaptive neural networks is combined with the PI control parameters to control the DC side voltage effectively. Especially in the process of harmonic processing, the neural network algorithm (such as BP, FFT) is added, which can make the main parameters more accurate and stable in the process of the harmonics detection.

2. HARMONICS DETECTION METHOD

In the recent power systems, especially the various kinds of interference harmonics appeared from the current three-phase AC power affect the power quality and efficiency. There are some methods in the traditional harmonics detection. The passive filter is only used for simple and original filtering which at the same time also brings a lot of inconvenience and problems, and it is eliminated slowly. So in the later several common methods are proposed, each of them has its own characteristics and application, so it is very important to understand the advantages and disadvantages of various harmonic detection methods and their applications. At present p-q method, method and the synchronous detection method based on the instantaneous reactive power theory and the detection methods based on the orthogonal property of the sine function are widely used. In view of the deficiency of the traditional methods, the multi adaptive neural network detection system is added, and combined with PI control module to be applied for the detection and the control of the load current harmonics and reactive power, so as to provide an effective theoretical and practical guidance for harmonic

suppression. The analysis and simulations show that the proposed method is very effective and practical.

2.1 Traditional $i_p - i_q$ detection method

At present, most of the harmonic detection methods are based on $i_p - i_q$ method. The basic working principle of the detection is to convert the current signals output into a voltage signal and to be amplified or reduced according to the actual signals output. The pulse width modulation is used for the signal transmission.

At first the order operation circuit is an important part of the harmonic detection, whose function is to obtain the order signal (current signal) in the compensation circuit with the use of APF. And the most important part is the detection method of three-phase circuit. There are two kinds of commonly methods: one is the circuit harmonic detection method, the other is reactive current detection method. Figure 1 is the schematic diagram of i_p - i_q harmonic detection. The basic principle is to use one phase in three-phase voltage source to achieve the sine signal and the corresponding cosine signal $\sin\omega t - \cos\omega t$, then they are obtained from the phase locked loop (PLL) and $\sin\omega t - \cos\omega t$ signal generating circuit. Then by the definition and the formulas to calculate i_{p2}, i_q . i_{p1}, i_{p2} in the figure is generated from i_{af}, i_{bf}, i_{cf}. Thus i_{af}, i_{bf}, i_{cf} can be calculated by i_{p1}, i_{p2}. At last calculate i_{ah}, i_{bh}, i_{ch}. As shown from formulas (1) to (4).

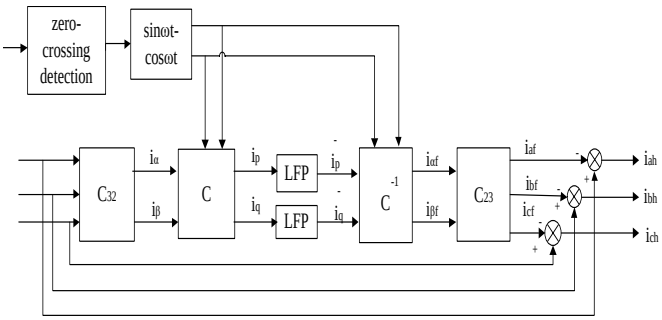


Figure 1. Schematic diagram of three phase current harmonic detection

$$C^{-1} = \frac{\sqrt{6}}{3}\begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = C_{32}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}, \begin{bmatrix} e_\alpha \\ e_\beta \end{bmatrix} = C_{32}\begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} i_{af} \\ i_{bf} \\ i_{cf} \end{bmatrix} = C_{32}C^{-1}\begin{bmatrix} i_p \\ i_q \end{bmatrix} = \frac{1}{e^2}C_{32}C^{-1}\begin{bmatrix} \bar{i}_p \\ \bar{i}_q \end{bmatrix}, \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = C_{32}\begin{bmatrix} i_a \\ i_b \\ c_c \end{bmatrix} \tag{2}$$

$$i_s = i_1 + i_c = i_{1f},\ i_q = i\sin\varphi,\ C = \begin{bmatrix} \sin\omega t & -\cos\omega t \\ -\cos\omega t & -\sin\omega t \end{bmatrix} \tag{3}$$

$$i_{bh} = i_b - i_{bf} \quad , \quad i_{ch} = i_c - i_{cf} \ , \ i_{ah} = i_a - i_{af} \tag{4}$$

With the above equations the compensation currents can be calculated, the controllable compensation is performed according to the required parameters, so as to achieve the purpose of harmonic suppression.

2.2 Current detection method based on neural network

To the traditional APF, it is difficult to measure the specific parameters (current, voltage) accurately. Consider combing the neural network and PI control with APF controller, a new detection method based on adaptive neural network is proposed, which uses advanced control algorithm to detect the harmonics and reactive power of the load currents. The neural network diagram is shown in Figure 2. It has the ability to track and capture the parameters, and it can be detected more quickly and accurately, the results are more close to the ideal value. So adding the neural network to APF is a trend in the future.

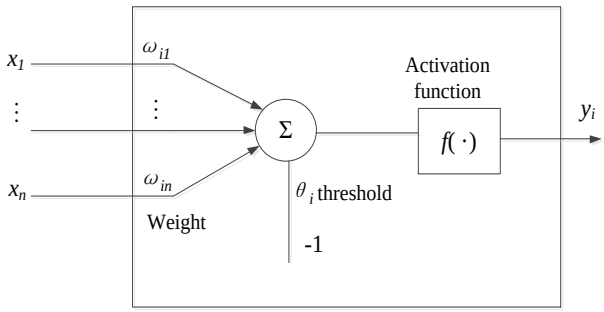


Figure 2. Neural network topology

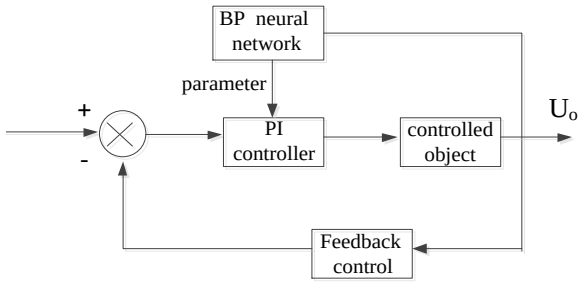


Figure 3. The frame of the neural network

The output function expression of the system is $y = f\left(\sum_{i=0}^{n}\omega x_i(t) - \theta\right)$, where n is the number of the input information, t is the time, ω_i is the weight coefficient represents the strength of the network connection, θ is the neuron threshold, $f(t)$ is the nonlinear function mainly for nonlinear mapping. Because of the threshold the output of the neuron can be effectively restricted.

3. SIMULATION MODEL

Adding the neural network module to APF filter is useful for more effective and accurate harmonic detection and compensation. The final required current (voltage) signal received are available for practical production. Neural network is added to the feedforward controlled parameters for reducing the unnecessary delays and reducing the working hours.

3.1 System model

Because this research is mainly aimed at the daily three-phase power system, this paper uses three-phase AC as the research object. The principle diagram is shown in Figure 4.

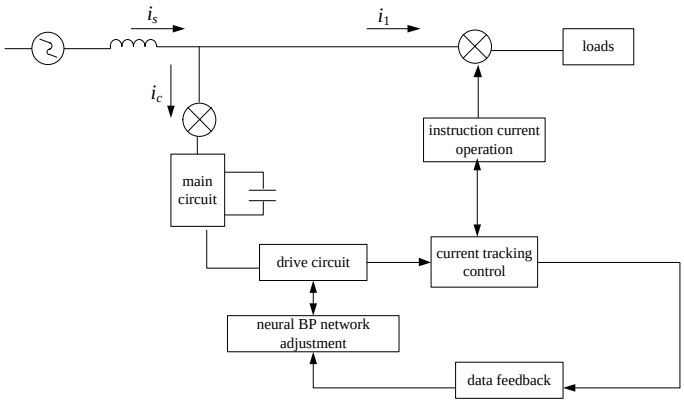


Figure 4. Diagram of APF with neural network module

We can see clearly that the main filter device (combined with parallel APF shown in Figure 5) makes the parallel APF as the main body. The hysteresis comparison method is used for the signal parameters controlling.

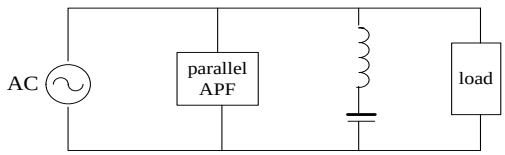


Figure 5. The structure of parallel filter

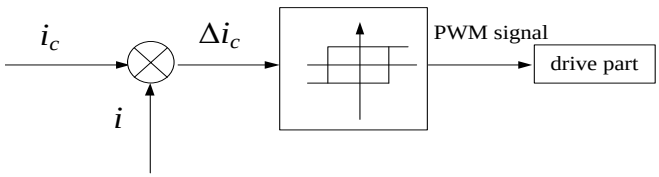


Figure 6. Hysteresis comparator

In Figure 6 the control module is added to the network. It can be seen that the compensation and the suppression of some related parameters such as AC current are achieved. In the actual operating environment a series of harmonic, internal and external oscillation and non stability factors have been suppressed and processed, the voltage (current) signals become more stable and have achieved compensation and improvement which are very close to the expected theoretical values. Finally, the operating environment and the quality of electric energy is improved, and the power can be saved effectively.

3.2 Simulation and analysis

In this paper, the main research object is to test the current parameters of three-phase AC, and the simulation results are obtained. The simulation images of the harmonics depressing and compensation are given as follows.

(1) Consider the voltage of 220v, 50Hz, α=45^0 , giving certain loads, the current waveform is shown in Figure 7. The harmonic is very obvious, and three-phase current waveform is disturbed, In the use of APF the harmonics are suppressed and provide the corresponding compensation, making the current waveform close to the normal.

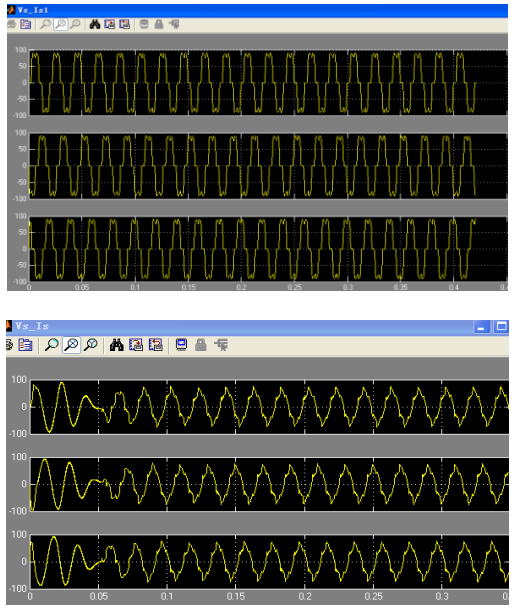


Figure 7. Simulation results of APF for current harmonics

(2) Consider the voltage of 220v, 50Hz, α=45^0 , giving certain loads, the current waveform is shown in Figure 8. The harmonic is also very obvious. In the role of the APF after joining the neural network, we can clearly see that the harmonic is well suppressed, and the compensation is also very good. The curve of the current is getting closer to the ideal, and the amplitude is higher. From the figures, the use of the neural network makes APF plays more perfectly.

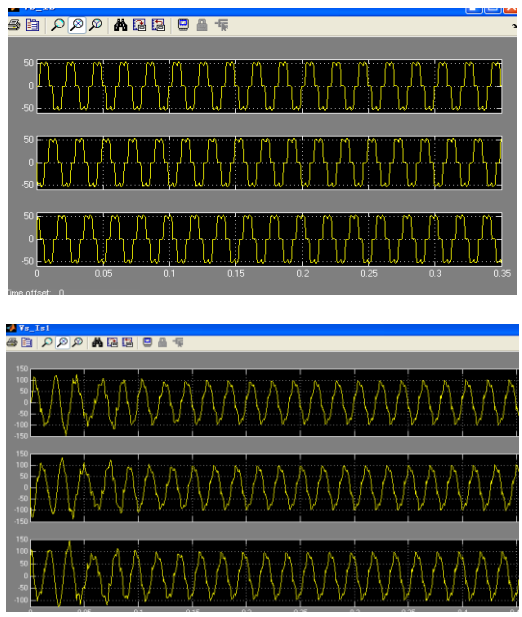
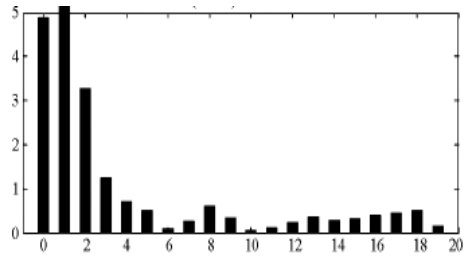
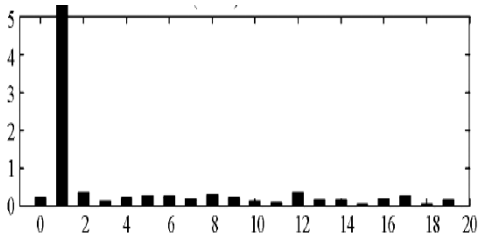


Figure 8. Harmonic suppression images adding neural network to PI control module

And from the THD harmonic spectrum before and after the compensation filter in Figure 9 we can see the advantages of the device. The harmonic detection module based on the neural network can obtain fast and accurate detection and suppression effect, it has a good prospect in the future.



a. THD spectrum before compensation



b. THD spectrum after compensation

Figure 9. Comparison of the THD spectrum

4. CONCLUSIONS

In this paper, we analyze and study the linear and nonlinear harmonic at the present stage of harmonic pollution. On the basis of traditional harmonic detection, multiple adaptive neural network detection system is combined with PI controller for the detection and control of the current harmonics and reactive power of the loads. So the method of active power harmonic detection based on neural network is proposed. With the advantages of neural network such as the ability to approximate any nonlinear function, fast response, small overshoot, small error, good robustness and so on, it improves the poor compensation performance and low efficiency of the APF. The validity and practicability of the design scheme is also verified by the simulations. This paper mainly focuses on the improvement of the hardware and software of the APF device, and it will make some useful attempt and exploration for the practical design.

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REFERENCES

[1] Jun Yang and Zhaoan Wang, "A study on the comparison of two mathods used to detect the harmonic cuurents of three-phase circuts," *Transactions of China Electrotechnical Society*, vol. 6(7), 2005. 09.

[2] Zhaoan Wang and Jianjun Liu, *Power Electronics*, Beijing: Mechanical Industry Press, 2010.

[3] Saifullah Khalid and Bharti Dwivedi, "Application of AI techniquesin implementing shunt APF in aircraft supply system," *Springer India*, pp. 333-341, 2014. DOI: 10.1007/978-81-322-1771-8_29.

[4] Zhihao Yu and Zhizhen Liu, "A detecting approach of harmonic current based on the circuit model and artificial neural networks," *Transactions of China Electrotechnical Society*, vol. 19(9), 2004.

[5] Zhaoan Wang, Jun Yang and Jinjun Liu, *Harmonic Suppression and Reactive Power Compensation*, Beijing: Mechanical Industry Press, 1998.

[6] Maksim Maratovich Habibullin, Igor Sergeevich Pavlov. L. M. Camarinha-Matos, et al., "Active power filter with relay current regulator and common DC link for compensation of harmonic distortion in power grids," (Eds.) in *DoCEIS 2014, IFIP AICT 423*, 2014, pp. 427–434. DOI: 10.1007/978-3-642-54734-8_47.

[7] Sravani Jennela and V. Raj Kumar, "THD analysis of one-cycle and PWM controlled active power filters power electronics and renewable energy systems," *Lecture Notes in Electrical Engineering*, vol. 326, pp. 225-236, 2015. DOI: 10.1007/978-81-322-2119-7_23.