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The Technology of Suppressing Harmonics with Complex Neural Network is Applied to Microgrid

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Abstract: According to the traits of harmonics in microgrid, a new CANN controller which combines BP and RBF neural network is proposed to control APF to detect and suppress harmonics. This controller has the function of current prediction. By simulation in Matlab / Simulink, this design can shorten the delay time nearly 0.02s (a power supply current cycle) in comparison with the traditional controller based on ip-iq method. The new controller also has higher compensation accuracy and better dynamic tracking traits, it can greatly suppress the harmonics and improve the power quality.

1. Introduction

At present, environmental pollution and energy crisis are major issues faced by the entire world. Microgrid is proposed to solve these problems [1] [2]. The microgrid is a small electrical network consists of distributed generation (DG), controllable loads and energy storage devices. However, due to the instability of DG power supply and the use of a large number of power electronic devices and nonlinear loads, the current and voltage in microgrid are distorted [3]. Harmonic can seriously affect power quality and cause loss to power system and users. Therefore, Harmonic suppression is very important to the development of microgrid.

Many devices have been proposed to suppress harmonics [4]. This paper focuses on active power filter (APF), it just need to measure the sum of the total harmonics without decomposing its components. It also has a flexible way of compensation [5]. There are also variety of available harmonic extraction techniques [6], including traditional ip−iq, p-q and d−q theory, genetic algorithm, wavelet, etc. Although these methods are applied well, there are still some problems, such as delay, caused by the complexity of the algorithm and the using of digital controllers. Microgrid, however, has more unstable factors than big power grid, which requires APF has better dynamic traits.

Therefore, this paper designs a complex artificial neural network (CANN) controller with the function of current prediction. Harmonic extraction and control are done by this new controller, it can improve the harmonic calculation speed and compensation accuracy of the APF, thereby improving the power quality of microgrid.

2. Structure and Principle of the CANN

In recent years, the artificial neural network has been widely used in the field of automation because of its strong self-organization and adaptive ability. It is very effective in modeling, tracking and forecasting in the automatic control system [7]. The neural network transfers data in parallel, which is much faster than the traditional orderly calculation.

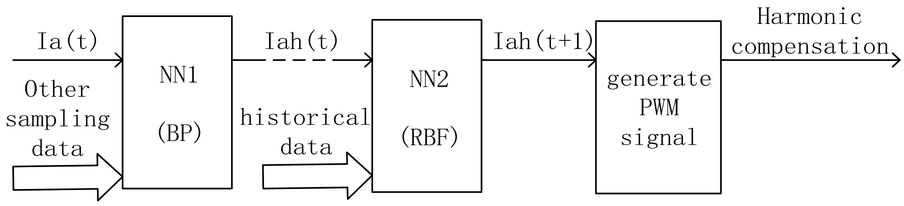

Fig.1 Block diagram of CANN controller

The controller proposed in this paper uses two kinds of neural networks which were trained in different ways before work. As is shown in Fig. 1, the total harmonics are calculated and extracted in NN1 layer. NN1 chose to use BP neural network which is the most widely used currently [8] [9]. Taking into account the traits of the current harmonics in microgrid, the distorted load current and other related data samples are adopted as the input of BP neural network. According to the principle of adaptive noise cancellation [10], the fundamental current harmonic is adopted as the output of BP neural network. Repeated off-line training to ensure that BP network has been able to detect the fundamental component. Finally, the fundamental is subtracted from the load current to obtain pure harmonics which were transmitted to NN2 layer.

RBF neural network [11] is used in NN2. Fig.1 shows the predictive control principle of RBF neural network. The next step reference current value *Iah(t+1)* is predicted based on the pure harmonic current *Iah(t)*, then the PWM inverter signal is generated by the driving circuit of APF and finally main circuit output the accurate compensation current. This method can further enhance the dynamic adaptability and anti-jamming capability of APF, in addition, reducing the impact of the delay on the compensation accuracy. In the APF control system, the delay mainly comes from A-D sampling, the realization of the control algorithm and the generation of PWM pulse and other links. Paper [12] indicates that when the system sampling frequency is 10KHZ, according to the work level of general hardware (assuming that the data sampling and processing time is 38μs), the average delay of the system can reach 88μs, and as the sampling frequency increases, the delay will decrease. In this paper, the system sampling frequency is 50KHZ, the average delay is less than 88μs. Furthermore, using BP neural network to detect the harmonic has reduced a part of the delay. Therefore, after repeated tests, using RBF neural network to predict the next step (20μs) output can achieve a good harmonic compensation.

3. System simulation and results analysis

The system is simulated in Matlab/Simulink (R2016a). This paper does not use the function generator, but the use of three-phase bridge rectifier circuit with resistive load to do the harmonic source in order to make the simulation results more reliable. The model power supply uses three-phase sinusoidal AC, and the voltage, frequency, load resistance R, load inductance L, respectively, set to 100 v, 50 HZ, 2 Ω, 0.03 H. Harmonic source model shown in Fig. 2. As the situation of three-phase is similar, the following only to phase-A as an example to introduce. Analyze the load current with FFT (Fast Fourier Transform) can get the harmonic components and distributions, the results shown in Fig. 3, the total harmonic distortion (THD) is 23.18%. The distorted current is sinusoidal and periodic. It is mainly composed of the fundamental component and the various harmonics. These harmonics are mainly odd times, and their impact becomes smaller while the frequency increases.

For CANN controller, the selection of training samples is very important. The 10000 groups of data were collected, including load current *Ia(t)* in phase-A, voltage phase angle *Φ(t)* and fundamental current *Iaf(t)*, as training samples of BP neural network, where *Ia(t), Φ(t)* as input and *Iaf(t)* as output. In this paper, the proposed BP neural network has three layers which first and second layers have 5 and 10 neurons, and third layer has 1 neuron. The training function is Trainlm, and the Tansig and Purelin are selected as the transfer functions for the first and second layers. This process is

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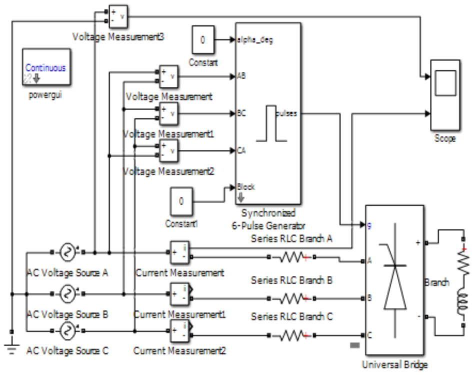
implemented by the neural network toolbox. It will converge to the required target 10^{-5} after 308 iterations. Fig. 4 is the pure harmonic current through calculation.



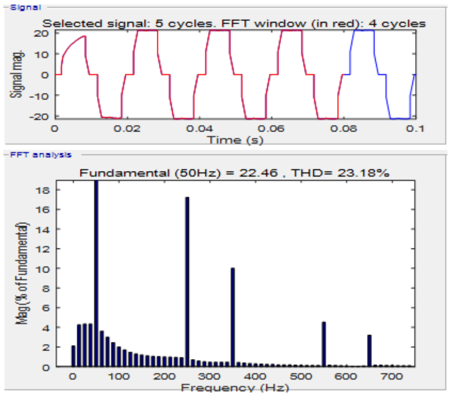
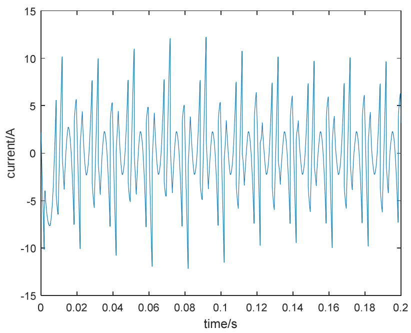


Fig.2 Model of harmonic source Fig.3 FFT analysis of the load current

According to the results of BP neural network, 3000 groups of harmonic data are used as samples for RBF neural network prediction. The sample *y(t)* (sample value at time *t*) is adopted as the input, *y(t+1)* (sample value at time *t+1*) as the output , the learning speed is set to 20. With neural network toolbox function, it is easy to get its network structure model. Finally, with all the data to test and the results are shown in Fig.7 and Fig.8.



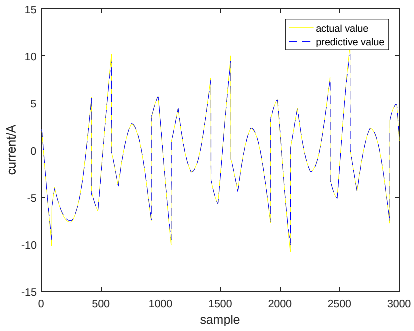
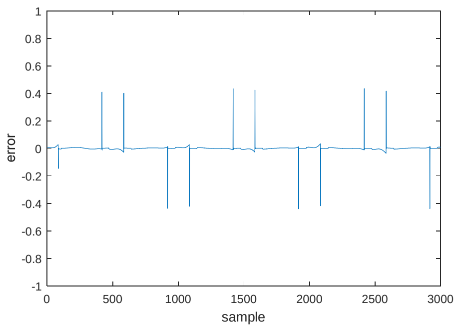


Fig.4 Pure harmonic current Fig.5 Predicted harmonics by RBF

The predicted results can follow the trend of the actual current well, and some parts even overlap, shown in Fig.5. Fig.6 shows the prediction error, the point relative error is basically between -0.5A to +0.5A. The analysis shows that the larger error point is the point at which the current passes through zero. In addition, large error has been quickly corrected when the system is running, which indicate that this method can not only predict the harmonic current and meet the requirements of equipment, but also make a quick response whenever the load current changes abruptly.



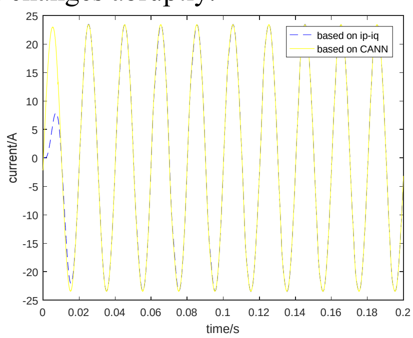


Fig.6 Error analysis Fig.7 Comparison of compensation results

The trained BP and RBF neural networks are combined and applied to the system, the compensation effect of it is compared with the traditional ip-iq[13] algorithm. Results are shown in Fig. 7, using traditional ip-iq algorithm to detect and compensate harmonics, the system would achieve a stable response, after nearly one cycle. However, the CANN controller can get a rapid compensation in the beginning of the first cycle. It shows that the design is effective. To further verify the superiority of the design, the above two methods are simulated in Simulink.

Fig. 8 and Fig. 9, show the FFT analysis of A-phase current which is compensated through the above two controllers, respectively. As shown below, in Fig. 8, when the current is compensated by APF with ip-iq controller, THD dropped to 16.82%. According to IEEEStd.1547.2003, THD should be around 5%, which means that this method cannot be used alone, it must be combined with other measures to further filter. In contrast, in Fig. 9, when the current is compensated by APF with a CANN controller, THD dropped to 3.15% and meet the IEEE standard, which means that the design shows an improved performance than convention control. CANN controller can eliminate harmonics in a fast and effective way without any extra equipment.

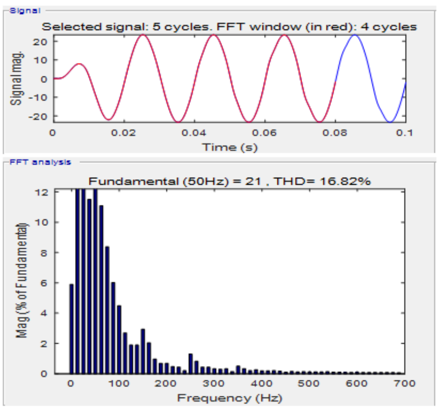


Fig.8 FFT analysis based on ip-iq

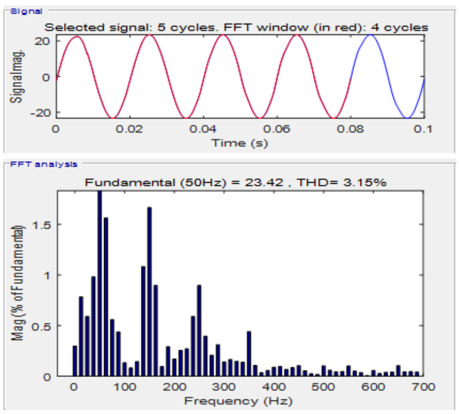


Fig.9 FFT analysis based on CANN

4. Conclusion

In order to solve the problem of harmonic pollution in microgrids, this paper proposes a CANN controller and introduced its structure and calculation method comprehensively. By comparing with the traditional ip-iq controller and simulating in the Matlab / Simulink platform, the feasibility and superiority of the new controller are verified. The design can be fully realized by software, it is economical and practical, with fast response speed, high compensation accuracy and good dynamic tracking performance. This controller can greatly eliminate the microgrid harmonics, improve power quality.

Artificial neural network is used to eliminate the harmonics of the microgrid, which fully reflects the superiority of the application of artificial intelligence in the field of power system. It not only provides a new direction for improving the power quality of microgrid but also lays the foundation for the popularization and development of intelligent microgrid.

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