Research on state evaluation system of power metering equipment based on BP neural network

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ABSTRACT

Because the more and more complex external environment affects the safe and stable operation of power metering equipment, this paper studies the state evaluation system of power metering equipment based on BP neural network. The hardware of the system includes multi-environment parameter acquisition module, signal processing module, data transmission module and error evaluation module. The software system includes systematically collecting detection data of power metering equipment, selecting ambient temperature, humidity, magnetic field strength and atmospheric pressure as state quantities of power metering equipment, and introducing BP neural network to perform iterative calculation of state quantities to realize automatic state evaluation of power metering equipment. The experimental results show that the shortest detection time of the system is 2s, and the detection results are consistent with the actual results, which verifies that the system has a high efficiency and accuracy of the equipment status detection.

Keywords: Power metering equipment, state evaluation system, BP neural network, iterative calculation, shortest detection time

1. INTRODUCTION

In order to ensure the accuracy and reliability of power metering equipment, it is necessary to carry out regular testing and maintenance. However, the traditional detection methods do not consider the influence of environmental parameters on power metering equipment, which results in large error of detection results. Therefore, it is necessary to study a measuring instrument evaluation technology based on multiple environmental factors to achieve real-time status assessment of intelligent power metering equipment, timely detection and solution of potential problems, so as to improve the stability and reliability of power system.

In literature [1], an automatic verification model of electric power measuring instruments was established, and the model was solved based on INSGA-II algorithm to obtain the best verification scheme of electric power measuring instruments. In reference [2], aiming at the problem of high false positive rate in unsupervised detection, a semi-supervised/direct push support vector machine (TSVM) detection model was constructed to realize automatic verification of smart watt-hour meters [2]. Based on this, a new online fault diagnosis system is designed to improve the effective detection of the electric energy metering device and ensure its stable operation [3]. Literature [4] studies the adaptive performance assurance tracking control of multi-agent systems, and solves the measurement sensitivity problem by adding power integrator technology. The above method does not consider the measurement problem of multi-parameter environmental influence, resulting in large error of measurement results.

Therefore, this paper proposes a state evaluation system of power metering equipment based on BP neural network to achieve high-precision power metering.

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2. HARDWARE DESIGN

2.1 Data acquisition module

The acquisition of state data of power metering equipment is mainly realized by a variety of sensors. These sensors can monitor various parameters of the device, such as ambient temperature, pressure, magnetic field strength and atmospheric pressure, and convert these parameters into processable data [5, 6]. After the collected data is processed, it can be used to analyze the running status of the device, predict faults, and optimize performance, thus providing strong support for the maintenance and management of the device.

The temperature sensor model WBI221QN05-20 is selected to detect the ambient temperature under the condition of electrical isolation, so as to ensure the normal operation of the power metering instrument and provide support for the status detection of the power metering equipment. FK-SJU humidity sensor produced by Fengkong is selected to provide accurate humidity data for the status detection of power metering equipment. The CE-C02/C03 magnetic field intensity and atmospheric pressure sensor was selected and installed in an appropriate position to monitor the environmental magnetic field intensity and atmospheric pressure parameters of the power metering equipment. The PCI-1751 data acquisition card is selected as the detection data acquisition device, which has the advantages of simple structure, rich resources, high efficiency, high stability, and low power consumption, and is suitable for collecting status detection data of power metering equipment, as shown in Figure 1.

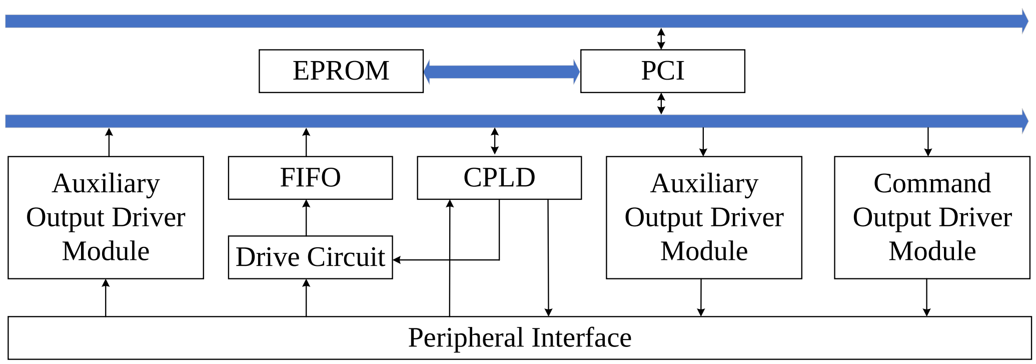

Figure 1. Overall structure of the PCI-1751 data acquisition card.

2.2 Signal processing module

In the process of state detection of power metering equipment, the accuracy and stability of signal are very important. However, due to the existence of various interference and noise in the actual detection environment, the collected detection signal often has a certain error. Therefore, in order to improve the accuracy and stability of the automatic state detection signal of power metering equipment, a signal processing module is designed to input the signal into the signal integrated circuit to amplify and filter the detection signal of the equipment. The circuit design consists of three main parts: signal amplifying circuit, signal filtering circuit and phase compensation circuit. In order to simplify the whole circuit structure, the detection signal amplifier circuit and the filter circuit are fused effectively, and the integrated design is realized. It not only realizes the amplification and filtering function of the detection signal, but also simplifies the circuit structure. The specific integrated circuit design is shown in Figure 2.

The signal amplifying circuit mainly uses the operational amplifier to construct the in-phase amplifying circuit. By adjusting the resistance value, the amplification ratio can be controlled, so that the detection signal can be accurately amplified. In addition, in order to suppress noise, the circuit uses a low noise operational amplifier. Low noise operational amplifier can effectively reduce the noise generated by the amplifier itself and improve the signal to noise ratio while amplifying weak signals. At the same time, decoupling capacitors are used to eliminate power supply noise and other interference in the circuit.

In the design of signal filtering circuit, the second-order active low-pass filter is mainly used. A low-pass filter allows low-frequency signals to pass through and blocks high-frequency signals. By adjusting the values of the resistance and capacitance, the cut-off frequency of the filter is set, that is, the lowest frequency that is allowed to pass. In order to further improve the filtering effect, the design adopts a multi-stage filtering structure, that is, multiple filters are cascaded or serialized to achieve more accurate frequency selection and smoother filtering effect.

The phase compensation circuit is mainly used to prevent the self-excited oscillation in the amplifier circuit, and eliminate the self-excited oscillation by introducing appropriate negative feedback to offset the effect of positive feedback.

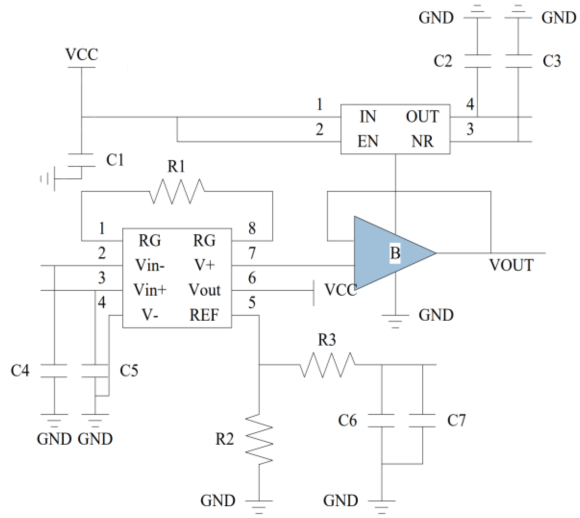

Figure 2. Integrated circuit design drawing.

2.3 Data Transmission Module

In order to make the power metering equipment status detection data transmission module has the characteristics of high efficiency, stability and reliability, can adapt to a variety of complex network environment and application requirements. The PCIE bus is used to optimize the data transmission path and processing flow, and the TCP/IP protocol is used to enhance the smoothness and confidentiality of transmission, realizing efficient transmission and accurate processing of data.

The PCIE bus architecture is applied in the design of data transmission module of power metering equipment status detection. Data packets are generated at the core layer of the device and processed from left to right at the transaction layer, link layer, and physical layer. After this series of transmission and processing, the data is accurately transmitted to the receiving end. At the receiving end, the data is processed by each layer in the order of right to left, and finally transmitted to the core layer. For data packet transmission, the core object of the PCIE bus is data packet. When the system queries data packets of PCIE devices, the transaction layer first encapsulates them. After encapsulation is complete, at least one TLP (Transport Layer Protocol Data Unit) is obtained. Then, through the cooperation of other layers, the whole data transmission process is completed. Figure 3 shows the PCIE bus architecture.

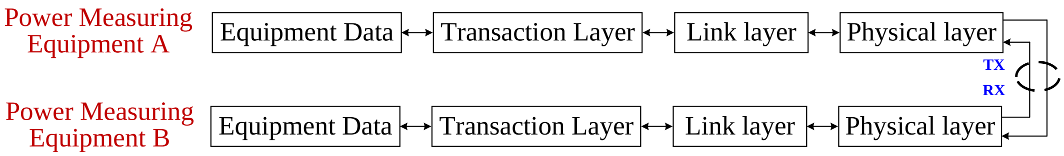

Figure 3. PCIE Bus Architecture.

3. SOFTWARE DESIGN

3.1 Power metering equipment state quantity selection

The hardware device of the data acquisition module is used to collect the status data of intelligent energy metering equipment, and obtain the status data set including temperature, humidity, magnetic field strength and atmospheric pressure, which is denoted as, $X = \{x_1, x_2, ..., x_i, ..., x_n\}$, n is the total number of devices.

Among them, the calculation formula of temperature and power measurement error is:

$$A_1 = \frac{|\delta_t - \hat{\delta}_t|}{\hat{\delta}_t} \times 100\% \tag{1}$$

Where, A_1 is the temperature power metering error, δ_t is the output result of the power metering equipment at the current moment, and $\hat{\delta}_t$ is the actual power value at the current moment.

The formula for calculating the error of humidity and power measurement is:

$$A_2 = \frac{|H_t - \hat{H}_t|}{\hat{H}_t} \times 100\% \tag{2}$$

Where, A_2 is the humidity power metering error, H_t is the output result of the power metering equipment at the current moment, and $\hat{H}_t$ is the actual power value at the current moment.

The formula for calculating the power measurement error of magnetic field strength is as follows:

$$A_3 = \frac{|M_t - \hat{M}_t|}{\hat{M}_t} \times 100\% \tag{3}$$

Where A_3 is the magnetic field strength power measurement error, M_t is the output result of the power measurement equipment at the current moment, and $\hat{M}_t$ is the actual power value at the current moment. The atmospheric pressure is measured directly by the sensor CE-C02/C03 and is denoted as A_4 without the need for further calculation.

The above process completes the selection of the state quantity of the power metering equipment, and expounds its calculation method, which provides data support for the subsequent establishment of the automatic state detection model of the equipment.

3.2 Power metering equipment status automatic detection

Based on the state quantity of power metering equipment selected above, it is input into the automatic state detection model of power metering equipment built by BP neural network as input quantity, and the detection result is output through iterative calculation.

BP neural network has the ability of self-learning, self-organization and self-adaptation, which is more suitable for multi-input and multi-output multi-objective optimization structure model. Figure 4 shows the neural network model structure of the system, which includes input layer, output layer, hidden layer and error calculation.

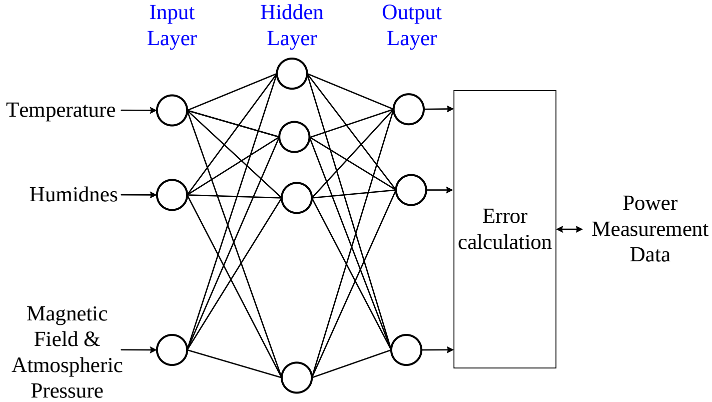

Figure 4. Neural network model structure.

Among them, the input layer is mainly composed of temperature, humidity, magnetic field strength, atmospheric pressure and other data, each parameter is a node of an input layer, and the total number is m. The output layer is power measurement data, and the total number of nodes in the output layer is n. The data of the output layer is output to the computer for comparison with the set target, and the results are fed back to the input layer and the hidden layer. The weights of each node in the input layer and the hidden layer are changed or the learning path is re-selected until the output results meet the system requirements. The hidden layer represents the path selected from the input layer to the output layer. It is a mapping process, and the number of nodes k is determined by the input and output layers:

$$k = \left\lfloor \sqrt{m^2 + n^2} \right\rfloor + a \tag{4}$$

Where, a is the experience value between 1 and 10, $\lfloor \ \rfloor$ indicating that it is rounded down.

The training set is input into the constructed model, and the weights and thresholds are iteratively corrected until the detection results of the type output device are consistent with the actual results, and the optimal values of the weights and thresholds are determined, thus completing the training and improvement of the constructed model. By inputting the test set data into the trained model, accurate automatic state detection results of power metering equipment can be obtained.

4. PERFORMANCE TEST AND RESULT ANALYSIS

The power monitor and power meter are selected as test objects to verify whether the intelligent power metering equipment is normal, ensure that it can accurately and reliably measure and record power data, and build a test environment. With reference [1], reference [2] and reference [3] as comparison system 1, and comparison system 2 and comparison system 3, intelligent energy metering equipment detection experiments are carried out in the test environment established by the above experiments. The application performance of the design system can be shown by detecting time and result of intelligent energy metering equipment.

Taking three intelligent energy metering devices as examples, the detection results of intelligent energy metering devices were obtained, and the detection results of different methods were compared, as shown in Table 1.

Table 1. Detection results of different methods.

Equipment number	Application System	Pre-compensation Result (kW·h)	Compensated result (kW·h)
1	Contrast system 1	11.821	11.836
	Contrast system 2	23.545	23.477
	Contrast system 3	35.268	35.117
2	Contrast system 1	46.993	46.76
	Contrast system 2	58.717	58.402
	Contrast system 3	70.44	70.04
3	Contrast system 1	82.16	81.68
	Contrast system 2	93.89	93.33
	Contrast system 3	98.58	97.99

Under the background of different numbered test equipment, the detection results of intelligent energy metering equipment obtained by the application of the design system are consistent with the actual results, while the detection results of intelligent energy metering equipment obtained after the application of the comparison system 1, comparison system 2 and comparison system 3 are somewhat different from the actual results, indicating that the detection results of intelligent energy metering equipment of the design system are more accurate.

5. CONCLUSION

In order to ensure the stable operation of intelligent energy metering equipment, it is necessary to carry out automatic detection. This paper puts forward the design and research of intelligent energy metering equipment state automatic detection system based on BP neural network. The experimental results show that the design system effectively improves the efficiency and accuracy of intelligent energy metering equipment detection, and provides effective system support for the subsequent development and application of intelligent energy metering equipment.

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