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# Research on Intelligent Fault Diagnosis and Early Warning Technology of Gateway Electrical Energy Metering Device

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**Abstract.** As the most important daily management work in power application, electrical energy metering is carried out throughout the whole process of power production, transmission and use. Ensuring the accurate and reliable operation of electric energy measurement is the key to establish a fair, just and orderly electric power marketing market. At present, there are many problems in the inspection process of electric power measurement device, which include large workload, long verification time, sampling accuracy and algorithm performance constraints. In this paper, the remote on-line diagnosis of electrical energy metering decice is studied. Based on a large amount of sampling datas of power measurement, voltage and current, it introduces the parallel computing in data mining. Based on support vector machine, data and task parallelization fault diagnosis modelsare established,the on-line real-time monitoring and failure warning for electric power measurement device is realized, which contains abnormal characteristics and fault state. The visualization method is used to upload the device failure pictures in time and the diversified fault early warning technology is adopted, in order that the staff can timely analyze the electrical energy metering device in the fault or abnormal condition. In this way, the remote state monitoring and operation management level of the electrical energy metering device are improved.

## 1. Introduction

In the process of building a strong smart grid, it is crucial for the power marketing market to develop in a fair, just, and orderly manner. The precondition for the healthy development of the power marketing market is to ensure that the energy metering device operates accurately and reliably [1, 2]. According to China's relevant verification regulations and the relevant measurement technical standards of the State Grid Corporation of China, the error performance of the gate energy metering device should be regularly tested and its operational status evaluated [3, 4].

The traditional on-site manual inspection method has problems such as large workload, long calibration time, and certain secondary circuit load requirements in the inspection process of the gate energy metering device. Therefore, the remote verification method is widely used to realize the verification of the gateway energy metering device [5]. At the same time, domestic scholars are also constantly exploring new technologies and methods for testing electric energy metering devices, realizing real-time, remote, intelligent inspections and on-line monitoring of their operational status, enabling timely warning of abnormal or malfunctioning devices and avoiding measurement accidents. Scholars designed the collection front device in the gate energy metering device. Using GPS synchronous sampling and wireless communication technology to achieve high-precision acquisition of voltage and current data. The data is uploaded to the master station, and the check and fault diagnosis of the electrical energy is completed in the master station, which effectively improves the on-line monitoring effect of the gateway electrical energy metering device.

This article focuses on the remote on-line monitoring and fault diagnosis techniques of energy metering devices. Based on a large number of energy measurement sampling data, voltage and current sampling data, the parallel computing in the big data mining and the support vector machine classification algorithm are introduced to establish a fault diagnosis model to achieve remote on-line real-time monitoring of the abnormal characteristics and fault status of the energy metering device. Using webcam devices to upload pictures in a timely manner. A variety of fault early warning technologies are adopted so that the workers can analyze the energy metering devices under fault or abnormal conditions. Improve the level of remote state monitoring and maintenance management of energy metering devices at the gateway to prevent and avoid measurement accidents.

## 2. Design and improvement of data acquisition device

In order to ensure the accuracy of the remote online monitoring and fault diagnosis of the energy metering device, the field data should be firstly sampled in real time. The device improves the accuracy of data acquisition from the aspects of voltage and current sampling, pulse synchronization design, and overall program design. In voltage and current sampling, considering that the substation current is affected by the load side, there is often a large range of fluctuations. The current transformer must have a wide enough dynamic range, and ensure a good angular difference and ratio in the full range. Therefore, the device uses a zero-flux transformer and a 24-bit Σ-Δ chip.

In the pulse synchronization design, pulse synchronization is used to perform synchronous waveform sampling. The flow chart is shown in Figure 1.

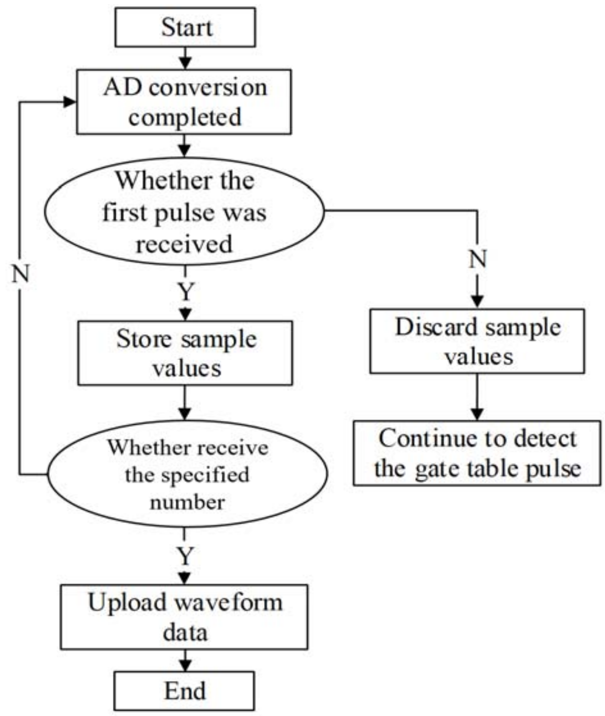


**Figure 1.** The flowchart of synchronous waveform sampling.

The device uses the ARM9 MPU solution. The voltage transformer is connected to the field voltage signal and the current transformer is connected to the field current signal. Through high-accuracy AD chip sampling, the data is transmitted to the on-board SDRAM through the ARM9 MPU's SPI interface, while receiving the pulse signal of the power meter. After finishing the big data in SDRAM, it is transmitted to the master station through the communication unit. ARM9 MPU is also responsible for the device display, temperature and humidity acquisition functions. The overall plan design is shown in Figure 2.

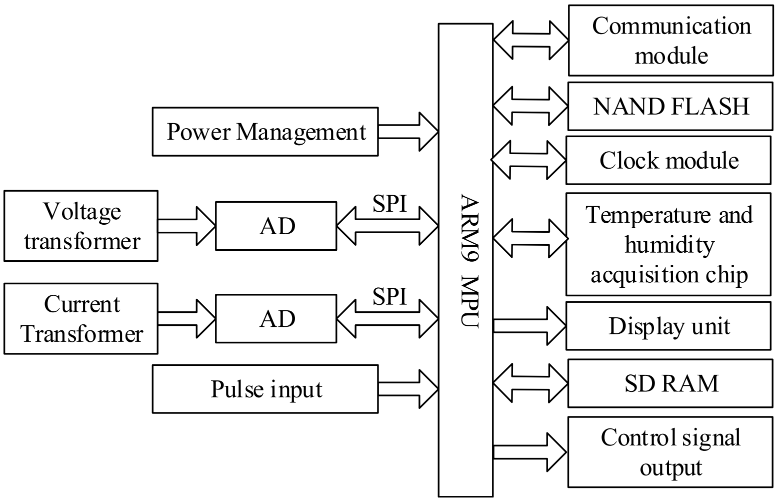


**Figure 2.** The design general plan of the front device.

In the data acquisition front-end device, zero-flux mutual inductor, 24-bit Σ-Δ chip, pulse triggering method, and ARM9 MPU solution provide accurate and reliable analysis data for remote on-line monitoring and fault diagnosis of the energy gauging device of the gateway.

## 3. Research on intelligent fault diagnosis technology

In order to guarantee the normal operation of the gate energy metering device and avoid measurement accidents, it is necessary to implement remote online monitoring of the energy metering device. The on-line diagnosis of the electrical energy metering device is implemented, through reverse polarity check, voltage/current phasor diagram analysis, voltage/current abnormality check, metering electrical energy overshoot check, etc.

The on-line monitoring and fault diagnosis acquisition device uses 24-bit AD. Therefore, the size of the acquired waveform data is much larger than that of a conventional fault recording device. The comparison of the wave recording data of a gate energy meter will be up to hundreds of megabytes. Accurate transmission of large amounts of waveform data to the master station is a major technical difficulty. To solve this problem, the device uses the waveform data to be stored and compressed in the form of a file, which can reduce the file size to some extent. At the same time, it is uploaded to the master station system as a file via an FTP server.

After on-the-spot waveform data acquisition and transmission, there are new problems such as large data volume and complex diagnosis during on-line detection and fault diagnosis. Therefore, this paper introduces parallel computing in big data mining in fault diagnosis. At the same time, support vector machines are used as fault recognition methods to achieve rapid, effective, and accurate status diagnosis.

### *3.1. Parallel computing on big data*

Establish a parallel platform for fault diagnosis of electrical energy metering devices based on the parallel programming environment. MPI (Massage Passing Interface) is a messaging standard that has

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been gradually produced and improved by a series of meetings of the MPI Forum. This messaging programming model supports C and FORTRAN languages and supports multiple operating systems. The user only needs to design the parallel algorithm and use the corresponding MPI library to realize parallel computing based on message delivery, which is convenient, fast, and compatible.

Parallel computing is mainly used to study concurrent execution of multiple processors. Parallel computing divides sequential execution of computational tasks into sub-tasks that can be executed simultaneously. Perform these subtasks in parallel to complete the entire calculation task. Parallel computing is often used to solve large, complex computational problems. According to the program and algorithm design division, parallel computing can be divided into data parallel and task parallel. Data parallelism is mainly to decompose a main task into the same number of subtasks. Task parallelism is to perform the main task at the same time, avoiding data competition. Data parallelism and task parallelism can achieve rapid processing of big data.

### *3.2. Support Vector Machines*

Support Vector Machine (SVM) is a classifier constructed on the basis of the principle of structural risk minimization and VC dimension theory. It belongs to the second class classification model. Compared with the traditional BP network, SVM is suitable for dealing with nonlinear problems. It can solve the problem of large numbers of samples. It is worth noting that since the support vector machine is a two-class classification model, the number of support vector machines should be selected according to the type to be identified in the pattern recognition process.

### *3.3. Intelligent fault diagnosis model based on parallel algorithm and SVM*

Based on the concurrent platform for fault diagnosis of energy metering devices built by MPI in a parallel programming environment, the selected server contains a master node and four child nodes. Data parallel and task parallel methods are adopted respectively, and the operation state of the energy metering device is diagnosed through a support vector machine. Common types of faults in energy metering devices are: power meter fault, transformer fault, current secondary loop fault, voltage secondary loop fault, and bus voltage switching relay fault. Therefore, sample data such as current and voltage obtained by reverse polarity check, voltage/current phasor diagram analysis, voltage/current abnormality check, and electric energy overshoot check are taken as the input amount of the fault diagnosis model. The above five common faults and normal operating conditions are used as the output of the fault diagnosis model. Therefore, the data parallelization fault diagnosis model and task parallelization fault diagnosis model are established as follows.

A data parallelization fault diagnosis model was established, historical data was used to train it, and then the model's diagnosis effect was tested in the actual online detection process.

(1) Based on the existing historical data, the current and voltage sampling data for each type of fault are obtained.

(2) The training sample is divided according to the number of child nodes. The sample data is evenly distributed to the processor. Each child node contains a complete support vector machine. Each child node is not associated with each other.

(3) Each child node is trained based on a support vector machine. The weight of each child node is counted. In this way, a parallelized fault diagnosis model is established.

The process of establishing a data parallelization fault diagnosis model is shown in Figure 3.

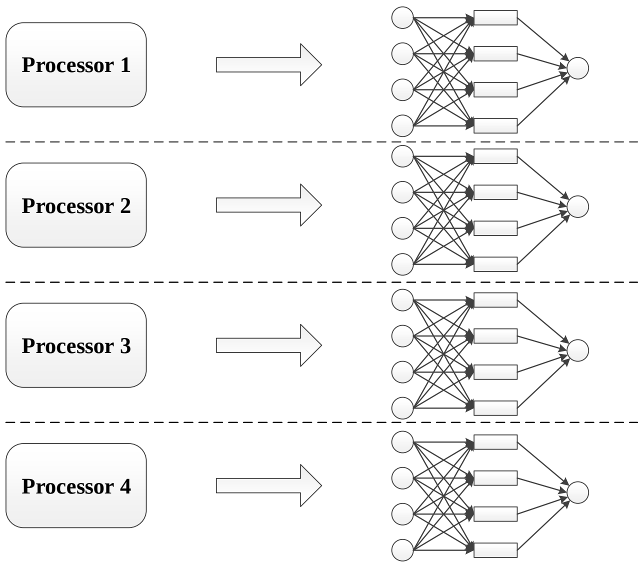



**Figure 3.** The processing procedure of data parallelization.

The specific implementation process of the diagnosis of the operational status of the energy metering device is as follows:

(1) Using an improved data acquisition device to obtain on-site sampling data. Sample data such as current and voltage that can reflect the operating status of the device is extracted as input information of the fault diagnosis module.

(2) Through the data parallel processing method in the fault diagnosis module, each sub-node is diagnosed with the operating status of the energy metering device.

(3) Output fault diagnosis results of each child node. The output of each sub-node shall be a type of fault in the power meter body, transformer fault, current secondary loop fault, voltage secondary loop fault, bus voltage switching relay fault, and normal state.

(4) Summarize the diagnosis results of each node according to the weight of each child node in the data parallelization fault diagnosis model. The device operating state with a high weight is output as a total node.

(5) Output the operating status of the energy metering device through the total node. If there is a fault, then determine the type of fault that exists, that is, the fault of the power meter body, the fault of the transformer body, the fault of the current secondary circuit, the fault of the voltage secondary circuit, and the failure of the bus voltage switching relay

Task parallelization fault diagnosis model is shown in Figure 4.

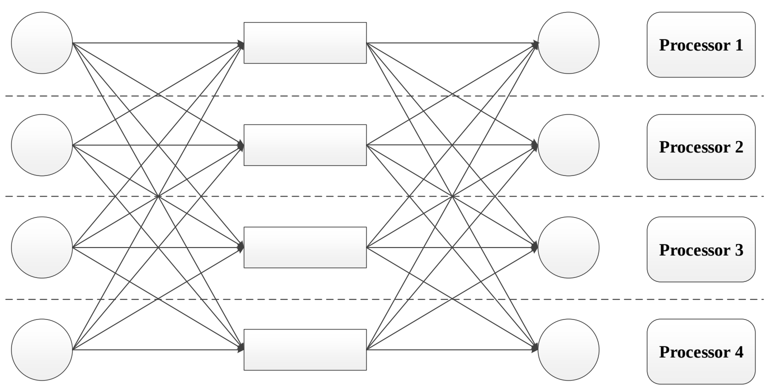



**Figure 4.** The processing procedure of task parallelization.

(1) Obtain sampling data such as current and voltage in each type of fault and normal operation based on the existing historical data.

(2) Transversely divide the processing unit of the support vector machine, and divide the kernel function of each layer in the support vector machine into equal parts according to the number of processors. Each layer of kernel function is assigned to the corresponding processor

(3) Select the input amount of the support vector machine, and the five common faults are the output results.

(4) Input history data for training. After the training, a parallel fault diagnosis model was established.

Based on parallel algorithm and SVM task parallel intelligent fault diagnosis model, the actual implementation process of the actual energy metering device diagnosis is similar to the data parallelization intelligent fault diagnosis process.

Based on parallel algorithm and SVM task parallel intelligent fault diagnosis model, the actual implementation process of actual electrical energy metering device diagnosis is as follows:

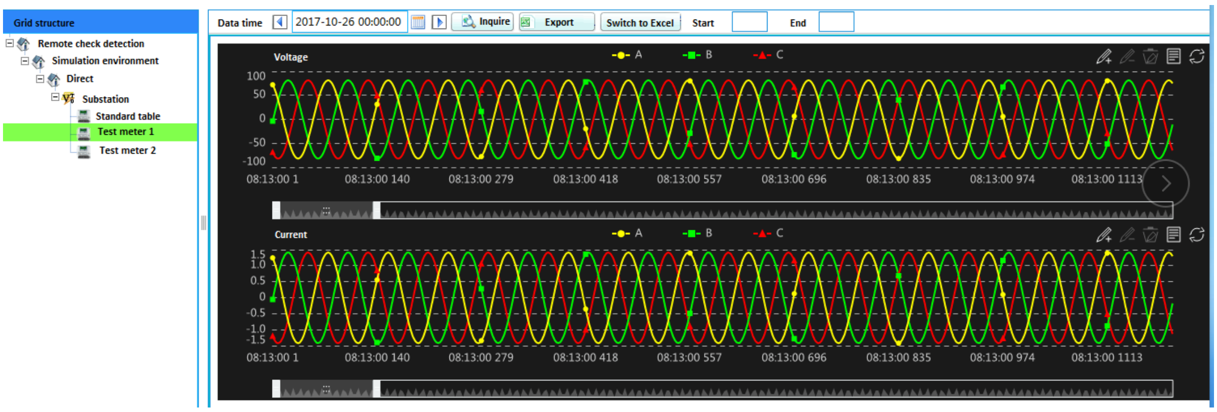
Based on the transmission of massive waveform data, the device uses a file storage and package compression method to reduce the file size to a certain extent, to facilitate the collection and analysis of data. At the same time, for large data volumes and complex diagnostics, the device introduces large-scale data parallel computing to solve the problem of difficult data volume diagnostics. At the same time, support vector machine SVM intelligent diagnosis algorithm was introduced. The data parallelized intelligent fault diagnosis model and task parallelized intelligent fault diagnosis model were constructed to realize on-line fuel gauge measurement and fault diagnosis.

## 4. Application introduction

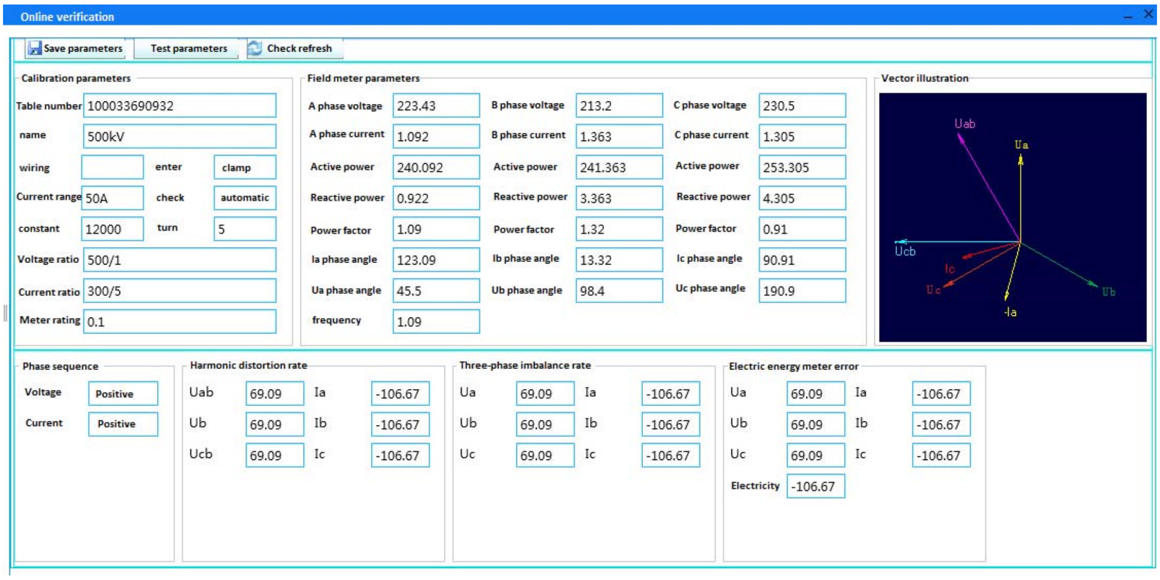
The premise of the intelligent fault diagnosis technology of the gateway energy metering device is to obtain current, voltage, and other sampling data through the system visual interface and online calibration interface. Analyze and diagnose the collected data, and give early warning of the fault.

Therefore, this technology can be used in the gate energy metering device detection system. Through acquisition of current, voltage, and other sampling data, the intelligent fault diagnosis model based on parallelization and support vector machines is used to diagnose the operation status of the gate energy metering device. For faulty devices, take a picture of the camera. Finally, a variety of early-warning methods were used to notify relevant personnel in a timely manner so as to avoid measurement failures. The technology has a good application effect in the detection system.

The system's user visualization interface and online verification interface are shown in Figure 5 below.




(a) Sampling current and voltage data interface




(b) Online Inspection Interface

**Figure 5.** A visual interface of online automation management system.

## 5. Conclusion

This paper designs and improves the data acquisition device to ensure the accuracy and reliability of the data obtained during the online monitoring of the metering device. Using support vector machines, data parallel intelligent fault diagnosis models and task parallel intelligent fault diagnosis models were established. It can realize remote real-time monitoring and fault diagnosis of the malfunction status of the energy metering device. For faulty devices, camera recording is performed automatically, and the relevant personnel are notified in a diversified manner of early warning to avoid measurement failures. The research on the intelligent fault diagnosis technology of the gateway energy metering device realizes the automatic remote operation status monitoring and diagnosis of a large number of energy meters scattered at various positions. Improve the remote operation and maintenance management level of the gate energy metering device.

## Acknowledgments

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