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Design of Measurement Automation System and Research on Abnormal Detection Method of Electric Power Enterprise Based on Data Mining

XiangrongDai[1,*]
[1]GuizhouPowerGridCo.,Ltd.,Guiyang,Guizhou, China, 550000

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Abstract

Electricity charge is the economic lifeline for the survival and development of electric power enterprises. Therefore, electric power measurement is the fundamental guarantee of electricity fee fairness. However, for a long time, the abnormal meter measurement has caused huge economic losses to power grid companies. Therefore, we must carry out scientific power metering abnormal diagnosis, which is an important means to ensure the operation and maintenance of power automation system. With the implementation of smart grid, power enterprise measurement automation system has become an important means of power measurement. Therefore, remote anomaly diagnosis has gradually replaced manual field diagnosis and become an important direction to promote power grid automation operation. However, the abnormal operation of metering devices will cause the loss of power enterprises, which not only reduces the technical and economic indicators of power companies, but also conceals the authenticity of inaccurate power measurement. Therefore, in the context of data mining, how to solve the abnormal power measurement has become the primary task of measurement work. First of all, this paper analyzes the important role of power metering automation. Then, this paper designs the Power metering automation system (hereinafter referred to as PMAS). Finally, based on the data mining background, this paper puts forward some methods for power metering anomaly detection.

Keywords: *Data Mining, Power Enterprises, Pmas, Design, Anomaly Detection;*

1. Introduction

With the continuous expansion of China's power grid, the traditional hierarchical and centralized control power grid is no longer suitable for the needs of the 21st century. Therefore, the basic structure of China's power grid has undergone significant changes[1]. Smart grid has become the infrastructure of modern power grid. It is a modern energy management technology which can meet the optimization of many aspects through automatic control, high-power converter, modern communication means, sensing and measurement technology, which greatly improves the efficiency and reliability of power grid[2].

Measurement automation system is one of the core of smart grid, which undertakes the important function of power system data acquisition and analysis[3]. Through the power grid metering automation terminal, we can realize the data acquisition and monitoring function of the whole process of "power generation, power supply, distribution and power sales", which provides support for the orderly use of electricity for users. Through the PMAS, we can achieve a variety of functions, such as remote meter reading, power consumption monitoring, load control, line loss statistical analysis, power supply quality analysis, customer energy-saving evaluation, etc., which not only reduces the power grid loss, but also improves the economic benefits.

In China, the measurement automation system is gradually improved, and the distributed metering automation system is being upgraded comprehensively, which will realize the centralized and unified collection and release of electric energy data[5]. Through the use of all kinds of metering automation field terminals, we can improve the stability of lines, equipment and acquisition terminals in the system[6]. At present, the automatic analysis and early warning of all kinds of anomalies in the PMAS are still relatively backward. The general process of fault handling is fault occurrence, manual confirmation, report for approval, on-site maintenance and confirmation results, which greatly restricts the troubleshooting and maintenance of the whole system[7]. Therefore, we need a set of reliable and effective automatic fault diagnosis method and system, which will quickly relieve the pressure of system maintenance and improve the stability.

2. The important role of PMAS

2.1. Improve system stability

PMAS can improve system stability, terminal online rate and data integrity rate[8]. The PMAS adopts wireless communication in the terminal, which will be affected by the quality of GPRS signal[9]. Therefore, in case of communication failure, the maintenance delay of the system may be longer. At present, the average online rate and data integrity rate of PMAS terminals are below 99%, which will lead to a large number of faults and data missing, including load control terminal, distribution transformer monitoring terminal and low-voltage concentrator[10]. Therefore, compared with the traditional metering methods, the online rate and integrity rate of PMAS have room for improvement. Therefore, only by keeping the on-line rate and data integrity rate at a high level, the whole metering system can work normally and detect anomalies as soon as possible.

2.2. Reduce manpower input

PMAS can reduce manpower investment, which will reduce the burden of operation and maintenance personnel[11]. At present, the detection and maintenance of power grid faults in China are mainly carried out manually, especially the on-site maintenance of faults, which will inevitably require human input[12]. For the power grid communication record data, the efficiency of only relying on manual experience analysis is very low, which requires us to choose with the help of data mining technology. Through data mining technology, we can find the fault in the first time, which will greatly reduce the manpower investment. At the same time, through the analysis of faults and anomalies, the operation and maintenance personnel can make plans and potential equipment failure in advance, which will improve the value of each action. By predicting in advance, the operation and maintenance personnel can reduce the need to repair and recover the fault site, which will reduce the manpower investment.

2.3. Improve economic efficiency

PMAS can improve economic benefits, which is mainly divided into three aspects. First, improve data integrity, which can avoid problems in key steps such as tariff settlement. Second, it can improve the income indirectly by reducing the operation and maintenance and manpower investment. Third, reduce the occurrence of abnormal line loss. By identifying the cause, we can investigate early, which will reduce the loss. PMAS can improve the overall stability, reduce operation and maintenance costs and improve economic benefits.

3. Inspection method of electric energy metering device

3.1. Visual inspection

The visual inspection method is to check the label, measurement data, capacity, place of production,

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production label, manufacturer and other links of the measuring device in the process of inspection, which is a means for the inspection staff to check by naked eyes. The visual inspection method is based on the operation of the watt hour meter, which is based on the quality and origin of the meter for wiring and wiring. The visual inspection method provides a good foundation for the normal and reasonable operation of electric energy devices.

3.2. On site measurement and inspection method

There are three main methods of on-site measurement and inspection. First, the current clamp meter is used to measure the primary and secondary phase current, which needs to judge whether the current transformer ratio is correct through the ratio. Second, measure the phase voltage or line voltage of the voltage terminal side of the watt hour meter, which can judge whether the voltage incoming line contact is good or whether there is broken line. Among them, whether the voltage connection piece is tight and whether the transformation ratio of the voltage transformer of the high-voltage metering device is correct is an important index. Third, use the measured current to calculate the time taken for the meter to turn a circle or send a pulse, which will calculate whether the meter has obvious out of tolerance.

3.3. Portable calibrator

Through the phase sequence diagram, we can check whether the phase sequence and wiring are correct. Through the field calibration data, we can determine whether the meter needs to be removed and recalibrated. Generally, when the on-site calibration error exceeds 1 / 2 of the verification error recorded in the account of the metering device of the meter and exceeds the error range of the verification regulation, we should remove the device for re calibration.

4. Abnormal analysis of electric power measurement

4.1. Big data of electric power measurement

With the deployment and application of smart meters, power companies can obtain the measured data of distribution network terminals with high frequency and wide coverage. The electric information acquisition system can not only provide power consumption data to power companies, but also obtain the power, voltage, current, power factor and other important electrical parameters of each measurement point in real time. According to the deployment location, the data acquisition system is divided into four parts: smart meter, sampling terminal, communication channel and server master station. Through the preset time, the smart meter can send the measurement data to the remote server, which will carry out the next step of storage, monitoring and data analysis. Power big data has five characteristics: large volume of acquisition system, high frequency of information acquisition, long data storage time, multiple data types and dense distribution of measurement points. The logic diagram of power consumption information acquisition system is shown in Figure 1.

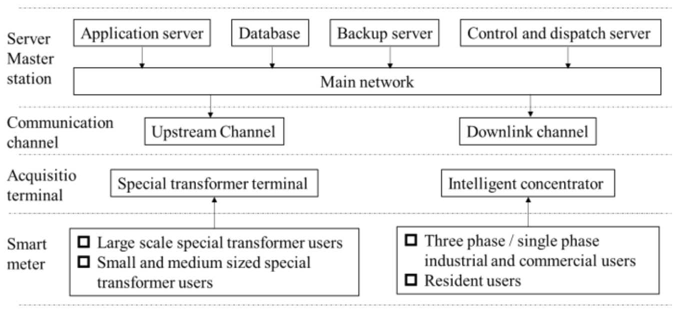

Figure 1. Structure diagram of power consumption information acquisition system.

4.2. Types of data collection information

The power consumption information acquisition system collects different energy meters for different users, which will collect data information in different ways. For example, large load users collect data through special transformer terminals; low-voltage users collect data through public transformer concentrator. This paper lists the information collected by users of large load special transformer, as shown in Table 1.

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Table 1. Collection information of users of large load special transformer.

NO.	Collecting information	Data description
1	Real time electrical parameters	Three phase voltage, current, active power, reactive power, power factor, etc
2	Real time power	The energy consumption per unit, total electric energy indication value of electric charge, electric energy indication value of each rate, maximum demand, etc
3	Working condition data	Collect the switch and maintenance information of terminal and metering equipment
4	Event	Various events and alarms of terminals and meters
5	Power quality	Power, voltage, harmonic, etc
6	Other data	Prepayment information, etc

4.3. Abnormal measurement index

The data collected by electricity meter is the real reflection of the user's electricity consumption at a certain time, which must meet the principle of gas metering. Under normal condition, the time sequence change rule of electrical parameters and the numerical relationship between electrical parameters must change in a small range. There are three kinds of abnormal indexes of electric power measurement, which are voltage unbalance, current unbalance and power factor, as shown in Figure 2.

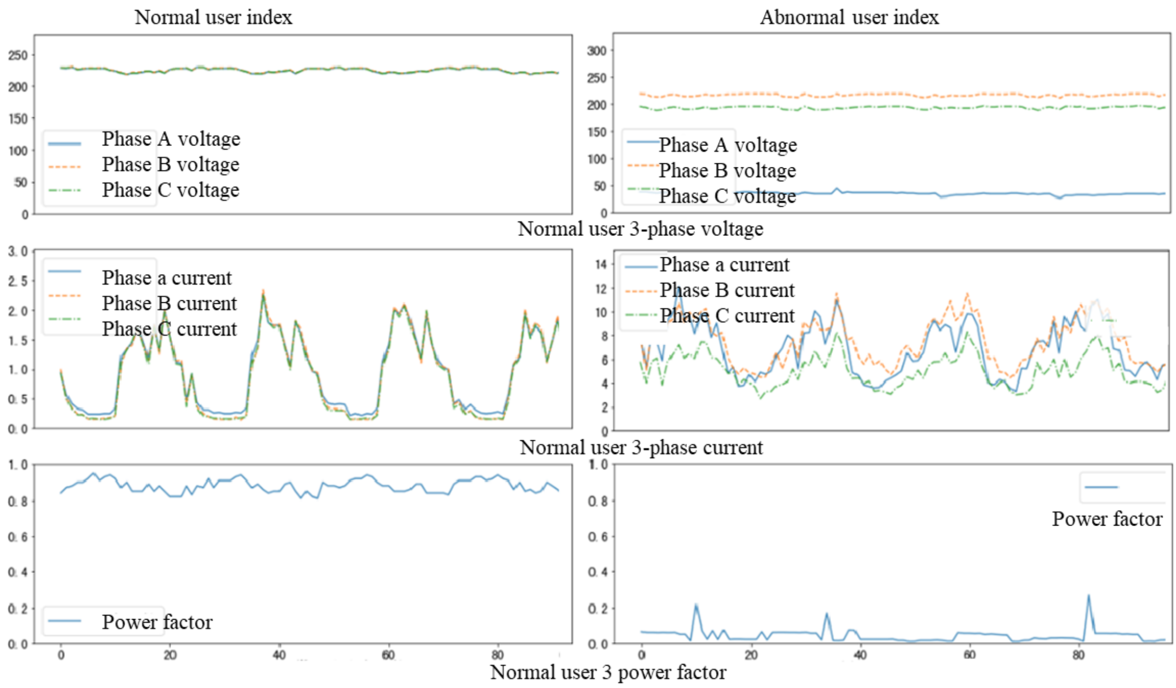

Figure 2. Comparison between normal users and abnormal users.

Under normal conditions, the measurement results of three-phase voltage should be close to and

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close to the rated voltage. The index of voltage unbalance indicates the balance degree of three-phase voltage, as shown in Formula 1.

$$V_{unbalance}=\frac{\max(v_a,v_b,v_c)-\min(v_a,v_b,v_c)}{\max(v_a,v_b,v_c)} \tag{1}$$

The three-phase current values of users shown in CJ are similar and have strong correlation. The index of current unbalance degree represents the balance degree of three-phase current, as shown in formula 2.

$$C_{unbalance}=\frac{\max(c_a,c_b,c_c)-\min(c_a,c_b,c_c)}{\max(c_a,c_b,c_c)} \tag{2}$$

5. Power metering system design automation

5.1. Overall framework of the system

The PMAS is a real-time information acquisition and analysis processing system which integrates modern digital communication technology, computer software and hardware technology, electric energy measurement technology and power marketing technology, which realizes the data communication between the computer master station and the field measurement terminal. The coverage of the system includes electric energy telemetry system, large customer load management system, distribution transformer management system, centralized meter reading system for residents, which can carry out real-time detection and real-time data acquisition. According to the principle of layered and block design, the overall structure of the system is shown in Figure 3.

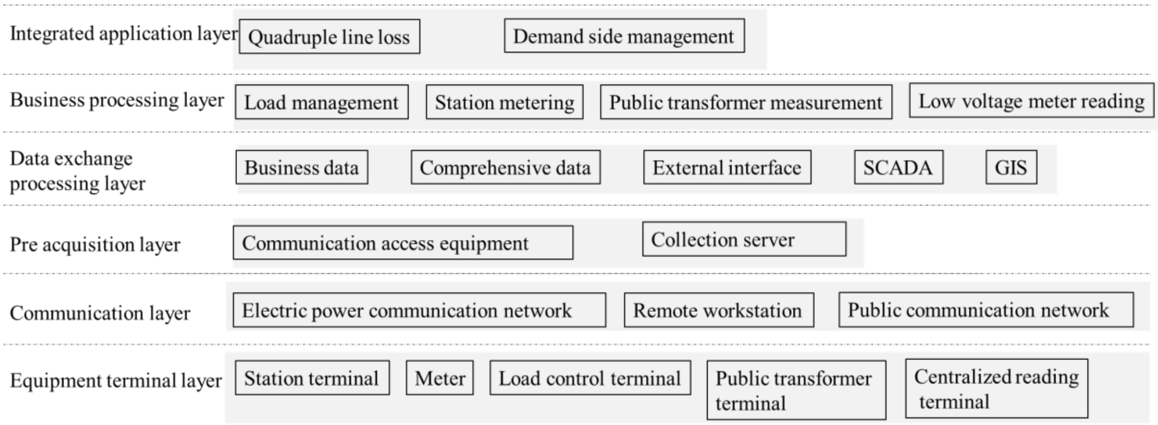

Figure 3. Overall structure of the system.

5.2. System network topology

According to the physical location of the equipment, this paper designs the main station network extension model of PMAS, which is mainly divided into three parts. The first part is the metering equipment and data communication terminal equipment at the power consumption field side; the second part is various communication network extension models to realize remote communication; the third part is the network extension model of computer application system. The network topology of master station is shown in Figure 4. Through the network routing equipment, we can achieve data transmission. Data transmission can be realized in substations and power plants by means of power line transmission network / telephone. According to the data acquisition and processing, we can design various functional servers, high performance / high reliability data storage units and application workstations, which will exchange data with the interface server and the application system.

In terms of data transmission security, the data transmission based on public communication network is through cooperation with network operators, which can ensure data security and reliability through dedicated APN access. On the

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software computer system, by installing the forward and reverse physical isolation device, we can make the system run in security zone II, which will ensure the security and reliability of the software operation system.

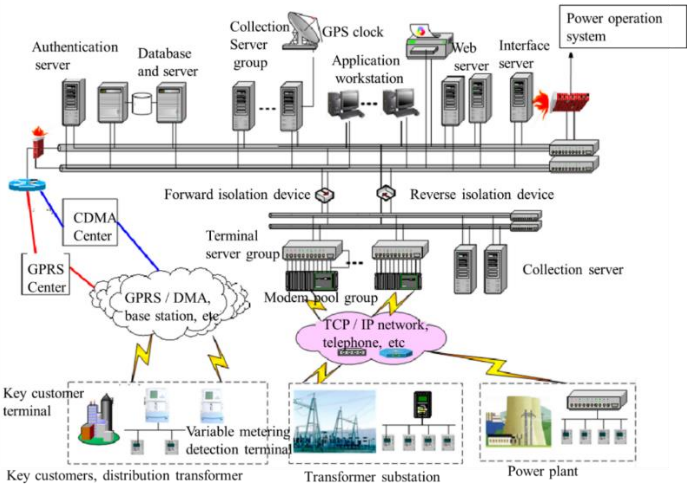

Figure 4. Master station network topology.

6. Anomaly detection of PMAS based on Data Mining

6.1. Data analysis

According to the respective protocols, we can parse the original message data of various protocols into uniform format data such as electric quantity, load and alarm. The data analysis module has good scalability. When the specification is changed or added, we need to configure a new parsing library or add a corresponding parsing module. The flow chart of data analysis is shown in Figure 5.

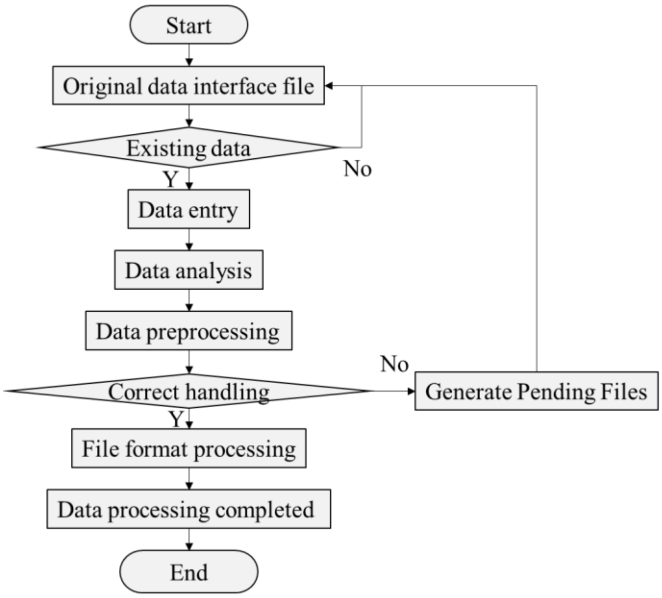

Figure 5. Data analysis process flow.

6.2. Data processing

Data processing includes simple data processing and complex data processing. Simple data processing extracts basic data. Then, by adding file data and certain operation models and methods, we will generate simple business data, which can be used as file format processing for complex data processing module. Complex data processing extracts simple business data, generates various complex user data and report data according to the system business requirements, including a variety of operations and preprocessing. In the stage of data preprocessing, it is necessary to observe the features of some data manually. By selecting the appropriate data features, we can screen out the characteristics that can reflect the corresponding terminals, which are mainly divided into four preprocessing methods, namely, the preprocessing methods of taking the mean and variance, only taking the mean value, two dimension correlation and statistical counting.

6.3. Common abnormal diagnosis model of electric power measurement

There is no unified data modeling method in the field of power anomaly diagnosis, mainly due to different technical conditions of power system, different emphasis on privacy and power grid

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construction, which will lead to huge differences in data accuracy, acquisition frequency and data types in different regions. According to the logical structure, common data models are divided into three types: vector model, sequence model and topology model, as shown in Table 2.

Table 2. Data model for abnormal diagnosis of power metering.

No.	Data model	Sample data type
1	Vector model	Electricity, electricity change characteristics, user attribute information, historical credit records, internal measurement data of electricity meter
2	Sequence model	Electricity quantity
3	Topological model	Voltage, current, electric quantity and topology of substation area

Vector model refers to that the original power data is constructed into a set of parallel features as the input of the subsequent model. This modeling method makes the abnormal diagnosis easier to transform into machine learning problem. The power consumption of users in a period of time is regarded as a time series, and the diagnosis is transformed into the problem of time series classification. The topology model needs to rely on the topological relationship of the electric meters in the substation area, which depends on the sub table of each user, the gateway table of branches and the general meter of the substation area to establish a line loss equation group. When the meter has abnormal behavior, we will destroy the balance state of line loss in the substation area.

6.4. Power data sample model

The original power data model can be constructed into a sample model similar to the picture, which can be transformed into spatial correlation. By transforming different electrical parameters and abnormal indexes into cross-channel characteristics, we can get the sample model, as shown in Figure 6.

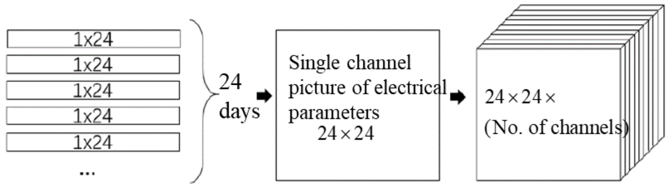

Figure 6. Power data sample model

The length of picture is equal to the number of days of the sample, and the width of picture is equal to the number of samples in the sample day. The frequency of power data acquisition is 24 times / day. In order to make the sample form a square with the same length and width, we take 24 days of power data sampling interval. Taking three-phase four wire high power supply and low-voltage meter as an example, 8 electrical parameters of three-phase voltage, three-phase current, power factor and active power correspond to 8 channels. At the same time, four abnormal indexes are added to the sample model as channels, which are voltage unbalance, current unbalance, estimated power factor and load rate. Therefore, the final sample form is shown in Formula 3.

$$x_i \in R^{h\times w\times c}, \quad i=1,2,3; h=24; w=24; c=12 \tag{3}$$

6.5. Small sample learning method based on measurement

Through the embedding network, we map the samples from the original sample space to the embedded space, which makes the similarity between the samples in the original space equal to the distance between the eigenvectors in the embedded space. Due to the high similarity, the samples of different categories will form a larger interval due to the low similarity. In the similarity calculation of prototype network reasoning and training stage, we can replace the support set samples with the similarity from prototype to the sample to be tested, which can reduce the model jitter during the training process. Through this

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method, we can improve the convergence speed of the model, which will find the global optimal solution and obtain higher accuracy. The small sample learning method based on measurement is shown in Figure 7.

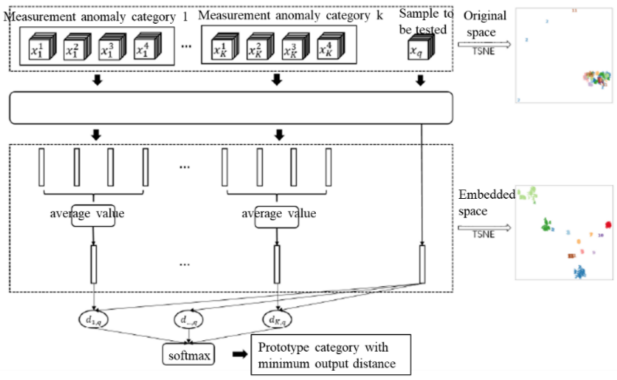
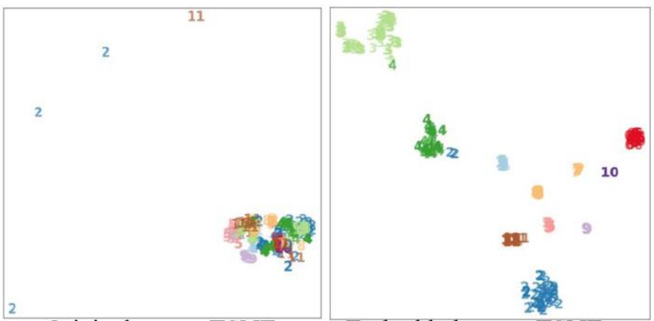


Figure 7. Measurement anomaly diagnosis model based on small sample learning.

6.6. Comparison of tsne visualization results

The embedded network can realize the feature Self Extraction of power samples, which makes the embedded samples better used for measurement and comparison. Through tsne visualization, this paper shows the distribution of samples in original space and embedded space before and after embedding network, as shown in Figure 8.



Original space TSNE   Embedded space TSNE

Figure 8. Comparison of TSNE visualization results.

It can be seen from the graph that the sample distribution in the original space is not separable. Therefore, we can't directly predict the class of samples to be tested by comparing the similarity between samples in the original space, such as KNN model. In the embedding space, the samples show obvious clustering distribution by category, which indicates that the embedded network has good feature extraction ability.

7. Conclusion

The automation system of electric energy and electric power measurement realizes the real-time monitoring of the power metering device points in the area under its jurisdiction, which can quickly and timely detect abnormal situations. For the meter code does not enter, loss of current, loss of voltage and other conditions of metering device abnormal, the PMAS can be analyzed and judged, which provides an advanced technical means for the smooth development of power marketing. Through the real-time monitoring of information collected once every 15 minutes for a cycle, we can accurately determine the time when the metering device is abnormal and the time to return to normal, which provides great help for enterprises to make up for electricity collection. The PMAS can timely recover the economic losses of enterprises, which is of great significance for the development of power enterprises.

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