Research on Key Technology of State Evaluation and Replacement Acquisition System of Intelligent Electric Energy Meter Based on Smart Grid

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Abstract. Based on big data technology, the smart meter operation status analysis system uses distributed storage, distributed analysis and calculation, and data mining to integrate the mass of energy meter information in the electricity information collection system, measurement and production scheduling platform, and marketing business system. The data is converted into a smart meter operation status report, which guides the staff to calibrate or rotate the meter, and solves the problem of wasting human and material resources in the current meter management method. The concepts and key technologies of big data technology and data mining are expounded, and the big data platform of the hierarchical structure smart meter operation status analysis system is introduced in detail.

1. Introduction
With the development of smart grid, smart electric energy meters, which are important support for power companies to strengthen lean management, improve quality service levels, expand power markets, and innovate trading methods, have been widely used in China. For this reason, the existing manual smart electric energy meter on-site fixed-period inspection determines whether the meter is out of tolerance. It not only consumes a lot of manpower and material resources, but also has a certain risk of on-site operation, and it is impossible to find the abnormal operation of the smart electric energy meter in a timely and effective manner. It has been unable to meet the lean operation and maintenance requirements of smart energy meters. Therefore, based on the technical characteristics of smart electric energy meters and making full use of data from information systems such as marketing business application systems, electricity information collection systems, and metering and production scheduling systems, an online inspection and evaluation indicator for smart grid status and its online platform are designed.

The related design of the acquisition system in the smart energy meter state evaluation and replacement of the supporting function of the acquisition system, mainly involves six types of measurement abnormal algorithm models related to the smart energy meter state evaluation, including the analysis model of the unevenness of the energy representation value, the energy meter fly-away analysis, the energy Meter backward analysis model, energy meter stop analysis model, reverse power anomaly analysis model, energy meter clock anomaly analysis model, etc.; based on measurement online monitoring analysis model, automatic diagnosis of measurement anomalies; interface with smart energy meter operation error monitoring Transformation; collection of basic data management,
including traceable management of historical electricity consumption of energy meters, collection and communication diagnosis abnormality, analysis of relationship between households and households, auxiliary analysis of load abnormality, auxiliary analysis of power consumption abnormality, auxiliary analysis of photovoltaic abnormality, auxiliary analysis of grid-side abnormality, etc. content [1].

2. The purpose of smart meter status evaluation and replacement of acquisition system

Optimize six types of measurement abnormality algorithm models related to smart energy meter status evaluation to achieve various types of measurement abnormality classification management; introduce automatic diagnosis of the master station to improve the accuracy of measurement abnormality analysis, provide reference for smart energy meter status evaluation and replacement; develop smart energy Table state evaluation and replacement related basic data governance, provide data support for the state evaluation algorithm, and improve the overall hit rate of the algorithm. At the same time, using big data analysis technology, fusing the massive data accumulated in the collection, marketing, and MDS systems, a set of energy meter misalignment replacement algorithm models is constructed, and through the model calculation, the energy meter misalignment work orders are automatically generated to develop the misalignment The on-site verification and disposal of electric energy meters provide support for ensuring the accuracy and fairness of electric power measurement [2].

3. System function analysis

3.1. Automatic diagnosis of measurement abnormality

The main station generates measurement data abnormalities for different data collection methods and trigger modes according to the measurement abnormality online monitoring and intelligent diagnosis analysis models, and then performs automatic diagnosis. The automatic diagnosis is divided into primary diagnosis and secondary diagnosis. The meter data is compared with the data of the master station. If the two are inconsistent, the meter data is used for secondary diagnosis. The measurement abnormality is generated according to the diagnosis rules. At the same time, the collected data error is generated and transferred to other processes. If the two are consistent, the classification is based on the abnormality Rules to generate a list of measurement abnormalities at various levels. Explanation of the situation of through-copy: the remote reading of the energy meter data of the main station is divided into two situations: if the through-reading is unsuccessful and meets the conditions of online measurement monitoring and intelligent diagnosis analysis model, various levels of metering abnormal lists are generated according to the abnormal classification rules; If the transcribing is successful, it will be processed according to the automatic diagnosis process. As shown in Figure 1.

![Figure 1. Smart grid electricity meter evaluation and acquisition abnormality diagnosis process](image-url)
3.2. Analysis of the effectiveness of automated diagnosis

According to the abnormal phenomena of measurement data, HES automatic diagnosis and measurement result data, and analysis and comparison data of measurement results, a comprehensive analysis of the effectiveness of automatic diagnosis is carried out to achieve a multi-dimensional visual display of effectiveness by power supply unit, abnormal type, statistics Cycle size division. Including the number of work orders before automatic diagnosis, the number of data errors collected, the number of work orders for the second diagnosis by IED through transparent recruitment data, the number of work orders after automatic diagnosis, the proportion of work order reduction, etc. Obtain the meter information through the recruitment data. As shown in Table 1, it is related to automatic diagnosis.

### Table 1. Related functions of automatic diagnosis

| Numbering | Process link          | Link description                                                                 | User role                                      |
|-----------|-----------------------|----------------------------------------------------------------------------------|------------------------------------------------|
| 1         | Intelligent diagnostic analysis | By judging the analysis rules and automated diagnosis rules issued by the State Grid on the voltage, current, electric energy indication and electric power, the abnormal events are analyzed and diagnosed according to the single abnormal analysis model and abnormal correlation model. | Collection and operation personnel, measurement personnel, power consumption inspection personnel |
| 2         | Abnormal measurement query | Based on the measurement and monitoring results of online measurement, provide measurement abnormal analysis result query | Collection and maintenance personnel, measurement personnel |

3.3. Analysis of automatic diagnosis algorithm

The method of determining abnormal measurement data through statistical analysis of measurement data, also known as statistical method, is the earliest data diagnosis method. The basic idea of the statistical method is: assuming the probability distribution model of the measured data, and passing the inconsistency test, the measured data that seriously deviates from the probability distribution curve are regarded as abnormal data. There are many specific methods for diagnosis of abnormal data based on statistical methods. This section only summarizes some of the representative methods. This method detects outliers of measured data that are close to the normal distribution function with a single variable [3]. The idea of this method is to find the measurement value of the maximum deviation from the probability distribution function in the measurement data and judge it. Define the following function:

\[
G = \max \left| y_i - \bar{y} \right| / s
\]

(1)

Among them, \(G\) is the measurement data; \(\bar{y}\) is the average value of the measurement data. When the following criterion is established, it is determined that the maximum deviation point is abnormal data, namely:

\[
G > \frac{N - 1}{\sqrt{N}} \sqrt{\frac{(t_{\alpha/(2N),N-2})^2}{N - 2 + (t_{\alpha/(2N),N-2})^2}}
\]

(2)

Where \(t_{\alpha/(2N),N-2}\) is the critical value of the distribution function with a confidence interval of \(\alpha ()\).
This method is also a single variable, multi-outlier data diagnosis algorithm. The principle of this method is that the measurement data is first sorted according to the absolute value, for example, the data with the largest absolute value in the measurement data. The detection statistics of the maximum point (minimum point) are defined as:

$$E_k = \frac{\sum_{j=1}^{n} (z_j - \bar{z}_k)^2}{\sum_{j=1}^{n} (z_j - \bar{z})^2}$$  \hspace{1cm} (3)$$

Among them, $\bar{z}_k$ is the average value of the samples after excluding the maximum point (minimum point). The definition of Euclidean distance is:

$$d_1 = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}$$  \hspace{1cm} (4)$$

$$d_2 = \sqrt{(x - \mu)^T C^{-1} (x - \mu)}$$  \hspace{1cm} (5)$$

The mean method divides this measurement value into a set, that is, optimizes the distribution of the collection to satisfy:

$$\arg \min \sum_{i=1}^{k} \sum_{x \in S_i} \Vert x - \mu_i \Vert^2$$  \hspace{1cm} (6)$$

Among them, $\mu$ is the average value of the measured data. After training, each subset will generate a centre point and the maximum radius that normally covers the measurement points of the subset. If the new measurement data falls outside the coverage of all subsets, it is judged as abnormal data.

3.4. Development of acquisition communication diagnosis function

3.4.1. Diagnosis of abnormal data communication in station area. For the stations with abnormal daily line loss rates, many of them are due to the abnormality of the line loss calculation caused by the abnormality of the low-voltage user or the measurement data of the public transformer measurement point. The data call function of the main station is used to develop the acquisition communication diagnostic function Realize the comparison and analysis of this type of abnormal data, as shown in Figure 2.
Figure 2. Acquisition and communication diagnosis function

SCADA system, in the field of data acquisition and monitoring control and process control and many other fields. According to the abnormal situation of the line loss rate in the station area, the main station periodically calls the daily frozen forward/reverse active power total energy values measured in the following table in batches, and analyzes and compares the call measurement data with the saved data. DMS has multiple communication methods, and the communication rate is low. Generally, this function is used to recalculate power and line loss based on the acquired data through call measurement, and determine whether the line loss rate of the station area after trial calculation is qualified. After trial calculation, if the line loss rate is qualified, the master station will mark the station area specially. The power generation and power supply of the grid managed by the EMS management are balanced, so the failure situation is different. For the grid area where the line loss rate is still unqualified after the trial calculation, the abnormal site area can still be further analyzed by other methods.

3.4.2. Statistics of abnormal data communication diagnosis results. According to the diagnosis results of abnormal data communication in the station area, the statistics of the abnormal station area are classified, which is convenient for the line loss management personnel of the station area to target the work of the line loss abnormal area. Support for further analysis of abnormal meter data in abnormal stations. Check the call data, historical data and other information of the abnormal meter to find the energy meter problem and improve the system data collection quality.

3.4.3. Development of analysis model of relationship between Taiwan and households. The abnormal relationship between Taiwan and households is caused by inconsistencies between the user’s file area and the site area due to file entry problems and on-site installation problems. Since the relevant characteristics of the abnormal household change relationship are not obvious, a single algorithm cannot be effectively identified, and multi-dimensional data such as power consumption behaviour, address information, line loss data, and operation data must be collected for comprehensive analysis. The abnormal relationship between Taiwan and households is caused by inconsistencies between the user’s file area and the site area due to file entry problems and on-site installation problems. Since the relevant characteristics of the abnormal household change relationship are not obvious, a single algorithm cannot be effectively identified, and multi-dimensional data such as power consumption...
behaviour, address information, line loss data, and operation data must be collected for comprehensive analysis [4].

3.5. Development of power consumption abnormal analysis model

3.5.1. Electricity level analysis model. Analyse the user's historical power data or similar user's power consumption data, and enter the low-voltage user's daily / tip / peak / valley power data to perform feature derivation to construct the power level related characteristics (maximum, minimum, and average) of each customer, Median, changes in the specified time interval). Univariate analysis and multivariate analysis are carried out on features, identifying and screening strongly correlated features, constructing a power level analysis model, outputting abnormal users and suspect coefficients, and identifying abnormal electricity consumers. As shown in Figure 3.

![Figure 3. Development of power abnormal analysis model](image)

3.5.2. Analysis model of electricity fluctuation. Analyse the user's historical power data or similar user's power consumption characteristics, input low-voltage user power data, perform feature derivation, and construct power fluctuation related characteristics (the fluctuation slope of the specified interval and related statistical characteristics). Univariate analysis and multivariate analysis are carried out on the characteristics, identifying and screening strongly correlated characteristics,
constructing a power fluctuation analysis model, outputting abnormal users and suspect coefficients, and identifying abnormal power consumers.

3.5.3. **Analysis model of electricity proportion.** Input low-voltage user power data and power supply data of the station area, perform feature derivation, and construct the relevant characteristics of the proportion of power (the proportion of user power in the power of the station area, and related statistical data). Univariate analysis and multivariate analysis are carried out based on the features, to identify and filter strongly correlated features, to construct an analysis model of electricity proportion, to output abnormal users and suspect coefficients, and to identify abnormal electricity consumers [5].

3.5.4. **Peak-to-valley ratio analysis model.** Analyse the user's historical peak and valley power data, and input the low-voltage user's peak and valley power data to perform feature derivation and construct spike-valley power-related characteristics (peak valley power ratio and related statistical characteristics). Univariate analysis and multivariate analysis are carried out for features, identifying and screening strongly correlated features, constructing a peak-to-valley ratio analysis model, outputting abnormal users and suspect coefficients, and identifying abnormal electricity consumers.

3.5.5. **Similar user analysis model.** Based on user profile data, electricity data, station area archive data, station area power supply data, station area line loss data and other characteristic data, perform feature derivation to construct similar user indicators (maximum, minimum, average, Statistical indicators such as the median). Univariate analysis and multivariate analysis are carried out for features, identifying and screening strongly correlated features, constructing similar user analysis models, and outputting abnormal users and suspect coefficients.

3.5.6. **In-depth optimization of electricity consumption behaviour analysis model.** Based on the analysis of the characteristics of electricity consumption, including the characteristics of electricity level, electricity ratio, peak-to-valley ratio, electricity fluctuation, and sudden changes in electricity, compare historical or similar user characteristics to identify abnormal electricity usage behaviours. Considering that the sample data in different regions are very different, the corresponding modelling methods are used for analysis. For power supply units with detailed sample data, supervised methods are used for model training, user feature engineering analysis is performed, and feature data with strong correlation is identified. In view of the lack of sample data in some regions, the strong features obtained from the analysis of the sample power supply area are used, the model training is carried out by an unsupervised method, and the users in the power supply area are analyzed to identify the characteristics and changes of power consumption behaviour that are obvious from other users Inconsistent users, and identified as abnormal users [6].

4. **Key technical analysis**

4.1. **Multi-dimensional perception data application architecture**

The application architecture is shown in Figure 4. It can be seen from FIG. 4 that the sensing device is only a part of the sensing data in the entire intelligent verification. In addition, the sensing data obtained through communication methods such as PLC and OPC is also the key underlying data. Based on the underlying sensor data, combined with the process flow to extract effective information to form process data. Based on the process data, process data is formed according to the interaction of data between the various subsystems. Comprehensive analysis of sensor data, process data and process data, from the partial to the overall control of the digital workshop operation status.
4.2. Data interactive communication architecture

Establish a comprehensive process information interaction architecture for complex manufacturing and production to obtain real-time sensor, process, and process data information in the production process to serve the decision-making execution and business circulation of production operations, as shown in Figure 5. In the method of real-time data and information interaction between the automated verification dispatching subsystem and each subsystem and upper management system, the communication mode based on WCF and MQ is adopted. Among them, the most basic communication mechanism of WCF is the Simple Object Access Protocol (SOAP). As long as the objects involved in the communication support the standard Web Service protocol, it can operate across processes, machines, and even platforms. The real-time data and information interaction problems are carried out; MQ connects different subsystem environments through the message queue framework, which provides good support for the non-real-time data and information processing of various subsystems [7].
4.3. Control architecture for automated verification

The production scheduling platform realizes the issuance and termination of energy meter verification tasks, and interfaces with the automated verification scheduling subsystem and automated warehouse management subsystem through the middle layer. The middle layer plays a bridge role in the whole intelligent verification. The operation of the equipment in the energy meter intelligent verification system will generate massive data. The use of the middle layer mode facilitates the unified management and query of system interactive information. The automatic verification and dispatching subsystem of the electric energy meter is the core dispatching system of the entire intelligent verification system. The overall scheduling is to execute the verification tasks from the production scheduling platform [8]. The control architecture is shown in Figure 6.

![A Conceptual Framework of Smart Water System](image)

**Figure 6.** Control architecture for automatic verification of electric energy meters

5. Conclusion

The paper proposes a smart grid state online inspection evaluation index and its online platform design scheme, which can provide a strong basis for the online smart energy meter defect inspection and operation and maintenance, on the premise of meeting the daily smart energy meter out of tolerance approval, greatly reducing the number of operation and maintenance personnel, saving enterprise costs.

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