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Study on Automatic Monitoring of Electricity Consumption for Maintenance of Low-Voltage Intelligent Distribution Boxes in Power Systems

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ABSTRACT

In the development process of China's power system, automatic monitoring mode has become an important development direction. In this context, how to achieve real-time monitoring of power data in the system has become an urgent problem. In this paper, considering the current range, the controller with input current is selected to collect voltage and current data signals and detect their circuits. Through metadata integration, the semantic integration of data expression is solved to achieve the management of electric power metadata. The collected data are sequentially accessed, handled and processed, the calibration of the voltage and current signals is agreed upon, the AD-converted values are read and the electrical parameters are calculated. Using the communication protocol IEC61850, the processed electric power data is uploaded into the server to complete the electric power data reading and monitoring tasks. The real-time management platform of intelligent maintenance power box constructed in this paper is used to monitor the abnormal power data. The abnormal power data appeared at different times, and the peak value of abnormal value 1 appeared at 14:00, and the peak data was 0.91 w. The evaluation value interval of the security threat in the transmission of power data is between 100-200 g, and the energy interval fluctuates around 1000 c. The results obtained are more reasonable, and the security of the data is guaranteed.

Keywords: Metadata integration, AD conversion, Communication protocol IEC61850, Power data monitoring

1. Introduction

Intelligent distribution box is an advanced low-voltage power distribution system, which integrates mechanical switches, metering appliances, circuit breakers, insulation monitoring equipment, power metering equipment and other equipment in a cabinet with automation, intelligence and integration [1-4]. It can effectively guarantee the stable, safe and efficient operation of the system, improve the

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utilization rate of electric energy, reduce the loss of power outage, and also meet the user's intelligent management needs. It has a number of advantages, simple internal wiring, and can meet different installation sizes and technical requirements [5-8].

At present, the trend of global industrial transformation is more and more inclined to intelligence. With the continuous development and use of power electronics technology, low-voltage distribution boxes are gradually moving towards intelligent, automatic control [9-11]. Intelligent distribution box monitoring technology, and the intelligent development of the global power grid is closely related, and "intelligent" technology has been widely used in all aspects of the power grid [12-14]. "Intelligent" monitoring refers to the original distribution room, combined with the traditional distribution room monitoring technology, combined with modern automatic measurement and control technology, high-speed communication technology and microcomputer technology, forming a new power monitoring system [15-17]. Intelligent monitoring of the power grid can effectively reduce the energy consumption of the power grid to achieve the goals of saving electricity and reducing energy consumption. In China, due to the object and organization of power supply is relatively complicated, therefore, to make the intelligent monitoring of the power system is more reliable, safe, energy-saving and environmental protection [18-21].

In this paper, we construct an intelligent circuit breaker by adding an RC low-pass filter at the end of the signal conditioning to complete the filtering and filter out the high-frequency components of the signal, and then through the FFT transform, harmonic analysis is carried out. The current and voltage coefficients are calibrated, and the values are read through the AD conversion convention to calculate the relevant electrical parameters. Metadata integration is used to solve the problem of semantic integration in power data expression. The data is then accessed from the grid side and generation side, and the management and conversion is done automatically within the database. Monitor the communication and network in the process of accessing data, and deal with the problem of access abnormality. An alarm system is set up to analyse the data in real time and confirm the status, priority and other conditions of the power data. Introduce the communication protocol IEC61850 to upload the read power data to the server to realise real-time monitoring of power consumption. Using simulation experiments, the abnormal power data read is analysed and the security of the power data information during transmission is evaluated.

2. Intelligent maintenance power box real-time management platform construction

2.1. Intelligent Circuit Breakers in Power System Automation

2.1.1. Controller Selection. For line protection, the current of the system during normal operation is the rated current, and according to the technical specifications mentioned before, it can be seen that when the system has a fault, the maximum current can reach more than ten times of the rated current, so the current range can be considered as $0.1I_n \sim 15I_n$. Assuming that the number of bits of the AD is n, the maximum value of the input current is $I_{\max}$ the minimum value is $I_{\min}$, and the sampling accuracy required by the system is less than $e\%$, so there is:

$$e\% = \frac{I_{\max}}{I_{\min} * 2^n} * 100\% = \frac{15I_n}{0.1I_n * 2^n} * 100\% < 10\% \tag{1}$$

Therefore, according to the above formula to calculate the number of AD conversion bit must be $n > 11$, in order to ensure that the error is less than 10%. Because the F2812 comes with a 12-bit ADC, the design requirements of the system have been met here without the need to choose another conversion chip.

2.1.2. Data acquisition. The voltage and current signal acquisition section is required to obtain as much information as possible that can respond to analogue changes in real time, and is therefore the basis for ensuring the reliable operation of the entire system. In the selection of transformers should mainly consider whether the sampled signal can maintain a good linear range and high accuracy in the entire detection range. At the same time, the current and voltage transformers in the system also serves as an electrical isolation role, the strong signal and weak signal separation, to improve the anti-interference performance of the control unit.

1) Current signal detection circuit. Current detection part of the SCT254 is a precision current transformer, its linear range of 0 ~ 20A, in the linear range of accuracy <1%, and non-linearity <0.1%, rated input current of 5A, turns ratio of 1:2000, the output rated current of 2.5mA, can be in the temperature range of -50 ℃ ~ +65 ℃ to use between. The op-amp chip is TI's LM324, which can support single-supply power supply and dual-supply power supply.

The current passes through the centre of the transformer, and the voltage signal is output from the 3 and 4 ends of the transformer, passing through the two diodes D1a and D2a to prevent over-saturation of the LM324 [22]. C1a is used to compensate for the phase shift caused by the transformer, and its capacitance is very small, usually taken as 400~1000PF.C1 and C2 are used to filter out the harmonics caused by the ±5v power supply of the LM324 to ensure the stability of the supply voltage, and to avoid interference with the signals. C1 and C2 are used to filter out the harmonics caused by ±5v of the LM324 power supply to ensure the stability of the supply voltage and avoid interference with the signal. Now assume that at this time A circuit on the input current is I_{ai}, the output is U_{ai1}, then the circuit's input and output relationship is shown below:

$$U_{ai1} = \frac{-R_{1a}}{K\left(1 + j\omega C_{1a} R_{1a}\right)} I_{ai} \tag{2}$$

Where K is the transformer ratio, $K = 2000$, due to C_{1a} is very small, equation (2) in the $j\omega C_{1a} R_{1a}$ is far less than 1 so can be ignored, and then choose the appropriate R_{1a}, to ensure that the amplitude of the output voltage of the first level does not exceed 1.5V.

2) voltage signal detection circuit. Voltage detection is selected SPT204 voltage transformer, it is a milliampere level precision transformer, accuracy <1%, rated input current of 2mA, the voltage limit of 50V~1000V, the ratio of 1, the rated output current of 2mA, because it is a current transformer, so when the detection of the voltage through the current-limiting resistor converted to a current close to 2mA, so that it can meet the Use conditions. The voltage signal acquisition circuit is basically similar to the current signal acquisition circuit. Still take A items as an example, assuming that the input voltage on the circuit is U_{ai} and the output is U_{av1}, the input-output relationship of the circuit is shown as follows:

$$U_{av1} = \frac{-R_{1ua}}{\left(1 + j\omega C_{1\,ua} R_{1ua}\right) R_a} U_{ai} \tag{3}$$

Similarly, since $C_{1\,ua}$ is very small, the $j\omega C_{1\,ua} R_{1\,ua}$ in equation (3) is much smaller than 1 and can be ignored, so choose the appropriate $R_{1\,ua}$ to ensure that the amplitude of the output voltage of the first stage does not exceed 1.5 V. Considering the fluctuation of the voltage in the later stage, so the amplitude of the transformed voltage can be designed to be about 1.3 V.

2.1.3. Conditioning circuits. Current and voltage signals after the respective amplitude conversion circuit, the output voltage signal are between -1.5V ~ +1.5V, however, the DSP AD conversion part of the signal received by the range can only be between 0 ~ 3V voltage, so the need to design a signal conditioning circuit, which includes the signal level lift, signal clamping and RC filtering. Level lift part of the design using in-phase addition operation circuit to achieve the input signal sum operation, the output signal of the pre-stage up 1.5V, so that the amplifier output level of all positive, that is, all the waveforms obtained in the DSP can be processed in the positive range. The input-output relationship of the level-raising circuit is:

$$\frac{R4}{R4+R5}*U2=\frac{R2}{R2+R3}*\left(1.5+U1\right) \tag{4}$$

Taking $R2=R3$ and $R4=R5$, equation (4) can be simplified as:

$$U2=U1+1.5 \tag{5}$$

From the simplified equation (5), it can be seen that it is achieved to change the secondary output signal into a weak voltage signal of 0~3V. At the same time, for insurance purposes, a clamp circuit consisting of two diodes is added before this signal is fed into the AD converter, and when the voltage exceeds 3V, the diode D3 conducts, and the input pin level of the ADC becomes 0. Therefore, this circuit ensures that the input voltage on the ADC is smooth between 0~3V, and serves to protect the input port of the ADC. In order to prevent the harmonic analysis through the FFT transform of the adjacent cycle harmonic signal aliasing, so in the signal conditioning circuit at the end of the RC low-pass filter to complete the filtering, filtering out the high-frequency components of the signal.

2.1.4. Intelligent Recognition. Intelligent identification module is the real-time judgement of the state of the line module, mainly refers to the CPU according to the signal transmitted from the previous data acquisition module through the software part of the logic operation and processing, the results of the operation and the pre-set protection parameter setting value comparison, and send out a command signal consistent with the protection characteristics of the actuator to control the intelligent circuit breaker whether the actuator action. In addition, the system is designed with external manual closing and manual breaking signals, which is convenient for the staff to operate the line externally in case of emergency. Therefore, the hardware circuit of the intelligent identification module is mainly composed of switching output circuit and switching input circuit.

2.1.5. Communications module:

1) Communication channel. Two CPUs are used in the system, F2812 completes the data acquisition and controller intelligent recognition output, STM32 completes the parameter setting and fault indication of the man-machine interface part, because the two parts are divided into two parts, and ultimately the F2812 needs to send the detected data and the fault information output to the STM32 for displaying, and in addition, the STM32 is responsible for the modification of the parameter setting, so it needs to transmit the parameter value to the F2812, which requires that communication must be achieved between the two. To the F2812, which requires the two must achieve communication between the two CPUs through the asynchronous serial port data transfer, can be directly connected, without the need to go through the level conversion can be directly communicated. By adopting the serial asynchronous communication method, the data can be exchanged between F2812 and STM32 very quickly. At the same time, in order to avoid data conflicts, each of them uses an external capture port to control the direction of data transmission.

2) Onboard Communication. Data communication can be divided into parallel communication and serial communication, parallel communication refers to the transfer of data sent or received at the same time, has the advantage of fast transmission speed, but the disadvantage is that the more data bits, the more communication lines used for transmission, and synchronisation between sending and receiving, is not conducive to long-distance transmission. Serial communication refers to the data one by one in accordance with the order of transmission, the transmission of data information is in the sender and receiver between the time-sharing, the advantage of only a pair of transmission lines, low cost, very suitable for long-distance communication, but the transmission speed is low. The general choice of which communication method depends on the distance of data and information transfer, generally greater than 30 metres when the serial communication, so the upper computer of this system

and the lower computer between the serial method.

2.2. Real-time data management platform functional architecture design

2.2.1. Metadata management. The adoption of metadata integration can well solve the semantic integration problem of data expression [23]. Massive real-time data management platform based on unified specification metadata integration can reliably, stably and effectively deal with the integration of site and measurement point data. Through metadata management, it can realise the location allocation and search management of global measurement points in cluster real-time/historical libraries, the attribute management of measurement points in specific real-time/historical libraries, and the maintenance and management of Yu-timed data models, including the mapping model of measurement points.

2.2.2. Data access. The data to be accessed by the massive real-time data management platform include grid-side and power generation-side access data. Grid-side access data include: SCADA information of main grid dispatch automation system, SCADA information of distribution automation, information of protection information system, information of electric energy metering system, information of transmission and substation on-line monitoring system, information of cable on-line monitoring system, information of meteorological monitoring, information of lightning monitoring, as well as information of centralised copying for large users, on-line monitoring of power quality, and information of collection of power consumption information. The access data on the power generation side include: DCS data of thermal power units, coal transmission programme control, water supply and drainage programme control, NCS network control data, flue gas on-line monitoring and other environmental protection data, cable on-line monitoring data and so on. As well as DCS data of hydropower, water regulator, electric regulator SCADA data access range data, gradient scheduling data, and so on. Wind power and other types of power plant monitoring system, network control system data. The platform needs to access the data of various source systems, in addition to providing data sources that meet the standard specifications, most of the access data needs to be in the form of interface adapters to automatically complete the access of real-time/historical information of different structures, to achieve the management of the statute library and the conversion of the access to the data process of communication and monitoring of the network, to complete the access to the handling of anomalies and other functions.

2.2.3. Data processing. Data processing refers to the conversion, calibration and checking of all types of data collected. When the source business system historical data changes in the history of the call synchronisation to ensure that the real-time data centre, and the business source data to maintain consistency between the value of multiple data sources, compatible with different real-time database processing. Can provide data verification for the validity and reasonableness of data, including multiple data sources processing, data verification, synchronisation processing, quality code processing, alarm recording, data calculation services.

2.2.4. Data processing. Data processing is responsible for further processing of data, which provides calculation services for the statistics of telecommunication volume, telemetry, and SOE event records and derivatives, through which the calculation formula can be defined and the algorithm library can be managed and configured, so as to realize the statistical calculation of historical and real-time data according to the algorithm library settings, and to provide more targeted information.
1) Secondary calculation. The secondary calculation takes the “virtual” point as the basic unit, which is calculated based on the state and value of the measurement points in the real-time database, with the support of embedded script language, which can flexibly and conveniently complete the customization of the algorithm, and the calculation results are saved to the massive real-time data

management platform. The secondary calculation configuration module is responsible for configuring the calculation method for each calculation point, and the configuration results are saved in the real-time database. The calculation algorithm is usually a piece of script language text, in addition to the standard program language also includes the real-time database of measurement point status and value of the acquisition function and other extended function library. Usually the calculation service is a background process that runs as a service. The calculation configuration module will notify the calculation service to update the algorithm, and the calculation service will investigate the script engine to execute the corresponding calculation algorithm through the scheduling policy such as time and priority, and then produce the calculation results, which will be saved in the real-time database as the values and states of the calculation points.

2) Data Statistics. Data statistics belongs to the data processing application based on real-time database, its external environment is completely dependent on the real-time database, through the real-time database interface to obtain the raw data for statistical calculations, calculations according to the configuration of the measurement point, the calculation results are saved in the real-time database or relational database, the user can query and call the statistical results.

3) Alarm system. Figure 1 shows the flow chart of the alarm point. In order to enable the platform to provide a fully functional alarm notification system for the actual measurement points and calculation points. It is required that the alarm system can be formed according to the user's needs of different levels of alarm points consisting of alarm groups, automatic real-time analysis of data, management of alarm points (displaying the current conditions, priorities and status) to monitor the alarm conditions, generating alarm information, and all the alarm information is permanently stored in a real-time database to be recalled at any time. Alarm system through the monitoring program for each measurement point in accordance with the pre-configured alarm conditions. Alarm points and alarm groups are the two basic components of the alarm system. In the system, alarm information is stored through specialized alarm switching quantities, which are alarm points, indicating the alarm status of the points in the real-time database. Their values can include priority, acknowledgement status and alarm conditions.

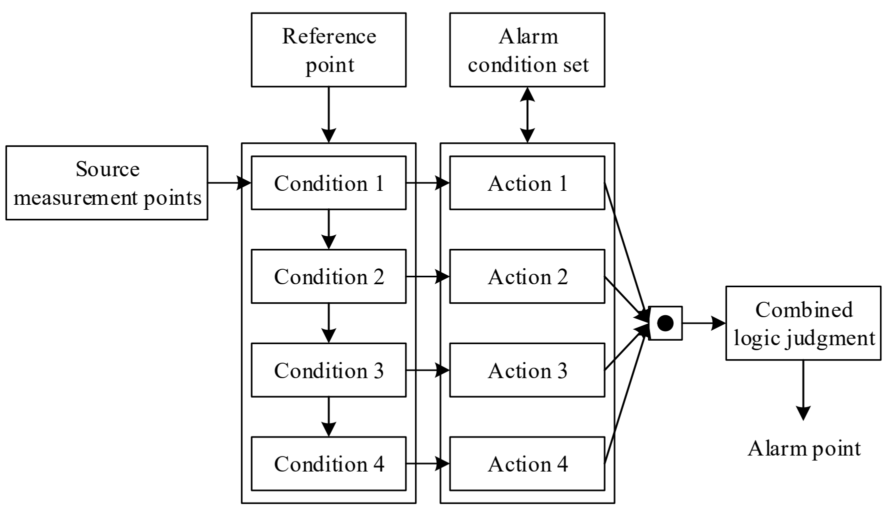


Fig. 1. The process of alarm points

3. Implementation of power data reading and uploading

3.1. Mathematical model for measurement calculations

The design of communication interface is an important embodiment of intelligent circuit breaker in intelligentisation, which is the medium for various information exchange and transmission between different modules.

3.1.1. Calibration methods:
1) Make a DC offset calibration of the device;
2) AC offset calibration of the device;
3) No gain calibration for the device, its internal gain register value is kept as 1, and the whole measurement system composed of peripheral circuits, CS5460A and MCU is calibrated for gain (the calibration method is as follows: add the standard signals of 5A (current input) and 220V (voltage input) to the signal input terminal, start the AD conversion, and then read the RMS values of the current and voltage at the end of the conversion, and then divide the result of the reading into the corresponding standard signal value), and the calibration result, i.e. the current coefficient and voltage coefficient, is stored in the memory of MCU. The result of calibration is the current coefficient and voltage coefficient in MCU memory, set the calibrated current coefficient as $I_{Coefficient}$ and the calibrated voltage coefficient as $U_{Coefficient}$.

3.1.2. AD conversion read value conventions. After calibration by 3.1.1 calibration method, enter into normal analogue-to-digital conversion, set the analogue-to-digital conversion from the current RMS register to read out the number of $I_{\mathrm{Re}adings}$, from the voltage RMS register to read out the number of $U_{\mathrm{Re}adings}$, from the power RMS register to read out the number of $E_{\mathrm{Re}adings}$ (the above are all 3 bytes of the long fixed-point number, according to the need to convert).

3.1.3. Calculation of electrical parameters. Current RMS $I_{Effective} = I_{Coefficient} * I_{\mathrm{Re}adings}$, voltage RMS $U_{Effective} = U_{Coefficient} * U_{\mathrm{Re}adings}$, active power $P = E_{\mathrm{Re}adings} * E_{Coefficient} / t_{Accumulation}$, power factor $F = P / \left(I_{Effective} * U_{Effective} \right)$, CS5460A power register initial value of 0, start AD conversion after the set number of AD conversion cycle N, the power accumulation value of $E_{\mathrm{Re}adings}$, waiting to read, and re-accumulation of power value from 0, so the power accumulation time is: $t_{Accumulation} = T_{AD} * N$, T_{AD} for the AD conversion cycle, N for the calculation cycle, $T_{AD} = 1024 * K / f_{MCLK}$, f_{MCLK} for the CS5460A external crystal frequency, K for the frequency division coefficient, set in the device configuration register Configuration Register, the typical value is $f_{MCLK} = 4.096MHz$, $K = 1$, $N = 4000$, power accumulation time is $t_{Accumulation} = 1s$.

3.1.4. Determination of the value of $E_{coefficient}$. To calculate P correctly, it needs to be clear that the unit value of $E_{Coefficient}$ represents the number of multi-electricity degrees, i.e., the unit electrical energy register reading represents the value of electrical energy $E_{Coefficient}\left(kW\right)$ according to the alternating current degree of electricity calculation equation $E = I * U * \cos\Phi * t$ (where E represents the number of electric degrees in t time, I represents the current RMS value, U represents the voltage RMS value, t represents the measurement time, and Φ represents the phase difference between the current and voltage). When the current and voltage are in phase, $\Phi = 0$, the electrical energy $E\left(kW \cdot h\right)$ used for 5A current and 220V voltage in 1s is:

$$E = 5 * 220 * 1 / \left(3600 * 1000\right) \tag{6}$$

Assuming that the AD conversion values corresponding to the standard signals 5A and 220V during calibration, (i.e. the readings) are $I_{\mathrm{Re}adings}$ and $U_{\mathrm{Re}adings}$ respectively, when the $\Phi = 0°$ currents and voltages are in phase, and using the default setting values, it can be easily seen that the electrical energy register readings should be in 1s:

$$E_{\mathrm{Re}adings} = I_{\mathrm{Re}adings} * U_{\mathrm{Re}adings} * 4000/1024 \tag{7}$$

Also according to the calibration method agreement, there:

$$I_{Coefficient} = 5 / I_{\mathrm{Re}adings} \tag{8}$$

$$U_{Coefficient} = 220 / U_{\mathrm{Re}adings} \tag{9}$$

The units of $I_{Coefficient}$, $U_{Coefficient}$ are amperes/unit current channel AD converted value and volts/unit voltage channel AD converted value, respectively.

Substituting Eq. (8) and Eq. (9) into Eq. (8) after transformation gives:

$$E_{\mathrm{Re}adings} = 5 * 220 * 4000 / \left(I_{Coefficient} * U_{Coefficient} * 1024 \right) \tag{10}$$

Equation (6) divided by equation (10) gives:

$$\begin{aligned} E_{Coefficient} &= E / E_{\mathrm{Re}adings} = I_{Coefficient} * U_{Coefficient} * 1024 / \left(3600 * 1000 * 4000 \right) \\ &= I_{Coefficient} * U_{Coefficient} / 14062500 \end{aligned} \tag{11}$$

3.2. Calibration method and data reading

3.2.1. Calibration methods. During the transmission of analogue signals, zero deviation is unavoidable due to device asymmetry, inconsistency, etc. Zeroing is therefore required, as there is an analogue signal transmission channel within the CS5460A, which also requires zero adjustment. Similarly, due to the inconsistency of the device performance such as amplification, it is necessary to carry out the determination of the input/output proportionality, and these two processes are called calibration. Figure 2 for the signal processing channel schematic block diagram, it is clear that the AC gain is calculated on the basis of inaccurate DC zero, from the mathematical calculation point of view, its value is bound to have error, and after the DC zero adjustment can not be corrected its value. The same AC gain is in the old AC gain (its value is 1) and the old AC zero (its value is 0) under the calibration, the new AC zero can not correct the error of AC amplification. Therefore, the calibration method suggested by the manufacturer inevitably exists in principle, but the error is very small and has been included in the device error index of 0.1%. It is recommended for the design of MCU, do not make internal gain calibration of CS5460A, so that the value of its internal gain register to maintain 1, made after the DC zero calibration directly for the AC zero calibration, and then the CS5460A for external gain calibration (i.e., the system input to the system output constitutes the full signal channel calibration) in order to find out the ratio of the analogue-to-digital conversion value and the amplitude of the input signal (or RMS), so as to ensure the accuracy of the analogue-to-digital conversion value and the amplitude of the input signal (or RMS). This ensures that the gain calibration of the system is accurate and avoids the principle measurement errors caused by the calibration method.

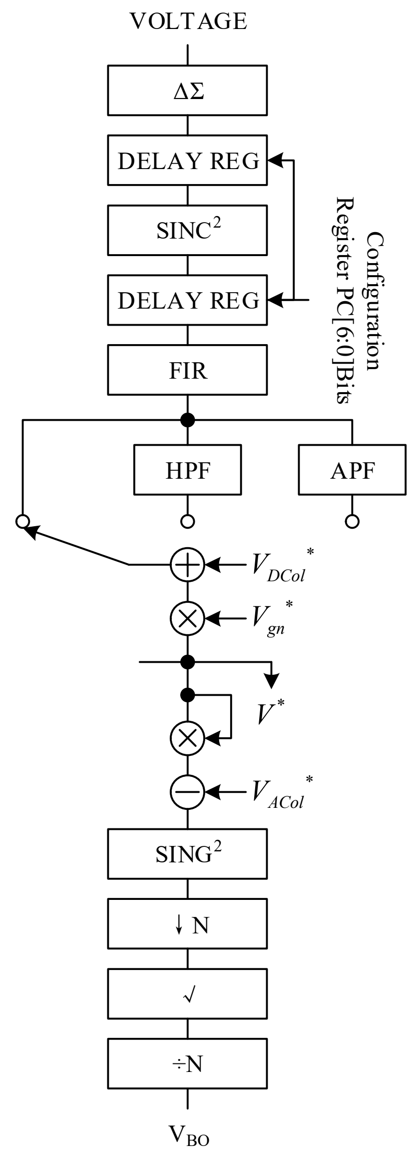


Fig. 2. The frame chart of signal processing channels

3.2.2. Data reading. Data reading time must be mastered in the AD conversion results to the next conversion results generated before the full use of the CS5460A INT pin interrupt function, the AD conversion results in a timely manner, such as not using the chip's interrupt function, in the middle of reading the conversion results of the data stream (the data is the output of the serial transmission), analogue-to-digital conversion results may be updated [24].

3.3. Data upload based on communication protocol IEC61850

3.3.1. Implementation process of the IEC 61850 standard:

1) Modelling of functions. In order to fulfil the requirements of communication, in particular the free distribution and assignment of functions, all functions are decomposed into logical nodes which are distributed in one or more physical devices. Since some communication data do not relate to any function, but only to the physical device itself, e.g. nameplate information, results of device self-tests, etc. For this reason, a special logical node LLN0 is introduced. The logical nodes are connected via a logical connection LC, which enables the exchange of proprietary data.

2) Modelling of data. The decomposition process of the application functions and information is

designed to obtain the majority of the common logical nodes. Firstly, according to the communication requirements of a certain application function of a substation that has been defined in IEC61850-5, the application function is decomposed into corresponding individuals, and then the requirement information contained in each individual is encapsulated in a group, and the information contained in each group represents a public group of specific meaning and can be reused, which is defined as the public data class CDC in IEC61850-7-3, and the information contained in each group is defined as the public data class CDC. CDC, the information contained in each group is defined as a data attribute in IEC 61850-7-3.

There are 30 types of public data defined in IEC61850-7-3 for representing information such as states, measurements, controllable states, controllable analogue quantities, state settings, and analogue settings.

The process of creating the information model is to build the device model using logical nodes, first using the defined public data classes, which belong to the specialised public data classes and each of which inherits the data attributes of the corresponding public data, the meanings of which are defined in IEC 61850-7-4. The required data are then combined to form a specific function of the substation automation system, and logical nodes can be repeated to describe public information for the same equipment of different structures and models.

3.3.2. IEC61850 server communication logic design. The server-side initialisation data is firstly to read the CID file directly, the purpose of reading the document is mainly to read the data model, the server-side has those logical devices, logical nodes, etc. The source of the CID configuration file is the communication pre-module, because the communication pre-module communicates directly with the lower intelligent device, only the communication pre-module has the data model and real-time data. After reading the configuration file start the TCP server waiting for the client to connect, the client connection in the initialisation of the MMS protocol, and finally through the previous implementation of the service interface, to get the server-side data model.

4. Analysis of simulation experiments

4.1. Power data reading results

4.1.1. Experimental preparation and design. The experiment prepares two power data packages, AIHRFAATAC and FGASGFHAH, respectively, and the size of the two power data packages is 1.26GB and 1.56GB, respectively, both of which contain seven kinds of power data, namely, voltage, current, capacitance, power, power, temperature, and power consumption, and the weights of each kind of data are the same, and the power data are derived from the annual power data of a certain area's distribution station in the years 2020 and 2021. The power data is derived from the power data of a regional distribution station for the whole year of 2020 and 2021. The real-time management platform of intelligent maintenance power box constructed in this paper is used to monitor the abnormal data. The two data packets are used to test the error auditing and HR performance of the automatic audit detection of power anomaly data, respectively, and the results of the anomaly data detection for the two data packets are shown in Fig. 3. In Fig. 3, 85 anomalous data of the AIHRFAATAC data packet, and 62 anomalous data of the FGASGFHAH data packet are detected in this experiment. In the two data packets, the number of samples before 137, the detection value is the same as the actual value, with the increase of the sample data, the number of abnormal data also increases, but the abnormal data is controlled within 15, and the correct rate is more than 80%.

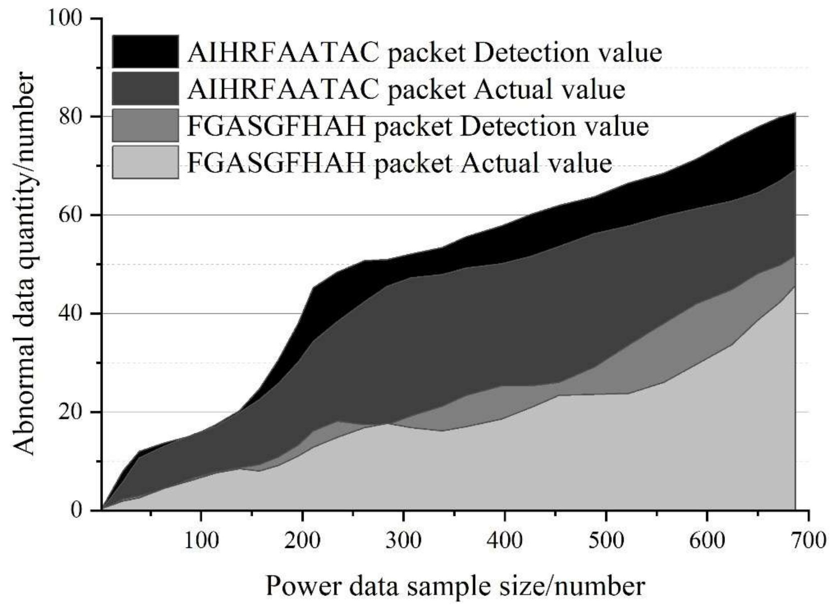


Fig. 3. Automatic detection of electrical abnormal data

4.1.2. Discussion of experimental results. The experiment selects the detection method based on data mining (IUFA) and the detection method based on isolated forest algorithm (FWKF) as a control, and the two methods are commonly used in reality. Using the AIHRFAATAC data package to test the error audit situation of the automatic audit detection method of power abnormal data, in this experiment the error audit is divided into two kinds, one is normal power data is detected as abnormal data, and the other is power abnormal data is detected as normal data, the experiment is on the AIHRFAATAC data package of the voltage, current, capacitance, power, power, temperature, power consumption of the seven kinds of power data error audit number statistics, each kind of data in the data packet are 100, the statistical results are shown in Table 1.

In Table 1, the total number of error audits of this paper's method for power anomaly data is 6, the total number of data samples is 800, and the ratio of error audits to the total number of data is 0.75%, the total number of error audits of IUFA for power anomaly data is 90, and the ratio of the total number of power data is 8.56%, and the total number of error audits of FWKF for power anomaly data is 111, and the ratio of the total number of power data of the data packet is 12.87%. The ratio is 12.87%. By comparing the experimental results, it is concluded that the number of error audits in this paper is less than that of IUFA and FWKF.Using FGASGFHAH data packet for automatic power anomaly data audit detection method HR performance test, HR is commonly used in audit detection to measure the recall rate of the evaluation index, also known as the hit rate, the higher the value is, the better the accuracy of the audit detection is proved, as shown in Equation (12):

$$HR = \frac{Number(F)}{GT} \tag{12}$$

Where HR represents the hit rate of automatic audit detection of power anomaly data, $Number(F)$ represents the sum of the number of detected anomalous data belonging to the experimental data set, and GT represents the number of anomalous data in the FGASGFHAH packet. 700 power data samples are included in the FGASGFHAH packet, and the audit detection under different sample numbers is statistically determined, and the HR value of the method in this paper is 97.37%, and the HR value of IUFA and FWKF is 57% and 64.27%, respectively, and the HR performance of this method is optimal. The HR values of IUFA and FWKF methods are 57.92% and 64.27% respectively, and the HR performance of this paper's method is optimal. Through the analysis of the above experimental results, it can be concluded that: under the application of the design method, the power anomaly data error audit detection is effectively reduced, the HR value is significantly improved, and the method of this paper has excellent performance for the automatic audit detection of power anomaly data.

Table 1. Automatic detection of electrical abnormal data

Data type	This method	IUFA	FWKF
Voltage data	2	13	18
Current data	1	15	17
Power data	0	11	16
Quantity data	0	13	15
Temperature data	1	14	14
Capacitance data	2	13	16
Power consumption data	1	12	17
Data sample size/Number	This method/%	IUFA/%	FWKF/%
100	99.4865	65.9885	76.5454
200	98.1677	63.4876	76.4881
300	98.6631	62.1568	74.6526
400	98.4845	61.9654	72.8548
500	98.5663	60.8978	70.5963
600	97.0846	59.9645	69.4888
700	97.3658	57.9156	64.2655

4.1.3. Normalised loads for abnormal power data. The six abnormal power data are numbered 1 to 6, and the load standardised curves of abnormal and normal power data are plotted. The standardised load curve of normal power data shows irregular jagged fluctuation from 8:00 to 24:00 hours, while the standardised load curve of abnormal power data fluctuates at different times with different amplitudes. Figure 4 shows the normalised load of abnormal power data, with different corresponding abnormal times for each anomaly; for example, the peak of anomaly 1 occurs at 14:00 with a peak value of 0.91.

Against the distribution time of abnormal values of power data, it can be seen that 11 February 2021 is the Chinese legal holiday Spring Festival, due to the special lifestyle different from the regular day caused by the special power data anomalies, the phenomenon is a normal use of electricity, is not anomalous power data caused by the power system failure, and no data correction is required. The experimental results show that the technology in this paper can not only detect and analyse the power data, but also combine with the actual situation to judge and improve the detection efficiency of equipment failure and abnormal causes of power consumption.

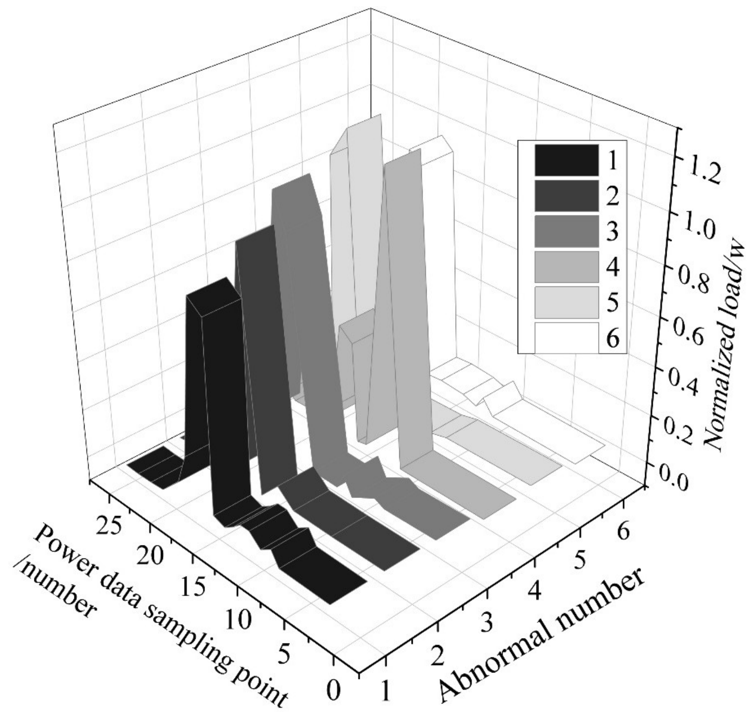


Fig. 4. Standardized load of abnormal power data

4.2. Transport protocol security analysis

4.2.1. Security analysis of transmission protocols. In order to analyse the performance of the proposed method for assessing the security of private information transmission under big data analytics in this paper, the simulation software environment used is Windows 10 operating system, Matlab 2015 toolkit, and 12 GB of RAM. The experimental data are taken from the dataset AIHRFAATAC. 40% of the information data are used as training samples, and the remaining 60% of the information data are used as test samples.

The network entropy is used to quantify the changes in the security performance of information transmission before and after reading the power data to obtain the subjective and objective weights of the security assessment indexes, combined with the principle of addition to integrate the subjective and objective weights into the comprehensive weight value of the security assessment indexes, and the unit of the value is set to g. The assessment results are shown in Fig. 5, and on this basis, the energy change curve of the attack on the electric power information attack is drawn based on the value of the attack energy, and the unit of the value of the energy is c, as shown in Fig. 6. c, as shown in Fig. 6.

Comparative analysis of Fig. 5 and Fig. 6 shows that the power information data transmission security threat assessment value range is between 100-200g. Using the information transmission security threat assessment value obtained in this paper is basically consistent with the trend of the information attack energy curve, which fluctuates around 1000c, indicating that the communication protocol IEC61850 used in this paper to assess the security of electric power information transmission, and the results obtained are more reasonable.

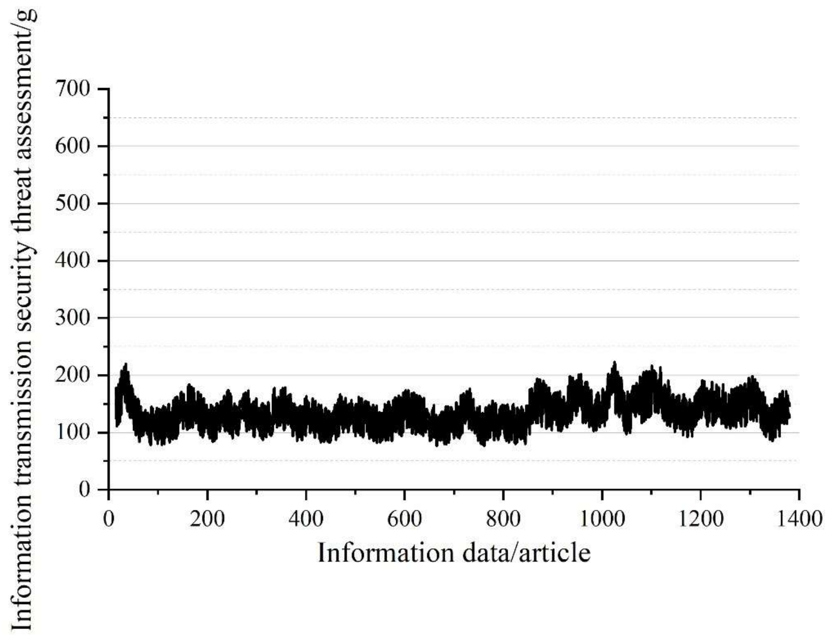


Fig. 5. Information data transfer safety assessment

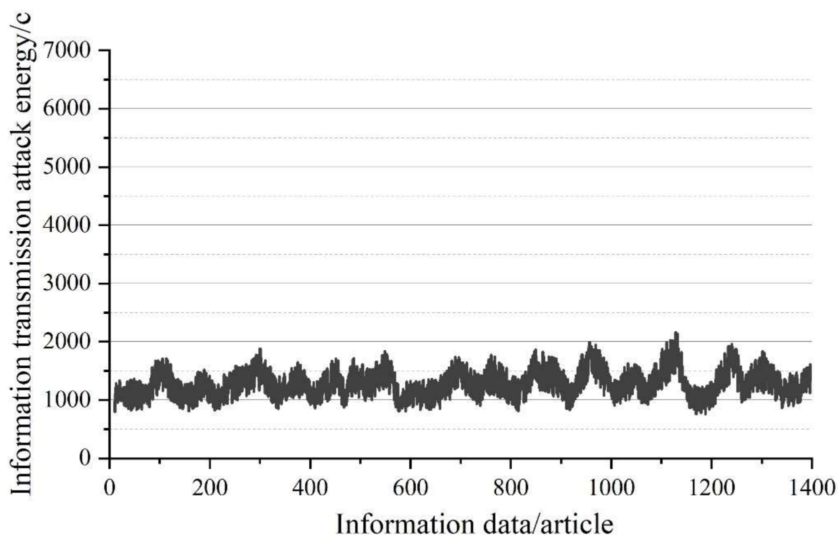
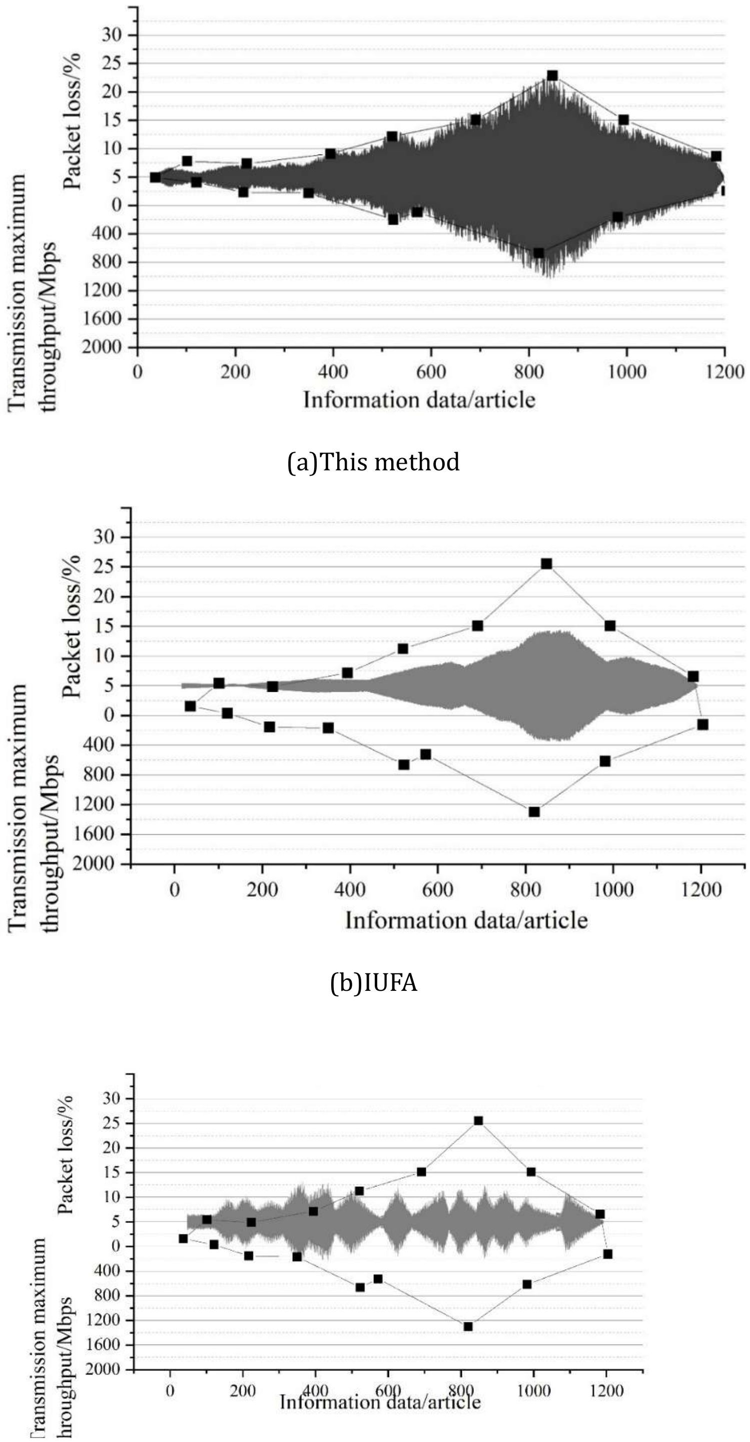


Fig. 6. Information transmission attack energy change

4.2.2. Security assessment. Fig. 7 shows the power information data transmission security assessment, and Figs. (a)-(c) show the method of this paper, the IUFA method, and the FWKF method, respectively.

By simulating the attack on the subject power data information and analysing the impact of virus attack on the security of power data information transmission, the changes in the information transmission packet loss rate (%) and maximum throughput (Mbps) are recorded in real time, and the evaluation results of the three different methods are compared with the actual results, and the coincidence of the curve changes is used to describe the evaluation accuracy of the different methods.

From Figs. (a)-(c), it can be seen that the evaluation results of the security assessment of power data information transmission using the methods of this paper are more consistent with the trend of the curve change of the actual results, and the estimation accuracy is higher in the actual packet loss rate in the interval of [5,22.5], while the IUFA method and the FWKF method have a larger difference from the actual results from the image. It is mainly because the mentioned methods evaluate the attack threat from the perspective of the defence side, and it is difficult to obtain the subjective and objective weights of the transmission packet loss rate and maximum throughput and other security evaluation indexes of electric power data information transmission, which leads to a large error between the evaluation results and the actual results.



(a)This method

(b)IUFA

(c)FWKF

Fig. 7. Electrical information data transfer safety assessment

5. Conclusion

In this paper, the data management platform and the intelligent circuit breaker in the power system are built respectively, and through the communication interface, the power data on the intelligent circuit breaker is obtained. Use the INT pin interrupt function of CS5460A to read the power related data. Construct the IEC61850 communication protocol to achieve the uploading of the read power data via the server. Design simulation experiments to analyse the results of power data reading using the method proposed in this paper and evaluate the security of the transmission protocol. For two packets of data reading, the detection value is the same as the actual value until 137 sample data, and then the abnormal data is controlled within 15, and the correct rate is kept above 80%. The accuracy of this paper's method for audit detection of anomalous data reaches 97.37%, and the accuracy of the two compared methods is only 57.92% and 64.27%, which gives the best performance of this paper's method. Using the communication protocol IEC61850 to assess the security of power information transmission, the security threat assessment value of power information data transmission is between 100-200g, which is in the lower threat area, and the results obtained are more reasonable.

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