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Research and Application of Power Monitoring System Based on Internet of Things

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Abstract. IoT technology is widely used in various fields because of its ability to intelligently process data. The operation of power facilities is closely related to human development. Real-time monitoring of the working conditions of power equipment is conducive to timely handling of faults and greatly reduces unnecessary accidents. This article mainly designs a software monitoring platform based on the Internet of Things framework to realize data collection and processing, wireless transmission, real-time monitoring, fault alarm. In order to improve the accuracy and stability of data processing, this article applies the unscented Kalman filter algorithm to the data processing link. The visualization function of the software monitoring platform can visually present real-time data and historical trends of power equipment in the form of charts and curves providing a user-friendly interface and operating experience. Finally, the functional test was completed on the monitoring platform, which can be used in fields such as power system working status monitoring and power equipment environment monitoring.

Keywords. IoT technology, electric equipment, surveillance system, UKF

1. Introduction

With the development of science and technology, Internet of Things technology has been widely used. The Internet of Things includes a three-layer structure, namely the perception layer, the network layer, and the application layer[1]. The realization of the Internet of Things technology first needs to realize the collection of object information through the terminal collection equipment, and then send the collected data to the upper layer equipment through the wireless network to realize the integration of data. Based on the huge underlying information collection terminal, the Internet of Things can form a Highly intelligent and integrated network. Finally, the status monitoring and intelligent control of the object are completed through the software platform of the host computer[2].

People's work and life are inseparable from the use of electricity. People have put forward higher requirements for the predictability and security of power systems[3]. Since power facilities usually consist of a large number of complex equipment and

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involve dangerous factors such as high voltage, high temperature, and large current, they are hazardous equipment[4]. There are potential failures and safety hazards in power equipment. Monitoring and maintenance personnel need to take special safety measures and equipment to maintain the system. The monitoring and maintenance of power systems have become a major problem that consumes human and financial resources[5]. For this reason, my country's research on integrated monitoring of power systems has never stopped.

In order to solve the above problems, this paper studies a method of applying Internet of Things technology to the power monitoring system to achieve remote monitoring of power equipment, reduce capital investment and accident risks, and integrate the unscented Kalman filter algorithm into the power monitoring system The software platform enables accurate processing and analysis of power data and provides strong support for the monitoring and maintenance of the power system[6]. The monitoring platform studied in this paper can well solve the problems of high power system maintenance costs and untimely fault detection[7].

2. Overall design of power monitoring system

In the power monitoring system based on the Internet of Things technology studied in this paper, the combination of C/S architecture and the three-tier architecture of the Internet of Things is adopted[8]. The system consists of four parts: information collection terminal, database, wireless transmission network, and power monitoring software platform.

The perception layer is responsible for completing the collection and transmission of data and sending the data to the host computer. Wireless transmission of network layer data is the prerequisite for realizing remote monitoring functions. The application layer implements terminal data processing through the monitoring system, such as data integration, filtering, visualization.[9]

The monitoring system platform is built using the Visual Studio 2017 development environment, and the database is built using SQL Server Management Studio 2012. The overall structure block diagram of the power monitoring system is shown in Figure 1.

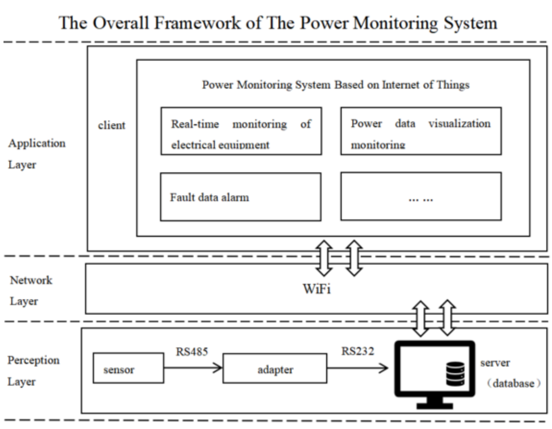

Figure 1. IoT three-tier architecture.

2.1. Power data collection and transmission

The perception layer of the Internet of Things is built based on the information collection terminal equipment of the sensor. The sensor sends the collected data to the server through the serial port. The data is received through the serial port APP based on the ModBus-RTU. The design diagram for hardware device connection is shown in Figure 2.

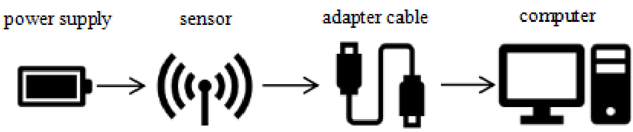

Figure 2. Hardware device connection design diagram.

2.2. Design of wireless transmission based on database

Wireless transmission is implemented using WiFi technology, and the wireless transmission function of data is realized through the database. The data collected by the sensor are classified and stored in the database in the server through the serial port program. The schematic diagram of wireless transmission is shown in Figure 3.

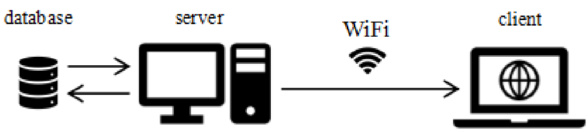

Figure 3. Schematic diagram of wireless transmission.

2.3. Data processing based on unscented Kalman filter algorithm

During the transmission process, data information will be affected by various factors such as sensors. Due to the presence of these interferences, the actual data content sent to the server will be incomplete and inaccurate. Therefore, after the server collects all the data, it needs to filter the data in the data preprocessing stage, monitor bad data and remove it. Considering that the power system is a nonlinear system, we introduced the unscented Kalman filter algorithm as Core methods of data processing[10].

The unscented Kalman filter algorithm uses an approximation method, using probability density to approximate nonlinear functions[11]. Because the power system is nonlinear, its state equation and measurement equation are also nonlinear. Construct a sigma point set $\{\xi_i\}$ through the sampling plan, and calculate the weights W_i^m and W_i^c of the corresponding sigma points, which can be expressed by the following formula:

$$x_k = f\left(x_{k-1}\right) + q_{k-1} \tag{1}$$

$$y_k = h\left(x_k\right) + r_k \tag{2}$$

$$\overline{x} = \sum_{i=1}^{L} W_i^m \xi_i \tag{3}$$

$$P_x = \sum_{i=1}^{L} W_i^c \left(\xi_i - \overline{x}\right)\left(\xi_i - \overline{x}\right)^T \tag{4}$$

In the prediction step, based on the state quantity x_{k-1} and covariance P_{k-1} at time $k-1$, the Sigma point set $\{\xi_{i,k-1}\}$ is constructed according to the selected sampling plan to obtain the statistics at time k.

$$\overline{x}_{k|k-1} = \sum_{i=1}^{L} W_i^m \xi_{i,k|k-1} \tag{5}$$

$$P_{k|k-1} = \sum_{i=1}^{L} W_i^c [\xi_{i,k|k-1} - \tilde{x}_{k|k-1}][\xi_{i,k|k-1} - \tilde{x}_{k|k-1}]^T \tag{6}$$

$$\overline{y}_{k1k-1} = \sum_{i=1}^{L} W_i^m y_{i,k} \tag{7}$$

$$S_k = \sum_{i=0}^{2n} W_i^c (y_{i,k} - \overline{y}_{k|k-1})(y_{i,k} - \overline{y}_{k|k-1})^T \tag{8}$$

$$C_k = \sum_{i=0}^{2n} W_i^c (\xi_{i,k|k-1} - \overline{x}_{k|k-1})(y_{i,k} - \overline{y}_{k|})^T \tag{9}$$

In the update step, sensor measurements and observation models are used to revise the predicted state. By comparing the predicted state with the actual measurements, the Kalman gain K is calculated, which is used to adjust the predicted state estimate x_k and covariance estimate P_k.

$$K_k = C_k S_k^{-1} \tag{10}$$

$$x_k = K_k (y_k - \overline{y}_{k|k-1}) + \overline{x}_{k|k-1} \tag{11}$$

$$P_k = -K_k S_k K_k^T + P_{k|k-1} \tag{12}$$

By applying the above algorithms, combined with specific data from the power monitoring system, preprocessing, noise filtering and state estimation of power data can be achieved, thereby improving data processing capabilities and the accuracy of analysis results.

2.4. Monitoring software platform design

The Internet of Things application layer is the power system monitoring platform mainly designed in this article. The monitoring platform completes data transmission by accessing the database, and can realize functions such as real-time monitoring of electrical equipment, visual display, abnormal situation alarms, and fault data display.

For the sake of software platform security, a user login interface design is also required. The following will conduct specific interface design analysis and functional design analysis based on these functions to form a complete technical route. The schematic diagram of the software function design is shown in Figure 4.

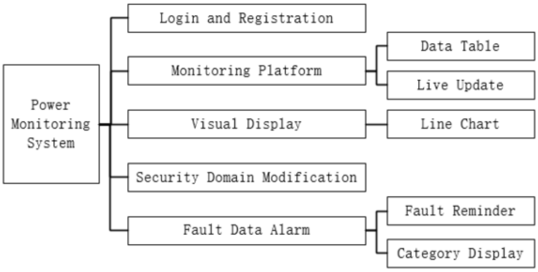

Figure 4. Monitoring software function design.

3. System hardware design

The hardware design of the power monitoring system will be introduced below focusing on the following two aspects. The first is to collect monitoring data from the sensor terminal, and the second is to complete data transmission based on the ModBus-RTU.

3.1. Sensors collect data

The construction of the IoT perception layer is achieved by collecting power and environmental data through sensors. The actual hardware connections are shown in Figure 5.

Figure 5. Sensor hardware connection.

The sensor used in this article uses RS485 communication interface and standard ModBus-RTU communication protocol. The sensor also has a protection function against incorrect operation, such as reverse power connection, to prevent equipment damage caused by reverse power connection.

3.2. Data transmission based on ModBus-RTU

In the standard ModBus-RTU communication using the RS485 communication interface[12], the host computer sends an inquiry frame first, and the slave machine processes and replies to the response frame after receiving the command, during which it is half-duplex communication. Therefore, there is a fixed query command for the sensor, and this query command is applied to the serial port software programming in the data transmission process to realize real-time data collection.

The sensor data transmission software designed in this article consists of three parts: serial port configuration, query command sending, and received data display. Through this software, you can send query frames to the sensor and receive response frames from the sensor. Finally, the received data is displayed on the interface, and the response frame is converted into actual data for display. The data transmission situation is shown in Figure 6.

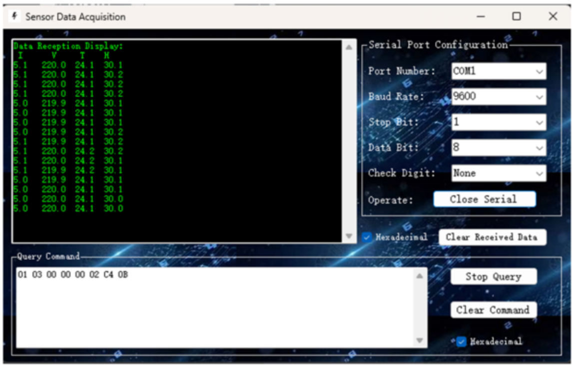

Figure 6. Sensor data transmission software.

In order to meet the needs of long-distance and large-scale data storage, the software will also classify and store the data into the data table of the SQL database while collecting and displaying the data. The data table contains various information involved in the monitoring system, realizes data integration, and forms a data network of the power system. The database serves as an intermediary for data transmission and realizes wireless transmission of data through WiFi.

4. Software monitoring platform design

Monitoring software platform design includes four aspects: function, interface, visualization and fault alarm design of the power monitoring system.

4.1. System function settings

The power monitoring system software platform mainly has four major functions: real-time monitoring, fault monitoring settings, visual display and fault alarm.

First, real-time monitoring is applied to the main interface and visual interface. The monitoring system uses tables and polylines to display data, and the data can be dynamically updated in real time. Real-time data update is the prerequisite for timely detection of power system faults.

Second, the monitoring system also provides users with a modifiable security domain, which can be adjusted independently according to the type of power equipment that the user needs to monitor to meet the application in multiple scenarios.

Third, Visual display is applied to the main interface and secondary monitoring interface. Equipment information is displayed on the interface in the form of charts, which facilitates users to intuitively discover problems and handle them in a timely manner.

Finally, fault alarm is implemented in the form of a pop-up window. When the data exceeds the safety threshold, such as overload, ambient temperature is too high, the software will pop up an alarm pop-up window to remind the user to inspect the electrical equipment to prevent major accidents.

4.2. System interface design

The interface design of the power monitoring system software platform is divided into two aspects, the login interface and the main interface.

In order to improve the security of the platform, login verification and registration functions are set up to satisfy security while enhancing practicality. User information is stored in the database, and user screening is implemented through data processing. The login registration interface is shown in Figure 7.

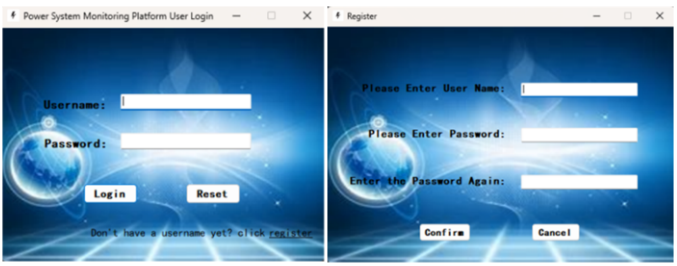

Figure 7. Login and registration interface.

The main interface displays all functions of the software platform. In order to satisfy the aesthetics, a menu bar and secondary interface are provided. The main interface is shown in Figure 8.

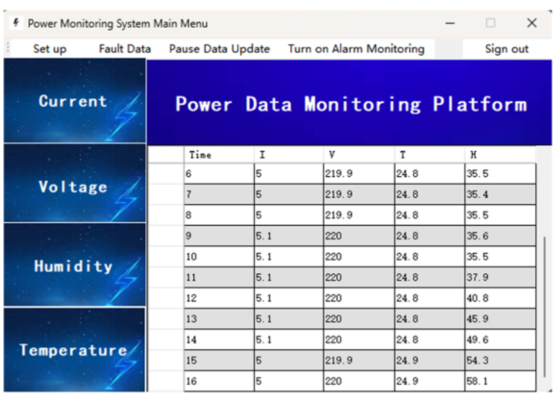

Figure 8. Main interface.

4.3. Visualization design

The secondary visualization interface uses line charts to visually display trends and changes in data. When there are outliers in the data, it helps observers quickly discover anomalies. The visual display interface is shown in Figure 9.

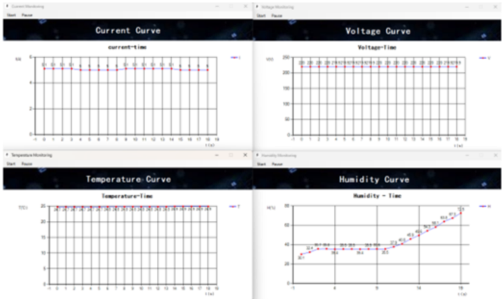

Figure 9. Visual display interface.

4.4. Alarm display design

The monitoring system provides alarm functions for abnormal situations, and sets alarm pop-up windows and fault data display interfaces. In order to meet more use places, fault monitoring settings have been added. The interface design is shown in Figure 10.

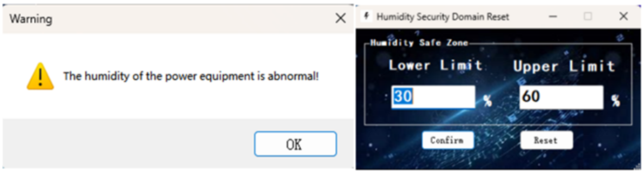

Figure 10. Alarm prompts and fault monitoring settings.

The fault data display interface is convenient for the user to enter this interface to view the fault data after receiving the alarm prompt. The fault data viewing interface design is shown in Figure 11.

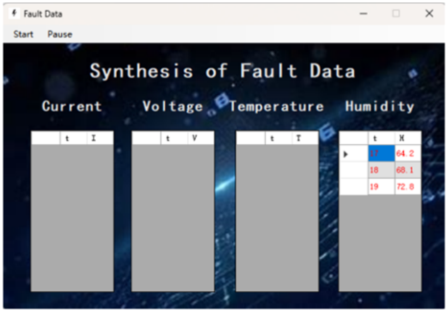

Figure 11. Fault data viewing interface.

5. Monitoring system function test

To verify its reliability and functional. Functional testing includes two aspects. The first is the real-time nature of power data display, which can show dynamic changes. On the other hand, software can filter out abnormal data and issue alerts for faulty data types.

5.1. Monitoring function test

After completing the connection of the hardware device, turn on the power of the sensor, open the software platform of the power monitoring system, and you can see the continuous update of the data on the main interface. The monitoring status of the software platform is shown in Figure 12.

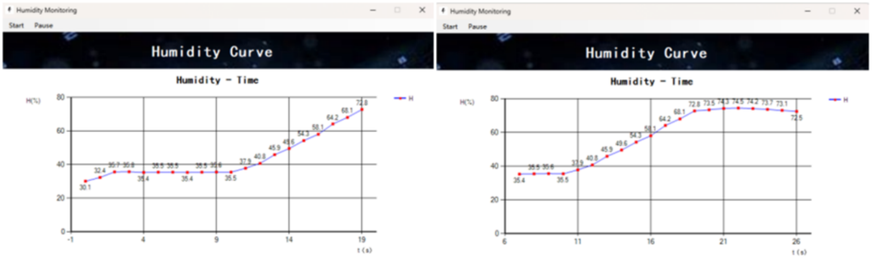

Figure 12. Data dynamic monitoring.

The pictures above are screenshots of the same interface at 19s and 26s respectively. It can be seen from the above pictures that the monitoring system can realize the visual display of real-time data. The specific changes in the data 14s-25s are shown in the table below:

Table 1. Specific changes in humidity data from 14s to 25s

	14	15	16	17	18	19	20	21	22	23	24	25
left	49.6	54.3	58.1	64.2	68.1	72.8	-	-	-	-	-	-
right	49.6	54.3	58.1	64.2	68.1	72.8	73.5	74.3	74.5	74.2	73.7	73.1

5.2. Fault alarm function test

Use changes in sensor data to detect whether the software platform is able to detect data that exceeds normal thresholds. Here we take humidity as an example to conduct alarm testing. By increasing the ambient humidity, the humidity of the sensor increases sharply and exceeds the safety threshold. The fault alarm and fault data display is shown in Figure 13.

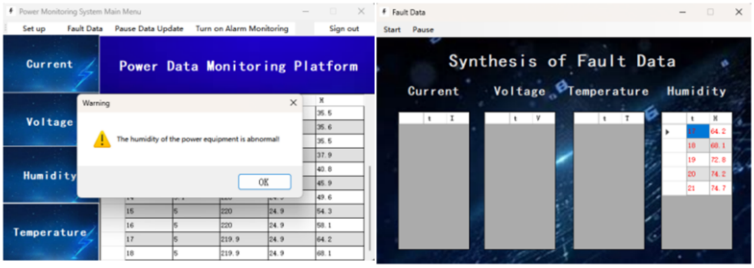

Figure 13. Fault alarm and fault data.

When ambient humidity poses hidden dangers to the operation of power equipment, the monitoring platform will alarm for humidity data and the fault data display interface will display abnormal humidity values. Monitoring this data effectively reduces the possibility of power short circuit due to high humidity and ensures the safe operation of power equipment.

By testing the power monitoring system software platform, real-time monitoring can be achieved, and alarm prompts for dangerous data can be realized, completing the expected goals of the software function.

6. Conclusion

This article designs a complete power monitoring system. Based on the ModBus-RTU communication protocol, the sensor data transmission design is completed, the database construction is completed based on SQL, and the data processing is implemented based on the unscented Kalman filter algorithm. The monitoring platform can realize real-time data monitoring, visual display, fault alarm and other functions to meet users' centralized monitoring of remote equipment. The system includes the interaction between hardware and software. Finally, the monitoring system is tested and verified as a whole. The monitoring platform can complete the expected functions.

The system integrates multiple key technologies into a complete solution. It can realize functions such as real-time data monitoring, visual display and fault alarm to meet users' centralized monitoring needs for remote equipment. It can be applied to power companies, operation and maintenance teams, safety and regulatory agencies and other departments to improve the stability and reliability of the power grid. Reduce the risk of power outages, provide better response and fault handling capabilities, and have a wide range of application scenarios.

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