Research and Development of An On-line Electric Energy Data Acquisition and Monitoring System

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Abstract: In view of the existence of manual meter reading various drawbacks, and achieving the remote monitoring, analysis and management of energy consumption, we present a practical application system: An Online Electric Energy Data Acquisition and Monitoring System. The system consists of intelligent data acquisition terminal and management platform. The intelligent data acquisition terminal gets data through Power Line Carrier or RS-485 from electric energy meter which is named downlink communication and uplink communication with the remote management platform by GPRS channel. Downlink communication uses "DL/T645-2007Multi-function watt-hour meter communication protocol", and uplink communication protocol is the "Q/GDW1376.1—2012 power user electric energy data acquisition system communication protocol". Both of the two protocols are in line with national standards which can ensure a good compatibility with electric energy meter product by different companies. To ensure high real time performance, a strictly time control mechanism for per meter reading and dynamic data storage management mode have been designed. Besides, a reasonable reconnection mechanism and an heartbeat frame between acquisition terminal and management platform is necessary to achieve high on-line performance.

Key Words: Power energy monitoring; On-line acquisition; Power Line Carrier; RS-485; GPRS;

1 Instructions

Information management of energy resources metering is an important part of the work in energy resources metering. By using modern network technology and wireless sensor one, for key energy-consuming industries, energy-using units and public institutions, online monitoring and management of electric energy metering data can be implemented and the electricity metering data can be timely and accurately reported to the management departments at all levels, which can guide energy-consuming enterprises to evaluate and conduct energy-saving management. In recent 20 years, with the development of communication technology and network communication technology, according to the cost of network communication in different areas, wireless data transmission methods, such as ADSL, LAN, GPRS/CDMA and the like, can be flexibly adopted to construct the energy monitoring system [1~4]. The energy data acquisition terminal/energy data gateway can support at the same time for the data collection of the metering devices for different energy using, including watt-hour meter, water meter, gas meter, heat meter, etc. There are many communication modes from the metering device to the energy data gateway, mainly including RS-485 wire mode, the way of power line carrier and Zigbee wireless mode [5~9]. Different from most of electric energy data acquisition system mainly used for metering and charging, the system is used for both the power energy monitoring and the on-line acquisition. So a high real time performance is an important feature for the system. This paper presents the design and implementation method of the electricity data real-time acquisition and monitoring system based on GPRS and power line carrier.

2 The structure and composition of the system

The hierarchical network is made up of electric energy meters, intelligent data acquisition terminals and remote management platform.These electric energy meters are responsible for measuring the energy data and sending the

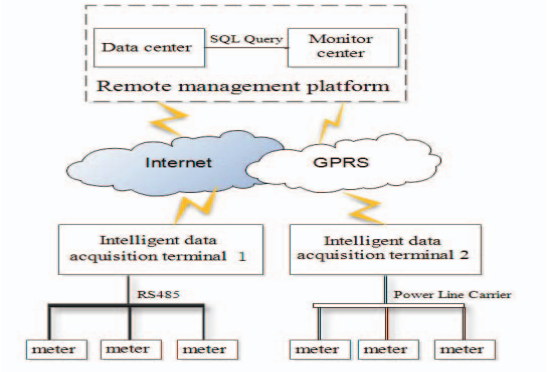

Fig.1 System composition block diagram

data to the acquisition terminals by RS-485 or Power Line Carrier channel, while the intelligent data acquisition terminals is set for sending the data which is collected from the electric energy to the remote management platform by GPRS channel. The remote management platform achieves the remote monitoring, save, analysis and management of energy data.

The intelligent data acquisition terminalis composed of online Data Acquisitionmodule (including RS-485 Module and Power Line Carrier Module), Microcontroller system,GPRS DTU and Human-machine interface, as is shown in Fig 2. The online Data Acquisition module which uses both RSM3485ECHT made by ZHIYUAN Electronic

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and Power Line Carrier made by East Soft as the downlink communication interface is responsible for data acquisition and control of Electric Energy meter. Using a Human-machine interface made up of button and LCD (liquid crystal display) is to meet the needs of site management and setting.GPRS DTU implements the transmission of the remote signals by GPRS network. Microcontroller system is made up of STM32 controller ,clock circuit and reset circuit. It is used to read the data of the electric energy from data acquisition module and exchange the data with the remote management platform by GPRS DTU. STM32 MCU is connected to RSM3485ECHT, Power Line Carrier and GPRS DTU respectively through serial port.

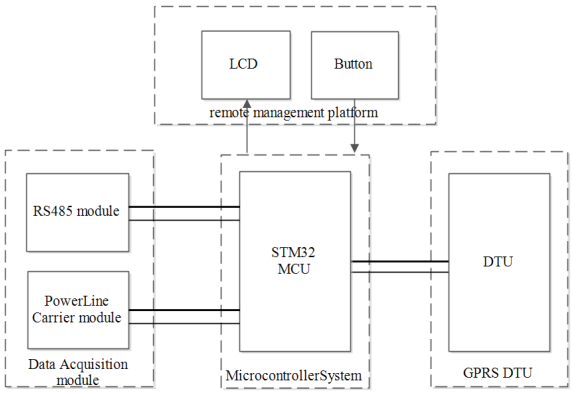

Fig.2 Components of the hardware of the intelligent data acquisition terminal

3 The soft design of the system

As an online electric energy data acquisition and Monitoring system, real time performance is an important indicator. The application of real time operating system is a common method to ensure the real-time performance, but it means larger amount of code and greater RAM costs. In this system, we can control multiple tasks without using real-time operating system. On the one hand, the system used STM32F103ZET6 without enough flash and RAM for operating system transplantation, which means additional memory chips cost. On the other hand, using a method similar to “Time-Round-Robin” can meet the requirements of design. For this method, using the design with timing interrupt interval is to ensure the real-time performance, and each functional module is designed as a task, and manages multi-tasking by "taking care" of all tasks in a timely manner, as is shown in Fig 3.

As is illustrated in Fig 3, on the left is the main program, only arranging the Protocol analysis tasks, and the right is the timer interrupt subroutine, arranging for all other tasks. These tasks include adjusting clock task, data collection task, LCD display task, RTC task, key management task and GPRS connect task. In our application, the clock task provides a time basis for the system so that each task can run at the specified tempo. Data collection task used to timing acquisition data of electric energy meter and acquisition frequency is adjustable. LCD display task and key management task is used for site management and parameter settings. RTC task is the source of time information of the intelligent data acquisition terminal. The GPRS connect task ensures the acquisition terminal always online and can implement automatic reconnection when the connection between terminal and the master station is disconnected . All tasks are placed in the regular monitoring cycle to "take care"so that each task is in real time "take care" , how the system "looks after" the various tasks is a critical issue. We set the 50ms timer interrupt and after testing we know that the time spends of running every task is less than timing interval which can meet real-time needs. Intelligent data acquisition terminal as the data transfer station between energy meter and the master station, it contains the uplink and downlink sets of communication protocols, so protocol analysis task is the most important task, and it has two main functions:1.Analyzing the uplink and downlink communication protocol, the terminal receives data packets from serial port and performs the appropriate action according to the contents of the data packet. 2.Completing the conversion of uplink and downlink communication protocols, the packet format between upstream and downstream is different. So before sending data packets to remote management platform by GPRS channel , we need to make some conversion.

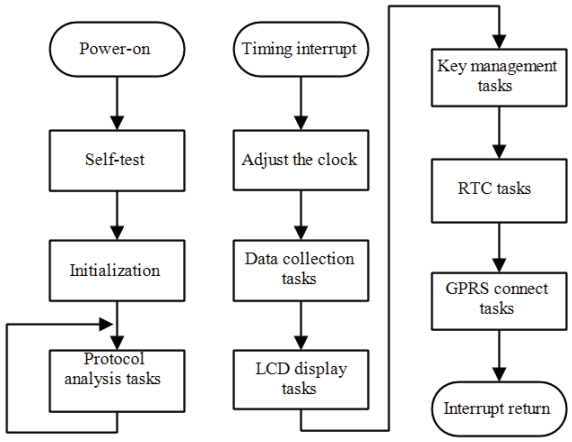

Fig.3 Block diagram of system monitoring and timer interrupt program

3.1 Downlink communication protocol

Downlink communication with RS-485 module and Power Line Carrier module is used as a hardware interface in order to meet different on-site needs. Power Line Carrier can use existing power lines carrier wave by way of analog or digital signals for high-speed transmission, but the power distribution transformer and switch has the barrier function to the power carrier signal. In addition, there are other shortcomings which limit the application range of power line carrier. Although RS-485 requires additional wiring, but the performance of transmission distance and Anti-interference ability is enough for system design.RS-485 is suitable for relatively concentrated energy meters on-site. The "DL/T645-2007 Multi-function watt-hour meter communication protocol" as a communication protocol for downlink. The protocol compiled with People's Republic of China electric power

industry standard. Through the communication protocol, we can realize the control and data reading of the electric energy meter in the power network , the general format for data frames is shown in Fig 4.

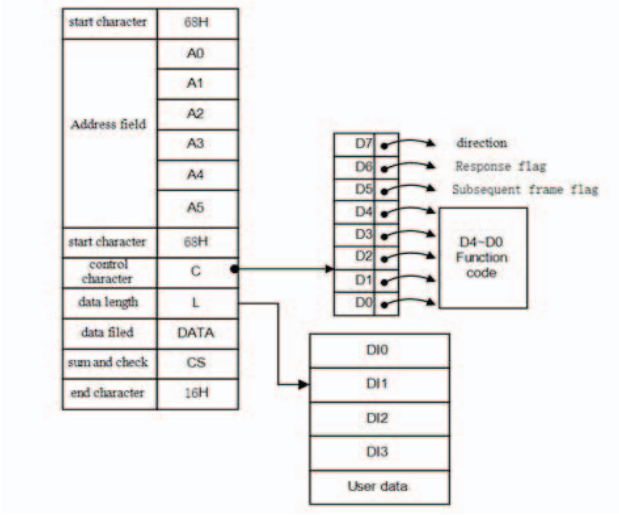

Fig.4 the general format of data frames for downlink communication protocol

In Fig 4, The data frame is composed of 7 parts: start character, address filed, control character, data length, data filed, sum and check code and end character. The start character, data length, sum and check code and end character are used for checking error code that appears in the transmission process. The terminal communicate accurately with every electric energy meter according to address filed. The control character contains transmission direction, transmission status, function code and other information. The data filed consists of two parts: Data representation and user data. There are 4 byte in data representation which determine the contents of the data to be written or read. By changing data representation, we can obtain different energy data, such as apparent power, apparent energy, apparent demand, combination active energy load profile, power factor and so on. User data filed contains the data requested.

A reasonable communication protocol is necessary for communication accuracy. In addition, through the meter reading time control, the meter file management can ensure the real time performance. Form the test, we know reading one kind of data costs 50ms at least, but not more than 2s in the baud rate of 2400bps. So when the acquisition terminal sends the meter reading instruction, the timer begins to time at the same time. If the acquisition terminal does not receive answer back after 2s, the meter address would be recorded, and the acquisition terminal stops reading this meter After all meters in the file have completed the collection, the terminal will read meters in the record again. In this way, the system could ensure real time and not miss any meters.

3.2 Uplink communication protocol

Uplink communication use GPRS channel for remote data exchange. The remote transmission function is implemented by GPRS DTU. GPRS DTU is a device for conversion between serial data and IP packet. It has the PPP dial-up and TCP/IP protocol encapsulated in GPRS DTU, enabling transparent transmission between serial devices and remote computers. A problem should be solved when using GPRS: by using GPRS channel, if the master and the terminal disconnect the link, the terminal needs to send a login request, and only in this way could the link re-connect. So a reasonable reconnection mechanism is necessary for on-line electric energy data acquisition and monitoring syst -em. In our system, we design this method: After the system powered up, the terminal connects to the master station and sends login frame, and then the terminal waits for confirm frame , if receiving confirm frame, the terminal begins to send heartbeat (The transmission frequency is adjustable), else the terminal connect to the master station and send login frame again, after sending heartbeat, the same as before, the terminal waiting for confirm frame, if receive it, the terminal send heartbeat in a common transmission frequency cyclically, otherwise, send three times consecutive heartbeats with an interval of 10 seconds, if one of this three heartbeats has been answered, the terminal sends heart beat in a common transmission frequency cyclically, if not, the terminal connects to the master station, as is shown in Fig 5. The method can ensure acquisition terminal always on-line. It's also a premise of real time.

The "Q/GDW1376.1—2012 power user electric energy data acquisition system communication protocol Part1: master station communication with data acquire terminal" as a communication protocol for uplink. The protocol compiled with People's Republic of China electric power industry standard. Through the communication protocol, we can realize the control and data reading of the intelligent data acquisition terminal by remote management platform, the general format for data frames is shown in Fig 6.

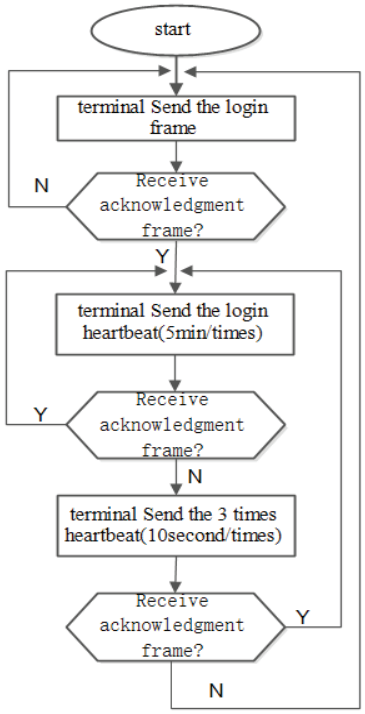

Fig.5 the program block diagram of the terminal connected to the master station

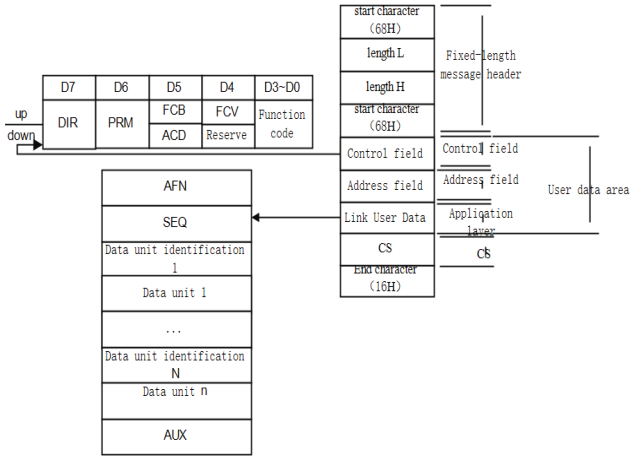

Fig.6 the general format of data frames for uplink communication protocol

As is illustrated in Fig 6, similarly, the data frame is composed of 7 parts: start character, address filed, control filed, data length, link use data, sum and check code and end character. The start character, data length, sum and check code and end character are used for checking error code that appears in the transmission process. The master station accurately combines with every data acquisition terminal according to the site address. The control character contains transmission direction (DIR), frame count bit (FCB), the frame count valid bit (FCV), function code and other information. The link use data filed consists of 4 parts: application layer function code (AFN), data unit, frame sequence domain (SEQ) and data identification. Both AFN and data identification determine the content for data exchanging. Data unit contains specific data information content.

Whether uplink communication or downlink communication, we have been complied with the protocol strictly. For that, we can achieve a reliable communication results and a strong error correction capability.

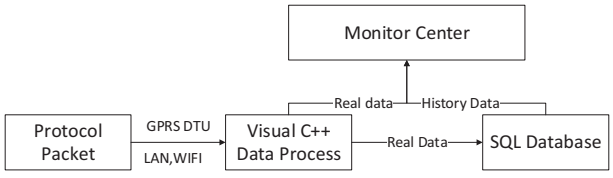

Fig.7 Architecture of remote management platform

4 Remote management platform

4.1 Data Sending

As is illustrated in Fig 7, the remote management computer receives the protocol packet which contains the value of all relevant electric energy meters. For easy operation, these data are converted to standard electrical protocol data and transmited with TCP/IP. The network service procedure listens in IP packets on assigned port, and sends the data with GPRS, LAN or WIFI.

4.2 Data Process Procedure

The data process procedure, implemented by Visual C++, is responsible for receiving standard protocol data from GPRS DTU, LAN or WIFI. Visual C++ must parse the order of DTU data before using. The obtained data is stored into database and displayed in the monitoring datacenter. In this way, the data can be stored into SQL database immediately in procedure cycle, and is displayed in a constant speed in consumer cycle.

4.3 Storage and displayed of the data

Visual C++ connects SQL database via ODBC interface. In order to improve the performance of displaying the data in database, the indices should be built up in constant time to avoid query in Visual C++. Meanwhile, the data should be not only displayed in real time, but also achieved for the purpose of historical inquiry and abnormal alarm.

5 Conclusion

This system combines the communication technologies of Power Line Carrier, RS-485 and GPRS to set up a complete online power energy monitoring system. In the field of power energy quality monitoring in our system, two different meter reading ways of Power Line Carrier and RS-485 can be selected to achieve the goals of power energy quality data collection and its remote transmission.The Power Line Carrier transmit information based on the power line network without additional lines, for that, it's widely used in power energy acquisition area, but there are some shortages: Serious signal attenuation , Significant noise and unstable reactance [10~11]. In these situations, the RS-485 meter reading way can be used to replace the way of Power Line Carrier. RS-485 way is best suited for the many centralized meters reading in the power distribution room of every energy consumption enterprises. The system is performing in the national center for urban energy metering (Jiangxi), which has been accessed nearly one thousand power meters of 10 energy consumption enterprises. Operating tests show that the system runs stably, and the meters reading correctness can meets the needs of the electric energy measurement and management.

6 Acknowledgments

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