IOP Conf. Series: Materials Science and Engineering 466 (2018) 012076 doi:10.1088/1757-899X/466/1/012076

Design of Intelligent Power Terminal System Based on Family Heterogeneous Network

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Abstract. In order to achieve intelligent control of electrical equipment and save electricity, in this paper, we design an intelligent power terminal system based on family heterogeneous networks. Firstly, it exploits the function of intelligent power terminal system for protocol design, which is compatible with WirelessHART protocol, PLC communication and Ethernet communication. Then the hardware and software design of the system are described in detail. Finally, we verify the effectiveness of the proposed scheme through the simulations.

1. Introduction

The power grid generally refers to the whole of the substation and the transmission and distribution line except for the power generation side. The smart grid is based on the physical grid and integrates modern advanced sensor measurement technology, communication technology, information technology, computer technology and control technology with the physical grid to form a new power grid[1].

In the future smart grid architecture, flexible intelligent power management will become an important part of it. In terms of electricity consumption, the important goal of the smart grid is to encourage and promote users to participate in their own operations and management, and to achieve user interaction[2-3]. Therefore, the study of reasonable and efficient intelligent electricity use methods is conducive to the rational use of power resources and energy conservation and emission reduction.

The literature[4] improved the k-means algorithm, which can accurately and efficiently mine the potentially useful information of the massive data of intelligent power consumption, and will provide favorable guidance for the relevant departments to formulate the optimal power consumption strategy and carry out the ladder pricing. The study in [5] designed a smart power terminal with DSP as the processing core, which can realize advanced power detection and remote power control for power equipment in municipal, commercial and residential buildings under the smart grid. The study in [6] proposes a stable and adaptive DR system architecture that can balance the dynamic demand of the grid with the dynamic will of the user and the balance between the power company and the user.

However, the above several methods are used for power grid companies or national departments to set electricity prices or macro-control, rather than for the users themselves to achieve smart power, thereby achieving the purpose of saving electricity. This paper designs a smart power terminal system based on home heterogeneous network[7], which is a heterogeneous network terminal system compatible with WirelessHART self-sufficient network, PLC communication and Ethernet communication, which can realize intelligent control terminal. (such as intelligent control of household appliances) and remote manual control functions. Finally, the feasibility of the system is verified by experiments, and the development direction of intelligent household appliances in heterogeneous network environment is discussed.

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2. Design of System software and hardware

The intelligent power terminal system is a device that integrates various home communication network technologies and sensor technologies to realize intelligent control of household appliances and energy conservation by acquiring and analyzing various factors of the surrounding environment. This paper designs a smart power terminal system based on WirelessHART and PLC for home heterogeneous network, which can realize intelligent control of home appliances, thereby realizing the function of saving electricity.

2.1 System Design Objectives and Principles

2.1.1 System Design Objectives. The main purpose of this system is to realize a smart power terminal system compatible with WirelessHART protocol and PLC technology, so the design function objectives of this system are as follows:

1) Support WirelessHART network. The WirelessHART network can be interconnected with the existing research results of the lab, the smart meter that supports the WirelessHART network, to control the meter system and obtain metering information.

2) Support PLC equipment, and form PLC interconnection equipment into a network to realize information exchange within the network.

3) Support the human body sensing probe as a sensor device to obtain information in the surrounding environment.

4) Support Ethernet network, so that intelligent Internet terminals can remotely access the system, support server-side charts to display terminal information, and support server control terminals.

5) Support the system's control of external appliances.

2.1.2 System Design Principles. To make the system work stably and reliably for a long time, certain principles must be followed in the design process. These design principles are:

1) Reliability: The reliability of the system means that the system can not only work in a normal environment, but also accurately measure and communicate with the background in a certain degree of harsh environment.

2) Intelligence: As the core function of the system, the intelligence is manifested in the system to quickly detect changes in the environment, and feedback the information to the main control module, which is analyzed and processed by the main control module, and then sends control commands to the drive module. The intelligent characteristics of the system need to be completed by the perfect logical structure of the upper layer software.

3) Low power consumption: The system should be able to work at a lower power consumption in the operating mode to save energy.

2.2 System design

The system designed in this paper needs to work in a home network and form a network to work together. As shown in Fig. 1, the left box in the figure is the system to be designed in this paper, and the right half is the typical application background of the system.

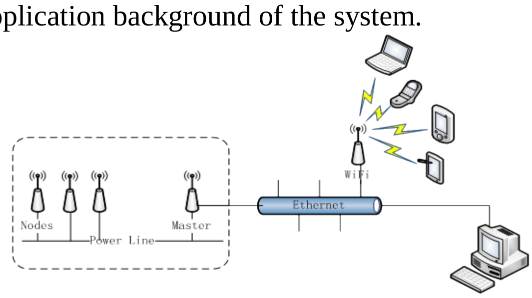

Figure 1 Intelligent power terminal

In the left half of Fig. 1, there are several intelligent power terminals. One of the terminals is connected to the Ethernet and acts as a server node (Master) to communicate with the external network.

Other terminals assume the role of ordinary nodes (Nodes), and can transmit data to each other, but cannot directly communicate with the outside world. Communication, which isolates the system from the outside network, to a certain extent guarantees data security and system stability. Each intelligent power terminal includes a WirelessHART wireless network module for wireless communication with other terminals. It also includes PLC modules that can be connected to each other through power lines.

2.2.1 System design of common nodes. In the intelligent power terminal system designed in this paper, each device, including the gateway node, has the function of a common node. For each common node, we want it to be compatible with the WirelessHART network and the PLC network, and can drive the sensors and peripherals to work, so the design scheme is shown in Fig. 2:

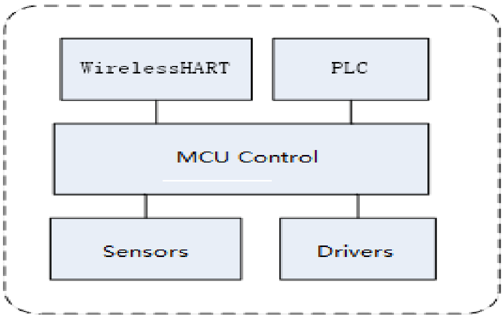

Figure 2 Design of a common node

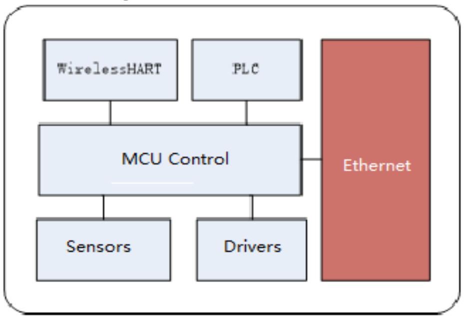

Figure 3 Design of the server node

A common node mainly includes a microcontroller main control module, a WirelessHART wireless communication module, a PLC module, a sensor module, and a drive module.

2.2.2 System Design of Server End Node. The server-side node, in addition to the above modules, contains an Ethernet module, as shown in Fig.3:

The Ethernet module on the server side allows the system to transfer data over the Internet.

2.3 System Hardware Design and Implementation

2.3.1 Microcontroller Main Control Module. The microcontroller main control module is the core of the whole system. Considering the complexity of the system and the diversity of the network, the system selects the STM32F103ZET6 chip as the core microcontroller. This is a 32-bit Cortex-M3 core ARM processor with up to 72Mhz processing speed, sleep, stop, and suspend three low-power modes of operation to minimize energy consumption and what is needed Less peripheral support, only need some basic power and external crystal to work[8].

2.3.2 WirelessHART Module. The WirelessHART module is mainly composed of a master chip MSP430 and an RF module CC1100E. Among them, MSP430 is a 16-bit low-power, low-cost MCU from TI, and CC1100E is a radio communication module of TI company that is used below 1Ghz band and supports multiple demodulation formats[9].

2.3.3 Power Carrier Module. The power carrier module is responsible for power line communication. Considering the cost and complying with Chinese national standards, we adopt the KQ330 ultra-low power carrier communication receiving module[10].

2.3.4 Sensor Module. In this system, in order to demonstrate the intelligent control function of the system, it is necessary to add a human body sensing sensor. It can detect whether there is any moving object moving within 10m, and generate a pulse signal when it is triggered, so that this pulse signal can be sent to the microcontroller through the GPIO port.

The sensor module is mainly composed of a chip and its surrounding circuits, and the CS9803 is selected as a human body sensing chip[11].

2.3.5 Driver Module. The drive module is used to control the peripheral equipment. In this system, 220v household electric light is selected as the controlled electric appliance to express the versatility of the system. The drive module is driven by a Darlington circuit. The Darlington circuit consists of two Darlington transistors. The two triodes are cascaded to greatly increase the sensitivity of the system, effectively amplify the input signal, and have a strong current drive capability.

2.3.6 Ethernet Module. The Ethernet module of the server is the basis for the server to communicate with the outside world. It not only provides the gateway function for the UART-PLC network, but also forwards the internal data to the external network. It also provides functions such as query and control for the external intelligent terminal device. . This system selects the ENC28J60 module as the Ethernet communication chip. The chip is a 28-pin Ethernet controller with low pin count, low cost, and ease of use[12].

2.3.7 Hardware Interface. The transmission of information between each module and the transmission of instructions are completed through a specific communication interface. The common inter-chip communication interface includes UART, SPI, I2C, etc. Among them, the UART and SPI interfaces are low-cost and easy to use. Easy to integrate, the system uses UART and SPI interface as the main protocol for inter-chip communication.

UART is a transceiver protocol widely used in EIA, RS-232 and other interfaces. It can convert information into and/or serially converted into byte streams. It can also aggregate byte streams and restore information through serial/parallel conversion[13].

SPI is a synchronous data link standard that can operate in full-duplex mode[14]. Participants in SPI communication are divided into master and slave. The master can specify the data frame structure. Multiple slaves in the system use chip select pins to determine whether they are working.

2.4 Implementation of System Software

The hardware of the system is the basis for supporting the system application, and the upper layer software of the system is the specific implementation of the application. This system uses IAR EWARM v5.30 as a development tool, selects C language as the development language, and selects STM32 Firmware Library v2.0.3 as the development library[15].

2.4.1 Software Design Framework. As shown in Fig. 4, the software system is mainly composed of three layers of modules. The STM32 firmware layer is a C language library provided by ST company for operating the internal modules of STM32, including operating RCC clock, GPIO interface, interrupt vector table, etc. Function; the microcontroller main control module is responsible for coordinating the work of each module and resource allocation, system timing, data processing and other tasks; the application layer contains a wide range, including the operation of the LED indicator on the hardware circuit module, UART serial device networking Communication, sensor control, and peripheral drive control modules.

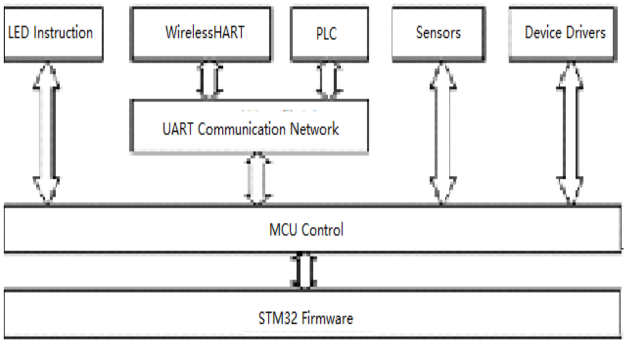

Figure 4 software system architecture

2.4.2 Microcontroller Main Control Module. The microcontroller master layer contains the main scheduling and control modules. The microcontroller master layer needs to initialize the STM32, including RCC clock configuration and GPIO pin configuration.

First, to configure reset and clock control, the system first calls the RCC_Deinit() function to initialize the RCC clock, then calls the RCC_HSEConfig() function to configure the STM32 to use the external crystal as the clock source, enable the crystal, and then turn on the STM32 internal flash pre-The access function then sets the internal high-level peripheral bus APB1 and APB2 high-speed channel clocks and enables the internal PLL phase-locked loop module as the system clock.

Second, the system calls the NVIC_SetVector- Table() function to initialize the embedded interrupt controller. Finally, the GPIO_Configuration() function is called to initialize each pin.

2.4.3 WirelessHART Module. The WirelessHART module communicates with the microcontroller via the UART interface. There are two main interfaces: the sending data interface and the receiving data interface. The send data interface function realizes the data transmission by calling the function library USART_SendData() and USART_ReceiveData() functions of the main control module, and the network layer and the lower layer transmission function are responsible for the MSP430 chip. The receive data interface is a buffer data character and uses the trigger interrupt to inform the MSP430 to further process the data.

2.4.4 Power Carrier Module. The PLC module used in this system can transmit data through the UART interface and the microcontroller. The TXD interface of the PLC module is directly connected to the RX data receiving end of the UART1 of the microcontroller, and the RXD interface of the PLC module is passed through the 2K current limiting resistor. Connect to the TX data sender of the microcontroller.

The PLC module has two working modes: a transparent working mode and a custom working mode. In order to facilitate development, the system uses a custom working mode.

2.4.5 Server Ethernet Module. As shown in Fig. 5, the Ethernet module is mainly composed of the Hardware Abstract Layer of the ENC28J60, the SPI interface, the TCP/IP protocol stack, and the upper-layer Web server. The SPI interface is responsible for communicating with the microcontroller for data transmission; the TCP/IP protocol stack implements basic TCP/IP network functions, and the Web server provides a limited-function Web server to interact with the user.

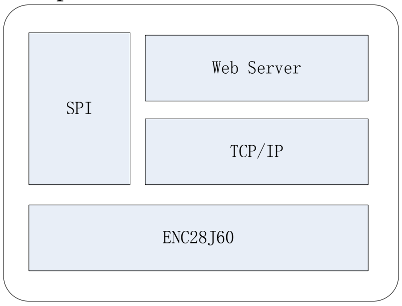

Figure 5 Ethernet module

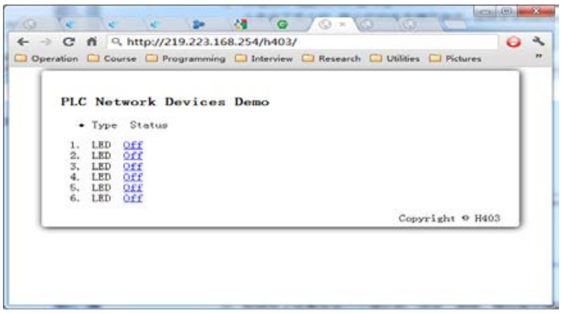

Figure 6 PLC network communication test

3. System function test

The test part of the intelligent power terminal system mainly has several aspects: sensor action, working status display and manual control function of the household appliance, power line networking and communication function between the peer nodes, WirelessHART communication and Mesh network formation.

3.1 Working status display and manual control function test of household appliances

Testing of this feature requires only a single node on the server side. Firstly, the server node is externally connected to the sensor module, the relay driver module and the Ethernet module, and the Ethernet module is connected to the local area network, and the notebook is connected to the same local area network through the wireless network. Power on the system, change the IP address and subnet mask in the system source code to connect to the Ethernet network for communication. Change the system's access password, then download the test code to the host chip and run it.

The results show that the system can quickly respond to people within 4-5m, turn on the lighting system, and manually query and control the working state of the lighting system through the web server.

3.2 Power Network and Communication Function Test

The power carrier module of the server is connected to the main control module, and five client nodes including the relay drive module and the power carrier module are added. Edit the test code to modify the UART address of each node to a separate address. In the test, change the UART address of the server to 1, and change the address of the five client nodes to 2~6. Power on each board and download the test code to each board to run.

As shown in Fig. 6, the power network is normal, and any one clicks the "close" button of the LED light, and the relay of the corresponding client node is closed, and the corresponding LED light is turned on, indicating that the power line communication function is normal.

3.3 WirelessHART ad hoc network communication function test

First, connect the WirelessHART receiving and transmitting module to the USB interface of the two laptops through the RS232 level conversion module and the USB-RS232 conversion module. Then, open the serial port debugging assistant on the two laptops, the receiving module listens to the serial port data, and the sending module sends data to the serial port to test whether the receiving end can completely receive the data. Finally, the notebook connected to the sending module is fixedly placed on the road, and the notebook as the receiving party is gradually moved away from the transmitting module to observe whether it can be normally received.

After testing, on the road, under the condition that the packet loss rate is $\leq$ 3%, two nodes are used to communicate with each other, and the obtained communication data is shown in Table 1.

Table 1 WirelessHART normal transmission condition test data

Receiving/transmitting device ground distance	Transmission rate	Longest communication distance
2.5m	250kbps	~240m
2.5m	150kbps	~640m
5m	250kbps	~560m
5m	150kbps	~700m

After the ordinary test, the equipment was tested for penetration ability, and the ordinary load-bearing wall was used as an obstacle. Under the condition that the packet loss rate was $\leq$3%, the transmission data of the two nodes was obtained as shown in Table 2.

Table 2 Test data under WirelessHART penetration’s condition

Receiving/transmitting device ground distance	Transmission rate	Longest communication distance
2.5m	250kbps	~25m
2.5m	150kbps	~32m

4. Summary

This paper is an intelligent power terminal system based on home heterogeneous network, which is proposed for home users. In combination with peripheral devices such as wireless sensors, the system realizes the purpose of intelligently controlling home appliances and supports Ethernet implementation. Remote manual control terminal. Due to the simplicity of the system structure and the combination of hardware and software, the reliability, intelligence and low power consumption of the system work are guaranteed.

In the future, intelligent power terminal systems in heterogeneous network environments will move toward higher compatibility, such as compatibility with more wireless sensing devices. At the same time, in the process of improving compatibility, it is also necessary to improve the load capacity of the system.

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