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Design of the Remote Wireless Meter Reading System Based on GPRS

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Abstract

Smart grid is the focus development direction of the national power grid construction, and remote power information collection is the important part of smart grid. The existing automatic meter reading system of remote electric power information collection has such problems as high cost, big power consumption, small networking and big line interference etc. Aim at these features, this paper proposes a new scheme of wireless meter reading based on GPRS, that is, the wireless communication module MC55 of SIMENS and STC89C58RD single chip are adopted as the core to develop a set of remote wireless meter reading system. The paper mainly introduces the overall design of the system, the hardware circuit and software design of each component, and the major software flow chart is given. The system has the characteristic of low cost, low power consumption, ad-Hoc network, self adaption, etc, and it has the strong portability and compatibility. Field test results show that the wireless meter reading system can finish the data collection and transmission task quickly and accurately, and has strong anti-interference ability and wide applicability.

Keywords*: Remote wireless meter reading, GPRS network, MC55, STC89C58RD single chip*

1. Introduction

As the increasing of industry and agriculture ,power consumption of urban residents and power consumer, the number of the watt-hour meter have increased dramatically. And due to the quality of residential building enhances unceasingly, the requirement of surrounding environment and property management level are also improved, there are many drawbacks in the traditional meter reading way [1]. Such as Manual Meter Reading, Local Automatic Meter Reading(Using hand-held terminal of easy to carry, simple operation and reliable meter reading equipment such as computers or handheld computers, to complete the automatic meter reading function on the site), Mobile Automatic Meter Reading (by use of bus load wireless transceiver, near to each electrical energy metering device, implements the data reading through wireless signals and devices communication.)[2], Prepayment Electricity Billing Way (by the combination of magnetic card or IC card and prepaid watt-hour meter, the users make money to buy a certain electric quantity firstly,and with this part of the electricity is run out, it will power off automatically) [3], these methods have such shortcomings as having some troubles in entering the user's home, too high management cost, existing safe hidden danger,etc, and they being washed out gradually, and at the same time, because of the high-rise buildings now, lot of lines are not easy to set up. Power supply enterprises are eager to realize the standardization automation of monitor for power use and the convenience of set ing up communications lines by means of modernization. Remote wireless automatic meter reading technology is easy to adapt to the situation of the rapid development of power system and the operation and management system of power system [4]. So, in recent years, remote automatic meter reading system has developed very Quickly.

In the paper, Section 2 summarizes the research situation of remote meter reading system. In section 3, we propose the overall design of the remote meter reading system and give the structure of the system. Section 4 discusses the detailed hardware design of each part of the system, which includes the design of intelligent watt-hour meter and meter reading concentrator. Section 5 is the software design of the system, we focuses on the algorithm of

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intelligent watt-hour meter and the flow chart design of main program. Section 6 is the conclusion of the paper, and it illustrates the advantages of this design through the operation on the field.

2. The Development and Research of Remote Automatic Meter Reading Syste

Generally, the composition of the remote meter reading system have such four parts as follows, watt-hour meter which has the function of automatic meter reading, meter reading concentrator, meter switches and central processor. According to the difference of transmission channel type in remote automatic meter reading system, it contains the types of meter reading using telephone network, remote meter reading using low voltage distribution lines carrier, remote meter reading by load monitoring channels and other types. Published papers [5][6][7], introduced the remote meter reading system based on telephone network. Papers [8][9] gave the remote meter reading system based on the low voltage distribution lines carrier respectively; Papers [10][11] presented the remote meter reading system by load monitoring channels. These meter reading methods has many advantages compared to traditional methods, for instance that the remote meter reading system using the telephone network has the ability of stable and reliable, less maintenance, but the system operation has a fixedfee,and it cannot cover all the electricity area, it is vulnerable to be restricted after it used,thus it is not conducive to be long-term planning and development. The way of low voltage power carrier for meter reading does not need additional communications lines laid, but it has the poor ability to resist electromagnetic interference. Remote meter reading based on power load monitoring channel has the disadvantages of many users, the more wide range, dispersion and small amount of information.

In view of the above characteristics, this paper presentes that the GPRS wireless communication is adopted to realize remote automatic meter reading. GPRS network has been built to run for many years in our country,and it has the characteristic of mature technology, high broad reach, especially the SMS short message service has low cost, strong strongtimeliness.Thus by use of the SMS data transmission between GPRS terminal equipments ,the SMS service function is added to the meter reading system, remote wireless meter reading system can be realized. Compared to other solutions, this method has the advantages of large coverage, low cost, strong timeliness, etc.

3. The Overall Design of the Remote Wireless Meter Reading System

In this paper, the communicaton way of the system is of the lumped type, and the system consists of the four major parts as follows, intelligent watt-hour meter, reading concentrator, GPRS wireless communication network and management center. The overall scheme of the system is shown in Figure 1.

The main data center is composed of the enterprise internal host, database server, printers,and other peripheral equipments. On the one hand, the system software of data center should ensure its interact with the remote meter reading terminals, data receiving and storage, on the other hand it should provide users with a visual interface, provide the classification and query, trend analysis, statistics on a regular basis and other functions. The user can choose the data according to their demand, and know the electricity conditions on the far side.

4. Hardware Design of Remote Wireless Meter Reading System

4.1 Hardware Design of Smart Meter

Multi-functional three-phase watt-hour meter is adopted is the system, and it has the following functions.

(1) Metrology Function. According to three times of the peak, valley, level,it can measure active energy and reactive energy, and give the accumulative total active and reactive energy. It can measure and display voltage, current, power, total power and total power factor in real time.

(2) Testing function of power failure. It can monitor power failure events and record the cumulative number of power failure.

(3) Testing function of loss of voltage in each phase.It can monitor loss of voltage in any phase. As long as one phase voltage of the smart meter is below the setting threshold value, that is considered the phase voltage lossed. When one or two-phase lossed the voltage, the smart meter can still work ,because that the phase lossing voltage don't calculate electricity.

(4) Clearing function. Smart meter has automatic clearing function, which settlement date can be set by programming. Settlement data of the last 12 months can be saved in the meter, which includes the active and reactive energy of positive and reverse, positive active energy consumption during the rate of that month, run time of the meter during the month, number of events during the month, maximum demand and the time of it occurrence.

(5) Display function.

(6) Communication function. It can provide a standard RS-485 communication interface, which communicates with meter reading concentrator.

Based on the function of the intelligent watt-hour meter, the hardware architecture is as shown in Figure 2.

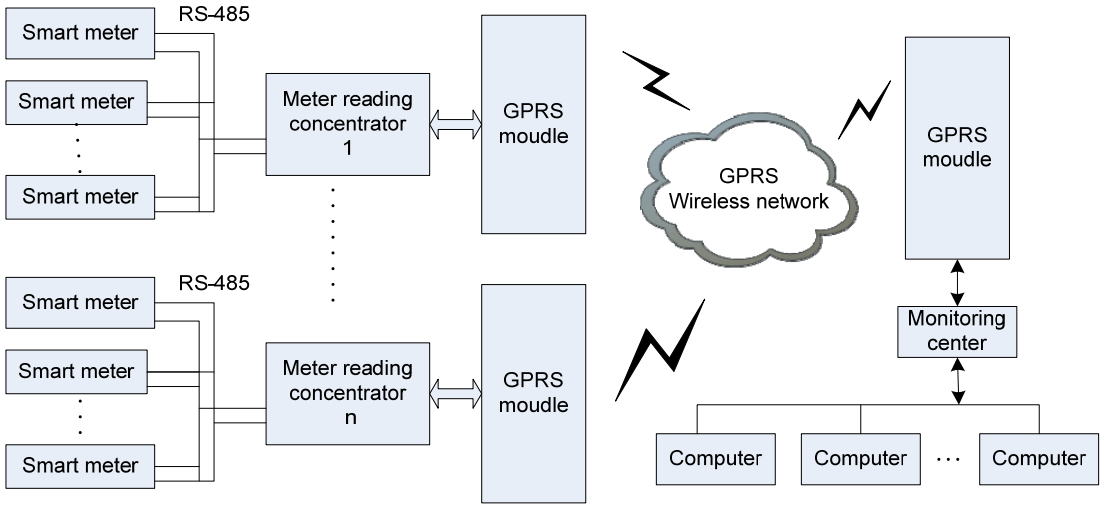

Figure 1. Overall structure of remote wireless meter reading system

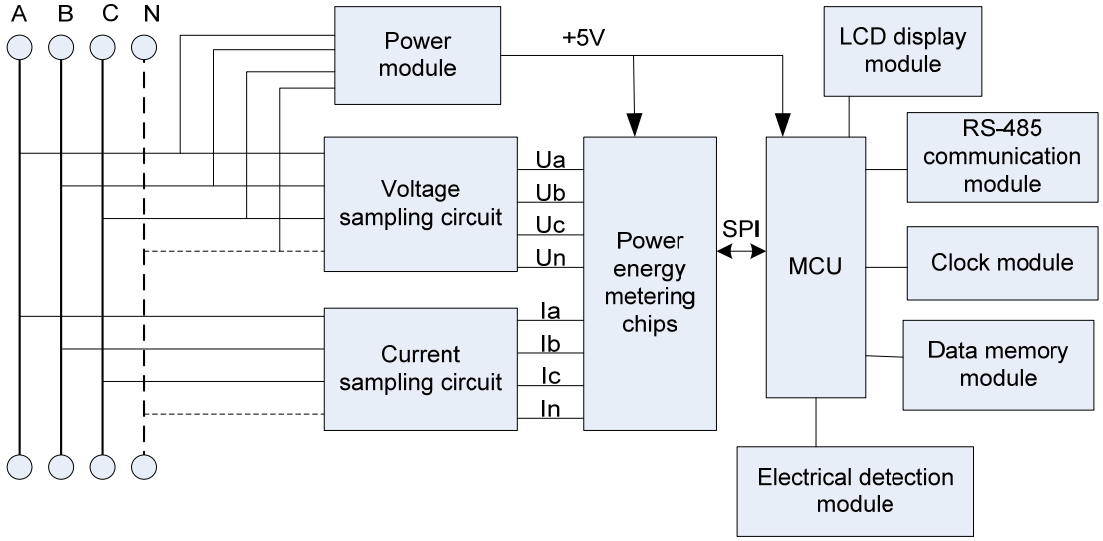

Figure 2. Hardware structure of smart meter

Modular design thought is adopted in the disign of Intelligent watt-hour meter, which includes power module, voltage and current sampling module, electricity metering module,MCU module,data memory module, clock module, LCD display module, RS-485 communication module, electrical detection module,etc. STC89C58RD + chip is chosen as the MCU, which is compatible with 51 series microcontroller, but its function is more powerful, its price is more cheaper. And it has1280 bytes of RAM inside which can undertake data processing of large capacity. Due to the limited space, the design of the other modules are no longer tired, it mainly introduces the designing of electrical energy measurement modules in the next text.

4.1.1 The Choice of Electricity Metering Chip

The electricity metering chip ATT7022B is a multifunctional chip of high precision, powerful function and a dedicated three-phase electric energy metering chip of preventing electricity-stolen. It integrates second-order sigma-delta ADC of seven roads, in which three roads are used for three-phase voltage sampling, three roads are used for three-phase current sampling, and the rest of road is used for zero line current sampling or other preventing electricity-stolen parameters sampling. It can output sample data and valid values, which is very convenient for use. The chip is very suitable for the applications of three-phase three-wire system and three-phase four-wire system.

4.1.2 Measuring Principle of Electric Energy Metering Module

Let the expression of alternating voltage and current on the load at time t are as follows.

$$\text{u(t)}=U_m \sin \omega t = \sqrt{2}U \sin \omega t \quad (1)$$

$$i(t) = I_m \sin(\omega t - \varphi) = \sqrt{2}U \sin(\omega t - \varphi) \quad (2)$$

Among them, $u(t)$ is the instantaneous value of voltage at time t; $i(t)$ is the instantaneous value of current at time t; U_m is the voltage peak; I_m is the current peak; U is the effective value of voltage; I is the effective value of current; φ is the phase difference between voltage and current; ω is the angular frequency。

Then the average active power P for a period is as follows.

$$P = \frac{1}{T}\int_0^T u(t)i(t)dt = \frac{1}{T}\int_0^T U_m \sin \omega t I_m(\omega t - \varphi)dt = \frac{1}{T}\int_0^T UI\left[-\cos(2\omega t + \varphi) + \cos\varphi\right]dt = UI\cos\varphi \quad (3)$$

The electric energy W for a period is as follows.

$$W = \int_0^T u(t)i(t)dt = TUI\cos\varphi \quad (4)$$

For three phase circuit, the total electric energy can be expressed as the sum of energy in three phases.

$$W = W_A + W_B + W_C \quad (5)$$

The total power in three phase three wire system is as follows.

$$P_3 = U_{AC}I_A \cos\phi_1 + U_{BC}I_B \cos\phi_2 \ , \ Q_3 = U_{AC}I_A \sin\phi_1 + U_{BC}I_B \sin\phi_2 \ , \ S_3 = \sqrt{P_3^2 + Q_3^2} \quad (6)$$

The total power in three phase four wire system is as follows.

$$P_4 = U_A I_A \cos\phi_A + U_B I_B \cos\phi_B + U_C I_C \cos\phi_C \ , \ Q_4 = U_A I_A \sin\phi_A + U_B I_B \sin\phi_B + U_C I_C \sin\phi_C \ , \ S_4 = \sqrt{P_4^2 + Q_4^2} \quad (7)$$

Active energy, which can be obtained by the instantaneous active power from the time integration.

$$E_p = \int p(t)dt \qquad E_q = \int q(t)dt \tag{8}$$

4.2 Hardware Design of Meter Reading Concentrator

Meter reading concentrator is responsible for collecting data from the user's smart electricity meter, and send them to data center.Its overall structure of hardware is shown in Figure 3.

The hardware of meter reading concentrator includes power module, MCU, GPRS moudle and SIM card, analogue switch, RS-485 communication moudle and indicating circuit. In

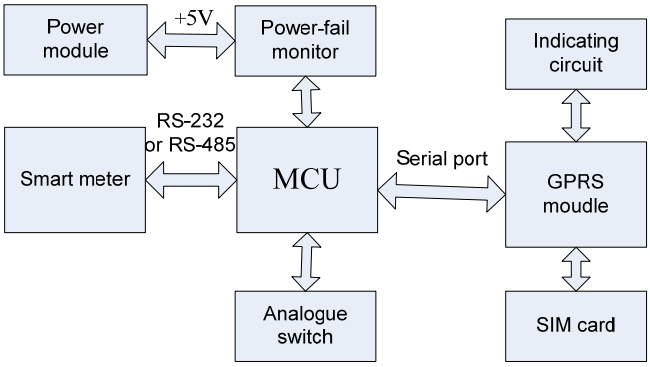

Figure 3. Hardware structure of meter reading concentrator

the paper, MSPS-5C3 power module and AT89C51 single chip are chosen, GPRS module is responsible for the communication with control center, RS-485 communication module is responsible for communication with smart electricity meter. Analog switch part is used to switch data transfer between MCU and MC55 module or RS-485 bus. Power failure detection circuit can inform the server on time when alternating current outage and inform the power outage site in order to power on in time and make the system back to normal work.

4.2.1 Design of GPRS Module and SIMCard.

At present, there are many GPRS data transmission modules used for industrial system. In this paper, MC55 module of Siemens company is adopted which conforms to the industrial standard and TCP/IP protocol stack is embedded. MC55 is the three frequency module that has the smallest size on the market today, which working power supply is 3.3 V ~ 4.8 V, transmission power is 1 w and 2 w respectively, supports such four kinds of data traffic as digital ,voice, short message and fax. It provides a standard interface of AT command, supports the standard SIM card of 3 V and l. 8 V.

The connecting circuit of MC55 module and the SIM card is as shown in Figure 4. Because the typical voltage of MC55 is 2.65V when the serial port sends and receives data, while the typical voltage of single-chip microcomputer is greater than 3.5 V,direct connection between them may cause data errors. So two level conversion circuit is designed, which convert 5 V to 2.5 V, 2.5 V to 5 V respectively. Two triode 9013 is used in each transformation circuit, pull up resistance is put on the last level of 9013 in order to get the voltage they need. It is as shown in Figure 5.

4.2.2 Design of RS-485 Communication Module

Interface standard of RS-485 serial bus transmits signals in differential balanced manner, and it has a strong ability of resisting common mode interference, allows one transmitter to drive more load on the device in a pair of twisted pair. By use of simple serial interface provided by the microcontroller itself and the bus driver,it can be combined into a simple RS - 485 network. The hardware circuit of RS-485 communication module is shown in Figure 6.

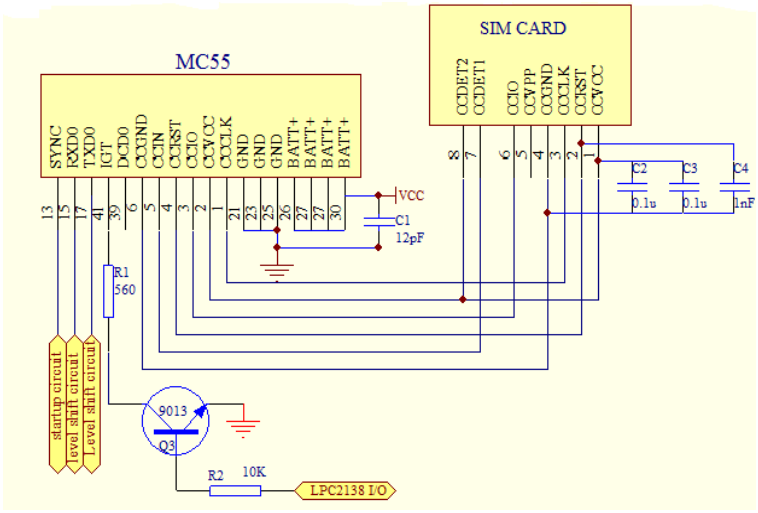

Figure 4. The connecting circuit of MC55 module and the SIM card

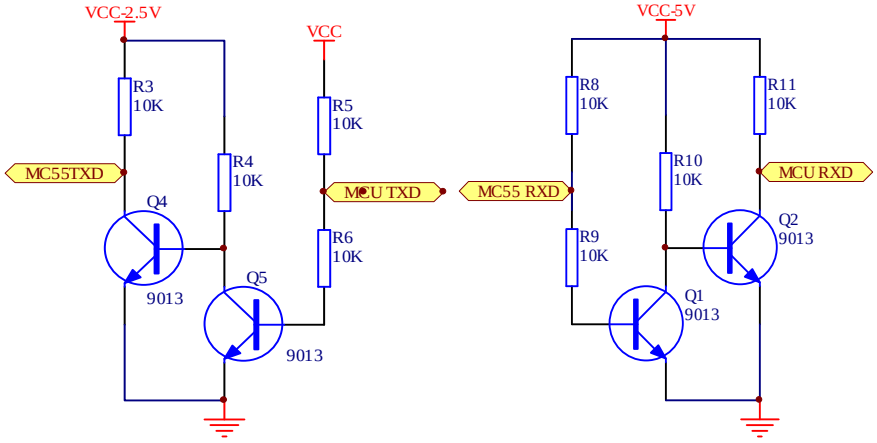

Figure 5. Level conversion circuit of MC55

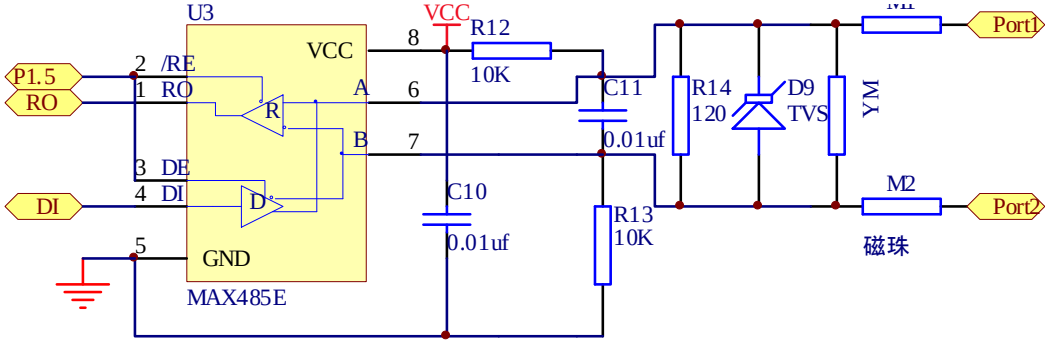

Figure 6. The hardware circuit of RS-485 communication module

4.2.3 Design of Analog Switch Part

The analog switch part is switched into the connection of MCU and the MC55 module in initial state.If the MC55 sent instructions for copying the data, and then switch to the 485 BUS. After gaining data, then switch to the MC55 module, and send the data to data centre.The hardware circuit of analog switch is shown in Figure 7.

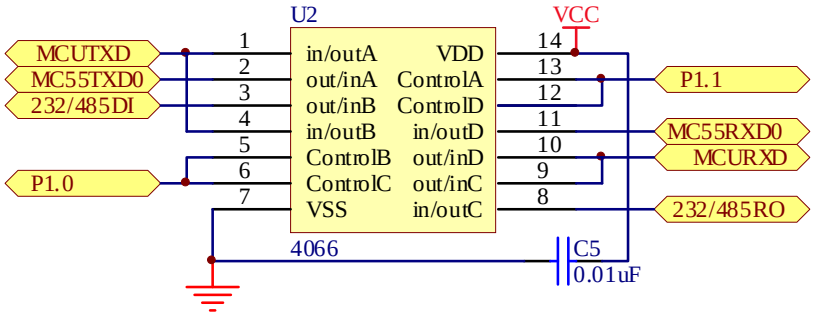

Figure 7. The hardware circuit of analog switch

5. Software Design of the System

Software design of the system includes both smart meter design and meter concentrator design parts, and modular design thought is used in its design. Here, only main program design thinking of the two parts is in focused on.

5.1 Software design of smart meter

Master control program of smart meter must enable MCU to command each part circuit to complete electrical energy measurement, data storage and communication and display in order, can call the subroutine modules to achieve various functions of the whole system. Main program flow chart of smart meter is as shown in Figure 8.

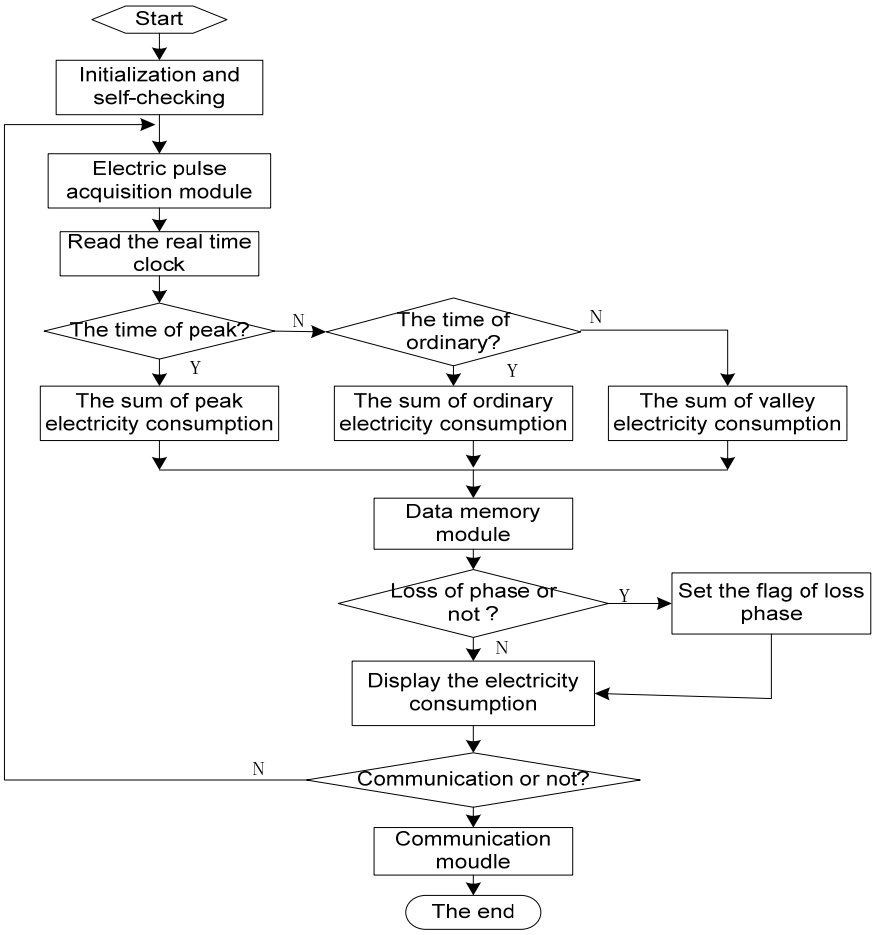

Figure 8. The main program flow chart of smart meter

5.2 Software Design of Meter Reading Concentrator

Program design of meter reading concentrator need initialization process and send the AT commands to the GSM network,etc. Meter reading concentrator is only waiting for the connection from the communication machine passively. When it analysis that these orders are for the smart meter under the jurisdiction of itself, CPU will say the word to the related smart meters through RS-485 bus, receive the back information from smart meters in the effective time, and package them into the data which GPRS will send to the data center directly. Main program flow chart of meter reading concentrator is as shown in Figure 9.

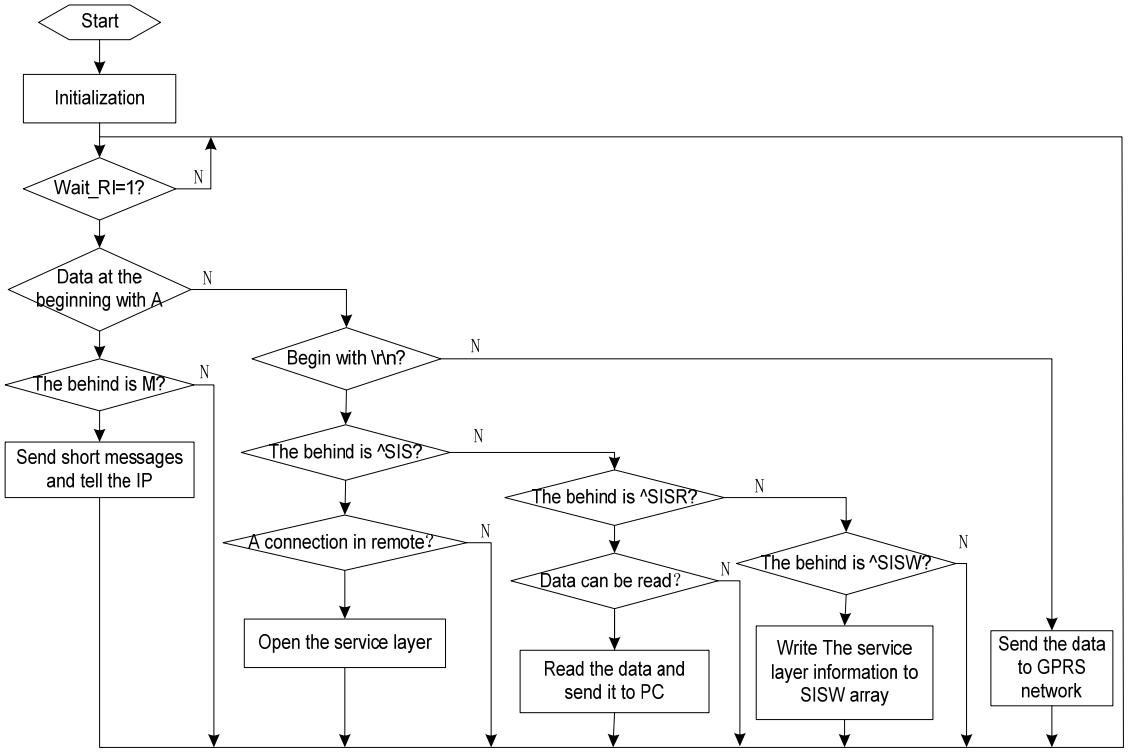

Figure 9. Main program flow chart of meter reading concentrator

6. Conclusion

The design scheme of remote wireless meter reading system based on GPRS puts forward in this paper has been used in our city for two years now. Practice has proved that the way of this reading meter has overcomed the insufficiency of other meter reading ways, brought economic benefits for the meter company of the city, save a large amount of manpower and material resources, be suitable for the installation of the large quantity. In addition, due to the use of the existing GPRS wireless channel of mobile communication company, the way has waken the influence of interference, improved the stability of data transmission. In the practical application, data copy and data management of the system are integrated, it not only can complete data acquisition and transmission of four kinds of meters accurately and timely, but also has strong portability and compatibility. Combined with some sensors, it can be used in smart home, coal gas detection and other fields, has the very good market value and application prospect.

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References

[1] Wang Xianchuang, Yan Youyun, Liu Jianguo. Design of the Wireless Meter Reading Terminal Based on AVR Single-chip Processor. *Journal of Changsha University*. 2011; 25(2): 36-38.

[2] Wang Kui, SunYing. Power System Automation (Second Edtion). Beingjing: China Electric Power Press. 2010:168-171.

[3] ZHAO Xingyong, AN Guanglan. Per-Payment Walthour Meter with IC Card. *Journal of Electric Powe*r. 2004; 19(12):22-23.

[4] Shihong Duan, Yadong Wan, Peng Meng, Qin Wang Hardware-in-the-loop and Parallel Simulation Architecture for Wireless Sensor Network. *TELKOMNIKA Indonesian Journal of Electrical Engineering.* 2013; 11(1):103-114.

[5] Tian Yongjun, Zeng Jianping.The Research of Direct Prepayment's System Based on Telephone Network. *China Instrumentation*.2007; 1(1):79-81.

[6] Li Xianzhi. Research of the Remote Meter Reading System structure Based on Telephone Line. *Science & Technology Information*. 2007; 25(1):70-71.

[7] Xu Chunhui. Research about Communication Interface of Remote Meter Reading System.*Journal of East China Jiaotong University*. 2005; 22(2):71-74.

[8] Luo Shuke, Zhang Yuanmin. Study on Smart Meter Reading System with Low Voltage Reactive Power Compensation for Electric Power Carrier. *Process Automation Instrumentation*. 2011; 32(10): 36-38.

[9] Qu Xinwen, Guan Jiangang. A method of Implementing Remote Reading Meter Based on Power carrier wave technology. *Inner Mongolia Electric Power*. 2006; 24(supplement): 34-36.

[10] Fang Qiu, Qu Zhibin, Song Yihong.New Application of the Electric Load Remote Supervising and Controlling System in Automatic Meter Reading. *Electrical Measurement and Instrumentation*. 2003; 40(445): 27-29.

[11] Weiming Yang, Jian Zhang. Jinxiang Peng Mean-square Error Distortion Computation Model Based on Wireless Sensor Network. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(7): 1723-1729.