Automatic Energy Metering & Control Using Zigbee

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ABSTRACT *Efficient Energy Metering & Control Using Wireless Sensor Network is presented in this paper. Presently, the human operator goes to the consumer's house and produces the bill as per the meter reading. Going to each and every consumer's house and generating the bill is a laborious task and requires lot of time. If any consumer did not pay the bill, the operator needs to go to their houses to disconnect the power supply. These processes are repetitive and take so much time. Moreover, human operator cannot find the Un-authorized connections or malpractices carried out by the consumer to reduce or stop the meter readings. AEM (Automatic Energy Meter) puts more control into the hands of both utilities and consumers by giving them more detailed information about power consumption. This system includes intelligent electric meter, concentrator, specialized algorithm software and has advantages:*

(1) Synchronous acquisition of various power parameter; (2) Anomalies on power line can be detected by running special algorithm. Also, proposes strategies of energy conservation by comparing relationship between electric power supply and consumption.

I. Introduction

Reading the data of electric meters automatically, promptly and accurately has been the outstanding issue for power supply departments. The development of electronic technology, communication technology and computer network technology makes it possible to provide complete solutions for constructing the AMR (Automatic meter reading) system. AMR system reads and processes the data of various meters automatically by utilizing communication and computer network technology [4].

According to communication mode, AMR system can be divided into the following types: infrared AMR, AMR based on power line carrier (PLC) communication, RS-485 AMR and AMR based on data radio station.

Infrared AMR is composed of the main station, the infrared handheld device, the meter and the data collector. Data collector is used to collect and store the data of meters in a certain box. The human operator first uses the handheld device to collect the data stored in the data collector, then goes back to transmit data to the master computer. The PLC communication AMR uses power lines as the communication medium to transmitting data [5]. However, power lines are originally designed for power signals of low-frequency. If it is used to transmit carrier signals of high-frequency with low-power, it will not be an ideal communication medium because of larger noise interference, high attenuation and so on [6].

RS-485 bus is widely used in industrial automatic field.
The AMR system based on RS-485 is composed of meter, data collector, concentrator, and the master computer. Data collector is responsible for processing, calculating and packaging up the data from a number of meters. Several data collectors are connected with a concentrator by twisted-pair to form a RS-485 network. The arrangement of wire in this kind of system is hard, and it is easy to be struck by lightning.

In AMR system based on data radio station, the data radio station is used as the transmission channel between concentrator and data collector. Because low frequency of the radio, data radio station is easy to be disturbed. Therefore, this communication network is insufficient to support the longer stable operation of AMR system [1].

AMR system composed of intelligent electric meter, concentrator, specialized algorithm. In order power line loss real timely, each meter must collect data at same time. To freeze meter data synchronously, high precision real time clock (RTC) and GPS module is used. Intelligent electric meter can cut-off power of subscriber. The instruction is send by concentrator. Relay is used in intelligent electric meter for this purpose.

II. BLOCK DIAGRAM

The Intelligent electric meter (R1and R2) possesses the function of power monitoring, metering, meter data gathering and local data storage. At the same time, it may parse instructions sent from server and execute corresponding actions. The architecture of the system is designed as shown in fig.1

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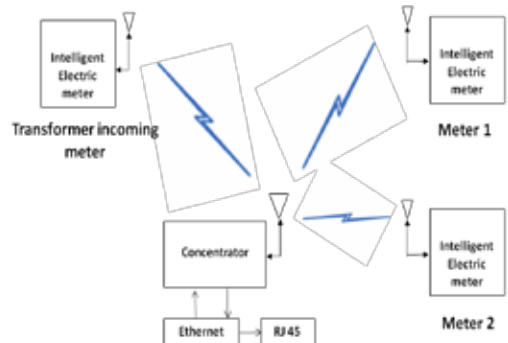

Figure 1.System Block Diagram

Intelligent electric meter can be single phase or three-phase. With the intelligent electric meter, the power consumption can be counted, power grid's parameters can be monitored, and the process of power consumption can be recorded. The transformer incoming meter is also an intelligent electric meter. It is fixed on the low-voltage side of the incoming line to record the incoming power consumption. It is the key device which can calculate the total power consumption of a transformer and monitor the general state of power lines.

The concentrator is mainly used to get and store the data of multiple meters simultaneously. It includes specialized algorithms to detect faulty meters and unauthorized connection. It also sends command to meter to cut-off power supply to subscriber. Besides, the main functions of software include data analysis, generation of electric power parameter curves, power consumption statistics and user-friendly graphic interface.

III. ZIGBEE TECHNOLOGY
With the development of semiconductor and wireless communication technology, to connect many wireless devices together with low cost and high reliability is possible. ZigBee is a low rate wireless technology designed for automation and control sensor network. The standard is aimed to be a low-cost, low-data rate and low power solution for systems consisting of unsupervised groups of devices in power and hydrological areas. Expected applications for the ZigBee include building automation, remote control, remote reading and many other sensor monitoring systems.

The ZigBee utilizes IEEE 802.15.4 standard as radio frequency layer. The standard is designed for the low bit rate Wireless Personal Area Networks (WPAN), and it defines physical (PHY) layer and media access control (MAC) layer. Three radio bands are defined: ISM 2.4 GHz band with 16 channels and data rate of 250 kb/s (global use); 915 MHz band with 10 channels and data rate of 40 kb/s (USA); 868 MHz band with single channel and data rate of 20 kb/s (Europe) [5]. It uses the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism for accessing the channel, like other wireless network standard such as IEEE 802.11 and IEEE 802.15.3. Application and network layers are defined by ZigBee Alliance.

It also defines three types of devices: coordinator, router and end device. And the ZigBee typically supports three kinds of topology, namely star, cluster tree and mesh networks. Each ZigBee network has a designated FFD (Full Function Device) which is a network coordinator. The coordinator acts as the administrator and in charge of joining and leaving of the devices in the network.

There are two types of address: the long 64 bit address and a short 16 bit network address. The long address should be unique globally, and the short address is assigned by network coordinator when a device joins the network and is unique within the given network. The network address is assigned in a hierarchical tree structure. In mesh topology, any router devices can communicate with other router devices except their parent devices, so the network has high scalability and flexibility. Besides, the self-reconfiguring and self-healing features make ZigBee more attractive to many applications.

In traditional AMR system, collecting the meter data is the most difficult task and impossible to complete especially for high frequency collecting. ZigBee modules embedded in local equipment are designed based on ISM 2.4 GHz band with 16 channels. In order to widen coverage, we add some ZigBee router devices, and the topology has been constructed as mesh network.

IV. HARDWARE DETAILS
The main hardware components of the AMR system are intelligent electric meter and concentrator.

V. Intelligent electric meter
The intelligent electric meter overcomes many defects of the traditional electric meter, such as data deviation, poor function of anti electricity-stolen, inefficient manual metering and so on. More data can be measured and stored. It can satisfy the precise and real-time measurement requirement of power management department. Intelligent multi-parameters electric meter is designed with ADE7758 [7].

Figure 2 shows five sections of the meter: AC signal sampling and processing section, power supply section, storing and isolation section, Communication interface section, relay.

The crucial part of this meter is ADE7758 which plays an important role in improving the precision. ADE7758 is a high accuracy and multifunctional three phase energy metering integrated chip. Based on the AC current and voltage, root mean square current, root mean square voltage, active power, apparent power and input line frequency are achieved.

All the measuring results and calibration data are transferred to the MCU via SPI (Serial Peripheral Interface) interface which integrated in this chip. Because the power unit is supplied by three-phase AC power, the Multi-parameter intelligent electric meter can work normally even if only one phase is powered on. ZigBee module wireless communication interfaces with intelligent electric meter. RTC (Real-Time Clock) is used to offer timing mark for data. The function of EEPROM is to store data.
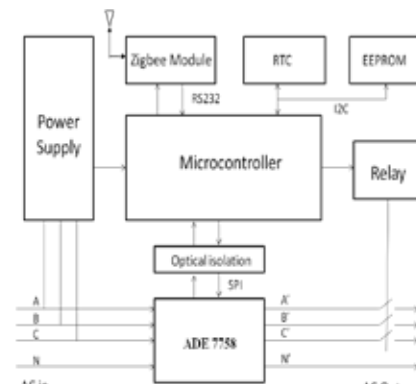

Figure2. Block diagram of an intelligent electric meter

VI. Concentrator:

The concentrator can collect up to 32 meters simultaneously. In AMR system, it collects and stores data from intelligent electric meters at a certain time interval. The key component of concentrator includes zigbee module, GPS module, Ethernet module RTC and EEPROM.

The concentrator has three main functions which is detailed described as the following:

1) Synchronize the concentrator's clock and the clocks of all intelligent electric meter within the same ZigBee network. At first, the concentrator gets reference time from GPS module which time is updated real timely. Then, the concentrator calibrates all the meter's clocks according to this reference time. Finally, all the clocks in the system can be synchronized.
2) Transmit supervisory instructions to meters. Receive the data stored in the intelligent electric meter at regular interval. Run the algorithm .The flow chart is as shown in Fig.
3) Act as server so client can monitor power loss, or faulty meters, or unauthorized connection. The client–server programming plays important role for long distance transmission. Power supply department can monitor the energy flow amount at any time through internet browsing.
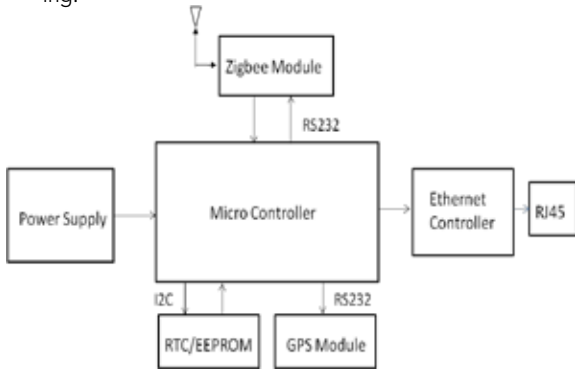

Figure3- Concentrator

The data could be gathered up, transmitted to the database backstage real-timely and synchronously by concentrator, and invoked easily by control software.

VII. APPLICATION

By means of installing intelligent electric meters in 10KV high-voltage incoming low voltage outlet at transformer and all branches, the power factor, power, and power consumption can be monitored real-timely and synchronously.

The power factor of transformer district is between 0.4 and 0.7. In order to improve the power factor and reduce power consumption, this transformer district is suggested to construct reactive power compensation system.

Table:- Meter's data of experiment

Main Meter Reading(W) (Incoming Transformer)	Meter 1 Reading(W)	Meter 2 Reading Reading(W)
80	40	40
100	60	40
60	0	60
40	40	0
100	illegal 40	60
100	60	illegal 40

VIII. Conclusion

This project constructs a practical AMR system based on ZigBee network and applies the system to Household metering System. The proposed AMR system realizes synchronous acquisition of large amount of data, and monitors the whole power consumption process. Anomalies on power line can be detected by running algorithm.

ACKNOWLEDGMENT

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