Design And Implementation Of Intelligent Meter Reading System Based On Internet Of Things

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Abstract

In order to facilitate the advanced measurement system with real-time interaction in smart grid and to satisfy the requirements for power quality management, a wireless ad hoc smart metering system for power quality using Internet of things (IoTs) technology is presented in the paper. By utilizing the energy metering module to collect energy information, the ZigBee ad hoc networks to transmit energy information, and the user monitoring terminal to support power grids management, the proposed system is able to efficiently realize the power quality information collection, transmission, processing and sharing. Experimental results demonstrate that the system performs real-time and precious monitoring of the distributed client power quality information, together with friendly and intelligent interaction capability.

Keywords

Smart meter; Power quality measurement; Wireless ad hoc network; ZigBee.

1. Introduction

With the development of modern communications, computing, networking and control technology, information technology continues to expand the use of fields. Thus the combination of energy and information technology has become an inevitable trend of future [1], and this combination has also spawned a new concept: Wisdom energy. Through taking the use of advanced information technologies to improve energy management level, it will achieve further energy precision of regulation.

In traditional grid information systematization, the problems of energy efficiency, environmental protection and other aspects stand out. The emergence of smart grid has brought out a viable way to solve these problems because of its distributed computing systems with many similar features to close contact with the computing network system. Smart grid needs to achieve grid information collection, transmission, analysis and problem solving [2] and guarantee the interaction of power generation side with the electricity side and management side, which is based on the security and reliability of smart grid. The implementation of smart grid consists of a large number of the physical node smart meters, a metering data management system and a communication system that connects them.

The remainder of this paper is organized in the following order: Firstly we briefly introduce related works and the architecture, and then the smart metering system design is presented. After the explanation of the wireless ad hoc networking solution, the power quality management system is presented. Finally the discussion and conclusion to the proposed system as well as the future work is described.

2. Related work

Household electric meter has gone from induction meter, pulse meter converted to electronic energy meter in three stages [3], and the current energy meter market is occupied by inductive meters and electronic meters. The former has both of complex production process and greater power, thus it is not conducive to saving energy. The latter is only one-way transmission so that it can not analyze power quality and participate in the market, which affects two-way interactive marketing. As a result, it does not have an ability to meet to the development of integrated smart grid services.

Meanwhile, with the development of wireless communication technology, GSM, GPRS and other fees required to use the wireless meter reading frequency bands [4] has appeared in the meter reading industry, as well as spectrum free use of wireless meter reading way such as ZigBee. As for the former method, its stability is good, but it charges by traffic. Along with chip manufacturers such as ADI, TI and other companies launched a series of high and low end-user solution for wireless communications chips [5], making its ZigBee low power, low cost and other advantages, and the meter has been widespread concern in the industry.

3. Architecture

The system relies on the IoTs technology, which includes the monitoring of the physical condition from sensor network to the upper application system, and to realize representation, transmission and processing of such information. Sensor network technology is used in the smart meter wireless sensor nodes data acquisition and information acquisition [6], carrying out the on-line monitoring for the power quality (voltage and current instantaneous value, effective value, apparent power, transportation, overvoltage, overcurrent and stealing electricity phenomenon) of the users through the smart meter wireless sensor nodes. The real-time and security communication technology are used for the transmission of power grid operation parameters [7]. The CC2430 module of the smart meter wireless sensor node sends the data to the CC2430 aggregation node. Then the data is sent to the user monitoring terminal via Ethernet module, so that the networking and fusion of the system are completed. Data storage and representation of information technology are used for storage, management, query and organization. User monitoring terminal analyzes the electric energy data quality. In the mean- while, completing users' fees and stepped price setting through the user monitoring terminal, which can encourage the users to use the electricity more scientifically. As a result, all of this can provide a strong guarantee for high efficiency and energy saving management realization of smart grid. The whole system is shown in figure 1.

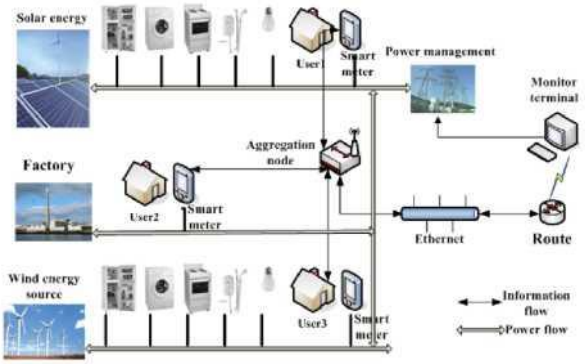

Fig. 1 Architecture of wireless ad hoc smart metering system for power quality

4. Smart Metering System Design

Smart grid has the bidirectional power flow and digital information flow, which is highly automated and widely distributed power supply network. It will be able to transfer the traditional closed power system into the open network, and then transfers the power users from passive recipients into friendly participants for system running by the smart meter node [8]. The existing time-sharing peak valley electric meter, prepaid energy meter and the electric meter that has the function of infrared reading and remote reading are all can't meet the requirements for real-time interactivities of advanced measurement system in the smart grid, which are still quite different from the true

meaning of the smart meter. Under the framework of the smart grid, to demand the smart meter to have the function of real-time weight measuring and to provide the electric energy information with time scale, in order to provide the real-time information for the high efficiency energy saving management of the electric grid. Also, it has the two-way communication function, which is the basis of achieving the interaction.

Design of Meter Data Acquisition Hardware Circuit. Smart meter wireless sensor nodes are designed and developed on embedded system hardware and software architecture, which is mainly composed of ADE7878 electric energy measurement module, CC2430 wireless communication module, infrared control and liquid crystal display module and power supply module. The hardware structure is illustrated in figure 2.

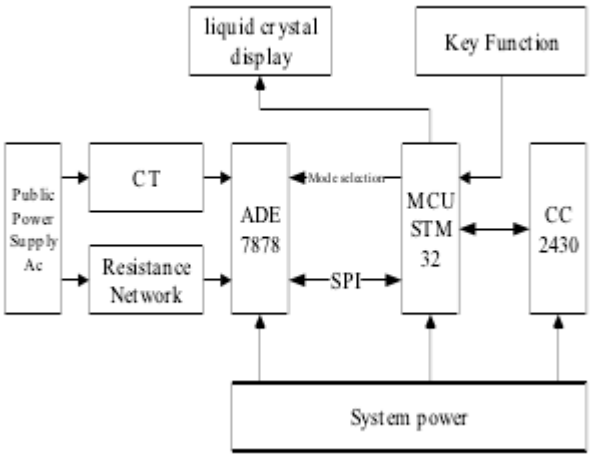

Fig. 2 Hardware structure of smart meter wireless sensor node

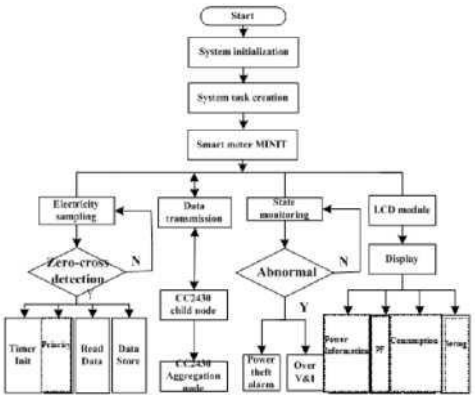

Fig. 3 uC/OS-II multitasking execution

ADE7878 is electric energy metering chip, which is ADI company specially tailored for the smart grid. It can accurately measure several programs of electricity, monitoring the power quality parameters and undergo harmonic measurement. This ensures on the hardware level that it can provide detailed information of energy metering and the measured data of electricity consumption situation currently.

Transplantation of Embedded Systems. As shown in figure 3, the smart meter wireless sensor nodes adopt multitask embedded operating system ^C/OS-II to finish each function module scheduling, processing and coordinating. This operating system is specially designed for embedded computer application, with high efficiency, small space occupation, good real-time performance and expandability etc.

According to the characteristics of the task, the system will arrange priority from high to low to configure to abort processing tasks, the user terminal operation, power information sampling task, and other tasks. The system's task priority in the user interface file APP_CFG file defines the task priority and task stack size.

Smart Meter Power Wireless Sensor Nodes Sampled Data. The pins of ADE7878 chip are the differential input current sampling channel. The selection of the current transformer is superior sampling phase current. Voltage sampling pins sample through the sampling voltage divider network.

When an exception of the zero line current phase occurs, it will alarm by electric trigger. ADE7878 energy sampling is done in the timer interrupt, through the appearance of high-pass filter configuration register enable filter output waveform sampling, followed by the completion of the energy data collection. STM32 processors through SPI to access waveform sample registers [9], the data will be stored on-chip RAM. Then it converts the data and waits serial communication network to transmit data through the first bit machine user monitoring terminals.

5. Wireless Ad Hoc Networking Solution

Currently, low-power, low-cost ZigBee technology is more acceptable for home network users. ZigBee Alliance also specifically formulated Smart Energy subset of applications. Wireless sensor network can obtain network running status, parameters and other physical information, and provide more comprehensive and complete data to grid operators. Thus it is conducive to the implementation of programs and decision-making system to control response plans. As a result, it will become an effective part of the smart grid. The system includes smart meter wireless measurement nodes, ZigBee wireless communication network, wireless gateway, Ethernet and data server. Smart meter ZigBee wireless gateway communicates with wireless measurement nodes by ZigBee wireless communication network [10]. The information transmission which is between wireless gateway and data server is based on the TCP/IP protocol backbone network. It is able to guarantee the overall system to be efficient and practical. The system networking is shown in figure 4.

6. Power Quality Management System

Power quality management system is designed under the national grid company smart meter enterprises standard. The system consists of the energy data management and analysis, endpoint policy setting and charging management, real-time monitoring and dynamic display, so smart meters can monitor power parameters measurement and display those at the same time. It achieves sub-time measurement event logging large amounts of data processing. In short, the system user monitoring terminals are designed around a guiding ideology, which uses information technology means. At the end, we take the use of price leverage and interactive strategy, mobilizing electricity demand-side response to user participation, to achieve an idealized electricity load demand.

Energy Data Management and Analysis. Embedded system sends energy data and user information collected by ADE7878 to Power Quality Management System through the network system. Users take advantage of MySQL 5.0 that is small, fast, and low total cost of ownership to build energy database. Electricity consumption information of each user will be stored through a terminal database. Data storage for electrical energy management and event logging are viable, too. Terminal Management Policy Settings and Charges. The user monitoring terminal has query, payment, price ladder setting, pre-paid, remote communications and other functions, so it can set time rate, time zone and other parameters at any time through the communication device. Meanwhile it can support demand-side management and manage electric equipment and distributed generations through the cooperation with intelligent interactive terminals, so it is able to help grid load shift and improve power supply reliability. With automatic clearing and manual clearing two ways, you can set the date in the settlement of forward, and reverse the active and reactive power to the balance sheet. Finally it can save the previous 12 months of data.

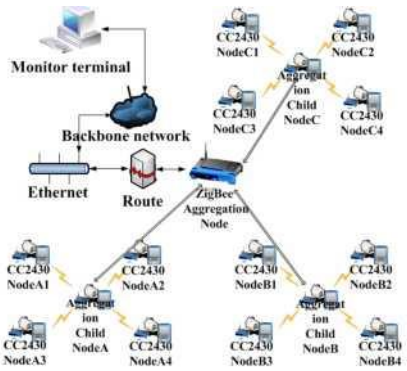

Fig. 4 Wireless ad hoc networking solution

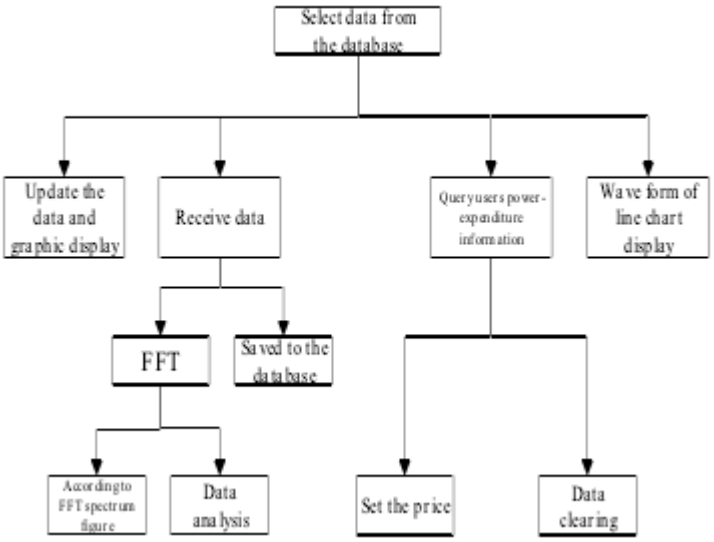

Fig. 5 Functional modules of power quality management system software

Real-time Monitoring and Dynamic Display. Real-time monitoring dynamic of the user monitoring terminal displays the energy data and each harmonic component diagram by FFT transformed on the user interface. The user monitoring terminal has set up a virtual oscilloscope, thereby displaying the users' electricity situation clearly. The amplitude of the waveform can be adjusted according to the change in scale. When an abnormal condition occurs, the system will alarm and the real-time monitoring interface will display the specific circumstances of what happened.

7. Implementation and Performance Analysis

In order to test the accuracy of such system, some smart meter wireless measurement nodes to a set of some common electrical equipments, which working under real-time measurement is implemented. The system's ZigBee network sends information to the user monitoring terminal, and the terminal automatically receives the appropriate data processing. Physical system and measuring results are showed in figure 6 and table 1. The smart metering system has the small relative error of the measured data and the measurement accuracy is higher, which is based on the comparison of voltage, current, power measuring results.

The system will deal with power parameters which is transmitted up by ZigBee wireless ad hoc network and stored in the user monitoring terminal. Then the energy data is used to make research on the FFT analysis. Finally, the real-time FFT displays the amount of power quality maps. This system has proved the stability of ZigBee network communications and the capabilities of data analysis. Mass storage interface and FFT power distribution are showed in figure 7.

Fig. 6 Wireless ad hoc smart metering system for power quality

Table. 1 Accuracy of performance

Test object	Vrms/V	Irms/A Active power/W	Reactive power/W
220V/40W Filament lamp	218.9	0.18 38.5	0
220/60W Filament lamp	217.6	0.27 63.2	0

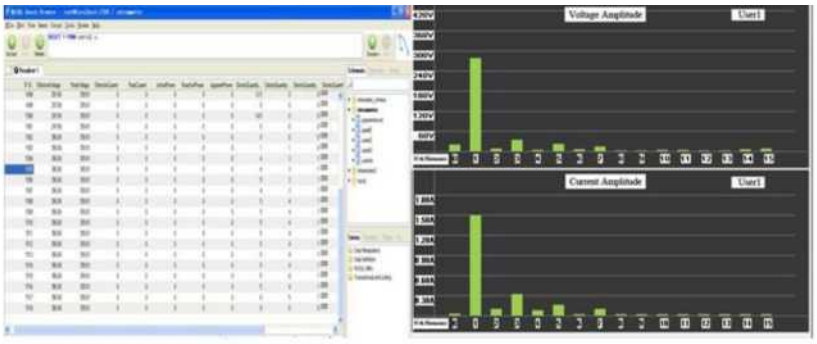

Fig.7 Data storage and waveform display interface

8. Conclusion

This paper presents a wireless ad hoc smart metering system for power quality and the functions of each module in such system are also introduced, and it focuses on developing a kind of novel networked smart metering system that is suitable for the future smart grid. We also develop a demonstration system and it is tested under the condition of some electricity equipments working. As a result, the performance of smart metering system is collected. In the demonstration system, progressive pricing and demand side response which is under two-way measurement are simulated. The system is able to reduce user's costs and it can help users save energy efficiently according to the experimental result.

Further research work will be focused on the establishment of a smart power utilization system. The system includes a full range of household electrical equipment, intelligent interactive terminals, home area networks, and small distributed power and energy. A management mechanism for a family user will be established, considering electricity strategy for ordinary family, so that to support more users who are allowed to participate in the interaction with the smart grid.

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