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Design and Development of Smart Socket - Energy monitoring and Controlling

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Abstract:We propose in this paper a technology that can perform remote control and monitoring of electrical appliances on Zigbee wireless network. To do this, a Smart power socket (SPS) module that is able to control and monitoring the power of electricity is realized in this research. ZigBee wireless smart loading monitoring and control system uses visualized program language to develop graphic control software, and the control module of this system which applied the Advanced RISC Machine (ARM7) single chip microcontroller and embedded ZigBee wireless integrated circuit (IC). In other to save energy, several countries recently made laws related to standby power consumption.To success this exertion, we should consider not only power reduction of consumer electronics itself but also efficient automatic control in networked home environment. This system can effectively solve the insufficiency problem of power supply while such problem happened in the electricity utility side and decrease peak power generation simultaneously in order to achieve the goal of energy conservation and carbon reduction. A typical automatic standby power cut-off outlet has a waiting time before cutting off the electric power. It consumes standby power during that time.. The integration of ZigBee smart power socket control module and digital meter, in the other hand, can also monitor and control the electricity consumption of household appliances and manage standby power as well.It effectively reduces the power consumption of peak hours and saves the cost of power rate for residential users and commercial clients.The proposed architecture has been shown to be very convenient and useful for remote control and monitoring of electrical appliances, and hence can facilitate the life of human beings.

Keywords: energy conservation, power consumption, standby power, wireless network, ZigBee.

Introduction

Today, around 80% of the world's primary energy is produced from fossil fuels; renewable energy sources add up to around 4.3%. However, the world is coming to realize, that keeping on burning fossil fuels is not an option in the long run. This affects not only electrical energy production in power plants but also the fuel demand of usual combustion engines in vehicles. On the other hand, as our world is suffering energy crisis on oil and natural resources shortages, how to make efficient use of limited power energy has remained a major problem to be conquered so far.

To achieve the goal of energy conservation and carbon reduction, the Bureau of Energy, Ministry of Economic Affairs, Taiwan, R.O.C. has declared that energy consumption should be in efficient, clean, and steady ways as the objectives of National Sustainable Energy Policy. Especially on the goal to consume energy more effectively, the bureau hopes to increase the efficiency over 2% every year through the promotion of smart household appliances and the development of home automation within the next eight years [4, 6].

To meet requirement of enhancing the efficiency of energy utilization, some governments present smart power demand response loading control strategy and the advanced meter structure plan. Such strategy and plan focuses on the terminals between electricity industries and clients in order to achieve the enhancement of power utilization and reaches the goal of restraining the growth of peak loading and the CO2 emission [1] by both ways at one swoop. Home power control and conservation system will be developed and introduced to the domestic in next few years, and the system will put household standby power under the management too, so that the estimated efficiency of power conservation is able to achieve 15%. In the case of residential client consumed low voltage power, the power consumption is 320 degree every month. The ratio of power consumption of household appliances in the summer is shown as Fig.1.In the figure, the consumption ratio of air conditioner is 41%;lighting is 18%, and 41% for main household appliances. If the Smart loading monitoring controller can be developed according to the priority of the loading of household appliances and the contribution of peak loading, and also combined with the coordination of the strategy of load shedding demand response for implementing the load shedding of household appliances or stopping the power supply. The objectives of restrained peak loading and energy conservation can be achieved firmly.

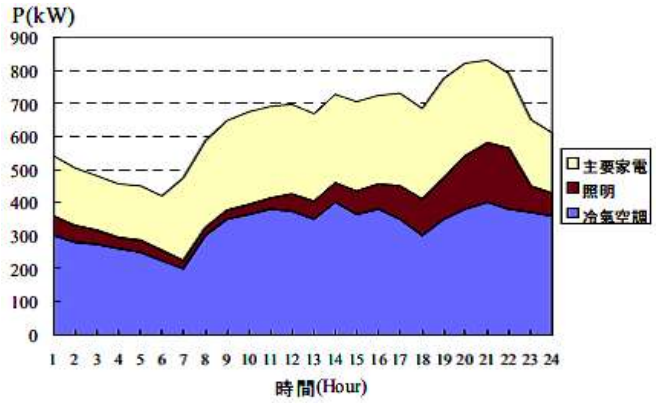

Figure 1: The load composition of Home Appliances.

The embedded remote monitoring and controlling power socket was developed for automatic and power management of home appliances [11]. To monitoring the power consumption, some ofthe researches propose measuring the power consumption in digital manners[12-13] or reading the power consumption remotely[18] so that the human resources of the power company originally arranged for recording the power meter of individual customer can be saved. On the other hand, the user can also know the status of individual electrical appliance remotely.

Proposed System

As can be seen in Fig. 2, the proposed architecture is mainly composed of two blocks, the Controlling unit, the realtime monitoring unit.The hardware function is for achieving the contractual loading control for demand response; the software is the smart power management system which aims to the objectives of electricity-saving and standby for energy conservation. The system functionality can be separated into two major parts: the side of electricity industries and the side of clients. About the demand response in the side of electricity industries, it is sent by power distribution centre through the bidirectional communication between the ZigBee wireless network and the ZigBee smart loading control module in the side of clients. Besides, ZigBee smart loading control module of the client side will also offer the information of power consumption, status of loading control, and the controllable loading margin to the electricity industries side.

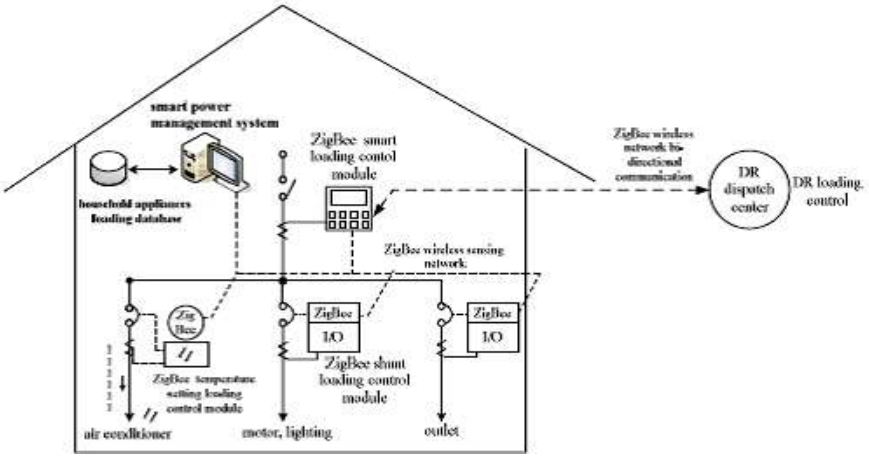

Figure 2: Zigbee wireless network based energy monitoring and controlling.

The structure of ZigBee wireless network smart loading control system of this paper is shown as Fig.3 and Fig.4. Its hardware includes (1) ZigBee smart loading control module; (2) ZigBee based Real time monitoring module.

ZigBee wireless network smart loading control system in the client side, it is planned to usethe integration of ZigBee smart loading control module and digital meter through ZigBee wireless network to process bidirectional communication with power distribution center of demand response. This way shows the real-time power rate structure or the message of demand response on the LCD monitor. The Wattmeter will sense the wattage consumption of the bulb and send through digital pulses to ARM 7. The gateway will then transmit the received commands to a Zigbee transceiver through the universal asynchronous transmitter and receiver (UART) interface. An automatic standby power cutoff outlet can contribute to the reduction of home energy cost. Fig. 4 shows the architecture of the automatic standby powercut-off outlet and the state transition diagram of it [14] [15].

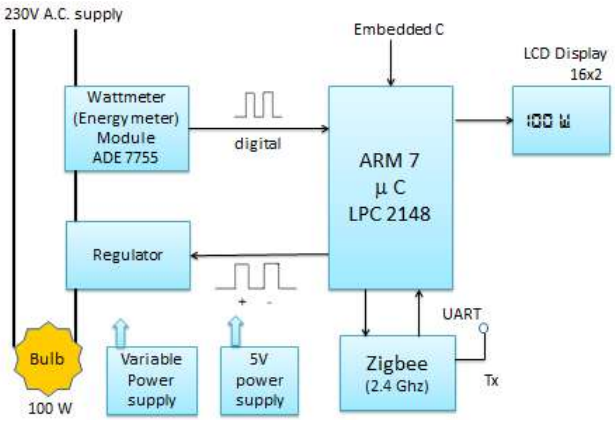

Figure 3: ZigBee smart loading control module

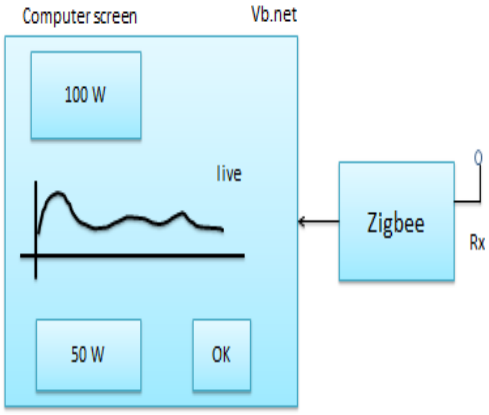

Figure 4: ZigBee based Real time monitoring module.

Energy Control and Wireless transmision

As shown in Figure 5, the frequency output CF is connected to an MCU counter or port, which counts the number of pulses in a given integration time that is determined by an MCU internal timer. The easiest way to interface the ADE7755 to a microcontroller is to use the CF high frequency output with the output frequency scaling set to 2048 × F1, F2. This is done by setting SCF = 0 and S0 = S1 = 1 . With full-scale ac signals on the analog inputs, the output frequency on CF is approximately 5.5 kHz. The average power proportional to the average frequency is given by: Average Frequency = Average Active Power = $\frac{\text{Counter}}{\text{Timer}}$. The energy consumed during an integration period is given by:

Energy = Average power x Time = $\frac{\text{Counter}}{\text{Time}}$x Time.

For the purpose of calibration, this integration time can be 10 seconds to 20 seconds to accumulate enough pulses to ensure correct averaging of the frequency. In normal operation, the integration time can be reduced to 1 second or 2 seconds . With shorter integration times on the MCU, the amount of energy in each update may still have some small amount of ripple, even under steady load conditions. However, over a minute or more, the measured energy has no ripple.

Figure 6 is a Schematic Diagram Connecting FT232RL Breakout Board to an XBeeZNet Module and connection of XBee module's internals. Incoming data flowing through the DIN pin is buffered by the DIN buffer until it can be transmitted. As programmer and commander, you have the option of sending characters as they enter the DIN pin or buffering up a number of characters to send as a packet. When the XBee module isn't sending characters, it can rest in Idle mode, enter Receive mode, process a command, or just sleep it off.

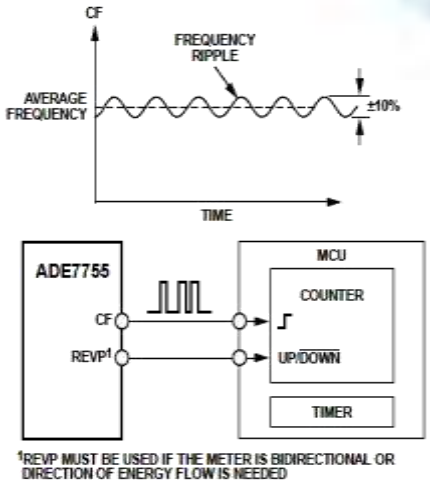

Fig. 5: Interfacing the ADE7755 to an MCU

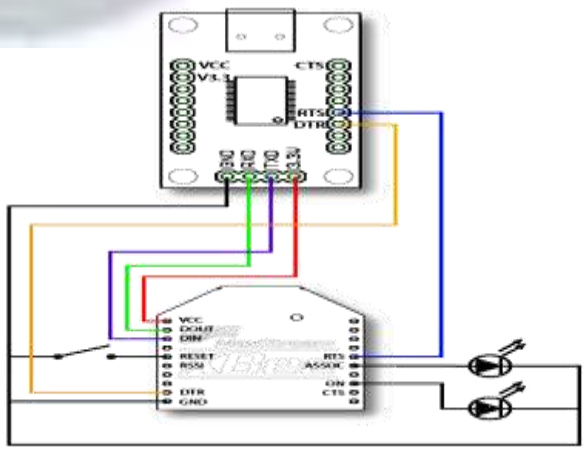

Fig. 6: Schematic Diagram Connecting FT232RL Breakout Board to an XBee ZNet Module

Realtime Monitoring and Controlling Energy Consumption

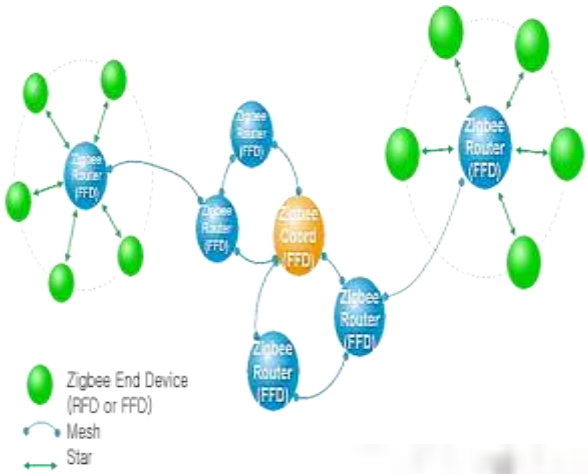

Fig. 7: The Model of Zigbee wireless network.

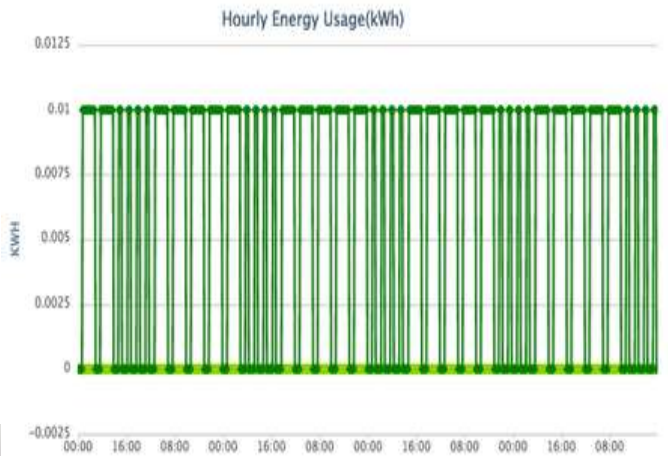

Fig. 8: Visual basic screen realtime analysis of energy consumption by household appliances

ZigBee wireless detection network is the network system composed of one to few wireless data receivers and numerous number of detectors. The network structure is mainly composite with components of coordinator, router, and end device, shown as Fig. 7. The communication way among components is adopting the wireless method.

The visualized program language is used to develop a well-completed and friendly man-computer interface for Smart power management system in this paper. The loading database of clients is established by the integration of this management system and control modules. It offers real-time information display and history inquiry, and allows to set the schedule of turning on/off for household appliances through Zigbee wireless network.

In order to know the connection status of ZigBee wireless network with the loading control modules of household appliances of every client, the VB graphical interface of connection status was designed by this thesis, shown as Fig. 8.The connection status among personal computer, ZigBee coordinator, and end devices can be checked by the VB interface. Users can set related settings of USB communication port by oneself, such as number of communication port, data transmission baud rate, transmitting data size, and number of stop bits. In the household appliance node labeled area of ZigBee wireless network, the interface allow user to know the status of power consumption and standby of household appliances of every client.

It also implements the analysis for the composition of the loading of household appliances and the smart standby management of household appliances. These features help to restrain power distribution of the loading of the peak hours and save the cost of power rate.

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Conclusion

By the realization of the above proposed system one can monitor and control many aspects of a home automation with saving energy consumption Systems and technologies are planned to apply to the market of home automation for the requested function of the energy and power conservation and the restraint of loading of peak hours for demand response. The system develops numerous numbers of residential and commercial clients of low voltage consumption and restrains the loading potential of peak hours in order to achieve the goals of power-saving and power conservation with standby control. In the household appliance node labeled area of ZigBee wireless network, the interface allow user to know the status of power consumption and standby of household appliances of every client. It also implements the analysis for the composition of the loading of household appliances and the smart standby management of household appliances. These features help to restrain power distribution of the loading of the peak hours and save the cost of power rate. Those records are with great help to the enhancement and improvement of the reliability of power consumption in the side of clients.

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