

SHORT COMMUNICATION

Design and Development of ZigBee Based Smart Meter with Front End Graphical User Interface

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Abstract

Recent developments in smart grid system open the new horizon in four quadrant sector of power system such as generation, transmission, distribution and consumption. In view of this, the smart metering concept is attracted and adopted in worldwide due to rapid development in Demand Response (DR) system. The DR system managed the customer consumption of electricity in response to changing supply conditions and balance between supply and demand. For such type of management the front and back end electronics is required. In this short communication, we report the hardware solution for DR system. The hardware solution consists of ZigBee transmitter and receiver which is communicated and controlled by PIC microcontroller. The PIC microcontroller is also used for controlling end devices using switching circuit. The front end VB and Microsoft SQL based database are used to store end devices electricity consumption at regular interval.

Keywords: Demand response system, smart grid, smart meter, ZigBee protocol, PIC controller.

Introduction

A smart grid is a next generation electrical grid and its primary function is to use information and communication technology to collect information and enhance the grid efficiency in the manner of reliability, economics and sustainability of electricity (Gerwen *et al.*, 2006; Smart grid, 2013). Smart grid is a front runner in today's scenario due to the new technological advance in the field of communication, power electronics, supportive embedded system, IDAPS (Intelligent Distributed Autonomous Power System), improved interface and decision support, micro grid, smart equipment, smart sensor technology, smart homes etc. The efficient function of smart grid relies on the full duplex communication and advanced ability of data functioning units. Its application is found in the electricity networks from the power plants and wind farms all the way to the consumers of electricity in homes and businesses (Tokyo electric power company, 2012; Alexander *et al.*, 2012).

Smart meters are key parts of the smart-grid power-distribution networks and it is now being rolled out internationally to achieve economic and environmental benefits (Renesas, 2013; Transportation demand management, 2013). Traditional energy meters are mechanical, but smart meters must be electronic with two way communication support, so this type of product represents a major new global mass market for semiconductor devices (Alexander *et al.*, 2012; Renesas, 2013). A smart meter is usually an electrical meter that records consumption of electric energy in intervals of an hour or less and communicates that information at least

daily back to the utility for monitoring and billing purposes (Smart grid, 2013). Smart meters enable two-way communication between the meter and the central system. Unlike home energy monitors, smart meters can gather data for remote reporting (Botha, 2008; Transportation demand management, 2013). Smart metering system is the first step toward moving the electric grid into the digital age. Our smart meters have two-way communication capabilities using ZigBee enabled wireless communication to allow consumers to view their electricity usage in unit interval increments and on demand, which can encourage them to save energy and money. Following are some of the features of smart meters reported by Neil (2009) and Jan Top (2010).

- *Remote meter reading:* Center Point Energy can read smart meters remotely, which means more privacy for residents, less meter Read and easy on-demand reads.
- *Remote service connection/disconnection:* Faster service, lower cost to consumers to move or switch retail electric providers.
- *Automated outage notification:* Smart meters will automatically notify Center Point Energy about power outages to help us restore power more quickly.
- *New products and services:* Retail Electric Providers, who sell electricity, can now offer new services such as pre-paid service, 'time-of-use' rates or energy analysis tools.
- *Home Area Networks (HAN):* Smart meters can interact with ZigBee-compatible HAN devices such as thermostats or other electric appliances, so consumers can better manage their electricity use.

- **Energy efficiency and savings:** Consumers can see their electric usage history to better manage energy costs by making small changes such as adjusting the thermostat.

The smart meter basically consists of transmitter module and receiver module. Here, the two way communication between transmitter module and receiver module is established using ZigBee protocol. ZigBee and IEEE 802.15.4 are standards-based protocols that provide the network infrastructure required for smart meter network applications. An IEEE 802.15.4 protocol defines the physical and MAC layers and ZigBee defines the network and application layers (Liu, 2009; Zigbee and IEEE 802.15.4 protocol, 2013). The smart metering will be improving operational efficiency in the conventional grid and decrease maintains cost. The DR system will be take care of peak demands and its proper utility. The DR system will be help to improve quality and coordination between the supplier and consumers (Coronet, 2005). The two key design requirements for smart meters are (Renesas, 2013).

- They should operate at low energy, so they can run for prolonged periods on battery power.
- They must include security features that can protect the content of communications and the safety of stored data.

The main constituent of this reported idea is ZigBee based smart meter model. The ZigBee is the product of the ZigBee Alliance, an organization of manufacturers dedicated to developing a new networking technology for small, ISM-bands (Coronet, 2005). ZigBee supported as a low-cost, low-power, low-data rate wireless mesh technology. The ZigBee specification identifies three kinds of devices that incorporate ZigBee radios, with all three found in a typical ZigBee network coordinator, which organizes the network and maintains routing table's routers, which can talk to the coordinator, to other routers and to reduce function end devices, reduced function end devices which can talk to routers and the coordinator (Coronet, 2005). In this short communication, we report design and development of zigbee based smart meter with front end graphical user interface. It is a hardware solution for Demand Response system. The hardware solution consists of ZigBee transmitter and receiver which is communicated and controlled by PIC microcontroller. The PIC microcontroller is also used for controlling end devices using switching circuit. The front end VB and Microsoft SQL based database are used to store end devices electricity consumption at regular interval.

Materials and methods

Figure 1 shows the basic block diagram of smart meter using ZigBee protocol and Fig. 2 represent the real time electricity measurement using PIC microcontroller.

Fig. 1. Basic block diagram of smart meter using ZigBee protocol.

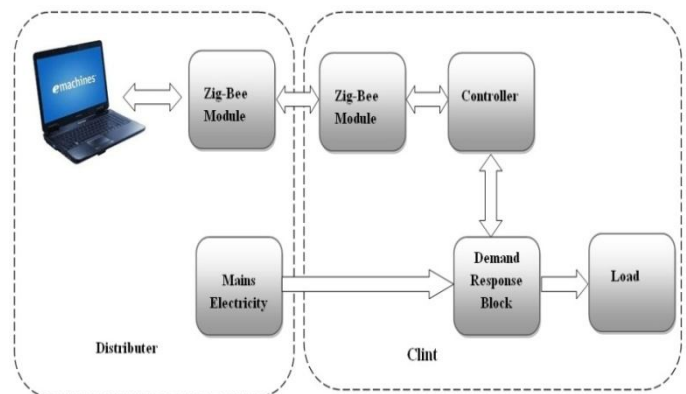
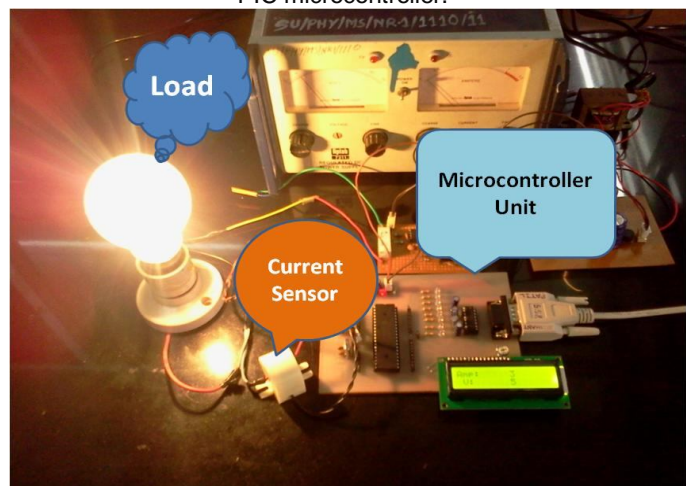


Fig. 2. Real time electricity measurement using PIC microcontroller.



Generally, the smart meter consists of electronic meter unit, communication unit and end device switching unit. Here, ZigBee transmitter and ZigBee receiver are used for communication between consumer and electricity provider.

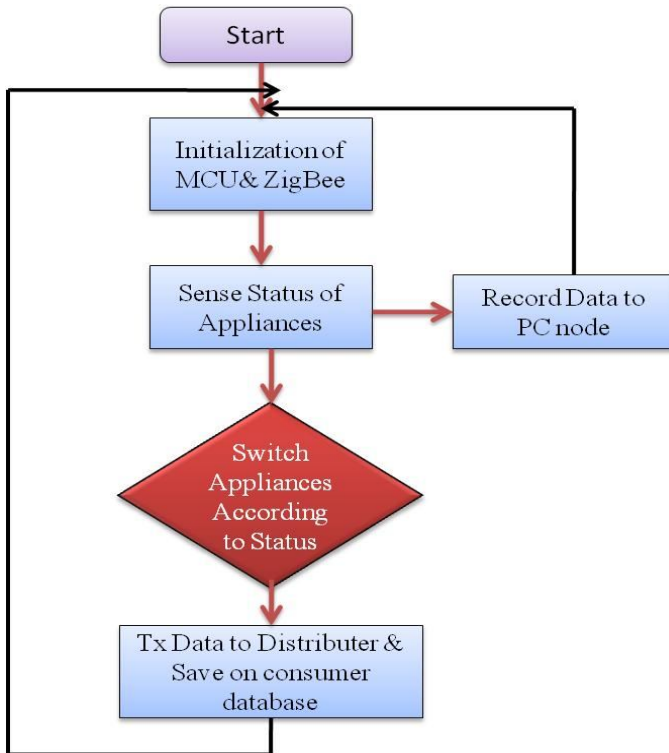
Results and discussion

In this study, we report that the supply is single phase to control the end devices. We also report some of the power electronics and soft computing related report in (Dongale *et al.*, 2012a-g; Ghatage *et al.*, 2012; Dongale, 2013a-c; Kulkarni *et al.*, 2013). The power supply is connected to the switching circuit block. The switching circuit determines the load operation at peak of supply, so end devices possess the smartness in their operation. The microcontroller PIC 16F877A is used for controlling switching circuit and it is also used for controlling the transmitter and receiver module. The front end GUI for data collection is created using VB platform and Microsoft SQL. This is used to store end devices electricity consumption at regular interval. The front end GUI and the system flow are shown in is shown in Fig. 3 and 4.

Fig. 3. Front End GUI of smart meter for recording electricity consumption.



Fig. 4. System flow diagram of ZigBee enabled smart meter.



The current sensors are used to sense the online status of appliances i.e. voltage and current, it provides data to microcontroller for further manipulation. Microcontroller will stage-manage this data and calculate the current usage status of appliances. After this brief manipulation, the microcontroller will send this data to computer node, where further operation on this data is performed by proper algorithms. The front end GUI will manage this data on their database. After extensive calculation, the microcontroller will transfer this data using ZigBee transmitter to distributor database, where data is stored in unit interval of time.

The system flow is shown in Fig. 4. The switching circuit will take care of peak demand of appliances. When peak demand of electricity is reported, then switching circuit automatically cut off the mains from appliances. This workflow will manage the demand response of electricity using ZigBee enabled smart meter. There is no drought that with proper algorithm and supportive resources, the smart meter will be only solution for next century smarter grid and smarter planet.

Conclusion

Although the smart meter concept is adopted worldwide, but as per cost effective point of view, this type of low cost PIC and ZigBee enabled smart meter platform can be better solution for conventional grid system. DR system benefits all electricity consumers and it changes end-use customer electricity consumption. This type of system can transform the conventional grid system to smarter grid system. Its benefits measure when, reduce the peak load and demand elasticity. This type of initiative can reduce the CO₂ footprint in nature. Apart from this unique transformation, the future of smart metering will heavily depend upon the energy policy and the governmental bodies.

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