ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Intelligent Power Management for Residential Buildings Using Sensor Networks and Zigbee Pro.

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ABSTRACT

One of the major problem in many households and Industries is the over consumption of power and also the protection of various equipment's from over voltage and over current. This paper discusses the design and development of a cost effective smart monitoring and controlling system for household electrical appliances in real time. The electrical parameters such as voltage and current are principally monitored and the power consumed is calculated. The proposed system allows the user to control his appliance in different ways using ZigBee and LabVIEW. Automatic control of the appliances is also done by setting required tariff rates. The developed system is low cost, easily operatable and flexible in operation, thus saving the electrical expenses of the user. The prototype has been extensively tested and the results are very encouraging.
Keywords: Power management, Smart Monitoring, Wireless sensor Networks, ZigBee, Wattmeter

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INTRODUCTION

It is foreseen that personal and wireless mechatronic system has become more useful in our household applications and it will be more useful for assistive healthcare particularly for elderly and disabled persons. Wireless sensor networks consist of many sensors distributed spatially with limited data collection and processing capability to monitor the environmental situations. WSN's have become very important for their ability to analyze and manage situational information's effectively. Due to those advantages, WSN's has been applied in many fields, such as the military, industry, and healthcare.

The WSN's are used largely in the home for energy management and controlling services. Regular household appliances are monitored and controlled by WSNs installed at home. With advancements is cutting-edge technologies like information technology, metering, sensors and electricity storage technology users were able to control their appliances with more flexibility and automation. The ZigBee Alliance, wireless communication platform is presently examining Japan's new smart home wireless system implication by having a new initiative with Japan's Government that will evaluate the use of the forthcoming ZigBee, Internet protocol specification, and the IEEE 802.15.4g standard to help Japan create smart homes that improve energy management and efficiency.

It is observed that 65 million households will equip with smart meters by 2015 in the United States, and it is a realistic estimate of the size of the home energy management market.

There are several proposals to interconnect various domestic appliances by wireless network to monitor and control them. Also, watt meters have been integrated to specific usage charges particularly related to geographical usage and are limited to specific places.

There has been design and developments of smart meters predicting the usage of power consumption]. How-ever, a low-cost, flexible, and robust system to continuously monitor and control based on consumer requirements is at the early stages of development. In this study, we have designed and implemented a ZigBee-based intelligent home energy management and control service. We used the ZigBee (the IEEE 802.15.4 standard) technology for networking and communication, because it has low-power and low-cost characteristics, which enable it to be widely used in home and building environments.

The remaining sections of the paper are as follows: Section II discusses the related work and investigations of WSN's constraints for home energy management systems; Section III discuss the various components used in the proposed system; Section IV describes the architecture and implementation of the proposed system; Experimental results of the proposed work are presented in section V; Section VI talks about conclusion and future scopes.

RELATED WORK

In this section, we briefly discuss the existing works about smart home systems based on the wireless communication technology. Han et al. proposed a Home Energy Management System (HEMS) using the ZigBee technology to reduce the standby power. The suggested system consists of an automatic standby power cutoff outlet, a ZigBee hub and a server. The power outlet with a ZigBee module cuts off the ac power when the energy consumption of the device connected to the power outlet is below a fixed value. The central hub collects information from the power channels and controls these power channels through the ZigBee module. The central hub sends the present state information to a server and then a user can monitor or control the present energy usage using the HEMS user inter- face. This facility may create some uneasiness for the users. For example, if the users may want low intensity of light, for some situation but the system will cut the power off leading to darkness.

Gill et al. projected a ZigBee-based home automation system. This system consists of a home network unit and a gate- way. The core part of the development is the interoperability of different networks in the home environment. Less importance is given to the home automation. Pan et al. recommended a WSN-based intelligent light control system for indoor environments, such as a home for a reduction in energy consumption. In this paper, wireless sensors are responsible for measuring current illuminations and the lights are controlled by applying the model of user's actions and profiles.

Song et al. suggested a home monitoring system using hybrid sensor networks. The basic concept of this paper is a roaming sensor that moves the appropriate location and participates in the network when the network is disconnected.

Suh and Ko proposed an intelligent home control system based on a wireless sensor/actuator network with a link quality indicator based routing protocol to enhance network reliability. Nguyen et al. have proposed a sensing system for home-based rehabilitation based on optical linear encoder (OLE); however, it is limited to motion capture and arm-function evaluation for home based monitoring. Huiyong et al. examined the integration of WSN with service robot for smart home monitoring system.

The above mentioned home monitoring and controlling systems have limitations with respect to true home automation such as: 1) energy consumption control mechanism is limited to only certain devices like light illuminations, whereas several house- hold appliances can be controlled; 2) energy control is based on fixed threshold power consumption, which may not be applicable to different consumers; 3) controlling the home appliances through network management functions, in practice inhabitant requirements may vary according to their behavior but not with network characteristics. Not a single system has taken into consideration of variable tariff of electricity, which is consumed throughout day and night.

COMPONENTS USED IN THE PROPOSED SYSTEM

The proposed system offers cost effective smart controlling and management of power in residential buildings using Zigbee. Components used in the proposed system are as follows:

PIC 16F877A Microcontroller

Peripheral Interface Control (PIC 16F877A) is a 40 pin microcontroller with 8k program memory. It is widely used due to its low cost, high application support and wide availability. Microcontroller is the heart of the proposed system and is responsible for performing various tasks

Voltage transformer

The voltage transformer used in our paper is the 44 127 voltage step-down transformer manufactured by MYRRA. The striking features include two bobbins compartments including self-extinguishing plastics and very light weight (100 g). The step-down voltage transformer is used to convert input supply of 230–240 V to 10 VRMS ac signal. The secondary voltage is rectified and passed through the filter capacitor to get a dc voltage.

The details are shown in Fig. 3. The available dc voltage is reduced by a potential divider to bring it within the measured level of 3.3 V of the ZigBee. This output signal is then fed to analog input channel of ZigBee end device. The acquired voltage signal is directly proportional to the input supply voltage. A voltage regulator is connected to the rectified output of voltage transformer to obtain the precise voltage supply of 3.3 V for the operation of ZigBee and operational amplifier. The scaling of the signal is obtained from the input versus output voltage graph as shown in Fig. 4. The actual voltage is thus obtained as follows:

$$\text{Vact} = \text{m1} \times \text{Vmeasured voltage} \quad (1)$$

where m1 is the scaling factor obtained from Fig. 4, Vact is the actual voltage, and V measured voltage is the measured sensing voltage.

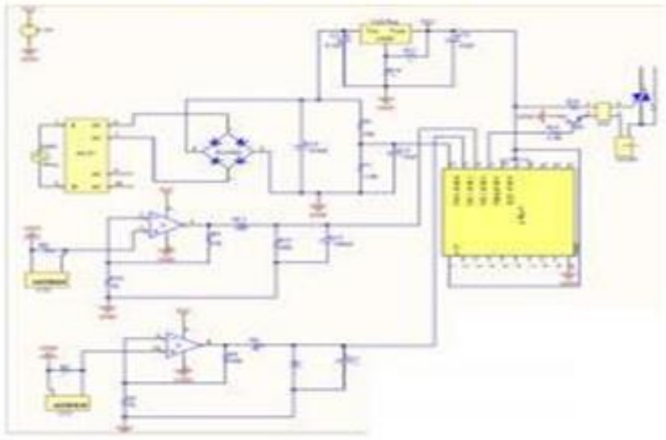

Fig. 3. Overall characteristics of voltage, current sensing circuit integrated with ZigBee module

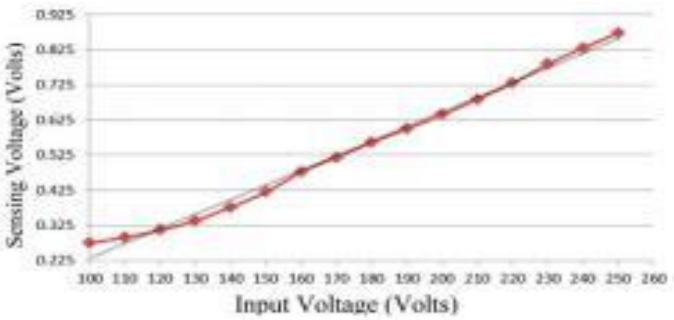

Fig. 4. Scaling Factor (m1) of voltage signal.

Many applications as well as for the safety of the electronic circuit

Iact = m2 × Vmeasured voltage for current (2)

where m2 is the scaling factor obtained from Fig. 5, different values of m2 to be used for different current transformers. Iact is the actual current; Vmeasured voltage for current is the measured sensing voltage for current. The developed system includes two current transformers; one is used for the measurements of loads up to 100 W and the other current transformer is used for the measurements of loads from 100 to 2000 W. The reason of providing two transformers is to provide two load outlets at the same sensing node. The number of turns is increased up to five turns to improve the resolution of the low current signal. Both outputs from the current transformers are fed to the analog input channels of ZigBee.

Current Transformer

For sensing current, we used ASM010 current transformer manufactured by Talema. The main features of this sensor include fully encapsulated PCB mounting and compact size. The circuit design layout for current measurement is shown in Fig. 3. In this current sensor, the voltage is measured across the burden resistor of 50 Ω. The necessary filtering and amplification is required to bring the voltage with the necessary measurement level of ZigBee. The scaling factors for current measurement for two different ranges of cur-rents are shown in Fig. 5. Two different current transformers are used for two different ranges: 0–1 A and 1–10 A, respectively. The actual current is thus obtained from (2). The line wire is connected to the load, which is passing through the current transformer. With the use of current transformer, the electrical isolation is achieved which is important in

Watt-Hour Mater:

Single phase induction type energy meter is also known as watt-hour meter. Induction type energy meter essentially consists of following components:

1. Driving system
2. Moving system
3. Braking system and
4. Registering system

It consists of two electromagnets, called "shunt" magnet and "series" magnet, of laminated construction. This coil is known as "pressure or voltage coil" and is connected across the supply mains. This voltage coil has many turns and is arranged to be as highly inductive as possible. The chopper shading bands are also called as the power factor compensator or compensating loop. This series electromagnet energized by a coil, known as "current coil". Fig 7 shows the watt hour meter that is used and fig 8 shows the working of the energy meter.

Fig. 5. Watt hour meter

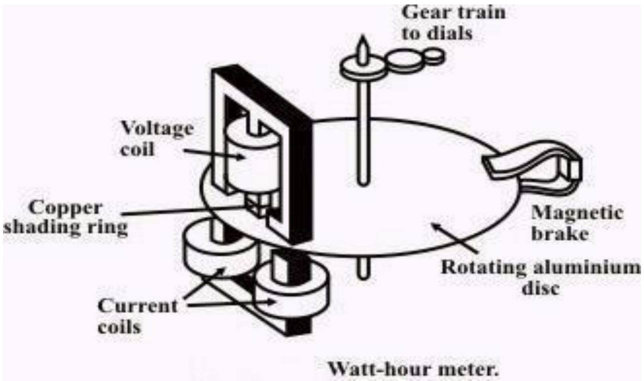

Fig. 6. Working of watt hour meter

ARCHITECTURE & IMPLEMENTATION

The system has been designed for the measurement of electrical parameters of household appliances. The voltage and current parameters of household appliances are monitored and correspondingly power consumed by them is calculated. The circuit for the proposed system is shown in fig 7.

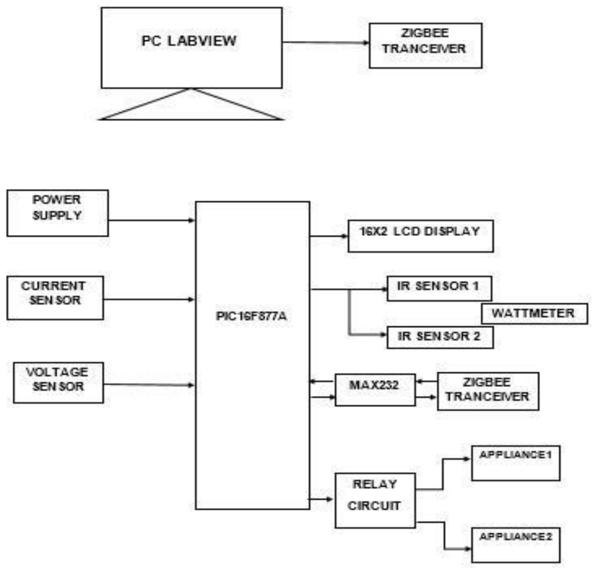

Fig. 7. Block diagram for the implementation of the proposed system

The measurement of electrical parameters of home appliances is done by interfacing with fabricated sensing modules. The output signals from the sensor are integrated and connected with ZigBee module for transmitting electrical parameter data wirelessly. The ZigBee modules are interfaced with various sensing devices and it is interconnected in the form of mesh topology to have a reliable data connection with the ZigBee coordinator. The maximum distance between the adjacent ZigBee nodes are less than 10m and through hopping technique of mesh topology, reliable sensor fusion data has been performed.

The ZigBee coordinator has been connected through the USB cable of the host computer, which stores the data in the database of computer system. The collected sensor fusion data has been integrated with LabVIEW where the collected fusion data are displayed. LabVIEW is the primary control software which principally monitors and controls the electrical parameters. By analyzing the power from system, energy consumption can be controlled.

An electricity tariff plan has been set up to run various appliances at peak and off-peak tariff rates. The appliances are controlled either automatically or manually. Automatic control has been done through relay driver circuit and the manual control has been done through LabVIEW software integrated switching's. A watt-hour meter has been connected to the system to display the amount of power consumed and automatic control is done by tripping off the additional powerconsuming electrical appliance, thus saving the electrical expense of the consumer.

The user has the options of switching the device on/off in two different ways:

1) Automatic control: Based on the electricity tariff conditions, the appliances can be regulated to work only for certain power consumption units. This enables the user to have more cost savings by auto switch off the appliance during electricity peak hours. The user himself can determine the amount of power than can be consumed or he can obtain the tariff rates from internet and update it at regular intervals.

2) Manual control: An on/off switch is provided in Labview software to directly intervene with the device. This feature allows the user to have more flexibility in operation by having manual control without automatic control. This feature can be used in cases where automatic control has to be bypassed.

The collected data has been continuously stored using software integration. This allows samples to be stored by time, sensor node and sensor channel. In the proposed system all the codes have been written by using embedded C#.

TESTING AND VALIDATION

The working model of the proposed system is shown in figure 10. It was tested with simulated concept where two bulbs are used as nodes and its operation is tested in real time. Current transformer and potential transformer measures the values of the current and voltage consumed and subsequently the power consumed is calculated. The values are transmitted wirelessly using ZigBee transceiver circuit. The amount of power consumed can be measured by the watt-hour meter. of appliances is done. Relay switching circuitry helps in the case of automatic switching. The manual control of the appliances is done by interfacing it with LabVIEW software. The interfaced working model of the proposed system with the LabVIEW software is shown in the following figure 1

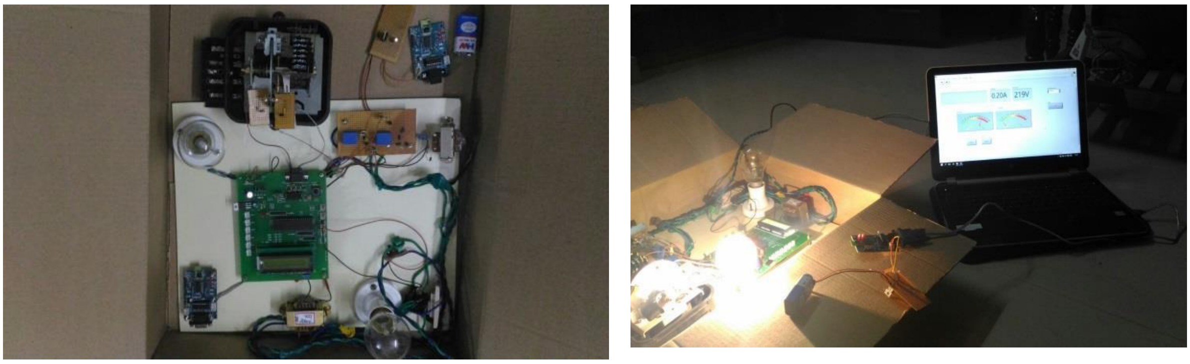

Fig. 8. Working model of the proposed system integrated with LabVIEW software

The experimental LabVIEW output of current and voltage measurements along with manual switching is shown in fig 10.

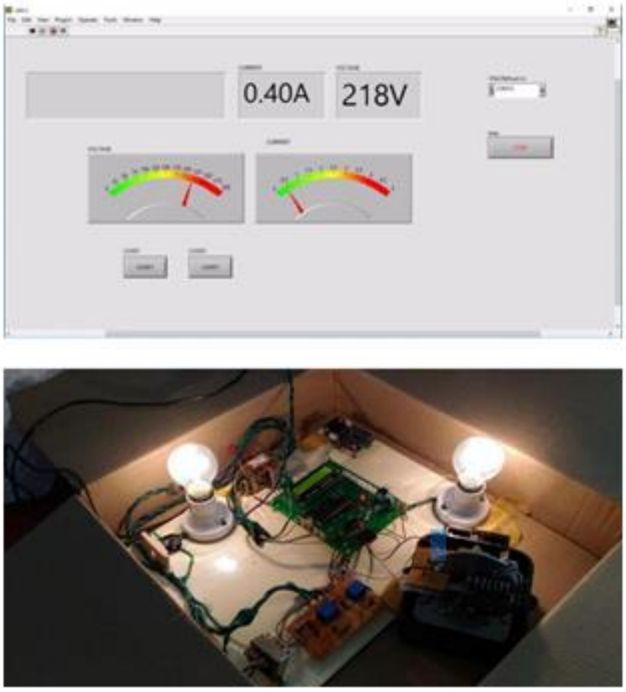

Fig. 10. Working model when two loads are switched on with manual Switch

Table 1 Values of Wattmeter Reading Consumption Table

S no	Wattmeter (normal operation)/month		Wattmeter (after connected to circuit)/month		Comparison (savings/ month)
	Readings	*Cum diff*	*Readings*	*Cum diff*	*Cum diff*
1	1700	0	1905	35	-
2	1750	50	1937	32	18
3	1780	45	1975	38	7
4	1830	50	2010	35	15
5	1870	40	2046	36	4

Analysis

On Testing bed, we have connected the controller circuit with IR sensors paired with a single phase wattmeter. The wattmeter reads the consumption value of the electricity through detection of obstacles by IR sensors. Certain pre-set value is set by programming onto the controller. This pre-set value compares the measured value and then the limiting control works out. In this state the heavy load is tripped using relay.

CONCLUSION AND FUTURE WORK

A smart power monitoring and control system has been designed and developed towards the implementation of an intelligent residential buildings. It efficiently monitors and controls the electrical appliance usage at home.

The real time monitoring of the electrical appliances can be done by using LabVIEW. The system can be extended for monitoring the whole building with various appliances. The daily peak hours of electricity usage levels can be determined and its values can be set as the input to the watt-hour meter by which we can lower the consumption of power and enhance better utilization of already limited resources during peak hours.

The sensor networks are programmed with various user interfaces suitable for users of varying ability and for expert users such that the system can be maintained easily and interfaced simply. The developed system is robust, cheap and flexible in operation. It is easy to handle and power management can be done effectively.

In future, the system can be integrated with co-systems like smart home inhabitant behavior recognitions systems to determine the wellness of the inhabitant in terms of energy consumption.

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