

WSN-Based Smart Sensors and Actuator for Power Management in Smart Home

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ABSTRACT: This paper describes more efficient home energy management system to decrease control utilization power consumption in home area. The design and development of a smart monitoring and controlling framework for household electrical appliances in real time has been reported in this paper. The system principally monitors electrical parameters of household appliances such as voltage and current and subsequently calculates the power consumed. The novelty of this system is the implementation of the controlling component of machines in various ways. The created system is a low-cost and flexible in operation and thus can save electricity expense of the consumers. The prototype has been extensively tested in real-life situations, all things considered and experimental results are very encouraging.

KEYWORDS : Energy management, home automation, intelligent control system, wireless sensor network, Zig Bee.

I. INTRODUCTION

As an ever increasing number of home appliances and consumer electronics are installed, residential energy utilization has a tendency to develop quickly. A large number of home devices increase power consumption in two viewpoints, standby power and normal operation power. Those two kinds of power consumption are proportional to the number of home devices. As a result, operational cost in home area is also likewise expanding. Standby power is electricity used by appliances and equipment while they are switched off or not performing their primary function. As around 10 % of a total household power is consumed during standby power mode [1], the reduction of standby power is significantly important to decrease the electricity cost in home.

Wireless mechatronic systems consist of various spatially distributed sensors with limited data collection and processing capability to monitor the environmental situation. Wireless sensor networks (WSNs) have become increasingly important because of their ability to monitor and manage situational information or data for different smart administrations. Due to those advantages, WSNs has been connected in many fields, for example, the military, industry, environmental monitoring, and social insurance [2][3]. The WSNs are progressively being utilized as a part of the home for energy controlling services. Regular household apparatuses are observed and controlled by WSNs introduced in the home [4]. The ZigBee Alliance, wireless communication platform is presently examining Japan's new brilliant home wireless system suggestion by having another activity with Japan's Government that will assess utilization of the inevitable ZigBee, Internet Protocol (IP) detail, and the IEEE 802.15.4g standard to help Japan to make smart homes that improve energy management and efficiency [5].

This paper emphasizes the realization of monitoring and controlling of electrical appliances from numerous points of view. The created system has the following features.

1. Use of Triac with opto-isolated driver for controlling electrical appliances: Household apparatuses are controlled either remotely or automatically with the help of fabricated smart sensing unit consisting of triac – BT138.
2. No microprocessor/microcontroller: The design of smart sensing unit does not require a processing unit at the sensing end.
3. Flexibility in controlling the appliances: Depending on the user necessities, appliances can be monitored and controlled in various ways.

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The technology to manage home energy more efficiently with the network capability is known as home energy management system (HEMS). A PLC-based HEMS combining home network and the Internet was proposed [6]. Architecture of home energy saving system based on energy-awareness was proposed for real-time home energy monitoring service and reducing standby power of home appliances [7]. The embedded remote monitoring and controlling power socket was developed for automatic and power management of home appliances [8]. However, the previous works just monitors and controls home devices, and shows the home energy information. Their standby power reduction method is passive. To reduce and manage home energy more efficiently, a more active standby power decrease strategy is required and the controlling of the power outlets with a remote control should be enabled. An easy to use and reconfigurable HEMS user interface (UI) is enormously essential.

II. RELATED WORK

In this section, we briefly discuss the current works about smart home systems based on the wireless communication technology. Han et al. [9] proposed a Home Energy Management System (HEMS) utilizing the ZigBee innovation to decrease the standby power. The suggested system consists of an automatic standby power cut-off 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 gathers 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 utilization utilizing the HEMS UI. This facility may make 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. The home appliances use a very small amount of power in the standby mode, it is more effective to totally cut off the electric power supply to those home devices. An automatic standby power cut-off outlet can contribute to the reduction of home energy cost. Fig. 1 demonstrates the design of the automatic standby power cut-off outlet and the state transition diagram of it [9], [10].

The microcontroller is supplied with electrical power through the AC/DC circuit and incorporates ZigBee Radio Frequency (RF) module to communicate with ZigBee controller. ZigBee is a low-power and low-cost wireless personal area network standard (WPAN) in view of IEEE 802.15.4 to configure wireless sensor networks [11]. The previously mentioned home checking and controlling systems have limitations with respect to home automation such as: 1) energy utilization control mechanism is restricted to only certain devices like light illuminations, while a few house-hold appliances can be controlled; 2) energy control is depends on fixed threshold power utilization, which may not be applicable to various consumers; 3) controlling the home appliances through network management functions, in practice inhabitant requirements may vary according to their behaviour but not with network characteristics. Not a single system has taken into consideration of variable tariff of electricity, which is utilized throughout day and night. Energy monitoring systems can influence residents by informing them of the real-time home energy utilization with a graphical interface. If the breakdown energy usage of each home apparatuses and consumer electronics is displayed on a wall pad, a PC, or a television, residents can make an effort to decrease the home energy.

III. SYSTEM DESCRIPTION

Fig. 1 demonstrates the useful description of the developed system to monitor electrical parameters and control appliances in view of the consumer requirements. The measurement of electrical parameters of home appliances is finished by interfacing with fabricated sensing modules. The details of the design and development of the sensing modules are provided in the following sections. The output signals from the sensors are integrated and connected to XBee module for transmitting electrical parameters data wirelessly. The ZigBee modules are interfaced with various sensing devices and interconnected in the form of mesh topology to have reliable data reception at a centralized ZigBee coordinator. The maximum distance between the adjacent ZigBee nodes is less than 10 m, and through hopping technique of the mesh topology, reliable sensor combination information has been performed.

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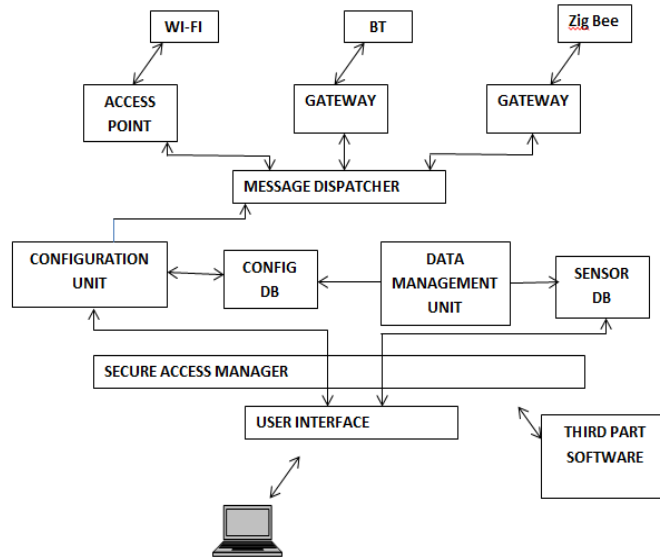


Fig.1: Functional block diagram of the system.

The ZigBee coordinator has been connected through the USB cable of the host PC, which stores the information into a database of computer system. The gathered sensor combination information have been sent to an internet residential gateway for remote observing and controlling the home environment. By examining the power from the system, energy consumption can be controlled. An electricity tariff plan has been set up to run different apparatuses at peak and off-peak tariff rates. The appliances are controlled either automatically or manually. The smart power metering circuit is connected to mains 240 V/50 Hz supply. Fig. 2(a) and (b) demonstrates the fabricated brilliant detecting measurement system.

IV. MEASUREMENT OF ELECTRICAL PARAMETERS

1) Voltage Measurement

The voltage transformer utilized as a part of our paper is the 44 127 voltage step-down transformer. 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. 2(a). 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. 3. The actual voltage is thus obtained as follows:

$$V_{act} = m_1 \times V_{measured\ voltage}$$

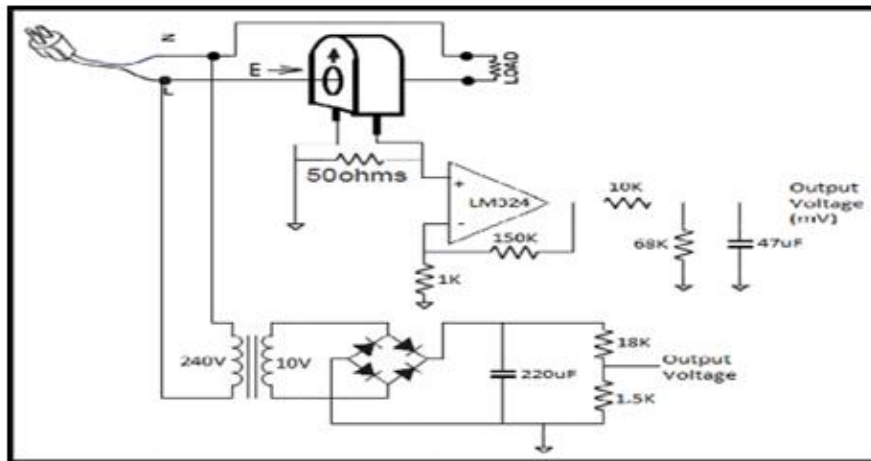
where m_1 is the scaling factor obtained from Fig. 4, V_{act} is the actual voltage, and $V_{measured\ voltage}$ is the measured sensing voltage.

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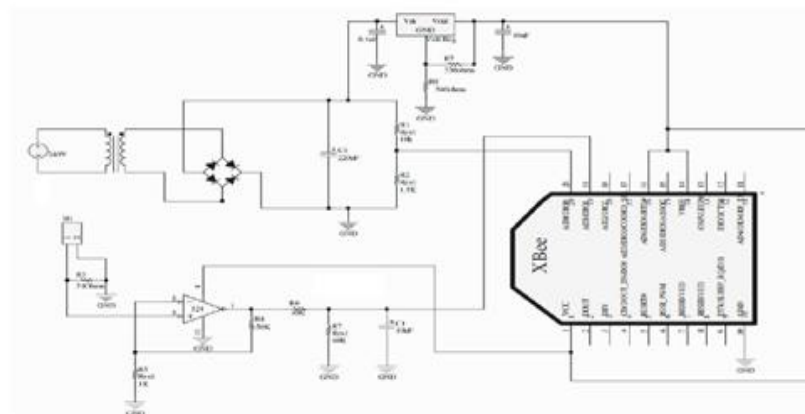
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(a)



(b)

Fig. 2. (a) Overall schematic of voltage, current sensing circuit integrated with ZigBee module. (b) Designed and developed prototype-electrical appliances power monitoring and control.

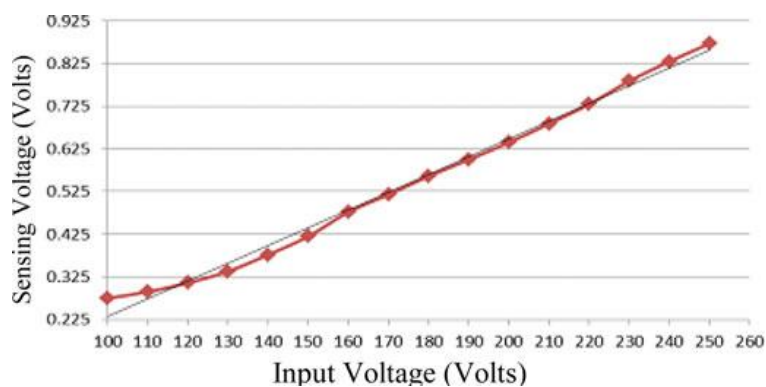


Fig.3: Scaling factor (m1) of voltage signal

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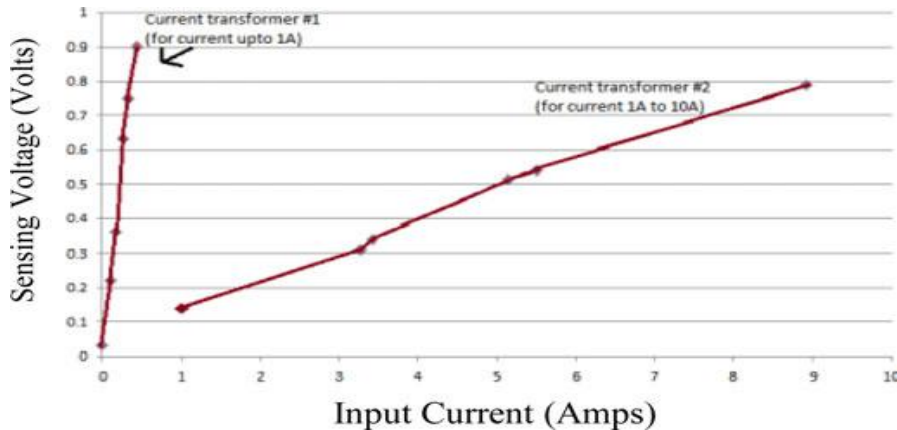


Fig.4: Scaling factor (m²) of voltage signal.

2) Current Measurement:

For sensing current, we used ASM010 current transformer made by Talema. The principle elements of this sensor include fully encapsulated PCB mounting and smaller size. The circuit design layout for current measurement is shown in Fig. 2(a). 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 essential measurement level of ZigBee. The scaling factors for current measurement for two different ranges of currents are shown in Fig. 4. Two different current transformers are utilized for two different ranges: 0–1 A and 1–10 A, respectively. The line wire is connected to the load, which is passing through the current transformer.

$$I_{act} = m^2 \times V_{measured\ voltage\ for\ current}$$

where m^2 is the scaling factor obtained from Fig. 4, different values of m^2 to be used for different current transformers. I_{act} is the actual current; $V_{measured\ voltage\ for\ current}$ is the measured sensing voltage for current.

3) Power Measurement:

In order to calculate power of a single-phase ac circuit, the product of root mean square (RMS) voltage and RMS current must be multiplied by the power factor as bellow,

$$P_{act} = V_{rms} \times I_{rms} \times P_f$$

where P_{act} is the actual power, V_{rms} and I_{rms} are the RMS values of voltage and current, respectively, and P_f is the power factor. Power factor is the as shown in the Fig.5.

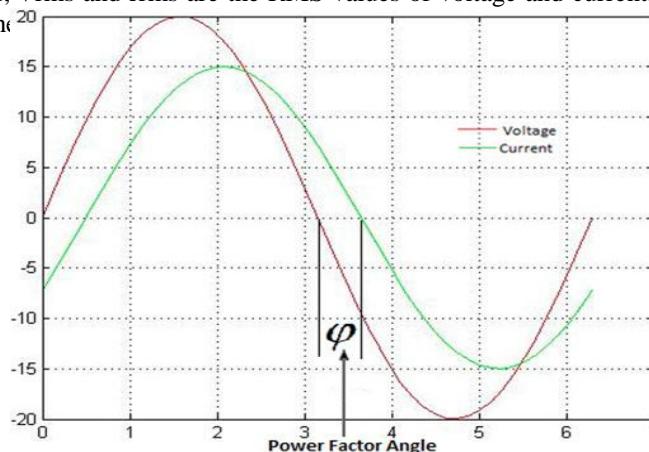


Fig.5: Representation of power factor.

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Hence, in our paper, rather than measuring power factor, we have introduced correction factor to normalize the received power with respect to the actual power based on the scaling factors of the voltage and current measured. The power consumed by the appliances is calculated in the computer system after receiving voltage outputs from corresponding current and voltage sensors by the following equation:

$$P_{cal} = V_{act} \times I_{act} \times C_f$$

where P_{cal} is the calculated power; V_{act} the output voltage; I_{act} the current value; and C_f is the correction factor. The term correction factor is introduced to calculate power accurately by the system. The correction factor is the ratio of actual power to the measured power. Correction factor is required for the power measurement for some loads.

V. CONCLUSION

A smart power monitoring and control system has been designed and developed toward the implementation of an intelligent building. The created system successfully monitors and controls the electrical appliance uses at an elderly home. Therefore, the real-time monitoring of the electrical appliances can be viewed through a website. The system can be extended for monitoring the whole intelligent building. The sensor networks are modified with different user interfaces suitable for users of varying ability and for expert users such that the system can be maintained easily and interacted with very simply. The developed system is robust and flexible in operation. the system was able to perform the remote monitoring, control of appliances effectively and adaptable in operation. Local and remote user interfaces are easy to handle by a novice consumer and are efficient in handling the operations. In future, the system will be coordinated with co-systems like brilliant home inhabitant behaviour recognitions systems to determine the wellness of the inhabitant in terms of energy utilization.

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