

Power Management and Wellness Determination in Intelligent Buildings with WSN based Smart Sensors

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Abstract — *The WSN based smart monitoring and controlling system for household electrical appliances in real-time have been discussed in this paper. The system basically monitors electrical parameters of household appliances like voltage and current and subsequently calculates the power consumed by the system. The goodness of system is the implementation of the controlling mechanism of appliances in various ways. The developed system is of low-cost and very flexible in operation and thus can save electricity expense of the end consumers.. The developed 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 and experimental results are very encouraging.*

Keywords— *Energy management, home automation, intelligent control system, wireless sensor network, ZigBee, Embedded Linux .Web Design; Power Management.*

I. INTRODUCTION

IT is always seen that service and personal care wireless mechatronic systems is very essential at home in the near future and become very useful in assistive for the people who are elder and disable for their Health care. this system is consist of the various types of specially distributed wireless sensors but having limited data collection and data processing capability to monitor the environmental parameter. Wireless sensing network (WSNs) have the ability to monitor as well as control the situational information for various intelligent service so day by day the demand for wireless sensor networks(WSNs) goes on increasing. Also for the field like Industry military, environment, healthcare, agriculture WSNs can be applied for various important applications. It is expected that service and personal care wireless mechatronic systems will become more and more ubiquitous at home in the near future and will be very useful in assistive health care particularly for the elderly and disabled people . Wireless mechatronic systems consist of numerous 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 for various intelligent services. Due to those advantages, WSNs has been applied in many fields, such as the military, industry, environmental monitoring, and healthcare.

The WSNs are increasingly being used in the home for energy controlling services. Regular household appliances are monitored and controlled by WSNs installed in the home [5]. The use of smart energy management system can assist in reducing the energy usage in an efficient way. Intelligent Power Management is the combination of smart sensors and actuators. The design and development of an intelligent monitoring and controlling system for home appliances in a real time system is presented in this paper. This system principally monitors the electrical parameters such as voltage and current and subsequently calculates the power consumption of the home appliances that are need to be monitored. 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 use of the forthcoming ZigBee, Internet Proto- col (IP) specification, and the IEEE 802.15.4g standard to help Japan to create smart homes that improve energy management and efficiency [6].

It is expected that 65million 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 [7]. There are several proposals to interconnect various domestic appliances by wireless networks to monitor and control such as provided in [8], [9]. But the prototypes are verified using test bed scenarios. Also, smart meter systems like [9]–[11] have been designed to specific usages particularly related to geo- graphical usages and are limited to specific places. There has been design and developments of smart meters predicting the usage of power consumption [4]–[8]. 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 GSM and GPRS based intelligent home energy management and control service. We used the GSM and GPRS 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. There has been design and developments of smart meters predicting the usage of power consumption [9]–[13]. However, 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 [10].

The article focuses on human-friendly technical solutions for monitoring and easy control of household appliances. The inhabitant’s comfort will be increased and better assistance can be provided. This paper emphasizes the realization of monitoring and controlling of electrical appliances in many ways.

II. RELATED WORK

In this section, we briefly discuss the existing works about smart home systems based on the wireless communication technology. Han et al. [15] 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 interface. 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. [16] 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. [17] 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.

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.

In this paper, a low-cost, flexible, and real-time smart power management system, which can easily integrate and operate with the home monitoring systems such as [22] is presented. By analyzing the power from the 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.

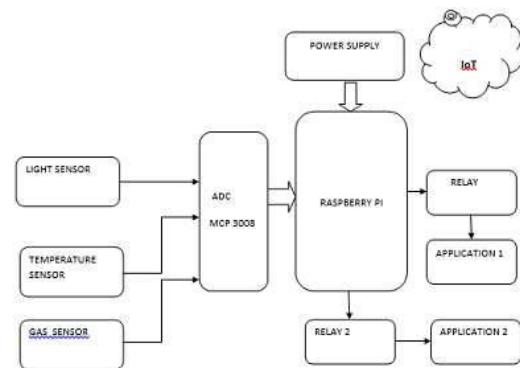


Fig 1. Functional block diagram of system

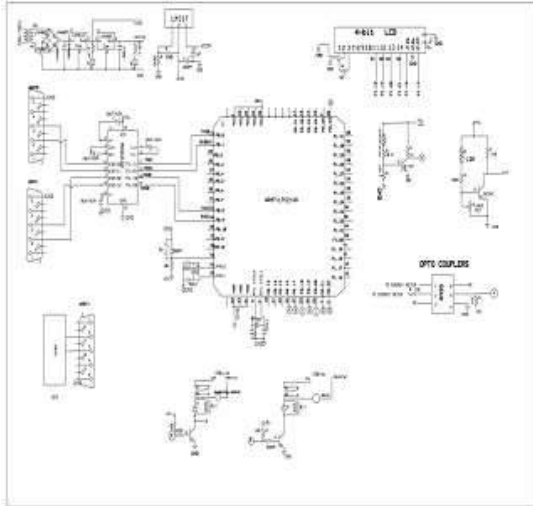


Fig 2. Schematic

The appliances are controlled either automatically or manually (local/remotely). The smart power metering circuit is connected to mains 240 V/50 Hz supply. Fig-2 shows different appliances connected to the developed smart sensing system.

III. SMART HOME MONITORING SYSTEM

Smart homes for ambient-assisted living involve the learning patterns of agent behavior from sensor data. Deviation from the regular behavior is an array of the data that either does not follow the anticipated behavior, which is an anomalous behavior, or follows the certain class of predefined irregular behavior. This deviation is an alert for an inhabitant. In our research for behavioral pattern generation, we used an advanced approach that is based on combined deviation over time because forecasting can be reliable only if we consider more than one event. The wellness forecasting model we have designed and proposed is divided into two sections. At the lower section, all the raw sensor data from household appliance usage and movement is delivered to the coordinator attached to the local home gateway and this local server stores the unstructured data sets for further processing and analysis. Raw sensor data collected at the lower information section can only identify which sensor is active or inactive and at what time. To discover the optimal activity of daily living for wellness, these data sets need to be analyzed by the upper section software logic. Intelligent data recognition and classification mechanisms are applied through the software at different levels of data generalization in real time, based on the time and order of the sensor usage. The ZigBee coordinator has been connected through the USB cable of the host computer, which stores the data into a database of computer system. The collected sensor fusion data have been sent to an

internet residential gateway for remote monitoring and controlling the home environment.

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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 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:

$$V_{act} = m_1 \times V_{measured_voltage} \quad (1)$$

Current Measurement: For sensing current, we used

ASM010 current transformer manufactured by Talema [24]. 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(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 necessary measurement level of ZigBee. The scaling factors for current measurement for two different ranges of currents. 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 many applications as

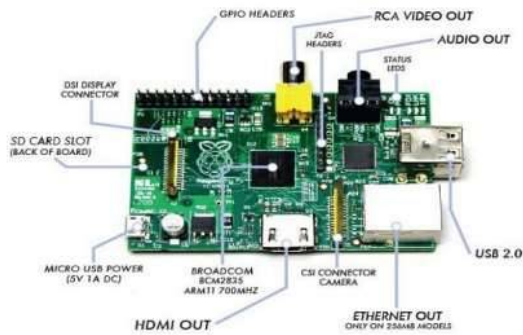
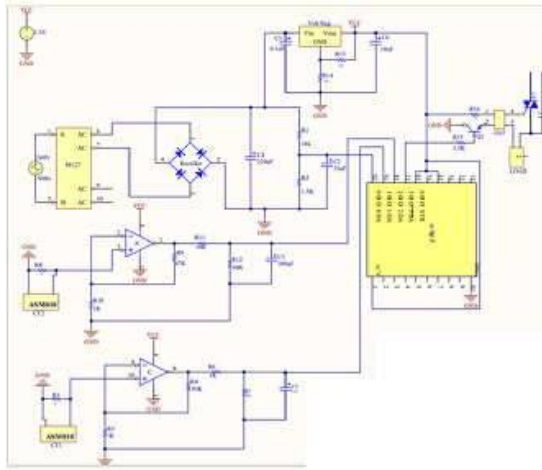


Fig. 3. Raspbery Pi

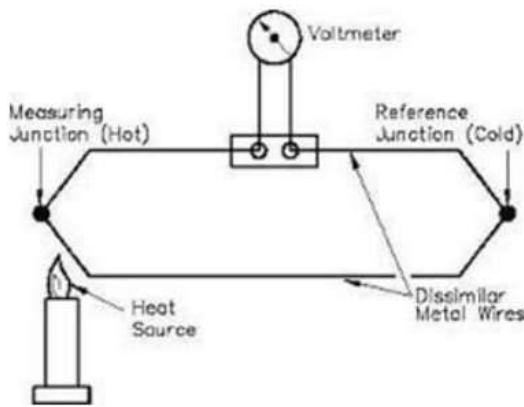


Fig. 4 . Thermocouple

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. This correction factor can be obtained by plotting graph for calculated power against the actual power. Thus, the power is calculated in computer using CSharp programming after receiving voltage outputs from corresponding current and voltage sensors.

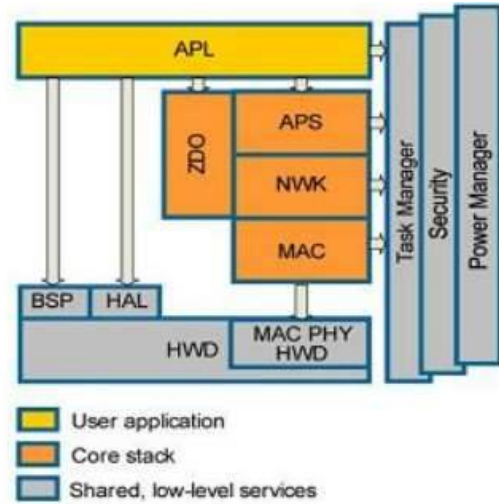


Fig. 5. Representation of power factor.

well as for the safety of the electronic circuit

$$I_{act} = m_2 \times V_{measured_voltage_for_current} \quad (2)$$

For sensing current, we used ASM010 current transformer manufactured by Talema [17]. The main features of this sensor include fully encapsulated for PCB mounting and compact size. The primary current ratings range from 1 to 100 Amps and operating temperature range from $-40^{\circ}C$ to $+120^{\circ}C$. The circuit design layout for current measurement is shown in Fig. 2. In this current sensor, the voltage is measured across the burden resistor of 50 ohms. The line wire is connected to the load, which is passing through the current transformer. When the mains are turned on, the current sensor will produce isolations in the current transformer. The amplified signal is then fed to analog input channel of ZigBee module. The desired voltage setting is achieved by using burden resistor on secondary side. The output sensed signal is directly proportional to the input current. Scaling is required to get correct input current of the appliance. This solution of measured signal can be improved by increasing the number of primary turns.

$$P_{cal} = V_{act} \times I_{act} \times C_f \quad (4)$$

The prototype has been tested and results achieved for many household electrical appliances are shown in the following section. It is seen that the maximum error is less than 5% for the domestic appliances. From the low percentage error of power, it has been decided that power can be calculated without considering power factor.

IV. EXPERIMENTAL RESULTS

The prototype is in operation in a trial homewith various electrical appliances regularly used by an inhabitant. The following applianceswere tested: roomheaters,microwave, oven, toasters, water kettle, fridge, television, audio device, battery chargers, and water pump. In total, ten different electrical appliances were used in the experimental setup; however, any electrical appliance whose power consumption is less than 2000W can be used in developed system.

The sampling rate for the fabricated sensing modules was setup with 50 Hz, so that electrical appliance usages within (less than 10 s) interval of time will be recorded correctly. By monitoring consumption of power of the appliances, data are collected by a smart coordinator, which saves all data in the system for processing as well as for future use. The parameters will be entered in the data coordinator in software from appliances include voltage, current, and power. These parameters will be stored in a database and analyzed. Collected data will be displayed on the computer through graphic user interface (GUI) window so that appropriate action can be taken from the GUI. Fig. 6 shows the smart power monitoring and control system at a house where the system is on trial.



Fig 6: Muasurement setup

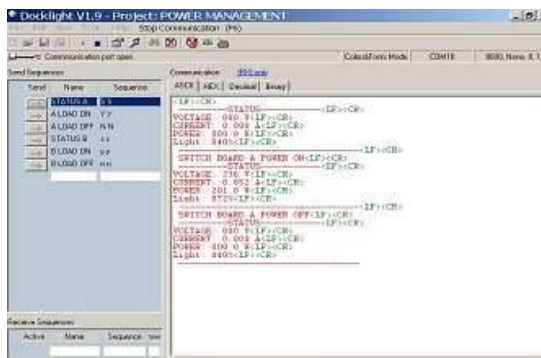


Fig. 7. Screenshot for smart power monitoring

V. CONCLUSION

A smart power monitoring and control system has been designed and developed toward the implementation of an intelligent building. The developed system effectively monitors and controls the electrical appliance usages at an elderly home. Thus, the real-timemonitoring of the electrical appliances can be viewed through a website. The system can be extended for monitoring the whole intelligent building. We aim to determine the areas of daily peak hours of electricity usage levels and come with a solution by which we can lower the consumption 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 interacted with very simply. This study also aims to assess consumer’s response toward perceptions of smart grid technologies, their advantages and disadvantages, possible concerns, and overall perceived utility. The developed system is robust and flexible in operation. For the last three months, the system was able to perform the remote monitoring and control of appliances effectively. Local and remote user interfaces are easy to handle by a novice consumer and are efficient in handling the operations.

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