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INTELLIGENT POWER MANAGEMENT USING WSN

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Abstract*— IPM - 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 reported 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 innovation of this system is controlling mechanism implementation in so many ways. Also the proposed system is an economical and easily operable. Due to these intelligent characteristics it become an electricity expense reducer and people friendly. The prototype has been extensively developed and tested in real time scenarios also the results are appreciable.

Keywords*— Intelligent Power Management, Smart sensors, Energy management, home automation, intelligent control system, wireless sensor network, ZigBee.

I. INTRODUCTION

The design and development of a smart monitoring and controlling system for household 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 mechanism of appliances in different ways. 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.

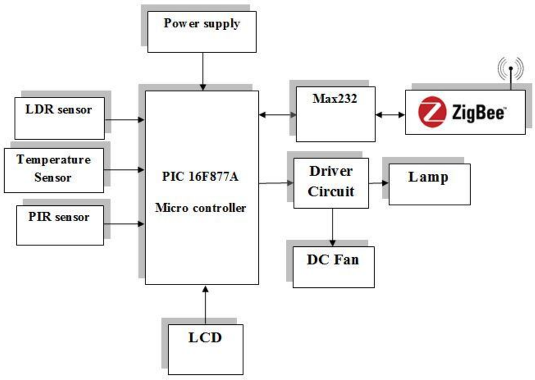
The WSNs are increasingly being used in the home for energy controlling services. Regular household appliances are monitored and controlled by WSNs installed in the home. New technologies include cutting-edge advancements in information technology, sensors, metering, transmission, distribution, and electricity storage technology, as well as providing new information and flexibility to both consumers and providers of electricity.

II. SYSTEM DESCRIPTION

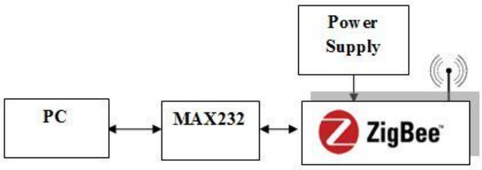
The system has been designed for measurement of electrical parameters of household appliances. Important functions to the system are the ease of modelling, setup, and use. From the consumer point of view, electrical power consumption of various appliances in a house along with supply voltage and current is the key parameter. Fig. 1 shows the functional description of the developed system to monitor electrical parameters and control appliances based on the consumer requirements. The measurement of electrical parameters of home appliances is done 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 XBee 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 fusion data has been performed.

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. By analysing 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. 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. Fig. 2(a) and (b) shows the child and parent units of smart sensing measurement system.



(a)



(b)

The count of child unit may vary depends on the floor otherwise equipment handled by the consumer in the real time.

III. WORKING METHODOLOGY

Parameter measurement – Electrical

1) *Voltage Measurement:* The voltage transformer used in our paper 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. 3(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.

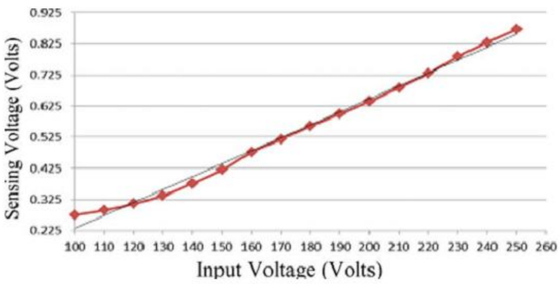


Fig.1.Scaling factor (m1) of voltage signal.

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. 1. The actual voltage is thus obtained as follows:

$$V_{act} = m1 \times V_{measuredvoltage} \quad (1)$$

Where m1 is the scaling factor obtained from Fig. 1, Vactis the actual voltage, and Vmeasuredvoltage is the measured sensing voltage.

2) *Current Measurement:* For sensing current, we used current transformer. The main features of this sensor include fully encapsulated PCB mounting and compact.

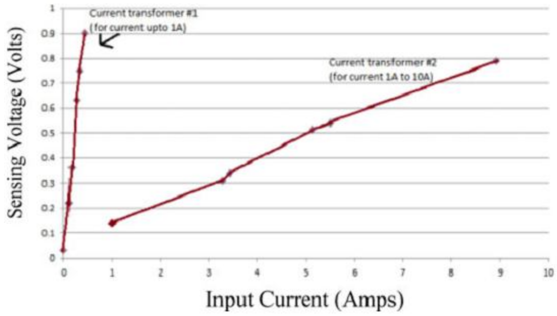


Fig.2.Scaling factor (m2) of current signal. size.

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 50Ω. 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 are shown in Fig. 2. 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 well as for the safety of the electronic circuit

Iact=m2×Vmeasuredvoltage for current (2)

Where m2 is the scaling factor obtained from Fig. 2, different values ofm2to be used for different current transformers. Iactis the actual current; Vmeasuredvoltage 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 given in (3). Power factor is the cosine of the phase angle of voltage and current waveforms as shown in the Fig. 3 for an ideal situation

Pact =Vrms ×Irms ×Pf

Where Pact is the actual power, Vrms and Irms are the RMS values of voltage and current, respectively, and Pf is the power factor.

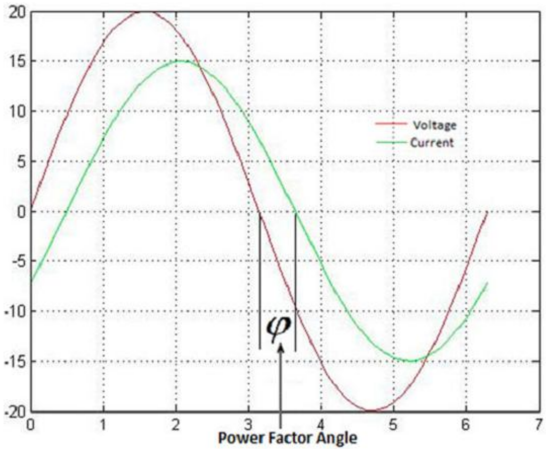


Fig3.Representation of Power Factor.

Hence, in our paper, instead of 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:

Pcal =Vact ×Iact ×Cf (4)

Where Pcal is the calculated power; Vact the output voltage as given in (1);Iactthe current value as given in (2); andCf is the correction factor.

Control of Home Appliances

The current paper is innovative in terms of other reported literature due to its control features.

1) *Automatic control:* Based on the electricity tariff conditions, the appliance can be regulated with the help of smart software. This enables the user to have more cost saving by auto switch off the appliances during the electricity peak hours. The electricity tariff is procured from the website of the electricity supply company and is updated at regular intervals.

2) *Manual control:* An on/off switch is provided to directly intervene with the device. This feature enables the user to have more flexibility by having manual control on the appliance usage without following automatic control. Also, with the help of the software developed for monitoring and controlling user interface, user can control the device for its appropriate use. This feature has the higher priority to bypass the automatic control.

3) *Remote control:* The smart power monitoring and controlling software system has the feature of interacting with the appliances remotely through internet (website). This enables user to have flexible control mechanism remotely through a secured internet web connection. This sometimes is a huge help to the user who has the habit of keeping the appliances ON while away from house. The user can monitor the condition of all appliances and do the needful.

Thus, the user has the flexibility in controlling the electrical appliances through the developed prototype.

IV. REAL TIME RESULTS

The prototype is in operation in a trial home with various electrical appliances regularly used by an inhabitant. The following appliances were tested: room heaters, 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 2000 W can be used in developed system.

V. CONCLUSION

An intelligent power monitoring and control system has been designed and developed toward the implementation of an smart building. The developed system effectively monitors and controls the electrical appliance usages at an elderly home. Thus, the real-time monitoring of the electrical appliances can be viewed through a website. The system can be extended for monitoring the whole smart building. 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.

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