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Smart Sensor and Actuator for Power Management in Homes Based on WSN

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ABSTRACT: The consumption of energy in residential buildings is increasing day by day due to increase in urban population and increase in usage of AC appliances. Energy generated is not sufficient to meet energy demand. Therefore there is a need to save energy. 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 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 becomes an electricity expense reducer and people friendly. The prototype has been developed and tested in real time scenario. Also the results are satisfactory.

KEYWORDS: Wireless sensor networks, Power, Voltage, Current, ZigBee.

I.INTRODUCTION

In a world of rising energy costs and dwindling natural resources capable of producing energy, people and businesses are starting to look for better ways to help reduce their increasing electricbills. One way of reducing these costs is to monitor, in real time, how much power is being consumed and from these data make informed decisions about how to manage the electrical devices being powered. A system that can give users an estimate of how much energy is being, has been, and might be consumed will allow them to adjust their habits and lower the costs. In this work, we design, build, and test a wireless sensor and actuator network for monitoring the energy use of alternating current (AC) appliances in a home environment. The measured energy use of individual appliances can be displayed through a user visual interface in real time; so that users can easily understand their electricity usage patterns and adapts their behavior to reduce their energy consumption and costs. Moreover, users are able to remotely control the power on/off of individual devices to actively control the power use of certain appliances. The system allows for inexpensive monitoring of home energy use and illustrates a practical way to control the energy consumption through user interaction.

A smart environment is a physical world that is interconnected through a continuous network abundantly and invisibly with sensors, actuators and computational units, embedded seamlessly in the everyday objects of our lives. A smart home is a residence in which computing and information technology apply to expect and respond to the occupants' needs and can be used to enhance the everyday life at home. Potential applications for smart homes can be found in these categories: welfare, entertainment, environment, safety, communication, and appliances. Automation is, where more things are being completed every day automatically, usually the basic tasks of turning on or off certain devices and beyond, either remotely or in close need to maintain as much control as we can over the automated processes. Automation lowers the humanusage, automation differs in its name as industrial automation, home automation etc.The rest of the paper is organized as follows: Section II discusses the existing system; Section III provides detailed implementation of the proposed system; Section IV presents the experimental results.;Section V has conclusion .

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II.EXISTING SYSTEM

In this section, we briefly discuss the existing works about smart home systems based on wireless communication technology. 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 gateway. 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.

Song et al. [18] 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 [19] 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. [20] 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. [21] 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 household 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.

III.PROPOSED SYSTEM

The system has been designed for measuring voltage and current readings of electrical household appliances. Fundamental to the system is the ease of modeling, setup and use. From the consumer point of view; electrical current and voltage consumed are the key elements to measure power consumption of various appliances in a house. Fig.1 shows the functional description of the developed system to monitor electrical parameters and control appliances based on the consumer requirements.

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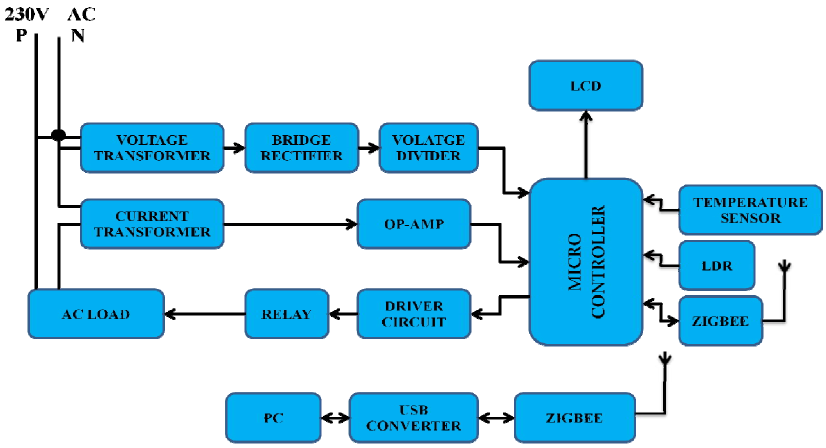

Figure1. Functional block diagram of the system

The output signals from the sensors are integrated and connected to ZigBee 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 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 analyzing the power from the system, energy consumption can be controlled. The appliances are controlled either automatically or manually (local/remotely). The smart power metering circuit is connected to mains 240V/50 Hz supply.

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:

A. Measurements of Electrical Parameters

1) Intensity Measurement:

The intensity of room is measured by using a LDR whose resistance decreases with increasing incident light intensity. The LDR works on the principle of photo conductivity. A photo resistor is made of a high resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance.

2) Temperature Measurement:

The temperature of room is measured by using a LM35.It is an precision integrated circuit temperature sensor whose voltage is linearly proportional to the Celsius. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. Theprocessor can instruct the sensor to monitor temperature and take an output pin high (or low) ifexceeds the programmed limit

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3) Voltage Measurement:

The measurement of the voltage is performed by using a step down transformer to reduce 230V to 12V RMS. The output signal was then fed into voltage divider to further step down the signal voltage below 5V. The signal is shifted up above the reference setting, before the signal is sent to microcontroller .The reason for this is because the Analog to Digital Convertor(ADC) of microcontroller only can take the positive values of signal and the signal has to be less than 5V which is safe for microcontroller. After that, the ADC discretized the sinusoidal waveform with 2 KHz sample frequency. The reason of selecting 2 KHz is because it will provide 500 micro second time spaced in between the samples and it is equal to 9 degree of interval by considering one cycle comprises as 360 degree

4) Current Measurement :

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° C to +120°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 inputchannel 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. There solution of measured signal can be improved by increasing the number of primary turns.

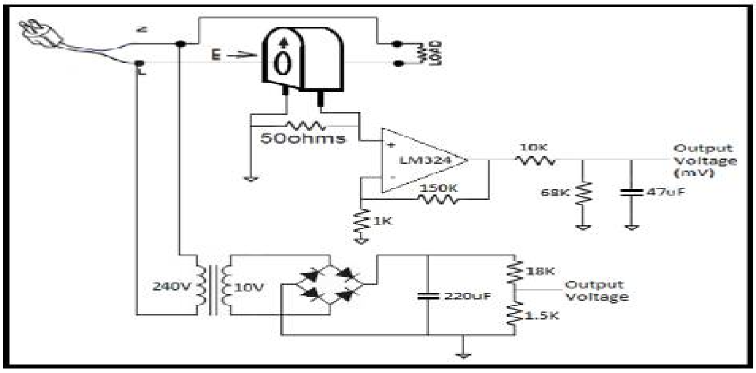

Figure 2: Smart voltage and current sensing circuitry

5)Power Measurement:

In order to calculate power of a single phase ac circuit, the product of volts and amperes must be multiplied by the Power Factor. Power Factor is the cosine of the phase angle of voltage and current waveforms as shown in the Fig.3

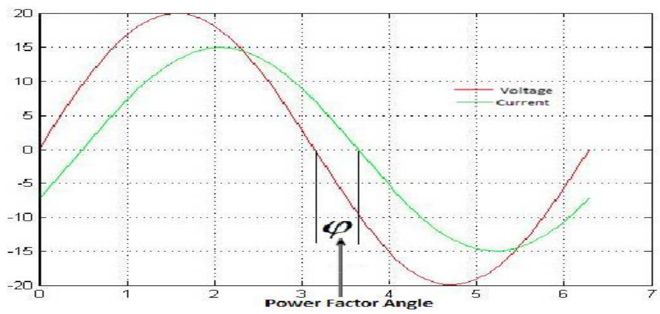

Figure 3: Representation of Power Factor

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Power factor is one, if the voltage and current are in-phase. The output signal of the current transformer completely depends on the nature of the connected appliance whether the connected load is purely resistive, capacitive or is inductive. In most of the cases, the output waveforms are not proper sinusoidal Hence, in our work, 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. Power is calculated in the computer system after receiving voltage outputs from corresponding current and voltage sensors by following equation.

P=□(v1 *v2)*Cf
Where
P = Calculated Power
v1= output voltage from the voltage circuit
v2= output voltage from the current circuit
Cf= Correction factor

The term correction factor is introduced to calculate power accurately by the system. The correction factor is the ratio of reference 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 microcontroller using Cprogramming after receiving voltage outputs from corresponding current and voltage sensors. The prototype has been tested and results achieved for many household electrical appliances are shown in the following section.

Appliance	Actual power in Watts	Measured voltage	Measured current	Measured power	% Error
Bulb	60	236	0.257	60.6	1
Bulb	100	236	0.427	99.28	0.72
Bulb	200	236	0.852	201.07	0.536
Blender/Chopper	350	236	1.489	346.20	1.08
Iron	750	237	3.139	745.54	0.59
Hair dryer	1000	237	4.255	993.51	0.64

Table I: Percentage Error Of Received Voltage, Current, And Measured Power

Table I shows the percentage error for all measured parameters with the corresponding references. 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.

B) Control of Home Appliances:

1) **Manual control**: An on/off switch is provided to directly intercede 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.

2) **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.

C) Residential IP Gateway:

Docklight is a testing, analysis and simulation tool for **serial communication protocols (RS232, RS485/422 and others)**. It allows you to monitor the communication between two serial devices or to test the serial communication of a single device. Docklight is easy to use and runs on almost any standard PC using Windows Vista/XP/2000/NT 4/98 operating system.Docklight can send out user-defined sequences according to the protocol used and it can react to incoming sequences. This makes it possible to simulate the behavior of a serial communication device, which is particularly useful for generating test conditions that are hard to reproduce with the original device (e.g. problem conditions).Docklight has also been successfully tested with many popular USB-to-RS232 converters, virtual null modem software drivers, and many other Embedded Development tools that appear as a virtual COM **port** in Windows.

Team Viewer: Team Viewer is a software application used to connect to any computer or server around the world in just a few seconds. It's many features include remote control, desktop sharing and file transfer between computers. You can even access a computer running TeamViewer with a web browser.TeamViewer is compatible with Microsoft Windows, Mac OS X, Linux, iOS and Android. Access any computer over the internet at any time, from anywhere as if you were sitting right in front of it.Fig 4 shows the team viewer screenshot

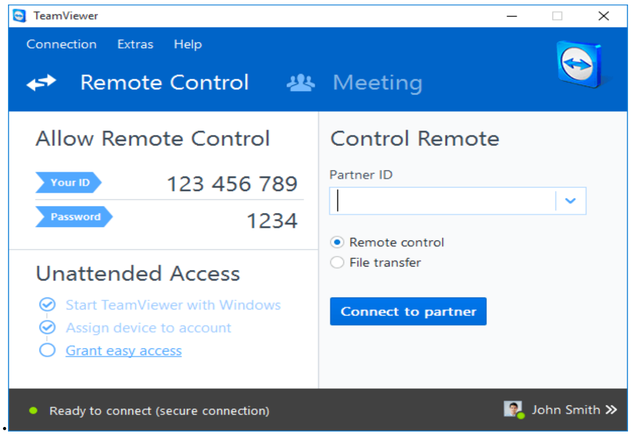

Figure 4: Team viewer screenshot

IV. RESULT AND DISCUSSION

The prototype is in operation in a trial home with various electrical appliances regularly used by an in habitant. 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 2000Wcan 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 Docklightwindow so that appropriate action can be taken.

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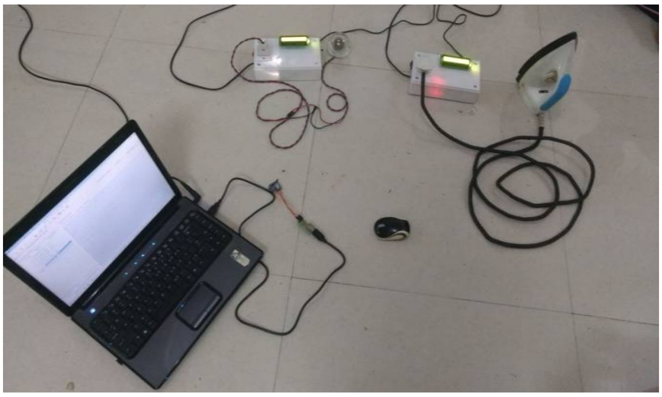

Figure 5: Measurement setup

Fig. 5 shows the smart power monitoring and control system at a house where the system is on trial.The design of the system prototype including two measurement nodes and a central server.

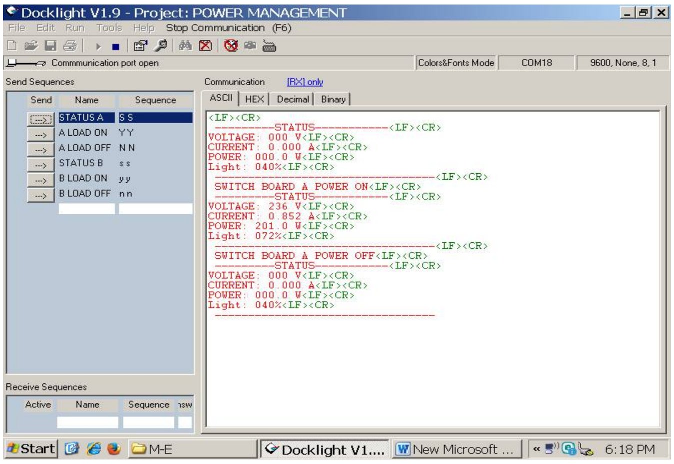

Figure 6: Screenshot for smart power monitoring and control using Docklight software

In this project the data acquired from the ZigBee can be viewed on computer in the Docklight Software window and the desktop can be shared anywhere around the world via TeamViewer Software application .With the help of TeamViewer we can view the status of the home appliance and control the home appliance. Fig. 6 shows the screen shot of Docklight software output.

V.CONCLUSION

This paper describes a design for Power Management in a home environment using a wireless sensor and actuator network for monitoring the energy usage of AC appliances. The design of the system prototype including two measurement nodes and a central server is explained. The system prototype meets the design criteria. Additionally, the implementation and performance analysis of this design have been completed. The system design and implementation illustrates an inexpensive way to monitor the home electrical energy use and control the energy consumption.

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