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Efficient Energy Management System using Zigbee for Residential Application

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Abstract*: Energy management system is one of the challenging tasks associated with residential buildings. The cost of energy is purely based on the amount of energy consumed during peak hours. This paper focuses on an efficient energy management system for the control of energy consumption during peak hours. ZigBee module is used to monitor the energy consumed by the home appliances. The working of the proposed system is categorized into two modes of operation: normal time and peak time. During normal time, all home appliances can be operated and the cost of energy will be at normal rate. Whereas, during peak time, high rating machines will be shut down, that is controlled by ZigBee and the light loads will be operated from battery supply. Thus the proposed system reduces the energy consumption and is cost effective. Simulation analysis is done using proteus software. Hardware model is also implemented which proves that the proposed energy management system improves the energy efficiency.

Keywords* : Energy management, energy consumption, energy efficiency, normal time, peak time, ZigBee.

I. INTRODUCTION

An energy management system is used to monitor, control, and optimize the performance of the generation and transmission. In the proposed work, energy management system is used to control the usage of home appliances as to reduce the power consumption and cost of energy. The energy efficiency depends up on the demand side management [4]. A demand side energy management is employed in [2] where game theory is formulated for energy consumption schedule. The users are the players of the game and their strategies are the schedules of the household appliances. An autonomous demand side management is developed in [3] for reducing the cost of energy. Here, an energy consumption scheduling device is built inside the smart meters so that energy can be shared between the neighborhoods. A real time electricity scheduling is proposed for residential applications to reduce the energy cost [10].

The smart home energy management system plays an important role to improve the energy efficiency, economics, and reliability and to reduce residential electricity cost [1]. Smart home energy management system is proposed for the control of energy consumption and generation using ZigBee and PLC [8]. PLC is used to monitor the energy generation and ZigBee for monitoring the energy consumption of home appliances. The ZigBee module is also used for monitoring and scheduling of home appliances in [5]. Here the smart home energyx management system is implemented by using LabVIEW Programing software. Reduction in energy consumption by using ZigBee and Infrared remote control is proposed in [7]. ZigBee is used for energy management and energy efficiency [9]. Emerging technologies like IoT and Big Data are used to manage and control energy consumption in residential, industrial and commercial applications [6]. In the proposed energy management system ZigBee module is used for the control of energy consumption during peak hours. The paper is organized as follows. Section II describes the block diagram of the proposed efficient energy management system. Section III shows the simulation analysis of the proposed system using proteus software. Calculation of energy for normal and peak time is discussed in section IV. Hardware implementation is done in section V. Finally, section VI concludes the paper.

II. EFFICIENT ENERGY MANAGEMENT SYSTEM

An efficient energy management system is proposed for the control of household appliances using ZigBee module. Figure 1 shows the block diagram of the proposed energy management system. The micro controller is interfaced with ZigBee transiever unit, RTC, solar panel and battery. The microcontroller coordinates the entire system and optimizes the power consumption. Here, demand side management technology is employed. The loads are classified in to light and heavy loads. DC motor and exhaust fan are taken as light loads and 60 W AC bulb and an iron box are considered for heavy loads. Heavy loads can be shifted from peak time to normal time for load balancing and reduction in energy consumption. RTC is used to define the normal time and peak time. At normal time the supply is obtained from the AC mains and simultaneously the battery is charged. During the peak time only the prior devices function by obtaining the supply either from AC mains or from battery source. Thus the power consumption can be efficiently used by the proposed system.

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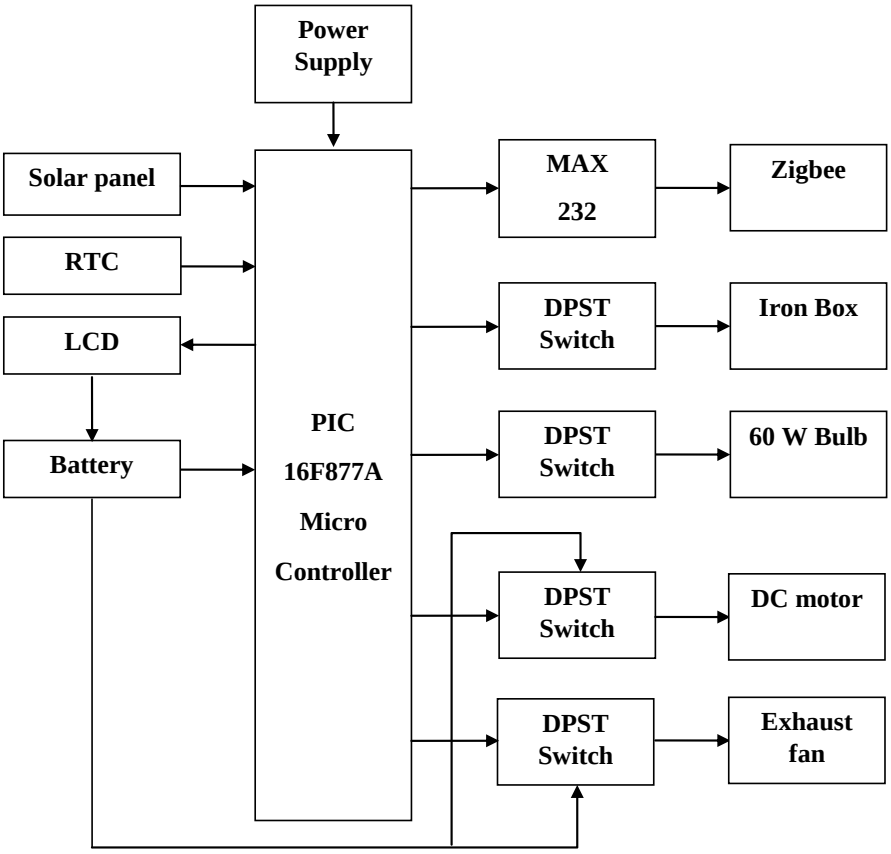

Fig. 1 Block Diagram of Efficient Energy Management System

III. SIMULATION ANALYSIS

The proposed energy management system is simulated and analyzed using proteus software. The program is coded by using Embedded C and complied using MPLAB complier software. The proposed system has two categories of devices, light and heavy load devices. The devices are classified based on the rating of the power consumption. The power rating of light load devices varies from 10 W to 200 W. Appliances like iron box, toaster, coffee maker are considered as heavy load devices whose power rating varies from 500 W to 1500 W.

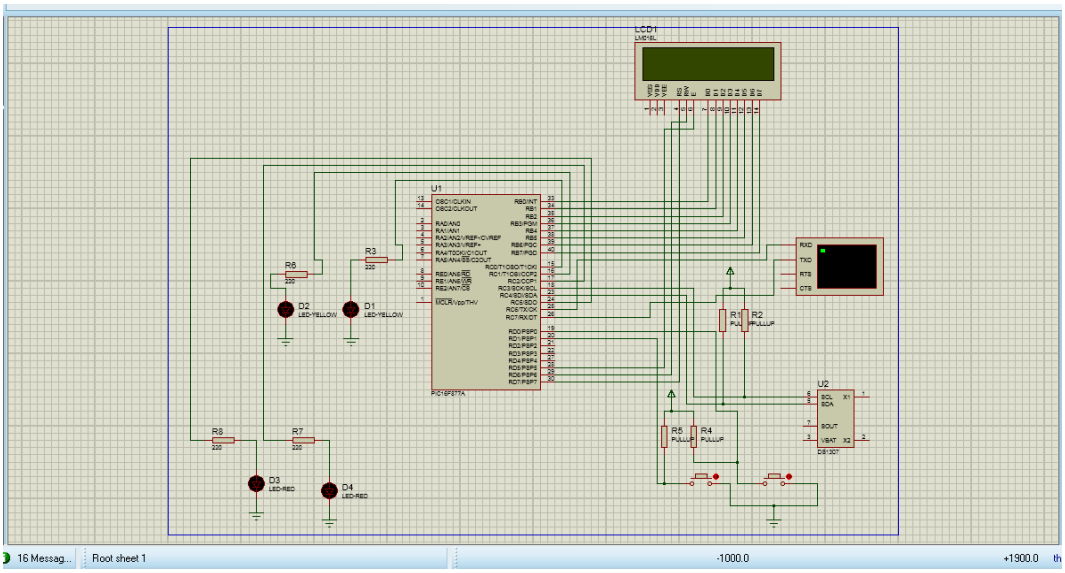

Fig. 2 Simulation Circuit of Energy Management System

The two modes of operation of the proposed energy management system are during normal time and peak time. In normal time the amount of electricity bill is at normal rate, even though the usage of devices at this time is more. But in case of peak time the amount of electricity bill will be high if we are using all devices at the same time. Hence during peak time the devices with high rating will be switched off by

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ZigBee receiving unit.

And all the light load devices will be supplied from AC or battery. Therefore the energy consumed during peak load will be reduced and the electricity bill is also reduced. The simulation circuit of the proposed energy management system is shown in figure 2. The light loads considered for analysis are the DC motor and DC exhaust fan and the heavy loads are AC 60 W bulb and heating iron box.

The light and heavy load devices are turned ON and OFF by using ZigBee. The simulation diagram in figure 3 shows the switching of devices at corresponding time intervals. Switches 1 and 2 are used to set time for the peak load and the normal load. The time for every month can be changed according to the demand.

During normal time, when the unit cost of electricity is low, both the light and heavy load devices in the home will be working by AC supply. Figure 4 shows the working of all devices during normal time. During peak time, the heavy load devices are turned OFF. Figure 5 shows the simulation diagram at peak time where only light loads are switched ON.

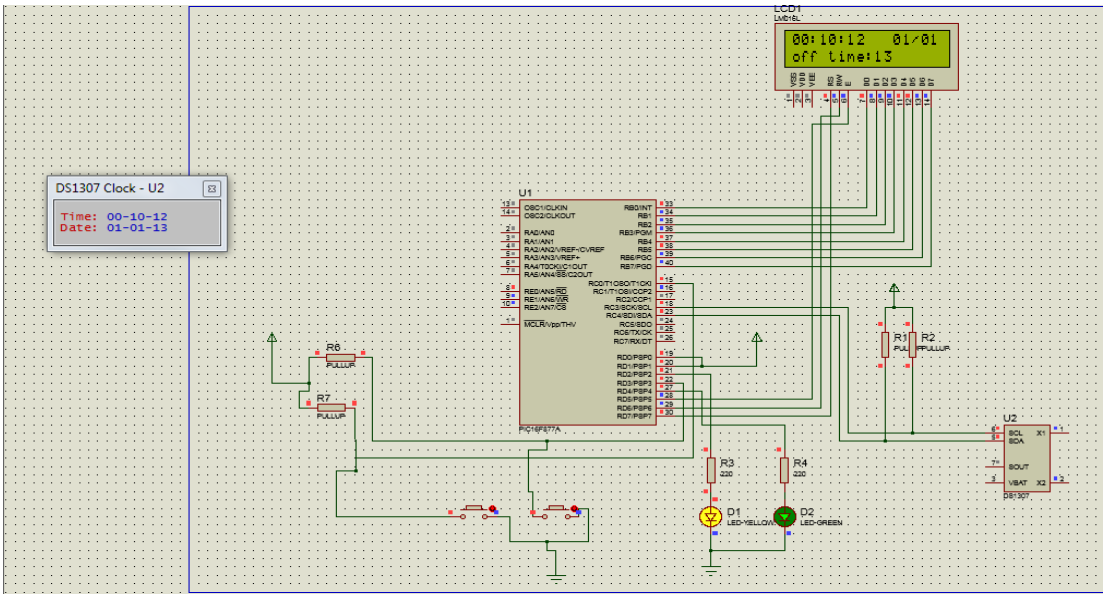

Fig. 3 Setting ON/OFF time of the devices

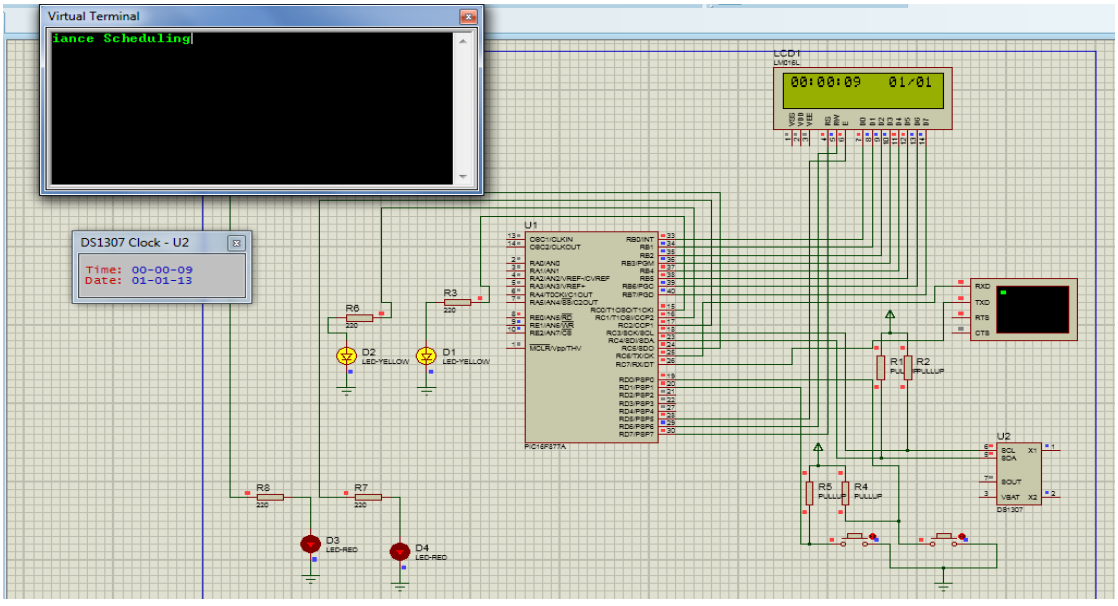

Fig. 4 Normal time when all devices are in ON condition

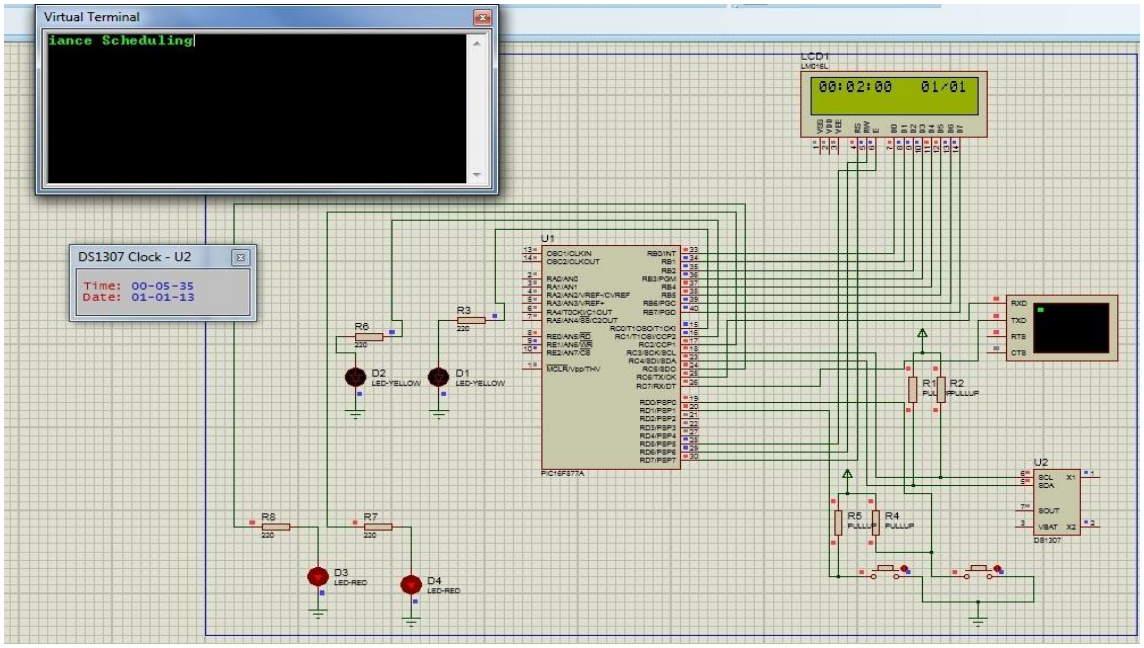

Fig. 5 Peak time when light load devices are in ON state

The control of these devices are interfaced with the laptop by using serial communication cable within a fraction of second. Hyper terminal software is used to link the controlling section with the laptop for switching of devices. The table 1 shows the commanding key controls for both the heavy and light load devices during peak time.

Table- I: Key Commands for controlling the devices at Peak Time

Loads	Heavy Load		Light Load	
	ON	OFF	ON	OFF
Load 1	Keypad 0	Keypad 1	Keypad A	Keypad B
Load 2	Keypad 2	Keypad 3	Keypad C	Keypad D

IV. ENERGY CALCULATION

In the proposed system, devices like iron box, AC bulb, DC fan and DC motor are taken into account for a time interval of 20 minutes. The total energy consumed by each device is calculated using the formula shown in equation (1).

Energy consumed, E (Kwh) = (P (W) * T (hr))/1000 (1)

During normal time, when all devices are running,

Energy Consumed by iron box = (1100 W * 0.33 hr)/ 1000
= 0.363 Kwh
Energy Consumed by 60W bulb = (60 W * 0.33 hr)/ 1000
= 0.0198 Kwh
Energy Consumed by DC motor = (18 W * 0.33 hr)/ 1000
= 0.00594 Kwh
Energy Consumed by fan = (18 W * 0.33 hr)/ 1000
= 0.00594 Kwh
Total usage of Energy is about 0.39468 Kwh

During peak time, DC devices will be operated by the battery supply. So that the energy consumed by DC devices can be minimized. Hence during peak time,

The total usage of energy = Energy Consumed by iron box + Energy Consumed by 60W bulb
= 0.363 Kwh + 0.0198 Kwh
= 0.3828 Kwh

Hence the energy consumed during peak time is less compared to normal time. Thus the proposed energy management system is highly efficient, which consumes less power even during the peak time.

V. HARDWARE IMPLEMENTATION

The entire hardware setup of the proposed energy management system is shown in figure 6. The proposed system works under two modes of operation, during normal time and peak time. The program is coded in the micro-controller, which has been scheduled for normal time and peak time and also for light loads and heavy loads. These commands are given from the controlling section using ZigBee. The controlling section of the proposed system is shown in figure 7.

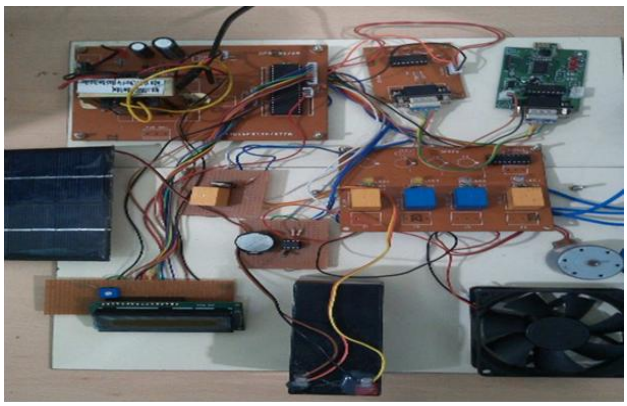

Fig. 6 Efficient Energy Management System

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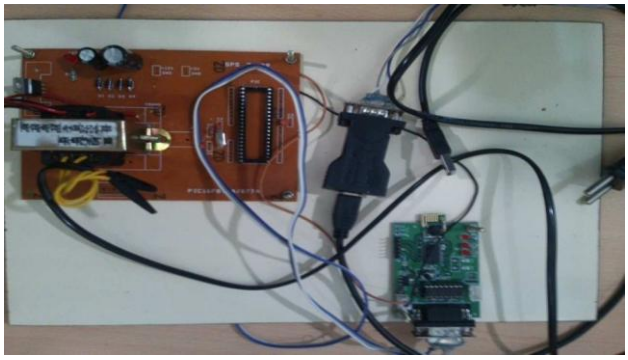

Fig. 7 Controlling Section of Energy Management System

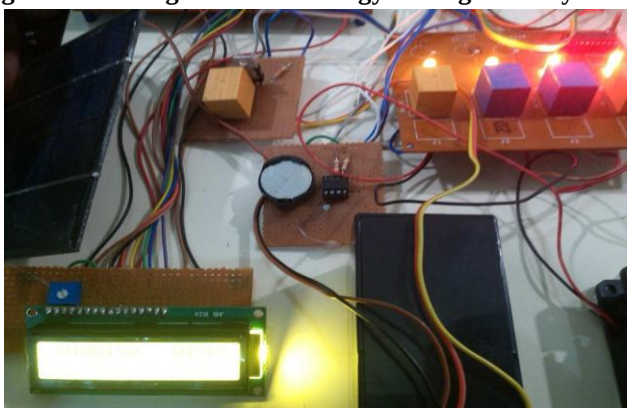

Fig. 8 All the devices are ON during normal time

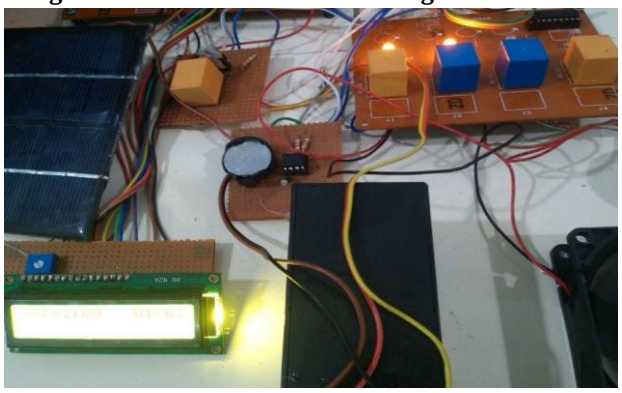

Fig. 9 DC devices ON during Peak time using Battery

During normal time, all the loads will be turned ON which is shown in figure 8. But during peak time all light load devices will be supplied from battery, shown in figure 9. At the same time heavy load devices are controlled by ZigBee as shown in figure 10. Thus there is reduction in energy consumption.

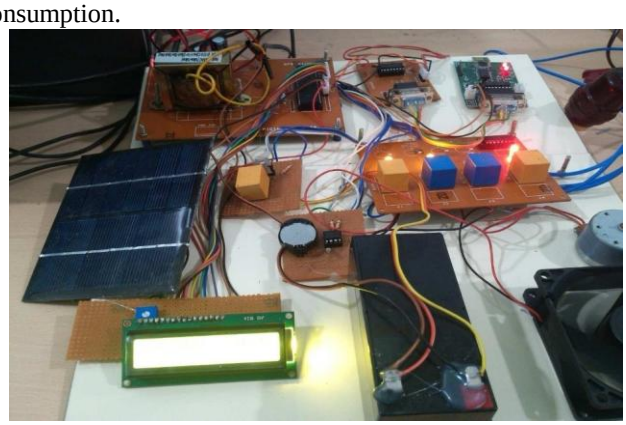

Fig. 10 AC or Heavy devices are controlled by ZigBee during Peak time

VI. CONCLUSION

An efficient energy management system is proposed for the control of energy consumption during peak hours using ZigBee module. It controls the usage of home appliances according to the priority of the users and is cost effective. The two modes of operation includes during normal time and peak time. All the home appliances will be operated from AC mains during normal time. Whereas, during peak time, only low rating machines will be operated from battery supply. The high rating machines are switched OFF, controlled by ZigBee, thus reduces the energy consumption. Simulation and hardware implementation analysis shows that the proposed system can control and manage the operation of various home appliances to reduce the electricity bill. The advantages of the proposed system includes reduction in energy consumption, load balancing and monetary expense reduction. As a drawback, the consumers have to sacrifice their comfort level to some extent. The proposed system leads to the development of energy management for residential and industrial applications.

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