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DEVELOPMENT OF AN INTELLIGENT HOME ENERGY MANAGEMENT SCHEME WITH EFFICIENT LOAD CONTROL AND GAS MONITORING BASED ON DEMAND RESPONSE

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ABSTRACT

Energy saving has become one of the most important issue now a days. The most wastage of energy is caused by the inefficient use of the consumer electronics. However, due to architectural limitations, the existing Energy management systems cannot be successfully applied to home and office buildings. Therefore, this paper proposes an intelligent lighting system considering energy management system based on Demand Response (DR). The proposed system utilizes multi sensors in order to control a light system and also provides user the ability to automatically perform smart load controls based on utility signals, customer's preference and load priority signals received .It provides user to know the Demand of the appliances using wireless communication technology (GSM). Hardware is developed to showcase the applicability of the proposed algorithm in performing DR at an appliance level. This paper demonstrates that the tool can be used to analyze DR potentials for residential customers. This paper presents the hardware demonstration of the proposed energy management system for managing high power consumption household appliances with simulation for demand response (DR) analysis.

Key words — lighting system, home energy management, demand response, minimum light intensity control, home automation, wireless sensor networks**.**

INTRODUCTION

Energy-saving solutions have been becoming increasingly essential in recent years because of environmental issues such as climate change and global warming. Environmental problems are very important issues and these problems are largely caused by the excessive use of n energy.

Recently, an intelligent lighting control system using various sensors and communication modules are actively studied and developed in both university and industry. However, since the existing lighting control systems can support only simple on/off or dimming control according to user movement or brightness of surroundings, it is hard to be applied to complex environments such as house or office. The complex environment means that there is a variety of control requirements, because of the presence of a variety of users. Because of this limitation of existing systems, they are mostly installed in the places such as the front door or the hallway. With the introduction of the smart grid, it is now possible to perform demand response at customer premises to get a finer control of the available resources. Demand response (DR) is defined as ―changes in electricity use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices. Due to this reason, and the fact that there has not been a mature time-varying tariff for residential customers, the DR concept for our hardware demonstration is based on the incentive based DR program—which involves a customer receiving some sorts of load control signals from a service provider. In this case, a homeowner has the freedom to choose what loads to manage and for how long. This is different from a pre-set load (kW) reduction target set by a local electric utility company in direct load control programs.

BACKGROUND THEORY

There are many researches on the lighting control system proposed a wireless sensor network-based intelligent light control system for indoor environments. This light control system manages lighting devices according to user's activities and profiles. Two algorithms (Illumination decision algorithm and device control algorithm) are proposed to meet requirements of the user and to save energy .

The LED light control system can control illumination intensity of an LED light based on brightness of surrounding and movement of residents. A logical low cost design is introduced

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to conserve electrical energy taking daylight illumination into consideration by using a controller area network (CAN) bus as the media for communication. In order to realize the proposed DR feature, it is necessary to deploy a fully automated DR solution, or auto-DR [6], which can be made possible through the use of a Home Energy Management (HEM) system. Today, interests in HEM systems have grown significantly. Various HEM systems are designed based on different communication schemes, such as ZigBee [7] and power-line carriers [8]. In our proposed system, energy consumption can be reduced based on LDR and load priority technique.

DESCRIPTION OF THE PROPOSED SYSTEM

The Fig. 1 shows an overview of the proposed energy management system. The concept of the proposed system is to design the intelligent household LED lighting system with an illumination sensor (LDR), and wireless communication interface (GSM) including monitoring and control functionalities for the home owner and load controllers that gather electrical consumption data from selected appliances and perform local control based on Demand Response from the controller board.

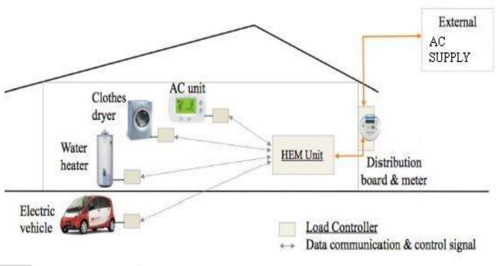

Fig 1: Overview of the Proposed System

A DR event is defined as a period during which the customer demand needs to be curtailed to alleviate a system stress condition. Customers who participate in a DR program can be informed of a DR event by an external signal from a utility via their smart meters. Different loads are used in this project and the corresponding priority is adjusted based on the priority of the loads. Gas sensor is used this project to monitor the detection of any harmful gases. Load cell is available in this project to show the available quantity of gas in the cylinder. As mentioned in Fig.1, a distribution board and meter can be used to provide an interface between utility and home owner in a real life environment.

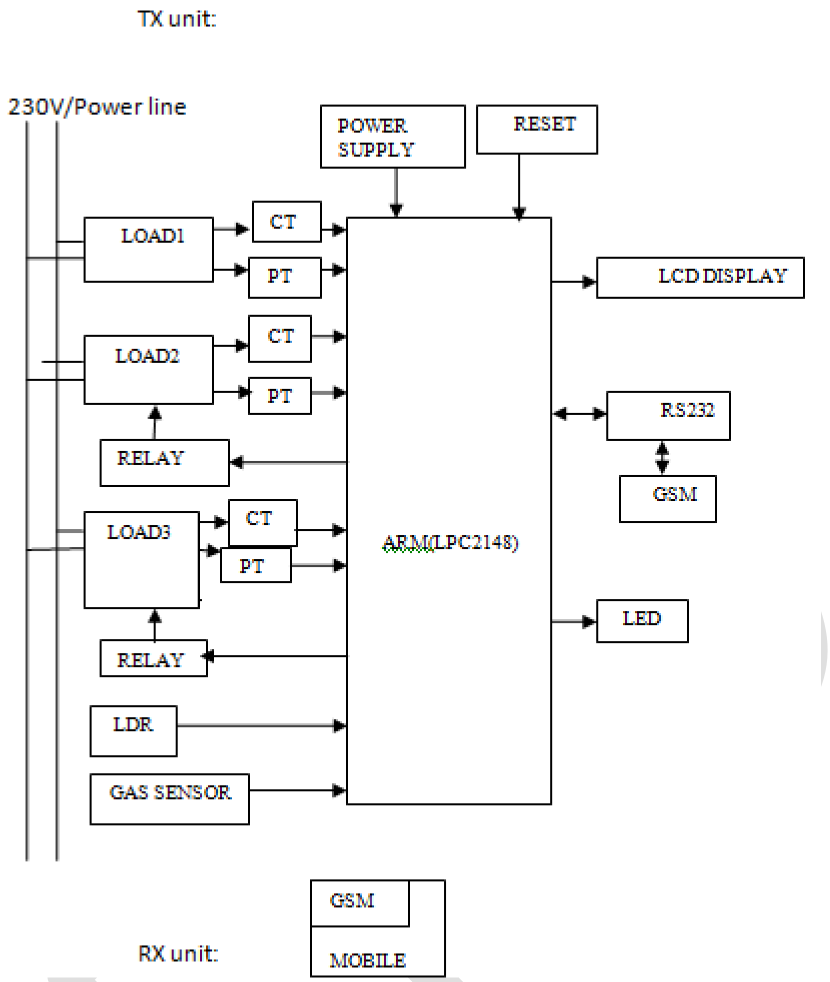

Fig. 2 Block Diagram of the Proposed System

The block diagram for the proposed system is shown in Fig.2. In this case, the distribution meter and board receives a DR (Demand Response) signal from a utility, which is used as an input for our controller unit. As mentioned in Fig.1. We focus on controlling power-intensive household appliances, for eg. Water heaters, air conditioners, clothes dryers, and electric vehicles. Other household loads, such as lights, TVs, computers, and other plug loads, will not be controlled because turning OFF these loads will result in noticeable impacts on customer's lifestyle.

The controller board makes a decision to switch ON/OFF selected end-use appliances based on the utility signal received, as well as homeowner's load priority and preference settings. It is also responsible for collecting electrical consumption data from all load controllers and providing an interface for homeowners to retrieve appliances' status and review their power consumption.

The GSM module which provide communication paths between load controllers and users to provide information about power values.

The main features of this product are:

- Autonomous control based on brightness of the room.
- ON/OFF of the load based on the priority of the load controllers
- Detect the gas leakage in the surroundings
- Know the readings of the load consumed by appliances using wireless communication protocol (GSM).

The proposed system can reduce energy consumption via interaction with the information about surroundings (e.g. brightness of a room) and control the load using controller board.

SYSTEM FLOW DIAGRAM

The flow diagram for the energy management system is shown in Fig 3. The system mainly focuses on controlling of household appliances like water heater, air-conditioner, refrigerator etc. by using automatic load priority algorithm. The system will works under four conditions for load value greater than 220v, greater than 180v, greater than 110v, and less than 110v. The system monitors the luminosity inside the room by automatically changing the light intensity according to the brightness of surroundings [8]. It also checks for the amount of gas usage and leakage detection. If there is gas leakage the system provides an alarm and also sends a message to the user. The load management algorithm starts by gathering system information demand limit, appliance power consumption in KW, load priority, customer's settings. In this system consider three loads as load 1, load 2 and load 3.The algorithm first check for the condition whether the load value is greater than 220v.If it is true all the load will work, else it check for the second condition if the load value is greater than 180v, then the highest priority load will OFF and remaining ON. In the third case, load value is greater than 110v, then two highest priority load will OFF and the remaining one ON. If there is not enough power supply to turn ON appliances, all loads will be in OFF condition.

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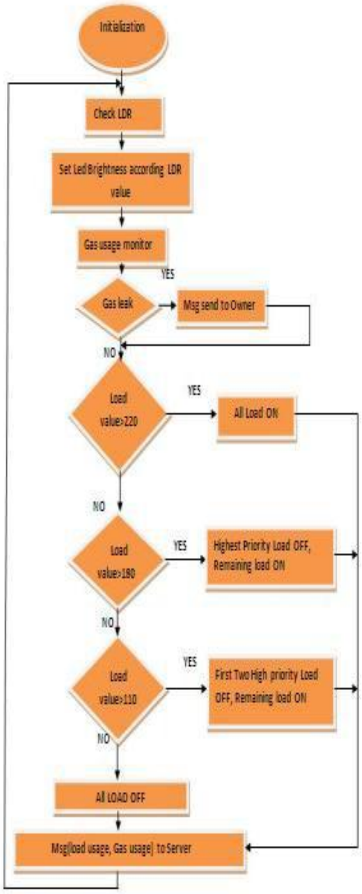

Fig. 3 System Flow Diagram for the Proposed System

SYSTEM COMPONENTS

Microcontroller used

Microcontroller (LPC2148) is the heart of this product. The processor available inside this processor is ARM 7 TDMI-S. The processor board for LPC2148 is shown in Fig.4. The ARM (Advanced RISC Machine) is 16/32 bit controller. The LPC2148 microcontrollers are based on a 32/16 bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combines the microcontroller with embedded high speed flash memory ranging from 32 kB to 512 kB. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code.

Fig. 4 LPC2148 Board

Advantages of using ARM processor are Low power consumption, Multi core processor, and three stage pipelines with an operating frequency of 60MHZ from programmable on chip PLL.

Load priority module

Current transformer produces a reduced current accurately proportional to the current in the circuit, which is given as input to the controller board to measure the amount of current consumed by consumer appliances. Potential transformer produces a reduced voltage accurately proportional to the voltage in the circuit, which is given as input to the controller board to measure the amount of voltage consumed by consumer appliances.

Table 1: Load Priority algorithm

Voltage (in volts)	Load 1	Load 2	Load 3
230	ON	ON	ON
180	OFF	ON	ON
110	OFF	OFF	ON
<110	OFF	OFF	OFF

This transformer provides an interface between the controller board and a selected appliance. It provides basic power management functions (i.e., monitor, control, communicate) via standard electrical outlet. Collects and calculates real-time electrical consumption data, such as voltage, current, apparent power, real power, and power factor from appliances. An electronic relay circuit that provides the capability to switch selected appliances to turns ON/OFF, depending on the command sent by the controller board.

Light illumination module

Light Dependent Resistors (LDR) is a light controlled variable resistor. The resistance of the LDR decreases with the increasing incident light intensity. In this Product based on the resistivity of the LDR normally it is 10-bit analog value input given to the controller board. The proposed system can reduce energy consumption via interaction with the information about user's state and surroundings (e.g. brightness of a room).

PWM module

In this product light intensity is varied using PWM technique based on the analog value from LDR. It performs the role of generating and stabilizing the PWM signal for LED control. It also performs the role of generating the signal to control an actual LED based on the data transferred.

Gas Detector module

In this product gas detector is used to detect combustible, flammable, toxic gases and oxygen depletion. Digital output from the sensor is given to the controller board to continuously monitor the gas leakage in the surroundings.

Wireless communication module

GSM module (sim300) is used in this product which is responsible for providing communication paths between a load controller and the user needs. This is to allow the collected electrical consumption data from a load controller to be sent to the controller board. The commands from the GSM unit are received by a load controller and response signals from the load controller to be sent to the GSM unit.

SIMULATION AND PERFORMANCE RESULTS

The Simulation Model is shown in Fig.5.The simulation work is carried out for four different conditions in the case of automatic load management. power supply greater than 220v,greater than 180v,greater than 110v and less than 110v.According to the power supply level and load priority algorithm the loads will ON and OFF automatically. In the case of 220v and above all the loads will have enough voltage to perform their specific functions. For intelligent light control strategy using LDR sensor can be represented as the light intensity increases the width of the PWM signal will also increases and the inverse occurs as the light intensity decreases. If there is any gas leakage, then there is a message will be displayed as “gas leakage detected”. The result of simulation is as shown in Fig. 6.

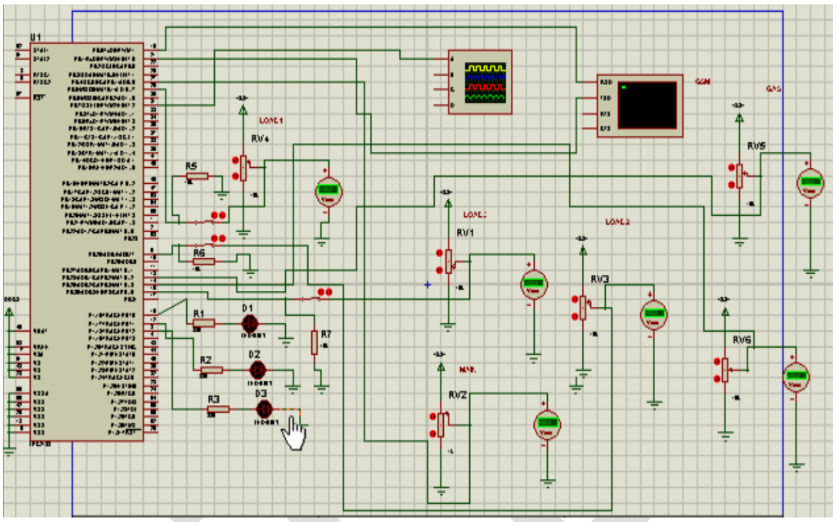

Fig. 5 Simulation Model

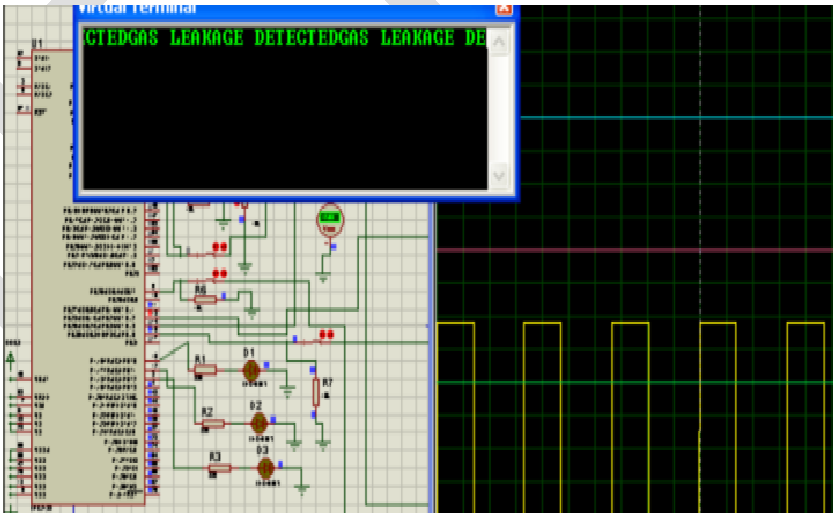

Fig .6 Simulation Results

EXPERIMENTAL RESULTS

As shown in Fig.7, Hardware demonstration for load priority system is presented to show the ability of the proposed system to perform load control based on the priority of the load. Electrical measurements such as voltage, current, volt-ampere and apparent power is shown in the below mentioned Table 2. We used different load such as 200W, 100W and 40W to demonstrate in hardware. Intensity of the light is varied using illumination sensor (LDR). Gas monitoring is done using the Gas sensor MQ series. Power factor is the ratio between the real power and apparent power.

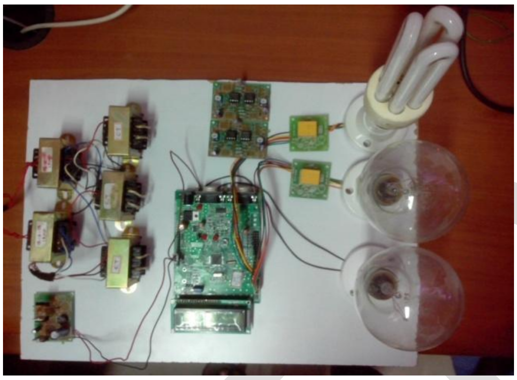

Fig. 7 Experimental Setup for the Load Priority System

Table 2: Experimental reading of the load priority system

POWER	200W	100W	40W
Voltage (in v)	230	180	110
Current (in Amps)	0.809	0.55	0.363
Volt Ampere	199.87	99	39.93
Power Factor	0.9993	0.99	0.978

CONCLUSION

This paper presents an intelligent lighting and home energy management system for demand response applications. Hardware results show that the proposed energy management system can proactively and effectively control and manage the appliance operation to keep the total household consumption below a specified demand limit with the inclusion of gas leakage detection. The proposed energy management system takes into account both load priority and intelligent lighting system based on the brightness of the room.

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