HOME ENERGY MANAGEMENT SYSTEM FOR DEMAND RESPONSE APPLICATIONS

Sarika Ambadas Shinde[1], Rupali S. Khule[2]

[1] *Student, Electronics and Telecommunication, MCEORC, Nashik Maharashtra, India*
[2] *Lecturer, Electronics and Telecommunication, MCEORC, Nashik Maharashtra, India*

ABSTRACT

Now a days, energy saving is one of the most important issue for development of smart grid. The utility companies have higher electric charge during peak periods, so smart grid emphasizes off-peak energy consumption. The Home Energy Management system shall play a very important role in realizing residential demand response in smart grid environment. Therefore, the HEM system with Demand Response (DR) is proposed, in which different loads are used and corresponding priority is adjusted based on priority of user. The controller board is used, which makes a decision to switch ON/OFF action of the selected end use appliances based on utility signal as well as home owners load priority and preference setting. It also demonstrates that how each appliance will perform when it will be controlled by HEM. The proposed system is also responsible for collecting electrical consumption data from all loads and provides an interface for homeowner to retrieve appliances status. It provides user to know the status of appliances wirelessly through sms.

Keyword: *- Energy managemen, HEM, demande response, smartgrid, home automation etc....*

1. INTRODUCTION

Nowadays, Utility companies across the world have taken various steps for efficient consumption of electricity. The process of observing, controlling and conserving electricity usage in an organization/ building is known as energy management or home energy management [1]. It has been reported that 40% of the global power consumption takes place inside residential buildings [2]. Home Energy Management systems are usually called smart grid systems. This allows for direct communication between the utility company and the consumer. The energy management system optimizes the energy usage by informing the customer on a live basis of their corresponding consumption rates. Utility companies have higher electric charges during peak periods, so the smart grid emphasizes off peak energy consumption. The employment of HEM systems in a residential area reduces energy bills for consumers and peak demands. A HEM system in smart grid enables Demand Response (DR) and Demand Side Management (DSM) programs. 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 are at times of high wholesale market prices` or when system reliability is jeopardized". The DR action can be either incentive-based (e.g., direct load control) or time- based (e.g., dynamic pricing, critical peak pricing) program. The concept of proposed HEM system is based on this topic while taking into account homeowner's load priority and comfort preference. DR programs help in managing and varying electricity consumption on electricity supply basis.

The maximum consumption of energy is caused by inefficient use on consumer side. In recent years many HEM systems are proposed to reduce energy wastage, such as HEMS withautomated DR strategies[3], SHEMS based on IEEE802.15.4 & Zig-Bee[4], HEM based on PLC[5],Smart HEMs using task scheduling approach[6], Green

HEMs[7], iHEMs[8] etc. however, with limitation in monitoring and control functionalities for home owner. Also in existing HEM systems the load controllers are incapable to gather electrical consumption data from selected appliances and perform local control based on demand response signal sent by controller board. The Home Energy Management system shall play a very important role in realizing residential demand response in smart grid environment.

1.1 Motivation

This dissertation is motivated by several rising applications of smart grid. Traditionally, over the past several decades, electric power systems have encountered more frequent stress condition due to ever increasing electricity demand, inefficient use of electric power generation and transmission resources. Transmission line outages have been a common cause of system stress conditions, which are possible to occur during critical peak hours. Such events will cause a supply limit situation where cascading failures and large area blackouts are possible. These problems have partially tackled by demand side management. Demand Response (DR) has been envisioned to deal with such unexpected supply limit events by selectively reducing system loads. DR also plays an important role in load shifting from peak hours to off peak hours that can help to increase reliability and efficiency in operation.

1.2 Objectives

1) Introduction To monitor appliance power consumption
2) Controlling and monitoring the Electronic Appliances Remotely
3) To measure electrical factors of the loads.
4) To analyze the communication time delay
5) To evaluate the HEM operation performance, Interoperability, scalability
6) Wireless Home Automation
7) Home Disaster Management
8) To Design a system which is easy to use and deploy

2. PROPOSED SYSTEM

Fig-1 shows an overview of the proposed energy management system. The concept of the proposed system is to design and developed the intelligent home energy management system with user friendly interface, and wireless communication interface including monitoring and control functionalities for the home owner and load controllers that gather electrical consumption data from the appliances and perform local control based on Demand Response by using controller board.
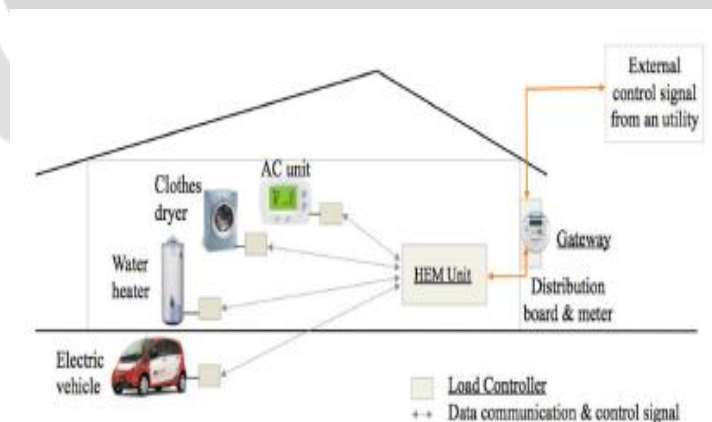

Fig-1: Overview of the Proposed System

An HEM system plays a crucial role in achieving automated DR within a house, as most residential customers do not have time, nor proactive enough to perform DR manually. 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. 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. HEM receives external signal, which includes demand curtailment request and duration, its algorithm is designed to guarantee the total power consumption below the specified demand limit level during the specified duration. The proposed HEM algorithm allows the home owner to operate their appliances when needed as long as the total household consumption remains below the specified limit during a DR event. In earlier, the system proposed would make use of GSM module, hand based gesture which took into limited working of project. In proposed system, the GUI view will be used to monitor and control appliances status and power consumption.

2.1 Block Diagram

The block diagram for the proposed system is shown in Fig-2. There are two modes of operation manual mode and auto mode. In manual mode each appliances is operated directly according to user requirement. Ones the user gets touch on any device it sends that command to controller board and also produces sound along with the SMS to user. Manual mode will play important role during any disaster. In auto mode, board receives a DR (Demand Response) signal from a utility, which is used as an input for our controller unit. 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. Here the HEM unit is the PC/laptop with GUI. The GUI image contains the buttons to control and monitor the appliances status and power consumption. The input provided by the user is processed on backend.
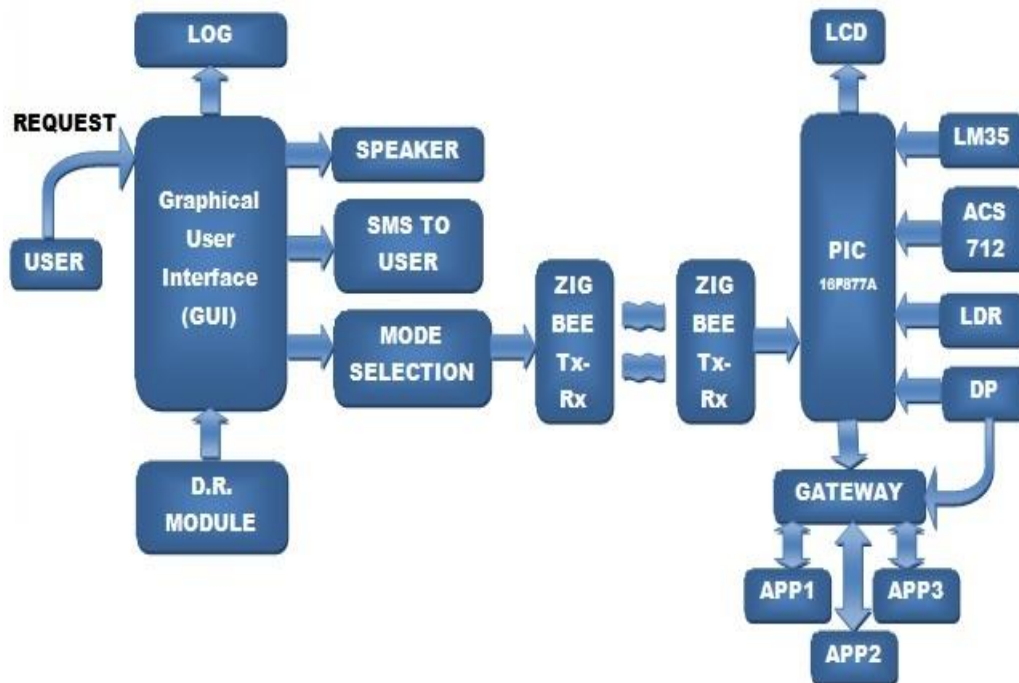

Fig- 2: Block diagram of Proposed System

- ***HEM Unit***

In general, an HEM unit comprises a laptop computer with a ZigBee-enabled communication Module.

   a) An embedded PC running a GUI software application. 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.
   b) An HEM communication module, which provides communication paths between the HEM unit and its load controllers. This module is attached to the HEM unit and enables the HEM unit to send load control commands to all load controllers, and receive responses back.

- **Load Controller**

A load controller provides an interface between the HEM unit and a selected appliance. It also includes a algorithm developed for implementation of Auto-DR that serves as the brain of the HEM system It makes a decision to switch ON/OFF selected end-use appliances based on demand response signal, as well as homeowner's load priority and preference settings. It provides basic power management functions (i.e., monitor, control, and communicate). It contains:

   a) A data capturing and processing module, which collects and calculates real-time electrical consumption data from appliances.
   b) A control module(gateway), which is simply an electronic relay circuit that provides the capability to switch a selected appliance ON/OFF, depending on the command sent by the HEM unit or user.
   c) A communication module, which is responsible for providing communication paths between a load controller and the HEM unit. This is to allow the collected electrical consumption data from a load controller to be sent to the HEM unit; commands from the HEM unit to be received by a load controller; and response signals from a load controller to be sent to the HEM unit.

2.2 Features

Two manual and automatic modes are available to user to change the status of end use appliances. The user request signal from user is send through communication module. 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 status of each appliance is provided to user wirelessly through SMS. The main features of this product are:

- Autonomous control based on brightness and temperature of the room.
- ON/OFF of the load based on the priority of the load controllers
- The status information transfer of appliances wirelessly.
- Saving of unwanted energy consumption due to lack of user awareness.
- Peak load reduction potential

Thus the proposed system can reduce energy consumption via interaction with the information about surroundings (e.g. brightness of a room), DR signal and control the load using controller. The proposed HEM system is more user friendly and easy to deploy.

2.3 System Requirements

The requirements for the proposed systems are as follows:

- Reliability of the system: The system should be highly reliable during the time of its functionality.
- Availability and accessibility: The system shall be able to function on a 24/7 basis.
- The system must be secure And its operation must be safe.
- User friendly: The user shall not take more time to learn system.
- Low power consumption: The overall power consumption of system should be less during its operation.
- High accuracy of the system: The system should provide an accurate status.
- Easy to use and Deploy.

The system as a whole should not cost more to buy and install, along with to maintain and operate during one year of the time of its operation.

2.4 The HEM Load Management Algorithm

In each time interval, the proposed HEM algorithm starts by gathering information, which includes the status and power consumption of all appliances, load priority and customer preference settings, as well as the demand limit and its associated duration. Then, the HEM algorithm checks for demand limit violations. The HEM decides on the status of each appliance based on the requested demand limit level from Fig- 4. After the decision is made, the HEM sends control signals to change the selected appliance status. The total household power consumption is compared with the requested demand limit. If the household consumption is lower than the demand limit, no action is taken. If the household consumption is greater than the demand limit, the HEM will turn OFF the lowest priority loads, to keep the total power consumption below the demand limit. If the household consumption is greater than the demand limit and there is a comfort level violation of the appliance app, then the HEM will compare the priority of all ON appliances with the priority of this appliance, starting from the lowest priority loads to the highest one. If the priority of the appliance APP is greater than any other appliances that are ON, the HEM will shut OFF the lower priority loads until the appliance APP can be turned ON and the total power consumption is below the demand limit.
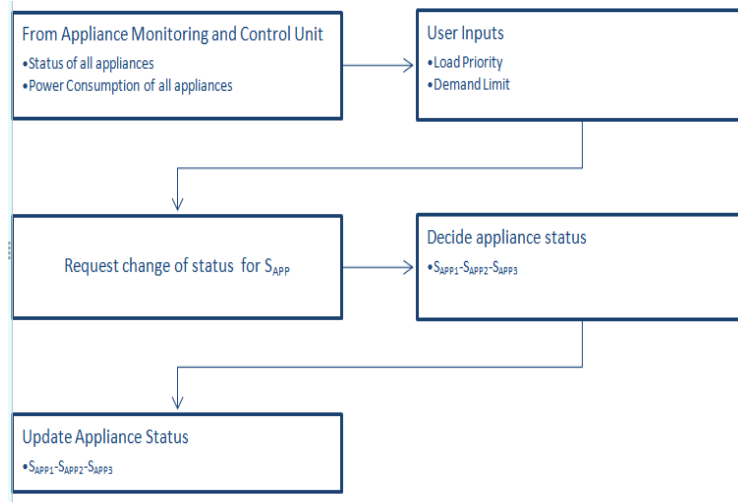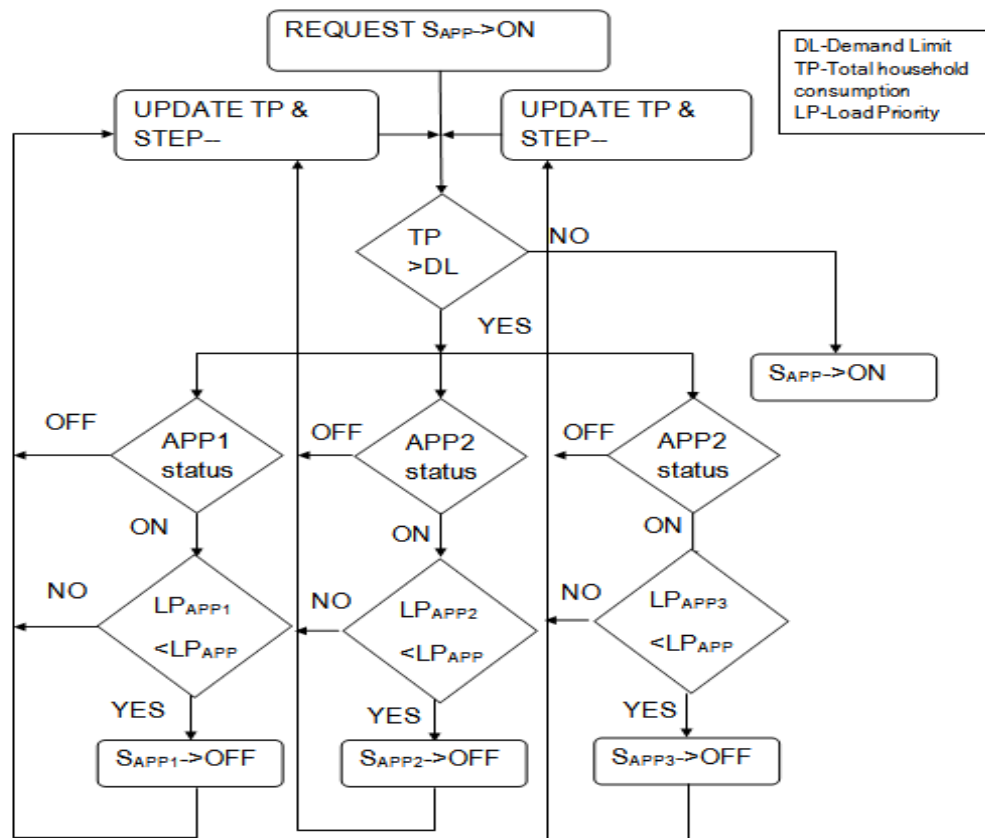
Fig-3: Flow chart 1 of HEM Algorithm

Fig- 4: Flow chart 2 of HEM algorithm

3. SYSTEM DESIGN AND IMPLIMENTATION

3.1 PIC 16F877A

PIC 16F877 controller is widely used for experimental and modern applications because of its low price, wide range of applications, high quality, and ease of availability. The 16F877A is a capable microcontroller that can do many

tasks because it has a large enough programming memory (large in terms of sensor and control projects) 8k words and 368 Bytes of RAM. The 40 pins make it easier to use the peripherals as the functions are spread out over the pins. This makes it easier to decide what external devices to attach without worrying too much if there are enough pins to do the job. One of the main advantages is that each pin is only shared between two or three functions so its easier to decide what the pin function (other devices have up to 5 functions for a pin).

3.2 ZIG-BEE Module

In any HEM systems, two types of communication modules are needed. One is integrated with the HEM unit and the other is built-in in load controller. The type of communication modules selected will impact the overall system's data communication rate, range, cost, and its residual power consumption. Hence instead of Wi-Fi (802.11/n), Bluetooth (802.15.1), ZigBee(802.15.4), and Power Line Carrier (PLC), ZigBee can be used to demonstrate the proposed HEM system. This is because Zig-Bee is a low-cost, low-power consumption option, and does not require an extensive new infrastructure. It also provide reliable delivery of data between devices. The modules operate within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other. Serial interface data rate is 1200 b/s - 250 kb/s. Devices that have a UART interface can connect directly to the pins of the RF module as shown in the Fig-5.
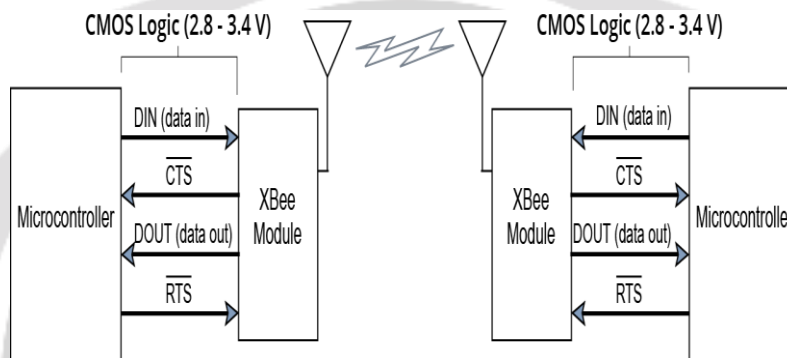
Fig-5: System data flow diagram in a UART-interfaced environment

3.2 LDR

A Light Dependant Resistor (LDR) is a resistor that changes in value according to the light falling on it. A commonly used device, the ORP-12, has a high resistance in the dark, and a low resistance in the light. Connecting the LDR to the microcontroller is very straight forward, but some software 'calibrating' is required. It should be remembered that the LDR response is not linear, and so the readings will not change in exactly the same way as with a potentiometer. In general there is a larger resistance change at brighter light levels. This can be compensated for in the software by using a smaller range at darker light levels.
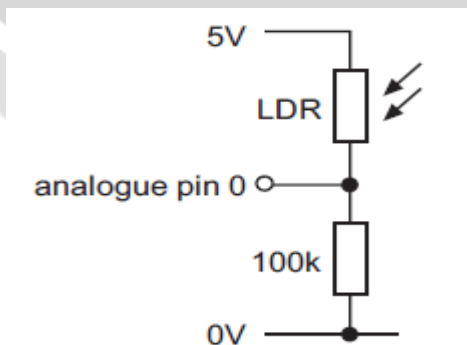
Fig-6: Interfacing circuit of LDR

3.3 LM35

LM35 is analog temperature sensor, it is a 3 Pin device, Two pins are for Vcc and GND and the third pin gives voltage proportional to the temperature. The output of LM35 will be a varying voltage proportional to the temperature, So Port A is configured as analog and the output of LM35 is given into any of the analog channels, this could be stored in any variable in the program and could be used for further analysis.

3.4 LCD

Liquid Crystal Display also called as LCD is very helpful in providing user interface as well as for debugging purpose. A liquid crystal display (LCD) is a flat panel display that uses the light modulating properties of liquid crystals (LCs). LCD Modules can present textual information to user. Fig-7. shows how to interface the LCD to microcontroller. The 2x16 character LCD interface card with supports both modes 4-bit and 8-bit interface, and also facility to adjust contrast through trim pot. In 8-bit interface 11 lines needed to create 8-bit interface; 8 data bits (D0 – D7), three control lines, address bit (RS), read/write bit (R/W) and control signal (E).
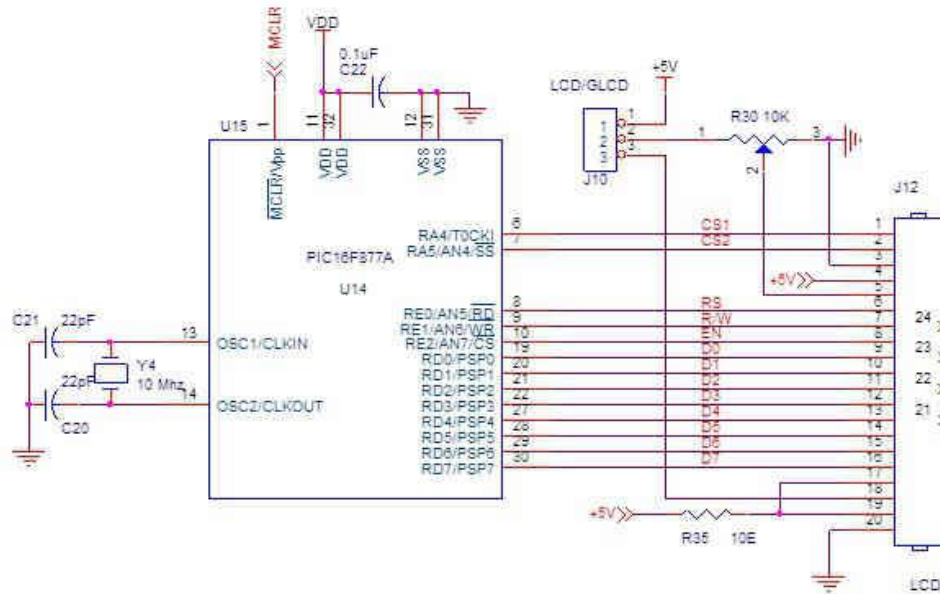
Fig-7: LCD interfacing

4. RESULTS AND DISCUSSION

4.1 Interfacing of PIC, ZIG-BEE and Different loads

PIC 16f877A is used having five input output ports. One serial port is used for Zig-Bee interfacing. Zig-Bee is connected to controller; it has a dedicated hardware UART that can communicate with a PC via this serial port. This is the main interface used by the PC to communicate with the controller to send commands and receive back data.
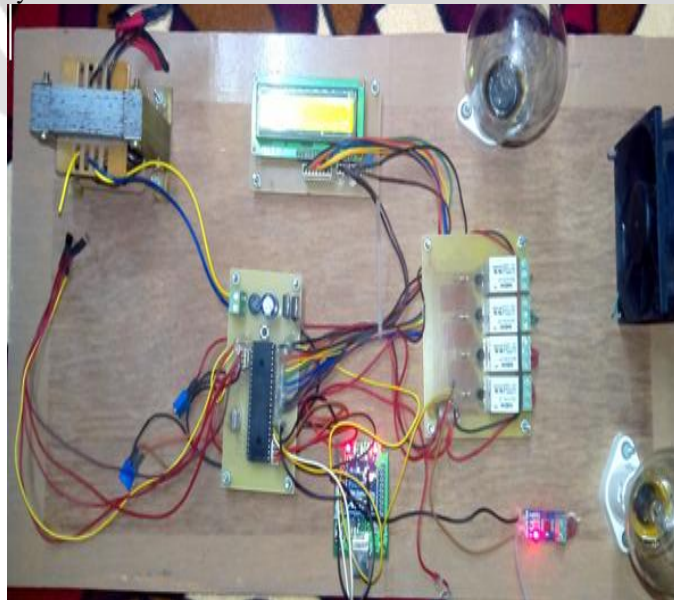

Fig-8: Interfacing of PIC, Zig-Bee and Sensors

The embedded device On Controller can also communicates through Zig-Bee, which makes the wireless operation possible. Fig-8. shows interfacing of Zig-Bee and PIC, interfacing of sensors and PIC and also the interfacing of different loads to controller.

Following are the objectives:

- Interfacing Zig-Bee with PIC and PC.
- Interfacing different loads with PIC.
- Interfacing Sensors with PIC.
- Setting up DR limit.
- Integrating complete system to achieve final task.

4.2 User Interface

The user interface is used to monitor and control appliances status and power consumption. The GUI is designed in the MATLAB from which user can easily access the appliances. The GUI image contains the buttons to control and monitor the appliances status and power consumption. There are two modes of operation manual mode and auto mode. In manual mode each appliances is operated directly according to user requirement. Ones the user gets touch on any device it sends that command to controller board and also produces sound along with the SMS to user. Manual mode will play important role during any disaster. In auto mode, board receives a DR (Demand Response) signal from a utility, which is used as an input for our controller unit. Fig- 9. shows the results getting at user interface.

The Fig -10 shows the power consumption without DR action and Fig.-11 shows the power consumption with DR action. The graph is plotted by measuring power consumption with and without DR action for different time period. The power consumption is more for system without DR action because the appliances are remain in on state even the user comfort conditions are satisfied. There comparison shows that the power consumption is 20 to 30% more for without DR action
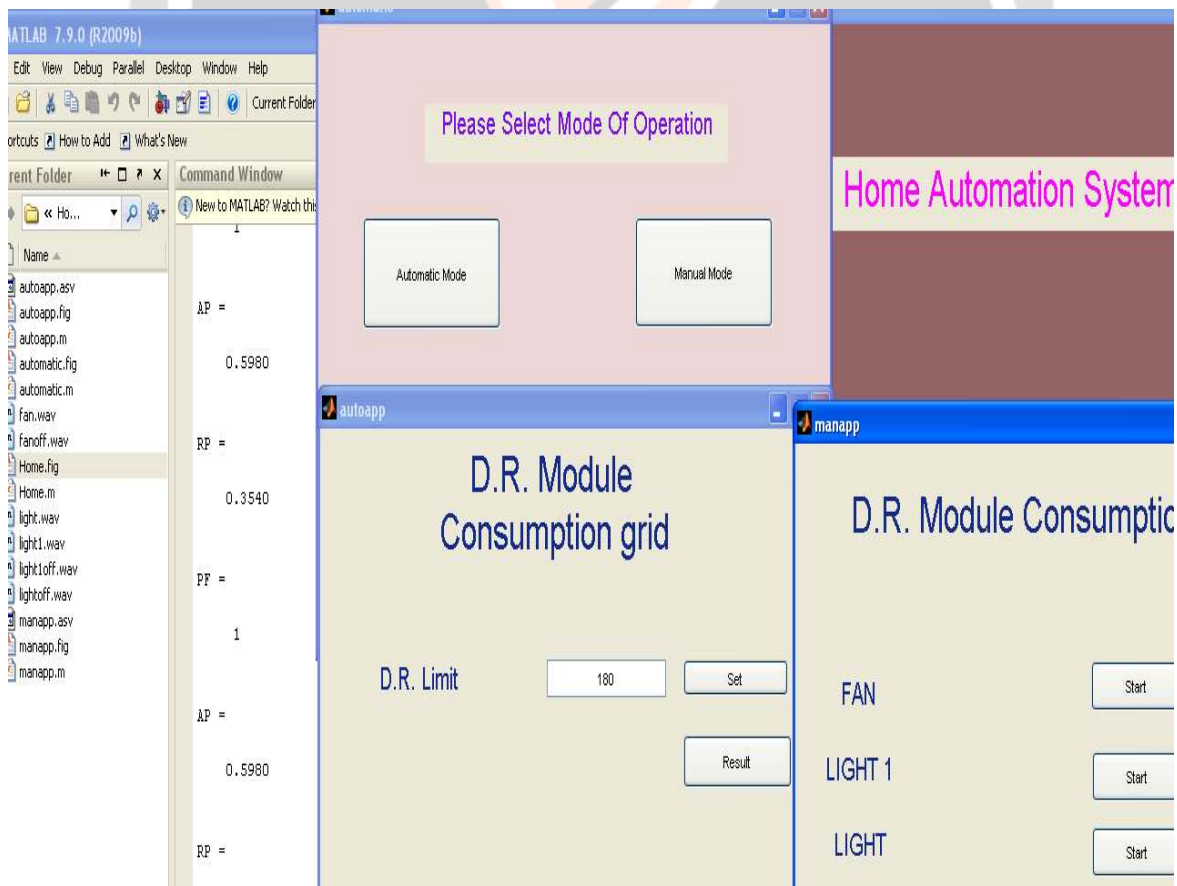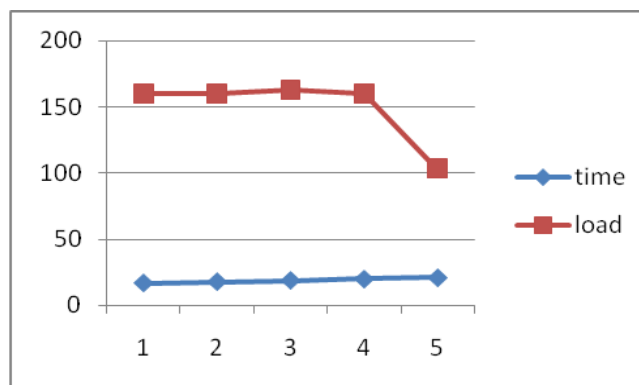

Fig- 9: GUI Interface and Results
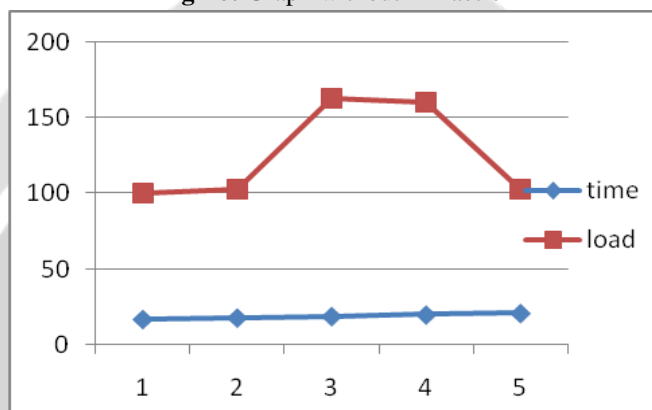
Fig-10: Graph without DR action

Fig- 11: Graph with DR action

5. CONCLUSIONS

The Home Energy Management system with demand response plays a most important role in effectively managing the wastage of energy on consumer side. This project presents a new design to control power consumption of appliances at home. The proposed Home Energy Management system for demand response applications which can proactively and effectively control and manage the appliance operation to keep the total household consumption below a specified demand limit by managing selected power-intensive loads according to their priority. The proposed energy management system takes into account both load priority and user preferences. The changes in status of appliances will be notified to user through SMS. Thus the project provides a low-cost, flexible, user-friendly, and very secure architecture for implementing a Home Energy Management System. In HEM system with DR action the power consumption is reduced by 20 to 30%.

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