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DEMAND RESPONSE BASED ABODE ENERGY MANAGEMENT SYSTEM

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***Abstract---* In recent years, power crisis has been a major issue which leads to frequent power shutdown that makes inconvenience to the consumers. During peak times the power demand is more which leads to more shortage of power. And during off peak times the power consumption is low and as a result generated power gets which will not be stored. This also leads to environment pollution too as energy is produced from non renewable sources. Hence Demand Response management plays a key role.**

To achieve this, the proposed Home Energy Management System will have control of different appliances that are available in the home. It manages household loads according to their predefined priority and guarantees the total household power consumption below certain levels. The home energy management system will receive the demand response from the utility side. The goal of the system is to encourage the consumer to use less energy during peak hours or to move the time of energy use to off peak times such as nighttime and weekends. Thus the high peak-to-average ratio (PAR) of power will be avoided and also we adopt real time pricing. The utility company use real time dynamic pricing to coordinate demand responses to the benefit of the overall system.

Keywords– PAR , HEMS, AVR, GSM, BU, MAC

I.INTRODUCTION

In recent years, the demand for power has been a major issue which is due to increase in consumption and limitations in power generation. In human life each and everything is getting automated which in turn emphasize the importance of electricity. Hence power shutdown is a major issue during such power demand. Efficient energy use, sometimes simply called energy efficiency, is the goal to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Installing fluorescent lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared with using traditional incandescent light bulbs.

Compact fluorescent lights use one-third the energy of incandescent lights and may last 6 to 10 times longer. Improvements in energy efficiency are generally achieved by adopting a more efficient technology or production processes or by application of commonly accepted methods to reduce energy losses.

Understanding how energy is spent and knowing how to monitor and control it are key prerequisites for residential energy conservation. Installation of new generating units, especially thermal power plants, to meet ever increasing demand of electricity has threatened our environmental sustainability along with the increasing cost of electricity. Aging infrastructure and inability of utilities to meet the demand have increased the severity of the problems. Recent developments in information technology may help in overcoming these problems. Concept of smart grid with energy management system may help to overcome problem of peak demand.

In Tamil Nadu, the annual electricity sale to domestic sector is 13 Billion Units (BU) which accounts for 22% of the total electricity sold. The domestic sector electricity consumption varies with respect to rural and urban segments and climatic seasonal variations. The price for consumers is increasing by approximately 2.4% on the total bill, for a household with a typical consumption pattern of 800 kilo Watt-hour (kWh) per month.

The art of managing the load demand by providing intimation to shed the load in critical situations when demand consumed is increased than predetermined demand value. Different techniques have been introduced for reducing residential cost either by reducing power consumption or by shifting load to off peak times.

II.EXISTING METHOD

Dongho Lee et al. (2011) proposed an unsynchronized duty cycle control scheme. This scheme achieved energy efficiency and congestion avoidance by duty cycle control in sensor-based home automation networks. One of the primary mechanisms for achieving low energy operation in energy constrained wireless sensor networks is the duty cycle operation, but this operation exhibits several disadvantage. It is overcome by the proposed scheme that reduces energy consumption from short preamble packet transmission. The proposed scheme not only provides energy efficiency but also achieves reliability compared with previous MAC protocols[1].

Dong Sik Kim et al. (2013) developed In-Home Display (IHD) system provides energy monitoring information for the consumer Demand Response (DR). Considering the building structures and the existing automatic meter systems, several types of IHD systems have recently been developed based on the 2.4GHz ZigBee radio, the power line communication technique, and the sub 1-GHz narrow-bandwidth radios. In these five cases of IHD system developments and implementations are introduced and their technologies including network architectures compared. A transmitter directly transmits the information data from the server to multiple IHD devices via repeaters in a star-shaped connection[3].

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Ji Hoon Yoon et al. (2013) made focus on developing a control strategy for the High Voltage Alternating Current (HVAC) to respond to real-time prices for peak load reduction. The proposed Dynamic Demand Response Controller (DDRC) changes the set-point temperature to control HVAC loads depending on electricity retail price published each 15 minutes and partially shifts some of this load away from the Peak. It has a detailed scheduling.

Phani Chavali et al. (2014) proposed a distributed framework for the demand response based on cost minimization. The cost function for each user and the constraints for the appliances are modeled. Greedy iterative algorithm can be employed by each user to schedule appliances. Each user requires only the knowledge of the price of the electricity. In order to coordinate with each other, users introduced a penalty term in the cost function, which penalizes large changes in the scheduling between successive iterations. Thus various appliances are modeled and it is easier to switch between various modes depending on the energy consumption[11].

III.OVERVIEW OF CONVENTIONAL OPTIMIZATION TECHNOLOGIES

In optimization of a design, the design objective could be simply to minimize the cost of production or to maximize the efficiency of production. An optimization algorithm is a procedure which is executed iteratively by comparing various solutions still an optimum or a satisfactory solution is found. With the advent of computers, optimization has become a part of computer-aided design activities. There are two distinct types of optimization algorithms widely used today. They are Deterministic algorithm and Stochastic Algorithms.

The constraints represent some functional relationships among the design variables and other design parameters satisfying certain physical phenomenon and certain resource limitations. The nature and number of constraints to be included in the formulation depend on the user. Constraints may have exact mathematical expressions or not.

IV.PROPOSED SYSTEM

The next task in the formulation procedure is to find the objective function in terms of the design variables and other problem parameters. The common engineering objectives involve minimization of overall cost of manufacturing or minimization of overall weight of a component or maximization of total life of a Product or others. Although most of the objectives can be quantified (expressed in mathematical form), there are some objectives (such as aesthetic aspect of a design, ride characteristics of a car suspension design and reliability of a design) that may not be possible to formulate mathematically. In such a case an approximating mathematical expression is used.

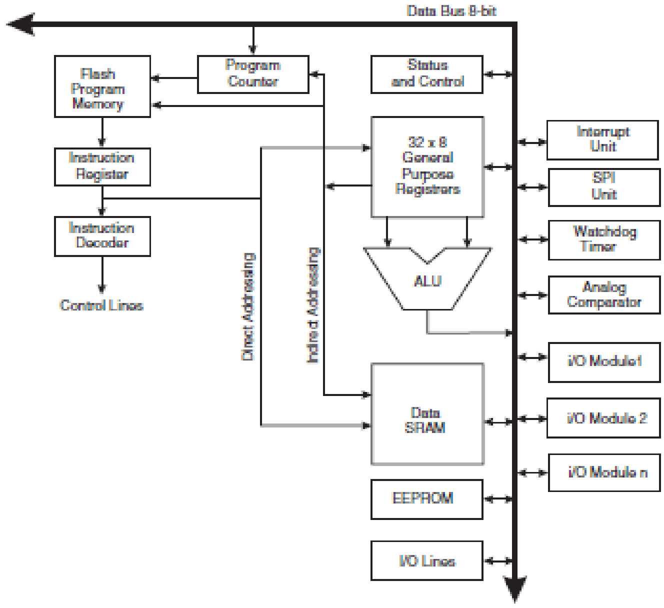

Fig:1. Block Diagram of the AVR MCU Architecture

In real world optimization, there could be more than one objective that the designer may want to optimize simultaneously. The multiple objective optimization algorithms are complex and computationally expensive. Therefore the most important objective is chosen as the objective function and the other objectives are included as constraints by restricting their values within a certain range.

A) General Format

Denoting the design variables as a column vector x=(x1, x2,….. xn)T the objective function as a scalar quantity f(x) j inequality Constraints as gi (x) ≥ 0 and K equality constraints as hk (x)= 0 the NLP problem is written as : Minimize f(x) Subject to,

$$g_i(x) \geq 0 \qquad j = 1, 2, 3, \ldots\ldots J$$

$$h_k(x) = 0 \qquad k = 1, 2, 3, \ldots\ldots K$$

$$g_l(x) \leq 0 \qquad l = 1, 2, 3, \ldots\ldots L$$

B) GREEDY HEURISTIC ALGORITHM

The Greedy algorithm is an algorithm that follows the problem solving heuristic of making the locally optimal choice at each stage with the hope of finding a global optimum. In many problems, a greedy strategy does not in general produce an optimal solution, but nonetheless a greedy heuristic may yield locally optimal solutions that approximate a global optimal solution in a reasonable time.

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Globally optimal solution can be obtained by making locally optimal choice and the choice at present cannot reflect possible choices at future. Optimal substructure is exhibited by a problem if an optimal solution to the problem contains optimal solutions to the sub problems within it.

To prove that a greedy algorithm is optimal these two Parts are to be exhibited. For this purpose globally optimal solution must be taken. The greedy choice at the first step generates the same but with the smaller problem, here greedy choice must be made and it should be the part of an optimal solution; at last induction must be used to prove that the greedy choice at each step is best at each step, this is optimal substructure.

C) Components of Greedy Algorithm

•A candidate set, from which a solution is created

•A selection function, which chooses the best candidate to be added to the solution

•A feasibility function, that is used to determine if a candidate can be used to contribute to a solution

•An objective function, which assigns a value to a solution, or a partial solution

i) Real scenario

The greedy heuristic algorithm created will be used in a real energy management system to reduce the overall electricity bill. The system is composed for smart appliances. In addition, every other appliance that is not born smart is equipped with an object called smart meter that can measure the consumption of that appliance and transmit it to the central station. Those appliances, unlike the smart one, cannot be scheduled along the day but contribute to the energy consumption. The central station that works also as a gateway for all the devices receives all the information from smart appliances and smart meters and, using this algorithm, decides the allocation of the four appliances in order to reduce the total electricity cost.

Moreover, the GUI installed on the central station lets the user browse all devices connected to the system like power sources and appliances as well as all the things connected with the smart meter. Each appliance connected can be controlled in detail and has a different GUI. In the case of a washing machine, for example, the user can decide the period of the day in which the washing machine has to be allocated, the type of cycle and all the other parameters that the washing machine lets change, like water temperature, etc.

V. SOFTWARE TOOL

A). Code Vision AVR

Code Vision AVR is a C cross-compiler, Integrated Development Environment and Automatic Program Generator designed for the Atmel AVR family of microcontrollers. The program is a native 32bit application that runs under the Windows 95, 98, NT 4, 2000 and XP operating systems. The C cross-compiler implements nearly all the elements of the ANSI C language, as allowed by the AVR architecture, with some features added to take advantage of specificity of the AVR architecture and the embedded system needs. The compiled COFF object files can be C source level debugged, with variable watching, using the Atmel AVR Studio debugger. The Integrated Development Environment (IDE) has built-in AVR Chip In-System Programmer software that enables the automatically transfer of the program to the microcontroller chip after successful compilation/assembly. The In-System Programmer software is designed to work in conjunction with the Atmel STK500, Kanda Systems STK200+/300, Dontronics DT006, Vogel Elektronik VTEC-ISP, Futurlec JRAVR and MicroTronics' ATCPU/Mega2000 development boards. For debugging embedded systems, which employ serial communication, the IDE has a built-in Terminal. Besides the standard C libraries, the Code Vision AVR C compiler has dedicated libraries for:

• Alphanumeric LCD modules

• National Semiconductor LM75 Temperature Sensor

• Philips PCF8563, PCF8583, Dallas Semiconductor DS1302 and DS1307 Real Time Clocks

• Dallas Semiconductor 1 Wire protocol

• Dallas Semiconductor DS1820/DS18S20 Temperature Sensors

•Dallas Semiconductor DS1621 Thermometer/Thermostat

• Dallas Semiconductor DS2430 and DS2433 EEPROMs

• SPI

• Power management

• Delays

• Gray code conversion.

Code Vision AVR also contains the Code Wizard AVR Automatic Program Generator, that allows you to write, in a matter of minutes, all the code needed for implementing the following functions:

• External memory access setup

• Chip reset source identification

• Input/ Output Port initialization

• External Interrupts initialization

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- Timers/Counters initialization
- Watchdog Timer initialization
- UART initialization and interrupt driven buffered serial communication
- Analog Comparator initialization
- ADC initialization
- SPI Interface initialization
- I2C Bus, LM75 Temperature Sensor, DS1621 Thermometer/Thermostat and PCF8563, PCF8583,DS1302, DS1307 Real Time Clocks initialization
- 1 Wire Bus and DS1820/DS18S20 Temperature Sensors initialization
- LCD module initialization.

B). Tools

Before starting with programming, we first need to set up the IDE to make life easier for ourselves later by configuring several 'tools'. These tools will allow us to program the target microcontroller and to debug it using a simulator all from within the CodeVisionAVR C Compiler window. It is beyond the scope of this tutorial to describe the detailed use of these tools. We will merely describe how to set them up so that they can be accessed from within the CodeVisionAVR C Compiler window.

If you have the Atmel AVRDB, you will also have received or can download through the Web, the two main tools; AvrProg.exe for programming the AVRDB and AvrDebug.exe for simulating and debugging assembled code. If you have some other development system, it will have a program for programming the target microcontroller. We need to tell the CodeVisionAVR C Compiler system where these files are located on your computer.

C). Assembly Interface

Assembly code is used for one or more of three reasons: speed, compactness or because some functions are easier to do in assembler than in a higher level language. It is well known that using a high level language always results in the faster program development but there are times when, for the reasons stated above, one wants to use assembly language.

The CodeVisionAVR C Compiler, like other compilers meant for microcontroller development, has an easy interface to assembly language. Assembler code may be imbedded anywhere in a C program by using the following 'inline' construct:

```
#asm
….
….
Assembly language code
….
….
#endasm
```

The only precaution one must observe is to use only registers r4 through r20 inclusive; a total of 17 registers are thus available for assembly language use. The other 15 registers are used by the compiler and using of some of them in the inline assembler code might compromise the rest of the program. The use of assembly language in a C program is described in the CodeVisionAVR C Compiler help files. We will start with a very simple example code here. Let's suppose we want to reproduce the very first program used in the project, tutor1 but we want to execute the read switches, write to LED loop as quickly as possible. We will get this speed writing the program mostly in assembly language.

Flow chart

D). Bit-wise I/O

Setting and clearing I/O bits in a microcontroller is not as simple as it may seem at first glance. Consider the following case. Let's imagine we have a controller with a lot of I/O being handled by interrupt routines. Somewhere in the program, we want to activate a relay which has been connected to bit 2 of PORTB. Let's assume PORTB is a general output port and the other pins go to other devices and let's also assume that the relay is activated by a logical zero and released by a logical 1. How do we do it? Because we don't know (or may not know) what the other pins on PORTB are doing, we have to be sure that we don't affect them. Therefore, we have to read the pins of the port latch (PORTB) and then rewrite that same word back to the output latch, PORTB, after making bit 2 a zero. The code to activate the relay would be something like:

```
data = PORTB;
PORTB = data & 0xfb;
```

These two actions are shown here as separate statements to emphasize that it requires a read of a register followed by a write of the register after some internal operations. What happens if some of the other bits in the latch get changed in the time interval between these two statements by an interrupt routine? The answer is that these pins will get put back to what they were before the interrupt routine took place – it is as if the interrupt never occurred. Note that changing the statement to:

```
PORTB = PORTB & 0xfb;
```

doesn't help – the compiled code will still have a read of PORTB followed by a write to PORTB at a subsequent time. To be safe, we'd have to turn the interrupts off before this

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operation and then turn them back on after. This is awkward and may cause time-critical interrupt routines to fail.

.VI. HARDWARE IMPLEMENTATION OF THE PROPOSED SYSTEM

A) Microcontroller used

The ATmega8 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega8 achieves throughputs approaching 1 MIPS per MHz, allowing the system designed to optimize power consumption versus processing speed. The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers. The ATmega8 provides the following features: 8K bytes of In-System Programmable Flash wit Read-While-Write capabilities, 512 bytes of EEPROM, 1K byte of SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte oriented Two- wire Serial Interface, a 6-channel ADC (eight channels in TQFP and QFN/MLF packages) with 10-bit accuracy, a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and five software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning. The Power- down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next Interrupt or Hardware Reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low-power consumption.

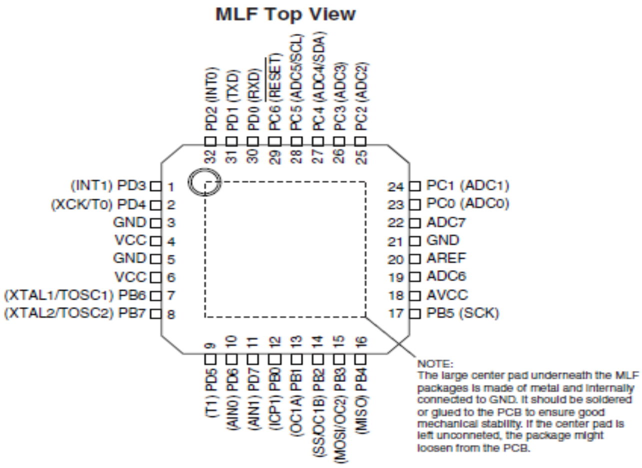
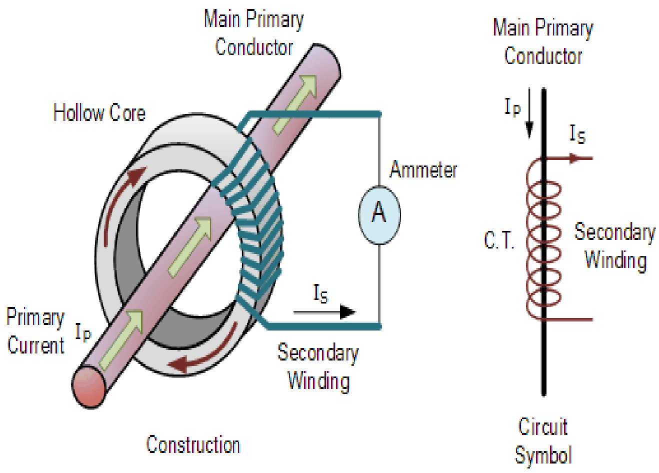


Fig:2. MLF Top view of ATMEGA 8

B) Current Transformer

Gyroscopes normally embrace a spinning wheel or disc in which the pin is free to assume any direction. This sensor is used to find the rotational motion of the steering which is fixed at center of the steering wheel.This sensor have three axis input axis, Output axis and spin axis. Rotation of this sensor which represents the output from each axis is analog voltage. This analog voltage will convert in to digital signal by using main system. Steering wheel is monitored in order to find the drivers way of handling.

Fig 3: Current transformer constructions



For most current transformers the primary and secondary currents are expressed as a ratio such as 100/5. This means that when 100 Amps is flowing in the primary winding it will result in 5 Amps flowing in the secondary winding. By

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increasing the number of secondary windings, N2, the secondary current can be made much smaller than the current in the primary circuit being measured. In other words, as N2 increases, I2 goes down by a proportional amount.

We know double wound voltage transformers that its turn's ratio is equal to:

$$T.R. = n = \frac{N_P}{N_S} = \frac{I_S}{I_P}$$ ----------- Equation (1)

From which we get:

$$\text{secondary current, } I_S = I_P\left(\frac{N_P}{N_S}\right)$$ --------Equation (2)

As the primary usually consists of one or two turns whilst the secondary can have several hundred turns, the ratio between the primary and secondary can be quite large. For example, assume that the current rating of the primary winding is 100A. The secondary winding has the standard rating of 5A. Then the ratio between the primary and the secondary currents is 100A-to-5A, or 20:1. In other words, the primary current is 20 times greater than the secondary current. It should be noted however, that a current transformer rated as 100/5 is not the same expresses the "input/output current rating" and not the actual ratio of the primary to the secondary currents. Also note that the number of turns and the current in the primary and secondary windings are related by an inverse proportion. But relatively large changes in current transformers turns ratio can be achieved by modifying the primary turns through the CT's window where one primary turn is equal to one pass and more than one pass through the window results in the electrical ratio being modified So for example, a current transformer with a relationship of say, 300/5A can beas one rated as 20/1 or subdivisions of 100/5. This is because the ratio of 100/5 converted to another of 150/5A or even 100/5A by passing the main primary conductor through its interior window two or three times as shown. This allows a higher value current transformer to provide the maximum output current for the ammeter when used on smaller primary current lines.

VII.RESULTS

A) LCD Display

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

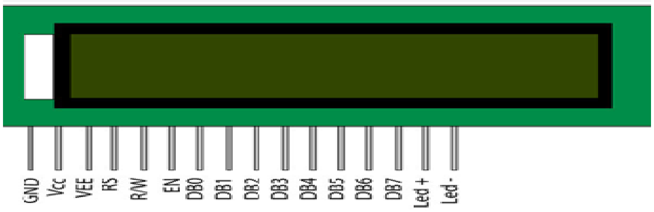

Fig: 4. LCD display

B) HARWARE SETUP AND RESULTS

The hardware setup that implements the proposed system is shown in Figure

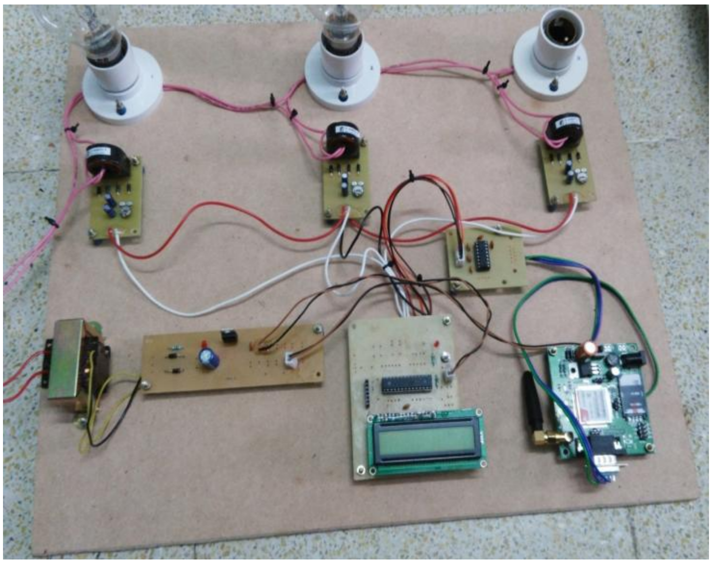

Fig: 5 Hardware Setup

The flowchart for the programming process shows the various steps involved in initializing and running the proposed Home Energy Management system. The flowchart for the proposed Home Energy Management system is shown in Figure 5.8.After initializing init() and 'adc_init() Modules, current consumption of each load is measured using current transformer and it is displayed continuously in LCD display. Initially all the loads run under normal condition until the demand limit is set. After this load would work under

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determined limit, violation in limit causes load to shutdown which is done by controller using relay.

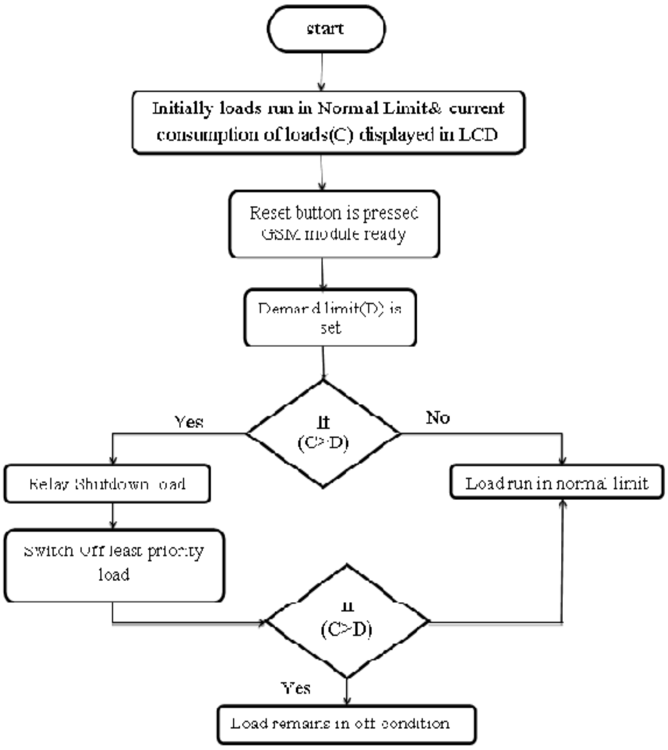


Fig: 6 Flowcharts for Programming Process.

C) Result

The results of the Home Energy Management system with dynamic demand response are shown in the Figures 5.9, 5.10 and 5.11. Initially all the loads run under normal condition and current consumption of each load is displayed in Figure 6.11. During peak hours demand limit is sent from EB to Microcontroller using GSM module. Figure shows the demand limit for a home. Now system works under demand limit condition. When current consumption of all loads go beyond the limit then system gets shutdown automatically. Customers can off their least priority loads so that current consumption got reduced. Now remaining loads got on automatically and run under Normal limit.

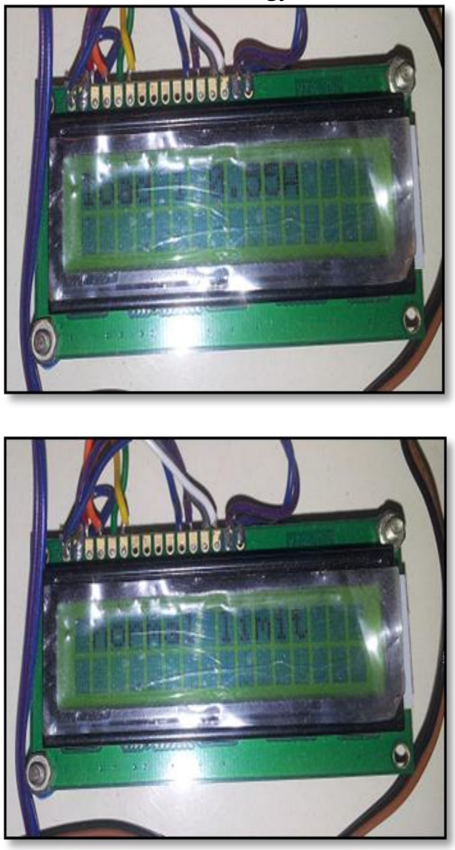
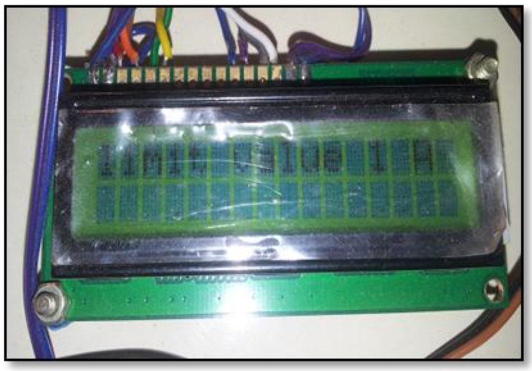


Fig: 7. HEMS During ON Condition



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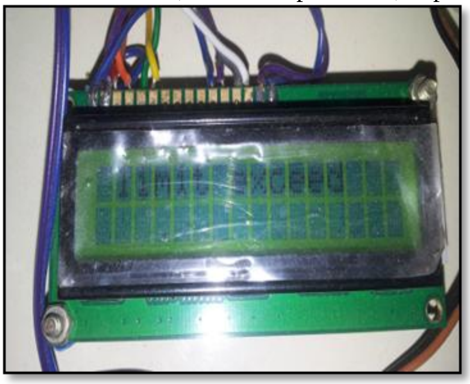

Fig:8. HEMS during Demand Limit Condition

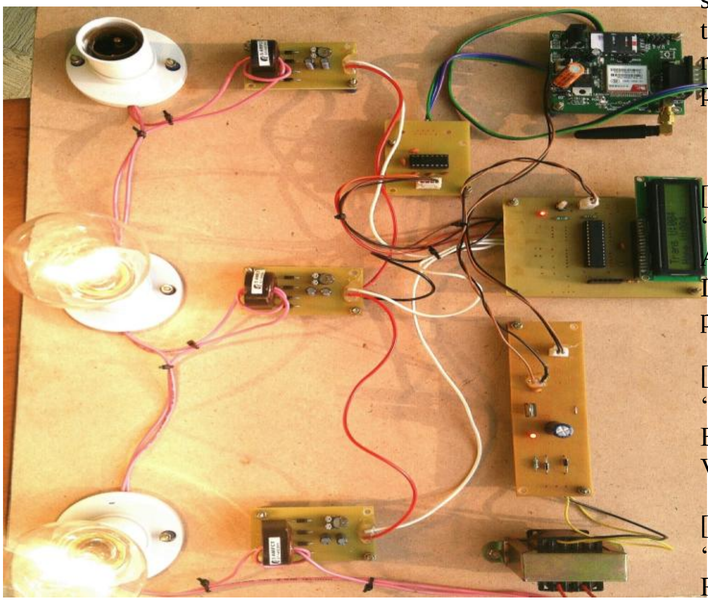

Fig: 9. HEMS after Removing the Excess Load

Thus the Design of Home Energy Management System with dynamic demand response is implemented as a prototype using ATmega8A microcontroller and it is found to work well in all situations.

VIII.CONCLUSION

Home Energy Management System can effectively and proactively control and manage the operation of various appliances to keep the total house hold consumption below a specified demand limit. The proposed algorithm takes into account both load priority and customer comfort level settings. Simulation results indicate that at a low demand limit level, the system is able to keep the total household demand below the limit. Also, it is possible that a DR event could create a high off-peak demand due to load compensation. Both prediction and neural based algorithm is compared and from the result it is found that the neural based algorithm can forecast the future demand more accurately. However it is expected that the results of work will benefit electric distribution utilities and DR aggregators in providing an accurate and deep understanding into the limits and potentials of DR available in residential markets.

In order to forecast future demand various optimization algorithms can be used for urban and rural areas. Algorithms can be proposed to reduce dynamic demand considering the seasonal variations. Along with the demand management real time price can also be taken into account for effective power reduction. The Future scope of this work is to implement this prototype in real time applications.

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