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Power Management in Intelligent Buildings

[1]Rangeetha . S, Asst.Prof / ECE, Sri Ramakrishna Engineering College, [2]Saraswathi.RM, [3]Sindhu kavi.G,
[4]Sivasakthi.S, Sri Ramakrishna engineering college, Coimbatore,Tamilnadu.

Abstract—The design and development of a smart monitoring and controlling system for household electrical appliances in real time has been reported in this paper. The system principally monitors the power consumed by the electrical appliances. The novelty of this system is the implementation of the controlling mechanism of appliances in different ways. The developed system is a low-cost and flexible in operation and thus can save electricity expense of the consumers. The prototype has been extensively tested in real-life situations and experimental results are very encouraging.

Index Terms—Energy management, home automation, intelligent control system, wireless transmission, GPRS.

I. INTRODUCTION

It is foreseen that service and personal care wireless mecha-tronic systems will become more and more ubiquitous at home in the near future and will be very useful in assistive healthcare particularly for the elderly and disabled people . Sensor networks have become increasingly important because of their ability to monitor and manage situational information for various intelligent services. Due to those advantages, it has been applied in many fields, such as the military, industry, environmental monitoring, and healthcare.

The sensors are increasingly being used in the home for energy controlling services. Regular household appliances are monitored and controlled by sensors installed in the home . New technologies include cutting-edge advancements in information technology, sensors, metering, transmission, distribution, and electricity storage technology, as well as providing new information and flexibility to both consumers and providers of electricity.

It is expected that 65 million households will equip with smart meters by 2015 in the United States, and it is a realistic estimate of the size of the home energy management market .

There are several proposals to interconnect various domestic appliances by wireless networks to monitor and control such as provided. Different information and communication technologies integrating with smart meter devices have been proposed and tested at different flats in a residential area for optimal power utilization , but individual controlling of the devices are limited to specific houses.

There has been design and developments of smart meters predicting the usage of power consumption . How-ever, a low-cost, flexible, and robust system to continuously monitor and control based on consumer requirements is at the early stages of development. In this study, we have designed and implemented a GPRS-based intelligent home energy management and control service. We used the GPRS standardized by the European Telecommunications Standards Institute) technology for networking and communication, because it has low-power and low-cost characteristics, which enable it to be widely used in home and building environments

The paper focuses on human-friendly technical solutions for monitoring and easy control of household appliances. The in-habitant's comfort will be increased and better assistance can be provided. This paper emphasizes the realization of monitoring and controlling of electrical appliances in many ways..

The developed system has the following distinct features.

1) Use of relay for switching and controlling electrical appliances: Household appliances are controlled either remotely or automatically with the help of GPRS.
2) PIC Microcontroller: The design of smart sensing unit does require only one processing unit at the sensing end.
3) Flexibility in controlling the appliances: Depending on the user requirements, appliances can be monitored and controlled in different ways. Section III-B discusses about the various options of controlling the devices

II. PREVIOUS WORK

In this section, we briefly discuss the existing works about smart home systems based on the wireless communication technology. Han *et al.* proposed a Home Energy Management System

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(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 informa-tion 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 inter-face. 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* projected a ZigBee-based home automation system. This system consists of a home network unit and a gate-way. 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*. 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*. 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 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*. 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*.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 house-hold appliances can be controlled; 2) 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 is presented.

III. System Description

There are numbers of publications addressing control systems for home/office appliance involving infrared remote controls but there is no such publication/protocol/standard addressing solution for mobile-to-home/office appliance controlling through general packet radio services (GPRS) networks without involving any Internet based servers. This paper addresses recent research and development efforts in constructing wireless real-time control system based on server/client architecture through GPRS networks. This paper includes an implementation example designed to control home/office appliance from anywhere & anytime even when user is not at home/office. The paper demonstrates a micro Java application as example of real-time control system for home/office appliances and addresses the development-time and implementation-time experiences.

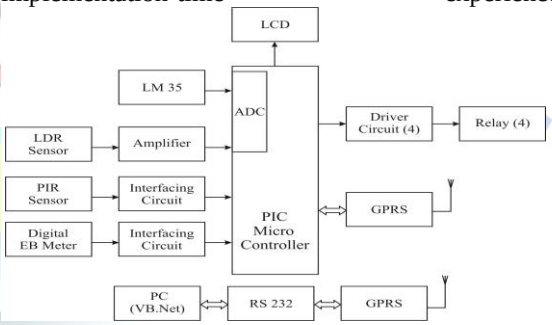

Figure 1: Functional Block Diagram

In this world which is evolving in new technologies everyday, automated monitoring systems have become a necessity and made our lives comfortable and risk free. This project focuses on the power management in intelligent buildings. The power monitoring is done by the energy meter and an alert is provided to the consumer(a privileged person in the home). The consumer can switch off the electrical appliances whenever necessary either automatically or manually. The automatic mode gets

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disabled when the manual over riding is provided by the consumer.

The system prevents the unwanted wastage of power by two different ways.

1. The electrical appliances gets switched off when the human is not detected. The human detection sensor serves this purpose.
2. The electrical appliances gets automated when the sensing values exceeds the preset threshold value.
   Example**:**
   - The light gets switched off if the brightness level of the surrounding is above the preset value as detected by LDR(Light Detection Resistor).
   - The fan gets controlled according to the temperature sensor values.

A.POWER MEASUREMENT:

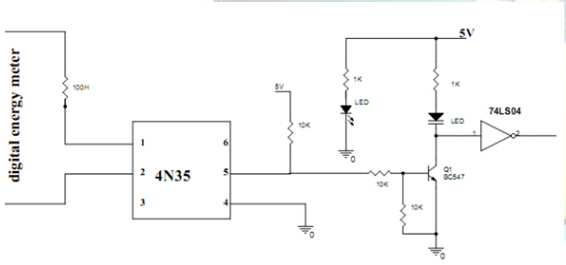

Figure 2: Shematic Diagram of Digital Energymeter

This circuit relates to measure the energy consumption through Digital energy meter. Here we are taken the output from digital energy meter and given to the 4N35 opto-coupler IC input. The opto-coupler is nothing but an isolation circuit. That is AC Line Digital logic isolator, which useful in AC line detection over short circuit prevention. 4N37 (short) consists of a gallium arsenide infrared emitting diode coupled with a silicon phototransistor in a dual in−line package. In that IC output will be always low. When input comes from energy meter gives logic high as output. If this IC output is low means the output of BC547 is High, so the LED behind that operation is in Off condition also the input given to controller also low. When the output of 4N37 is high means the output of BC547 is Low, so the LED behind that operation is in On condition also the input given to controller also high. Like this whenever the input comes from digital energy meter, the LED on board will glow, also the input to controller is changing their logic from high to low. Otherwise the output of circuit remains high condition. The output logic is inverted through 74LS04 which is placed on the circuit at final point. So through the logic changes we can measure the unit of consumption.

B.MEASURMENT OF DIFFERENT

PARAMETERS USING SENSORS:

1)HUMAN DETECTION SENSOR:

PIR(Passive Infrared Sensor) allows to sense motion, almost always used to detect whether a human has moved in or out of the sensors range. They are small, inexpensive, low-power, easy to use and don't wear out. For that reason they are commonly found in appliances and gadgets used in homes or businesses. They are often referred to as PIR, "Passive Infrared", "Pyroelectric", or "IR motion" sensor.

PIRs are basically made of a pyroelectric sensor (which you can see above as the round metal can with a rectangular crystal in the center), which can detect levels of infrared radiation. Everything emits some low level radiation, and the hotter something is, the more radiation is emitted. The sensor in a motion detector is actually split in two halves. The reason for that is that we are looking to detect motion (change) not average IR levels. The two halves are wired up so that they cancel each other out. If one half sees more or less IR radiation than the other, the output will swing high or low.

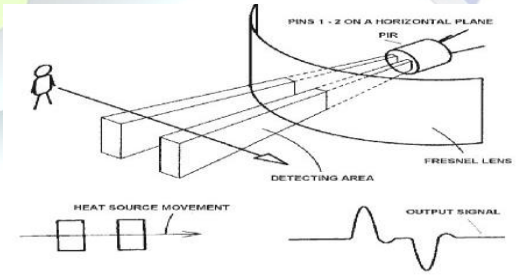

Figure 3: PIR Sensor Working

PIR sensors are more complicated than many of the other sensors explained in these tutorials (like photocells, FSRs and tilt switches) because there are multiple variables that affect the sensors input and output. To begin explaining how a basic sensor works, we'll use this rather nice diagram .

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The PIR sensor itself has two slots in it, each slot is made of a special material that is sensitive to IR. The lens used here is not really doing much and so we see that the two slots can 'see' out past some distance (basically the sensitivity of the sensor). When the sensor is idle, both slots detect the same amount of IR, the ambient amount radiated from the room or walls or outdoors. When a warm body like a human or animal passes by, it first intercepts one half of the PIR sensor, which causes a *positive differential* change between the two halves. When the warm body leaves the sensing area, the reverse happens, whereby the sensor generates a negative differential change. These change pulses are what is detected.

2)LM 35 - TEMPERATURE SENSOR:

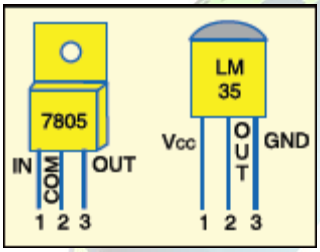

Figure 4: LM 35 Pin Diagram

It is a precision integrated-circuit centigrade temperature sensor whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in degree Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. For each degree Celsius change in temperature, the sensor output changesby10mV.The sensor can measure temperature in the range of 0 to 100°C, i.e., the output of the sensor varies from 0 to 1000 mV. The LM35 operates over the temperature range of -55° to +150°C, while the LM35C is rated for a -40°C to +110°C range (-10°C with improved accuracy).

It has an output voltage that is proportional to the Celsius temperature. The scale factor is .01V/ºC. The LM35 does not require any external calibration or trimming and maintains an accuracy of +/-0.4 ºC at room temperature and +/- 0.8 ºC over a range of 0 ºC to +100 ºC. Another important characteristic of the LM35DZ is that it draws only 60 micro amps from its supply and possesses a low self-heating capability. The sensor self-heating causes less than 0.1 ºC temperature rise in still air.

3) LDR-LIGHT DEPENDENT RESISTOR:

To cadmium sulphide(cds) photoconductive cells with spectral responses similar to that of the human eye. The cell resistance falls with increasing light intensity. Applications include smoke detection, automatic lighting control, batch counting and burglar alarm systems.

Sensitivity: The sensitivity of a photodetector is the relationship between the light falling on the device and the resulting output signal. In the case of a photocell, one is dealing with the relationship between the incident light and the corresponding resistance of the cell.

Spectral Response: Like the human eye, the relative sensitivity of a photoconductive cell is dependent on the wavelength (color) of the incident light. Each photoconductor material type has its own unique spectral response curve or plot of the relative response of the photocell versus wavelength of the light.

C. DATA PROCESSING AND CONTROL OF HOME APPLIANCES:

The data is processed using the PIC microcontroller. The analog and the digital parameters obtained from different sensors are processed. Depending on those values the corresponding devices are automated.
The microcontroller that has been used for this project is from PIC series. PIC microcontroller is the first RISC based microcontroller fabricated in CMOS (complimentary metal oxide semiconductor) that uses separate bus for instruction and data allowing simultaneous access of program and data memory.

The main advantage of CMOS and RISC combination is low power consumption resulting in a very small chip size with a small pin count. The main advantage of CMOS is that it has immunity to noise than other fabrication techniques.

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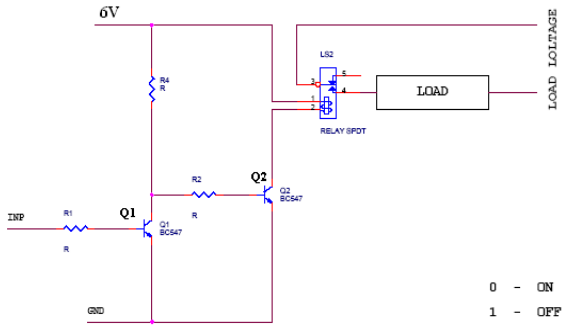

Figure 5:Implementation of PIC microcontroller

This circuit is designed to control the load. The load may be motor or any other load. The load is turned ON and OFF through relay. The relay ON and OFF is controlled by the pair of switching transistors (BC 547). The relay is connected in the Q2 transistor collector terminal. A Relay is nothing but electromagnetic switching device which consists of three pins. They are Common, Normally close (NC) and Normally open (NO).

The relay common pin is connected to supply voltage. The normally open (NO) pin connected to load. When high (5 Volt) pulse signal is given to base of the Q1 transistors, the transistor is conducting and shorts the collector and emitter terminal and zero(0 Volt) signals is given to base of the Q2 transistor. So the relay is turned OFF state.

When low pulse is given to base of transistor Q1 transistor, the transistor is turned OFF. Now 12v is given to base of Q2 transistor so the transistor is conducting and relay is turned ON. Hence the common terminal and NO terminal of relay are shorted. Now load gets the supply voltage through relay.

VOLTAGE SIGNAL FROM MICROCONTROLLER	Transistor Q1	Transist-or Q2	Relay
1	On	Off	off
0	Off	On	on

Table 1: Relay control based on the microcontroller value.

There are 2 methods in which the devices could be controlled:

Automatic control: Based on the power consumed and on the sensor values ,the electrical appliances gets automated when the human is detected. This enables the user to have more cost saving by auto switch off the appliances during the electricity peak hours.

Manual Control: An on/off switch is provided to directly intervene 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. Thus, the user has the flexibility in controlling the electrical appliances through the developed prototype.

D. TRANSMISSION OVER GPRS:

General packet radio service (**GPRS**) is a best-effort service, implying variable throughput and latency that depend on the number of other users sharing the service concurrently, as opposed to circuit switching, where a certain quality of service (QoS) is guaranteed during the connection. In 2G systems, GPRS provides data rates of 56–114 kbit/second.[3] 2G cellular technology combined with GPRS is sometimes described as *2.5G*, that is, a technology between the second (2G) and third (3G) generations of mobile telephony.[4] It provides moderate-speed data transfer, by using unused time division multiple access (TDMA) channels in, for example, the GSM system. GPRS is integrated into GSM Release 97 and newer releases. A GPRS connection is established by reference to its access point name (APN). The APN defines the services such as wireless application protocol(WAP) access, short message service , multimedia messaging service (MMS), and for Internet communication services such as email and World Wide Web access.

In order to set up a GPRS connection for a wireless modem, a user must specify an APN, optionally a user name and password, and very rarely an IP address, all provided by the network operator.

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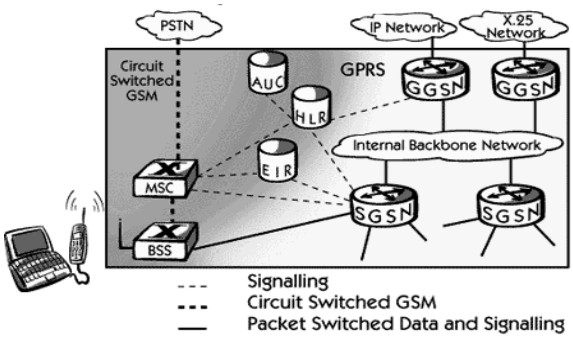

Figure 6: GPRS Architecture

GPRS Support Nodes:

Following two new components, called Gateway GPRS Support Nodes (GSNs) and, Serving GPRS Support Node (SGSN) are added:

1.Gateway GPRS Support Node (GGSN)

The Gateway GPRS Support Node acts as an interface and a router to external networks. It contains routing information for GPRS mobiles, which is used to tunnel packets through the IP based internal backbone to the correct Serving GPRS Support Node. The GGSN also collects charging information connected to the use of the external data networks and can act as a packet filter for incoming traffic.

2 .Serving GPRS Support Node (SGSN)

The Serving GPRS Support Node is responsible for authentication of GPRS mobiles, registration of mobiles in the network, mobility management, and collecting information on charging for the use of the air interface.

The advantage of GPRS, in today's technological environment, is that it is a great backup option. The portability factor has diminished somewhat, with the advent of much faster data cards, which plug directly into the laptop.

IV.EXPERIMENTAL RESULTS:

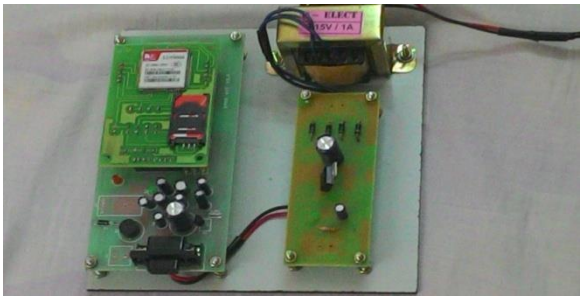

Figure 7:GPRS Transmitter Module

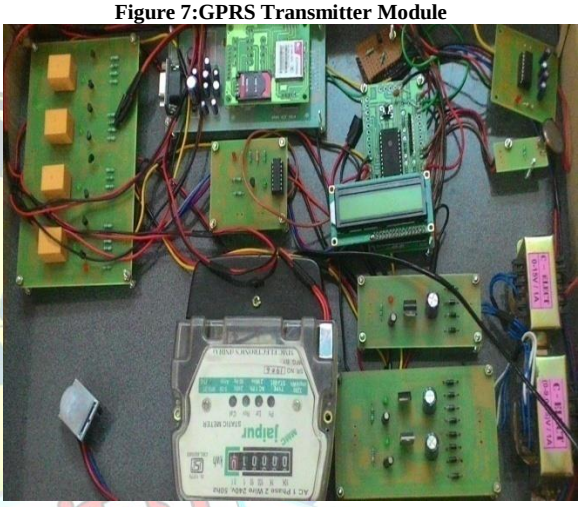

Figure 8: GPRS Receiver and processing Module

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. Thus the user interface shown in this experiment is by using the visual basic 6.0 software.

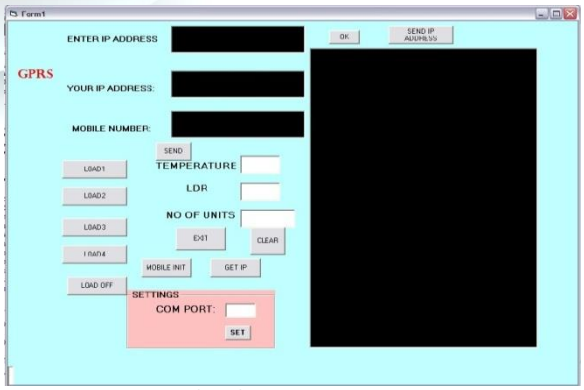

Figure 9: User interface for the smart power monitoring and controlling device.

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The above figure is the graphical user interface used for the control of the electrical appliances.

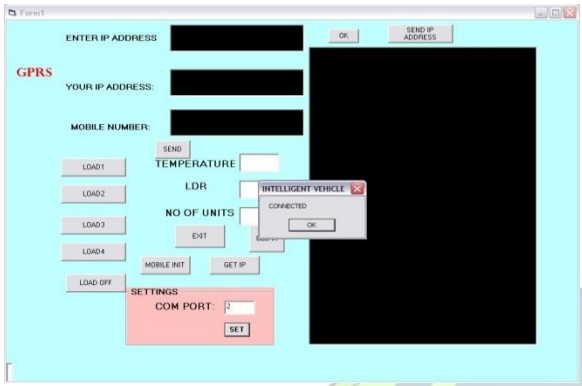

Figure 10: com port connection

The com port has to be mentioned and the OK button should be pressed. So now the port gets connected to the transmitter through RS 232.Then the receiver has a SIM card which gets initialized once when power supply is given. This initialization also allocates an IP address for the GPRS connection that gets transmitted to the user. The mobile initialization of the transmitter SIM is done by the user manually. That facility will be provided in the user interface. The right side area gives the status of the connection. Then IP addresses is entered and the GPRS connection is established.

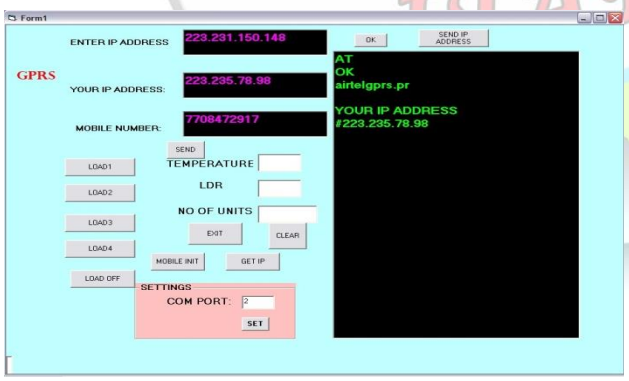

Figure 11:Mobille Initialization Of The Transmitter

The connection has been established and now the temperature and the light intensity values are displayed and updated each 10 seconds. Each load can be turned off manually by the user.

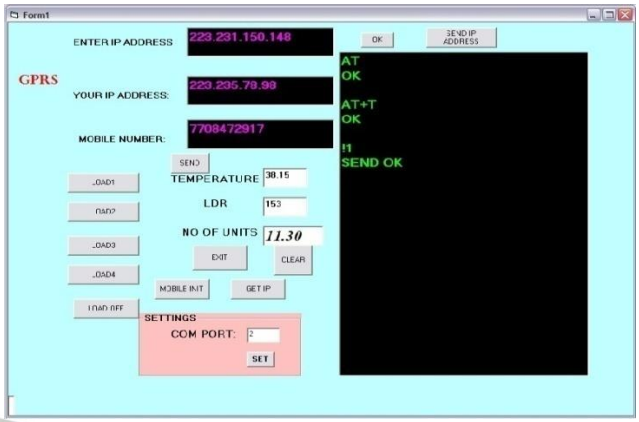

Figure 12: The sensor values display when the IP is paired.

If the sensor values exceeds certain limit the corresponding electrical appliances gets automated. Manually these appliances could be turned off by the load buttons. In this the load 1 and 2 are used to switch on the light and increase the intensity. Load 3 and 4 is connected to the fan switch. The load 5 is used to disable the manual mode and the automatic will get enabled.

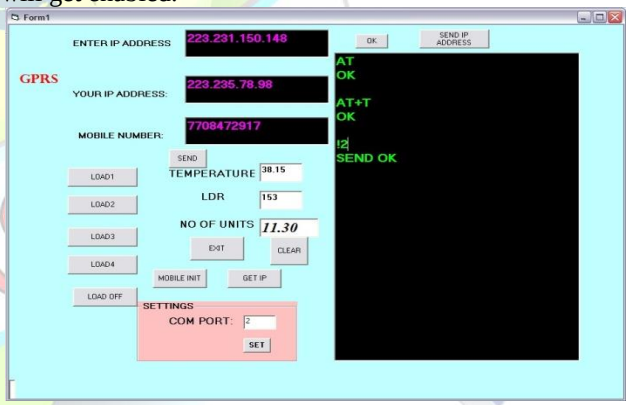

Figure 13: Load 2 Switched On

The electrical appliances connected to the relay 2 gets switched on. The load 5 disables the manual mode and automatic mode gets enabled by default. Then the electrical appliances now totally depends on the sensor values.

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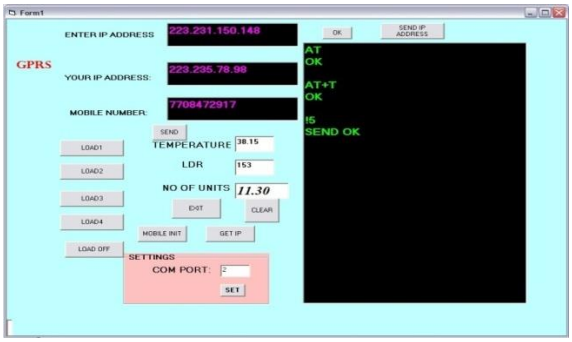

Figure 14: Load 5 switched On -Automatic mode gets enabled.

V. CONCLUSION AND FUTURE WORK

A smart power monitoring and control system has been designed and developed toward the implementation of an intelligent building. The developed system effectively monitors and controls the electrical appliance usages at an elderly home. Thus, the real-time monitoring of the electrical appliances can be viewed through a website. The system can be extended for monitoring the whole intelligent building. We aim to determine the areas of daily peak hours of electricity usage levels and come with a solution by which we can lower the consumption and enhance better utilization of already limited resources during peak hours.

The sensor networks are programmed with various user interfaces suitable for users of varying ability and for expert users such that the system can be maintained easily and interacted with very simply. This study also aims to assess consumer's response toward perceptions of smart grid technologies, their advantages and disadvantages, possible concerns, and overall perceived utility. The developed system is robust and flexible in operation. For the last three months, the system was able to perform the remote monitoring and control of appliances effectively. Local and re-mote user interfaces are easy to handle by a novice consumer and are efficient in handling the operations.

In future, the system will be integrated with co-systems like smart home inhabitant behavior recognitions systems to determine the wellness of the inhabitant in terms of energy consumption.

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