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Development of an Internet of Things based Electricity Load Management System

Dr. D. O. Dike[1], R.E. Ogu[1], Dr. L. O. Uzoechi[1], I. A. Ezenugu[2]
[1]*Dept. of Electrical and Electronic Engineering, Federal University of Technology, Owerri, Imo State, Nigeria.*
[2]*Dept. of Electrical/Electronic Engineering, Imo State University, Owerri, Imo State, Nigeria.*

ABSTRACT: *Continuous overload to a power system is a problem as it reduces the life span of the generators. Load management is very vital in optimizing the performance of generating plants by properly managing the generated energy. During peak demand times, the energy used by consumers are expensive compared to that used during off peak demand time; this is because utility companies need to engage bigger generators and other infrastructures in order to supply the demanded energy. To prevent the need for the procurement of bigger generators and other infrastructures needed to augment electrical power needed by consumers during peak demand time, an Internet of Things (IoT) based Electricity Load Management System is developed in this paper. The Arduino mega 2560 board and the Arduino WiFi Shield 101 are used in the controller and connectivity elements respectively, ACS712 module is employed in the sensory block to measure current; in order to determine the power being used by loads while Solid State Relays are used for actuation purposes. The entire blocks were integrated to form a functional system whose mode of operation is based on IoT technology that can be employed for effective management electrical energy.*

Keywords: *electricity, load, management, power, smart, grid, IoT.*

I. INTRODUCTION

Short term generation of electrical energy to meet consumers' demand especially at peak demand hours is very expensive. In order to meet consumers' demand, bigger generators that are capable of delivering huge amount power needed by the consumers during peak demand time are employed. Also, in some cases; alternative generators are started to augment the power needed by the consumers during peak time. The two approaches above are expensive and contribute to higher tariff rates which are often passed to the customer.

High tariff on the other hand, encourages consumers to engage in electricity theft. Electricity theft when not curbed affects the power system negatively. It has been identified as one of the greatest challenges facing power companies in developing countries [1].

Any energy the customer uses during peak demand time is expensive when compared with the cost of the energy used during non peak demand time. The total cost associated with the generation of extra power to meet up with the consumers' demand during peak demand time is eliminated, if the consumer can reduce the amount of energy he uses during peak demand, this in turn has a very big effect on the tariff. Electricity load management is importance because it eliminates the need to increase transformer, cable sizes and generator capacity; which are very costly [2].

Following the advancement in technology, the Internet of things (IoT) is currently applied in various areas; home automation, infrastructure management, transportation, smart grid and energy management.

The Internet of Things technology is to be explored in the management of electrical energy. This will involve the constant measurement of the loads connected to a power grid to determine the peak demand time and subsequently manage electrical energy properly by shedding off low priority loads, this will lead to a smart grid, which is the expectation of today's power system.

To this end, an embedded system will be developed which will monitor the amount of load connected to a power grid in order to ascertain whether the peak demand time has been entered. If the peak demand time is reached, the system should be able to shed of some loads to prevent the grid from being overloaded and possibly eliminate the need for the services of bigger generators that would have been needed to augment the additional power during peak demand time.

Also, at any point in time, the system updates the status of the grid to a web page so that the utility company can view the amount of load connected to the grid.

II. LITERATURE REVIEW

A Smart Energy Management System (SEMS) was developed using Field Programmable Gate Array (FPGA) to efficiently manage the load connected to the grid. The system gathers data of the grid and transfers the load from the utility grid to an alternative power source (Photovoltaic power system) and vice versa [3].

A metering system that was mounted at the electricity consumers' end which can monitor, communicate with the utility company through power line communication and then control the load from a centralized control room located at the utility company has been developed [4].

Energy Management System (EMS) that consists of two main parts was proposed. One part is an Energy Management Unit (EMU) which has a graphical user interface for runtime monitoring and control. The second part is sensor nodes which measure the power consumption of the different loads and transfer it to the EMU via multihop network. The building of Electrical Engineering Department at Assiut University was used as a case study to implement the Energy Management System (EMS). They implemented the EMU using NI LABVIEW while the hardware model was implemented using Arduino Uno microcontroller, ZigBee module and the ACS712 current sensor [5].

A load management system that has Zigbee wireless sensor unit as the connectivity unit, AT89C52 microcontroller as the processor and Relay as the actuating element was developed. This system overcomes the problems associated with failure in providing sufficient power towards the load center, by distributing the load properly [6].

A distributed intelligent load management and control system was proposed. The control system contains a smart demand response controller and distributed intelligent gateways. In this system, the cost function of a load is modeled to reflect the dissatisfaction of the occupant for switching off or dimming the loads and a two level optimization method is deployed to minimize the participant's aggregated cost [7]. Each intelligent gateway collects the cost functions of loads in the neighborhood of an occupant, generates its optimal cost function and sends to the smart demand response controller.

A look at the system reviewed above show that they are becoming obsolete, following the growth in technology. There is need to explore state of art technologies in energy management, hence; this study.

III. METHODOLOGY

An Internet of Things based Electricity Load Management System (IoTELMS) is developed here, to effectively manage generated electrical energy. The Internet of Things (IoT) is employed to develop an embedded system that will be mounted at the output of a distribution transformer. This system will monitor the amount of load connected to the distribution network, updates the web page of the utility company and take actions depending on the result of its measurement.

When the power grid is overloaded, the system will shed off some loads connected to the distribution network, thereby managing the generated electrical energy effectively.

The block diagram of the IoTELMS is as shown in Figure 1.

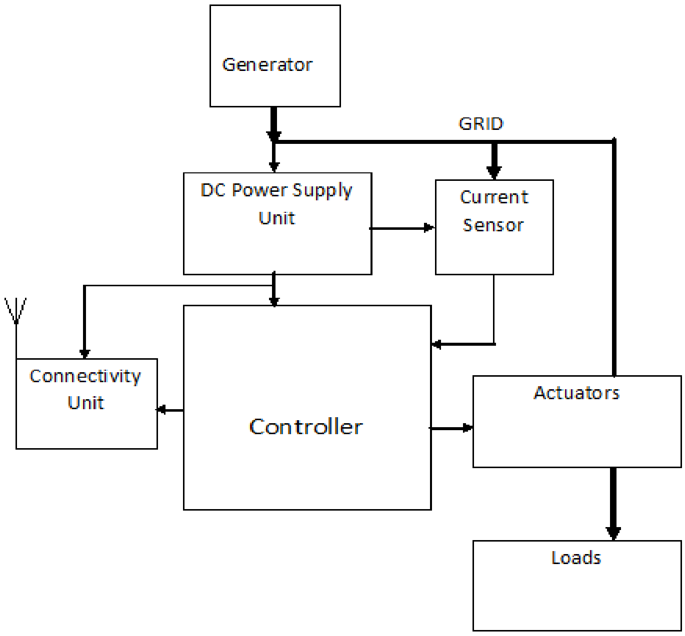

Figure 1- Block diagram of IoTELMS.

The system is made up two categories of units: external and internal units. The designed system includes only the internal components.

The external components refer to the generator, grid and loads. These are specifically not part of IoTELMS; they are already in place in every power system. The generator refers to the machine that generates the electrical energy that the utility company supplies to the consumers. The grid refers to the power network at which the consumers tap energy from.

The Internal components include all other sub units seen in the block diagram above. The system is designed in a way that the various units will work together in order to achieve the desired objective of energy management. The Internal components are;

DC Power Supply Unit; this unit steps down the 220V AC of the grid to a lower value, rectifies it (converts it to DC voltage), filters it and subsequently regulates it to 5V DC which are needed by the other units of the system. The components of the DC power supply unit are: step down transformer, diodes, electrolytic capacitor and LM7805 voltage regulator. The schematic diagram of the power supply unit is shown in Figure 2.

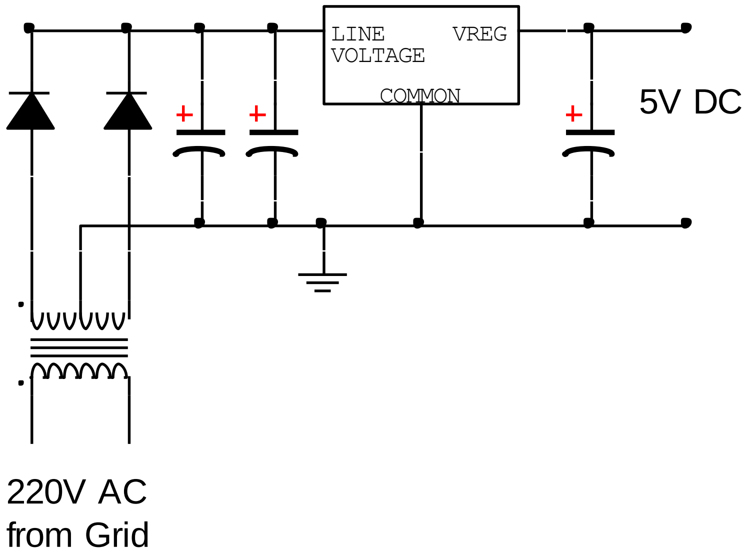

Figure 2- Schematic diagram of the Power Supply Unit.

Connectivity Unit; this unit connects the entire system to a network and then subsequently connects the system to the Internet so that the status of the grid can be uploaded to the web page of the utility company. The Arduino WiFi Shield 101 is used here.

Controller, this co-ordinates the activities of other parts of the system. It is the decision making unit of the system. The Arduino Mega 2560 board is used for this purpose.

Current Sensor; this element measures the energy being used by a consumer, ACS712 module is used for this purpose.

Actuators, this comprises of series of switching elements which are used to connect loads to the grid, they can disconnect the loads from the grid when there is need. Actuators can be as many as possible depending on the number of loads to be connected. For sake of prototyping, four Solid State Relays are used to connect four loads to the network.

3.1 SOFTWARE DESIGN

Every embedded system must have software that governs the mode of operation. The software for this system was written, compiled and uploaded to the board using the Arduino IDE 1.6.8. It should be noted that the system was programmed in a way that it followed the mode of operation illustrated in the flow chart of Figure 3.

When power is supplied to the system, all components of the system will be initialized. The system connects all the available loads to the grid; it monitors the grid to see if the peak demand time is reached and updates the Internet. If the peak demand time is entered, the system sheds off low priority loads.

The system continues to monitor the grid, updates the Internet and subsequently sheds off loads and connects loads to the grids during peak and off peak demand times respectively.

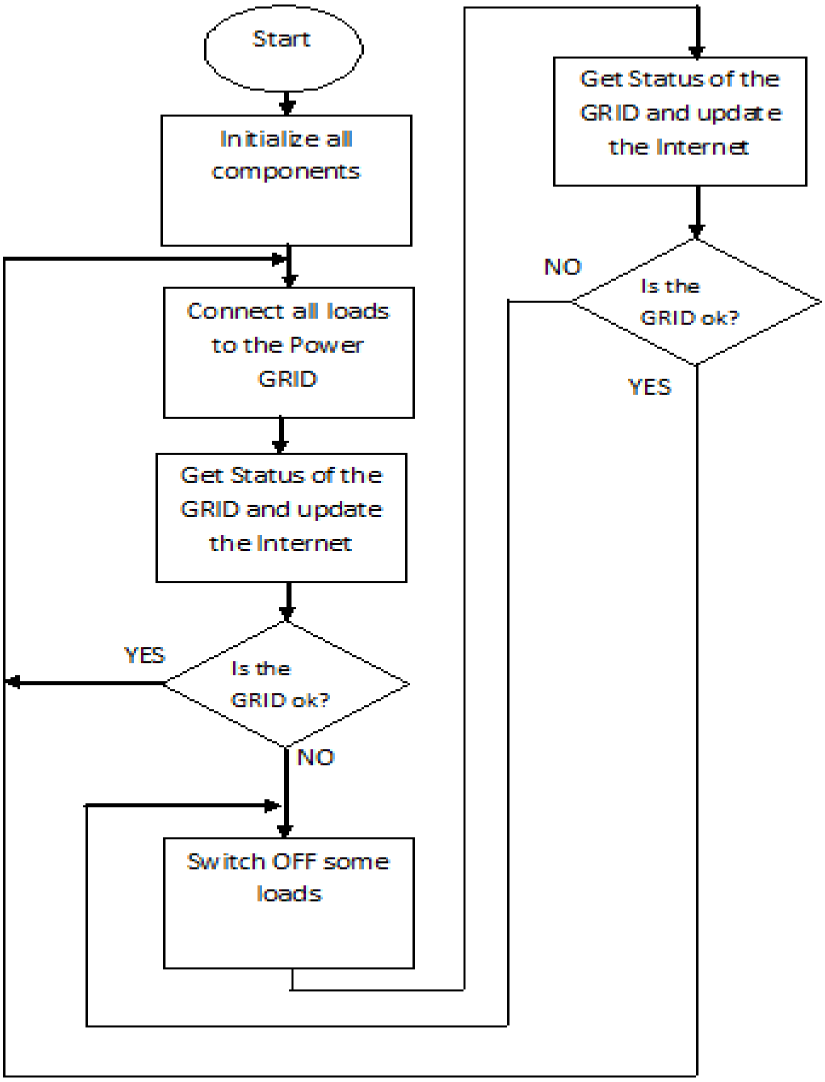

Figure 3- Flowchart of IoTELMS

3.2 WEB PAGE

A channel was created to display the status of the grid at the Thingspeak.com. Thingspeak.com is an open platform for the Internet of Things. From this web page, the overall status of the grid can be viewed and load actuation can be initiated following the data uploaded to this web page. The status of this system can be viewed on:www.thingseak.com/channels/13472 and a visualization aid to interpret the status of the grid can be seen at https://thingspeak.com/apps/plugins/80263

3.3 INTEGRATION AND TESTING

The entire units were connected together to form a functional system. Normally, Arduino shields are often mounted on top of the Arduino board. This means that the Arduino WiFi shield 101 was mounted on top of the Arduino Mega 2560 board.

The output of the current sensor was connected to A0 input of the Arduino WiFi shield 101. The inputs of the four Solid State Relays were connected on the digital pins 2, 3, 4 and 5. After this; the sketch was uploaded to the set-up from a computer using a USB cable.

Immediately after the sketch has been uploaded, the USB cable was removed. The 5V DC output of the power supply unit was connected to the Arduino Mega 2560 board using a power jack and the system was left to run on its own.

Loads were connected to the grid using four Solid State Relay (SSR), the relays were prioritized; relay 1 has the highest priority while relay 4 has the lowest priority. This means that when the grid is becoming overloaded (during peak demand time), the system will start disconnecting the loads connected to the grid through relay 4. From relay 4, it disconnects the loads connected through relay 3, then relay 2 before disconnecting loads connected to relay 1. To this end, loads connected through relay 1 will have regular supply of energy than other loads (even at peak demand times).

IV. RESULTS

It should be noted that at any point in time, the status of the grid can be viewed on a web page as can be seen in the snapshots below. Figure 4 shows a graphical representation of the loads connected to the grid over a period of time.

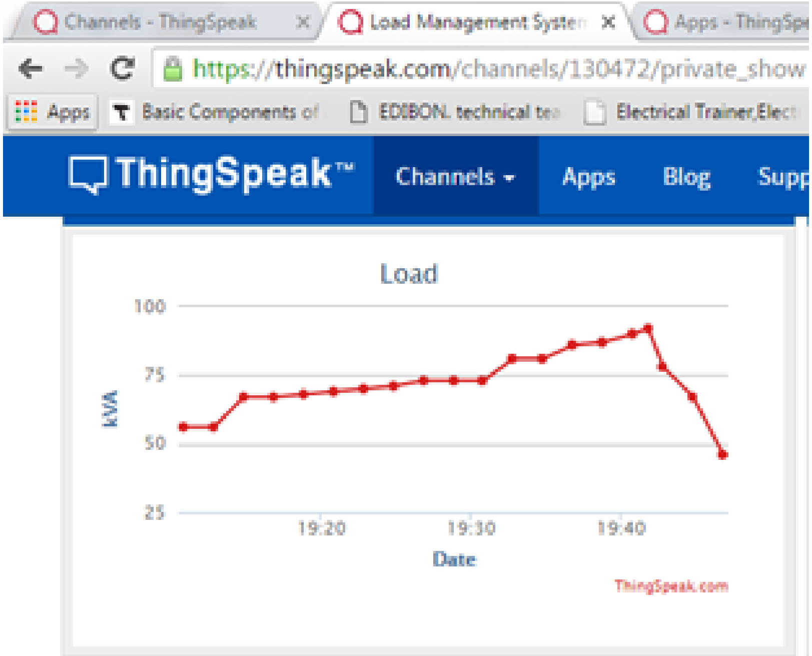

Figure 4- Graphical representation of the amount of load connected to the grid.

Figure 5 below shows the gauge that helps in interpreting the amount of load connected to the grid.

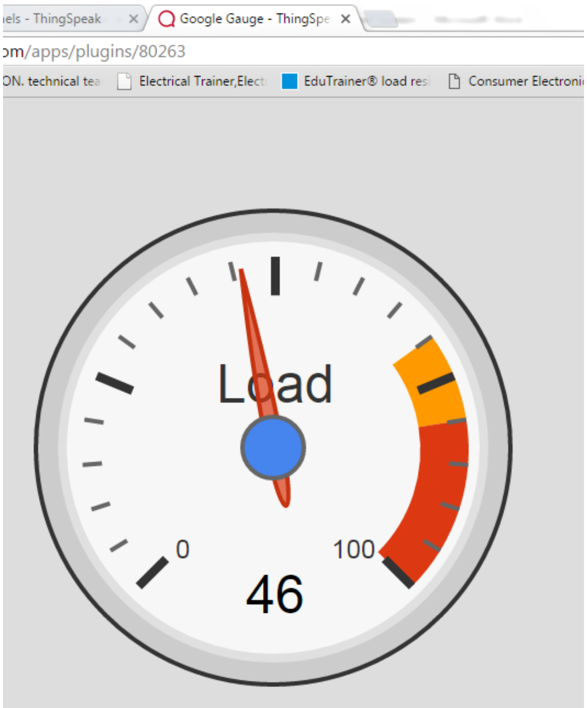

Figure 5- Gauge showing the loads connected to the grid.

Figure 6 shows the entire web age showing status of the grid at any point in time.

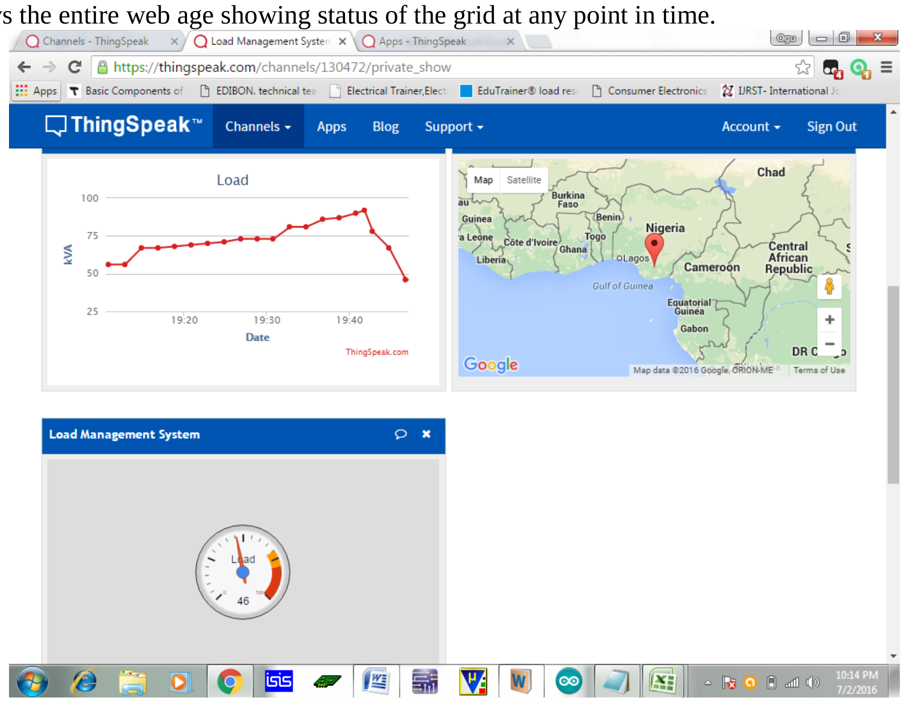

Figure 6- Load Management System's web page.

Table 1 shows a spreadsheet of the data uploaded by the system to the web page during the testing period.

Table 1- Data uploaded by the system to the web page.

created_at	entry_id	field1
2016-07-02 12:00:00 GMT+1	1	4
2016-07-02 20:04:50 GMT+1	2	6
2016-07-02 20:04:50 GMT+1	3	8
2016-07-02 22:00:50 GMT+1	4	16
2016-07-02 20:02:50 GMT+1	5	45
2016-07-02 20:04:50 GMT+1	6	56
2016-07-02 20:06:50 GMT+1	7	56
2016-07-02 20:08:50 GMT+1	8	56
2016-07-02 20:10:50 GMT+1	9	56
2016-07-02 20:12:50 GMT+1	10	56
2016-07-02 20:14:50 GMT+1	11	67
2016-07-02 20:16:50 GMT+1	12	67
2016-07-02 20:18:50 GMT+1	13	68
2016-07-02 20:20:50 GMT+1	14	69
2016-07-02 20:22:50 GMT+1	15	70
2016-07-02 20:24:50 GMT+1	16	71
2016-07-02 20:26:50 GMT+1	17	73
2016-07-02 20:28:50 GMT+1	18	73
2016-07-02 20:30:50 GMT+1	19	73
2016-07-02 20:32:50 GMT+1	20	81
2016-07-02 20:34:50 GMT+1	21	81
2016-07-02 20:36:50 GMT+1	22	86
2016-07-02 20:38:50 GMT+1	23	87
2016-07-02 20:40:50 GMT+1	24	90
2016-07-02 20:41:50 GMT+1	25	92
2016-07-02 20:42:50 GMT+1	26	78
2016-07-02 20:44:50 GMT+1	27	67
2016-07-02 20:46:50 GMT+1	28	46

V. DISCUSSION

The graphical representation of the loads connected to the grid was presented in Figure 4. The loads were gradually increased until a point when the current sensor detected that the current being drawn from the generator has passed the preset threshold (92kVA), this meant that the peak demand time has been entered. As the load was increased further, the system immediately disconnected the loads connected to the generator through Relay 4. The loads connected to the remaining three relays were increased further; a point was reached when the system also disconnected the loads connected through relay 3 (at 78kVA). The loads connected through relay 2 were disconnected; this reduced the total load on the grid to 46kVA.

Switching off the loads further led to the reconnection of the loads connected through relay 3 and relay 4 (this means that the peak demand time has elapsed).

The gauge in figure 5 serves as a visualization aid in easy interpretation of the load connected to the grid. Figure 6 shows the entire Load Management System web page, also shown on the web page in conjunction with the amount of load connected to the grid is the location of the grid that is monitored. This can be seen with the help of the map on the web page.

VI. CONCLUSSION

A low cost embedded system has been designed and prototyped, this study has achieved its main goal of developing an electricity load management system whose mode of operations is based on the Internet of Things (IoT) technology.

The approach used here is a flexible; the entire system was developed in separate units and then, integrated to form a functional system, this makes the system robust.

With this system the need to procure bigger generator augment for the high energy requirement during peak demand time is avoided. Also, the need to procure bigger cables and other power system infrastructure to handle the huge electric current requirement during peak demand time is prevented.

VII. RECOMMENDATION

After the design, a prototype of the system was produced and tested. Any study that will go to extent of implementing the designed system in a real world/big power grid is recommended.

Also, studies that will use different embedded system design approaches other than the ones used here to achieve this same goal are recommended.

REFERENCE

[1] S. Anusha, M. Madhavi, & R. Hemalatha. Detection of Power Theft Using GSM. *International Journal of Advanced Research Trends in Engineering and Technology (IJARTET), Vol. 1, Issue 3,* (2014), pp.15-17.

[2] Leonardo Energy. Importance of load management. (2009, January). http://www.leonardo-energy.org.

[3] H. K. Yousaf, M. Tahir, A. Khurshid, S. Tahir, U. Inayat, & U. Hanif. Smart Energy Management System for Utility Source and Photovoltaic Power System Using FPGA and ZigBee. *American Journal of Electrical Power and Energy Systems. Vol. 3, No. 5,* 2014, pp. 86-94.

[4] M. V. Aleyas, A. Nishin, T. Sandeep, K. M. Sudheesh & B. Vishnu. Automatic Meter Reading and Load Management Using Power Line Carrier Communication. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, Issue 5,* (2014).

[5] M. Abo-Zahhad, S. M. Ahmed, M. Farrag, M. F. A. Ahmed, & A. Ali. Design and implementation of building energy monitoring and management system based on wireless sensor networks. *Computer Engineering & Systems (ICCES), 2015 Tenth International Conference on, Cairo,*pp.230-233.

[6] S.S. Munde, P.S. Kumbhar, & R. H. Madhavi. Automatic Load Management of Electric Power by Use of Zigbee Technology. *International Journal of Electrical and Electronics Research ISSN 2348-6988 Vol. 3, Issue 2,* (2015), pp: (106-110).

[7] Zhang, W., Zhou S., & Y. Lu. Distributed Intelligent Load Management and Control System. *2012 IEEE Power and Energy Society General Meeting, San Diego, CA,*2012,pp.1-8.