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Smart Energy Management Using Internet of Things Platform

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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 developed system is a low cost and flexible in operation and thus can save electricity expense of the consumers. The wastage of electricity can be avoided by switching off the electrical appliances when not in use. This can be achieved by using Smart home system which automatically turns off loads when not in use, the system can save energy in homes and offices. The system will automatically switch off based on the presence of people at home. Exact metering, detection of energy overload, cost sparing, energy management/monitoring as well as automatic billing systems are the major objectives of the project. Considering this, a microcontroller based smart meter utilizing remote correspondence and IoT is proposed. Proposed Work includes a small light weight web server designed on Raspberry-Pi board, which will make the system to work much faster and smarter using PIC microcontroller. This system allows easy saving of energy through priority scheduling of loads when it crosses the given threshold, greater data accuracy; improved billing speed, energy management and cost saving. The PIC microcontroller and ZigBee are used to transfer the load reading wirelessly. At the receiver side, Raspberry Pi is used to display the value of power consumption from meter, output loads connected to PC GUI.

KEYWORDS*:* PIC Microcontroller, ZigBee, Raspberry Pi, Internet of Things, Demand response

I. INTRODUCTION

The WSNs are increasingly being used in the home for energy controlling services. Regular household appliances are monitored and controlled by WSNs installed in the home. The ZigBee Alliance, wireless communication platform is presently examining Japans new smart home wireless system implication by having a new initiative with Japans Government that will evaluate use of the forthcoming ZigBee, Internet Protocol (IP) specification, and the IEEE 802.15.4g standard to help Japan to create smart homes that improve energy management and efficiency [11].Recently, organizations use ZigBee to effectively deliver solutions for a variety of areas including consumer electronic device control, energy management and efficiency home and commercial building automation as well as industrial plant management. As an ecosystem, the Agreement offers everything future product and service companies need to develop ZigBee products [12]. The smart energy networks could include both ZigBee 2006 and IEEE 802.15.4. It is suggested that the majority of the nodes in the network should be based on one stack profile or the other to get reliable performance. ZigBee smart energy certified products must be based upon a ZigBee Compliant Platform (ZCP).

Grid is the electricity system that consists of electricity generation, electricity transmission, electricity distribution, and electricity consumption. In traditional power grids, electricpower is carried from a few central generators to a large number of load centers with electricity users or customers. A smart grid (SG) is a new type of power grid under development, which allows unconventional power flow and two-way information flow to create an advanced automatic and distributed energy delivery network.

In this paper, we have designed and implemented a ZigBee-based intelligent home energy management and control service. We used the ZigBee (the IEEE 802.15.4 standard) 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 project focuses on human-friendly technical solutions for monitoring and easy control of household appliances. The

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inhabitants 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.

II. PROBLEM STATEMENT

This paper concentrates on two tasks; they are home automation and monitoring, controlling through web server. To design a system for home and society. This will reduce the human efforts, saves the electricity and energy billing in terms of money. Under automation it addresses turning ON/OFF household electrical appliances when not required, such as electric bulbs, fans etc.

III. LITERATURE SURVEY

(Qie Sun et al., 2016) The significant increase in energy consumption and the rapid development of renewable energy, such as solar power and wind power, have brought huge challenges to energy security and the environment, which, in the meantime, stimulate the development of energy networks towards a more intelligent direction [2]. Smart meters are the most fundamental components in the intelligent energy networks. In addition to measuring energy flows, smart energy meters can exchange the information on energy consumption and the status of energy networks between utility companies and consumers. Furthermore, smart energy meters can also be used to monitor and to control home appliances and other devices according to the individual consumer's instruction. This paper systematically reviews the development and deployment of smart energy meters, including smart electricity meters, smart heat meters, and smart gas meters.

(Kun-Lin Tsai et al., 2016) To avoid resources on green earth being exhausted much earlier by human beings, energy saving has been one of the key issues in our everyday lives. In fact, energy control for some appliances is an effective method to save energy at home since it prevents users from consuming too much energy.

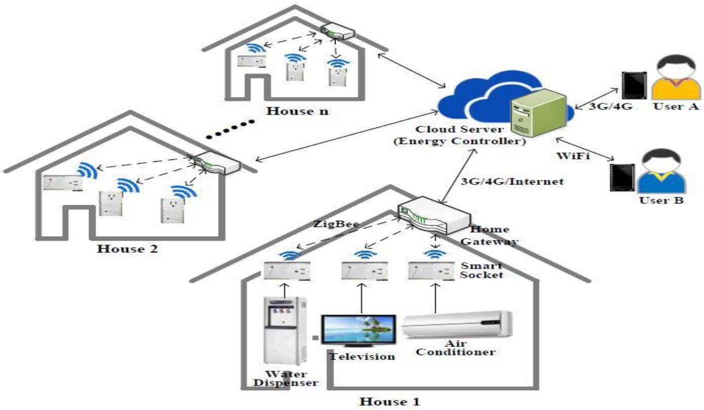

Figure 2.1: The IoT-based system architecture of the RECoS

Even though thereare numerous commercial energy-effective products that are helpful in energy saving for particular appliances, it is still hard to find a comprehensive solution to effectively reduce appliances energy consumption in a house[3]. Therefore, in this paper, an intelligentenergy control scheme, named the Residence Energy Control System (RECoS for short) is proposed, which is developed based on wireless smart socket and Internet of Things (IoT) technology to minimize energy consumption of home appliances with-out deploying sensors. The RECoS provides four control modes, including peak-time control, energy-limit control, automatic control, and user control. The former two are operated for all smart sockets in a house, while the latter two are used by individual smart sockets, aiming to enhance the functionality of energy control. The experimental resultsshow that the proposed scheme can save up to 43.4% of energy for some appliances in one weekday. An intelligent energy saving scheme, named the Residence Energy Control System (RECoS for short), is proposed to reduce the energy consumption of home appliances without

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deploying sensors. The RECoS, based on wireless smart sockets and IoT technology, not only monitors/controls the standby power consumption of an individual appliance, but also manages energy consumed by all controllable appliances. The RECoS also invokes the neural network algorithm to study user's lifestyle and automatically turns off the power of each smart socket connected to IoT when the electric appliances are not in use. The experiments demonstrate that the RECoS can save up to 43% of energy for some appliances in a weekday.

(Francesco Benzi et al., 2011) The recent worldwide measures for energy savings call for a larger awareness of the household energy consumption, given the relevant contribution of domestic load to the national energy balance. On the other hand, electricity smart meters together with gas, heat, and water meters can be interconnected in a large network offering a potential value to implement energy savings and other energy-related services, as long as an efficient interface with the final user is implemented [4]. Unfortunately, so far, the interface of such devices is mostly designed and addressed at the utilities supervising the system, giving them relevant advantages, while the communication with the household is often underestimated. This paper addresses this topic by proposing the definition of a local interface for smart meters, by looking at the actual European Union and international regulations, at the technological solutions available on the market, and at those implemented in different countries, and, finally, by proposing specific architectures for a proper consumer-oriented implementation of a smart meter network. The electronic meters for electricity (smart meters) are undergoing an increasing deployment in private homes all over the world, which is mostly triggered from the government decisions in order to fulfill energy-saving targets. As a consequence, an ever growing physical communication network, made up of millions of local meters, has been established, whose considerable advantages are so far in favor primarily, ifnot solely, of the energy distributors, since they are enabled at simplified, more efficient, and less costly transactions with the customers, e.g., for meter reading, billing, and energy supply administration. By its nature, however, a digital communication net-work has, among its features, the flexibility and extensibility of the structure, so that new applications can also be provided. Therefore, it seems reasonable to assume that the meters themselves, by increasing their capabilities, become players in a more ex-tended and different network, which is available not only to the distribution or energy production companies but also to the domestic energy final users, by providing them with useful services: 1) Value-added services specifically based on the meter data, such as power consumption in-home display, automatic load management in order to comply with the maximum contract power, and demand response (DR) programs, and 2) General functions, addressed to the needs of the home inhabitant, which can take advantage indirectly from the meter information, like optimal heating, air-conditioning, or lighting based on actual energy tariffs such services should preferably be integrated with other home automation networks.

(In-Ho Choi et al., 2012) A smart grid-base AMI (Advanced Metering Infrastructure), which checks electricity consumption and controls the electric energy used with the demand response technique, is necessary for remotely managing the load of the energy and power consumed in order to comprise energy efficiency for electrical devices in homes. The smart controller calculates the amount of electricity consumed by customer on real time basis from the utility supplier like Electric Supply Company. In this paper, we propose the hardware architecture and software of the smart controller for use as the platform in smart grid system to reduce energy consumption [5]. The smart controller can be installed on the electric plug of the electric appliance. The smart controller grasps the energy amount used in the electric appliance and delivers to the AMI / EMS (Energy Management Server). In addition, we evaluated an experimental system to practically verify functions of the smart controller which is attached to the lighting device. From the system, we showed that the electric source of the illumination can be controlled according to the load change and saved energy effectively.

(Qinran Hu et al., 2013) The smart grid initiative and electricity market operation drive the development known as demand-side management or controllable load. Home energy management has received increasing interest due to the significant amount of loads in the residential sector. This paper presents a hardware design of smart home energy management system (SHEMS) with the applications of communication, sensing

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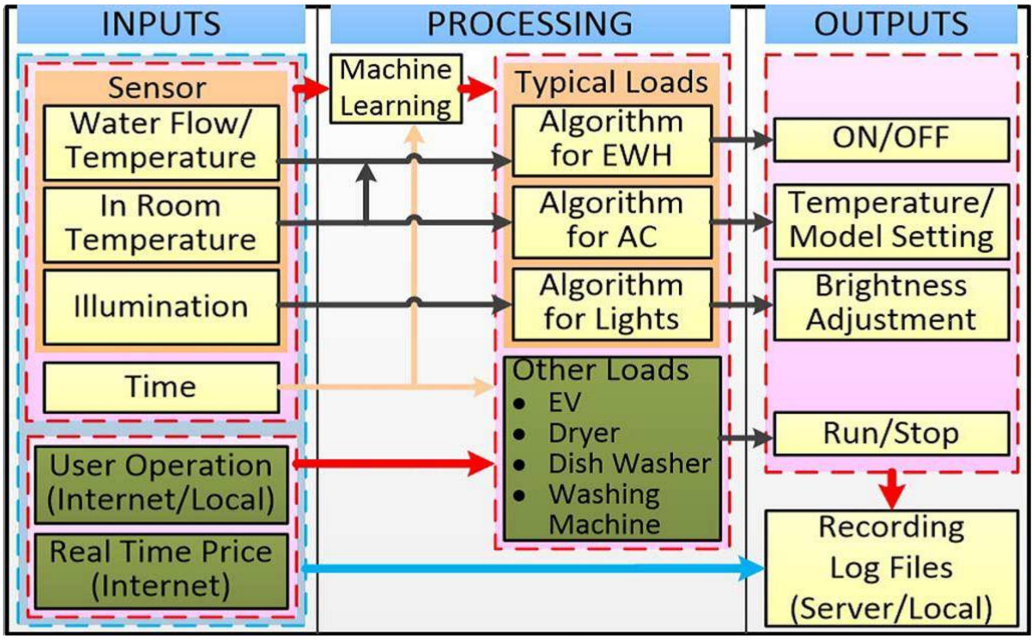

Figure 2: Schematic design of SHEMS (user end)

consumers may interact with suppliers or load serving entities (LSEs) to facilitate the load management at the supplier side. Further, HEMS is designed with sensors to detect human activities and then a machine learning algorithm is applied to intelligently help consumers reduce total payment on electricity without or with little consumer involvement. Finally, simulation and experiment results are presented based on an actual SHEMs prototype to verify the hardware system.

IV. PROPOSED METHODOLOGY

A. SYSTEM OVERVIEW

Four loads are connected to the microcontroller interface through TRIAC to four loads which make them ON/OFF and also used for dimming application. It is microcontroller based system.

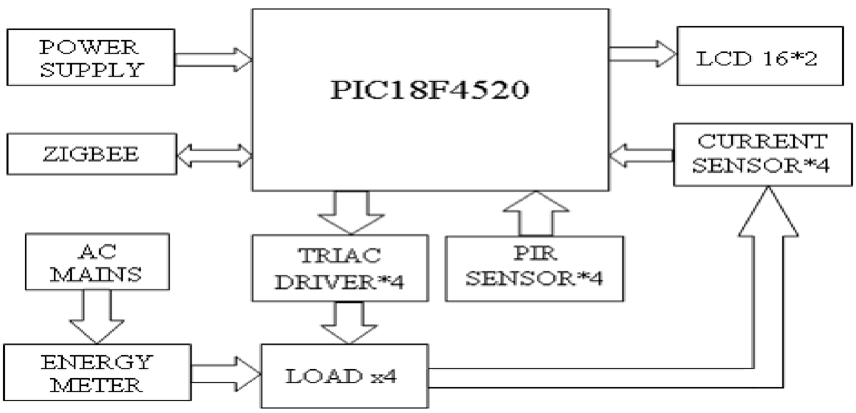

Figure 1: Block diagram of proposed system

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Current sensor senses the input current form the connected loads and converts it to proportional voltage which in turn calibrated through microcontroller displayed on the GUI using Raspberry Pi. ZigBee interface to microcontroller acts as a Trans-receiver which sends and receives the all control signal to load through microcontroller.

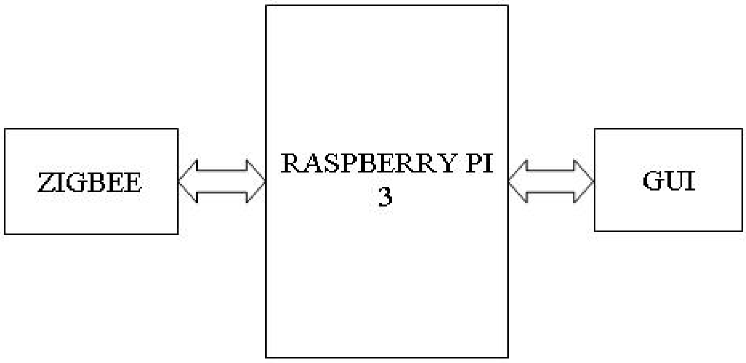

Figure 2: Block diagram of proposed system at server side

Again back to the Raspberry Pi. Figure 1 &2 shows the block diagram of the proposed system. At server side as shown in figure 2 there is ZigBee connected to Raspberry Pi used to send and receive the load switching. Graphical user interface shows the values of current, voltage, power consumption, unit, billing cost. It consists different ON/OFF options for the four loads connected. It also displays the real time graph of power vs time according to the loads when they are ON/OFF. There are two modes given on the GUI manual mode and system mode. In manual mode loads can be switched manually. System mode monitors the power consumption of the loads ifit exceeds the set threshold value in the set time of use it will automatically bring down the power consumption to normal level based on the condition using PIR sensors to detect humans and then take certain action to dim or off the load when it is ON.

IV. FLOWCHART

The flowchart shows the step by step working of the project. Figure 3 shows the flowchart of proposed system. Firstly we turn on the power supply required for the model. Initialization of LCD, Microcontroller, and Raspberry Pi takes place. Reading of current and load status on/off is displayed on the LCD as well as it is stored in web server. GUI designed using Raspberry Pi displays the following values of current, voltage, Power consumption, units, bill. We select the manual mode in which load is applied through buttons which is on the web page of designed GUI.Microcontroller keeps monitoring power consumption if load exceeds the set threshold of power wattage in the given time of use we select the system mode where priority based switching is applied to the ON loads. The loads are turn OFF if no human is present or dim if human is detected in room using PIR sensor. Switching is done until it is equal or below the set threshold. It checks all loads from lowest to highest priority once it crosses the set threshold.

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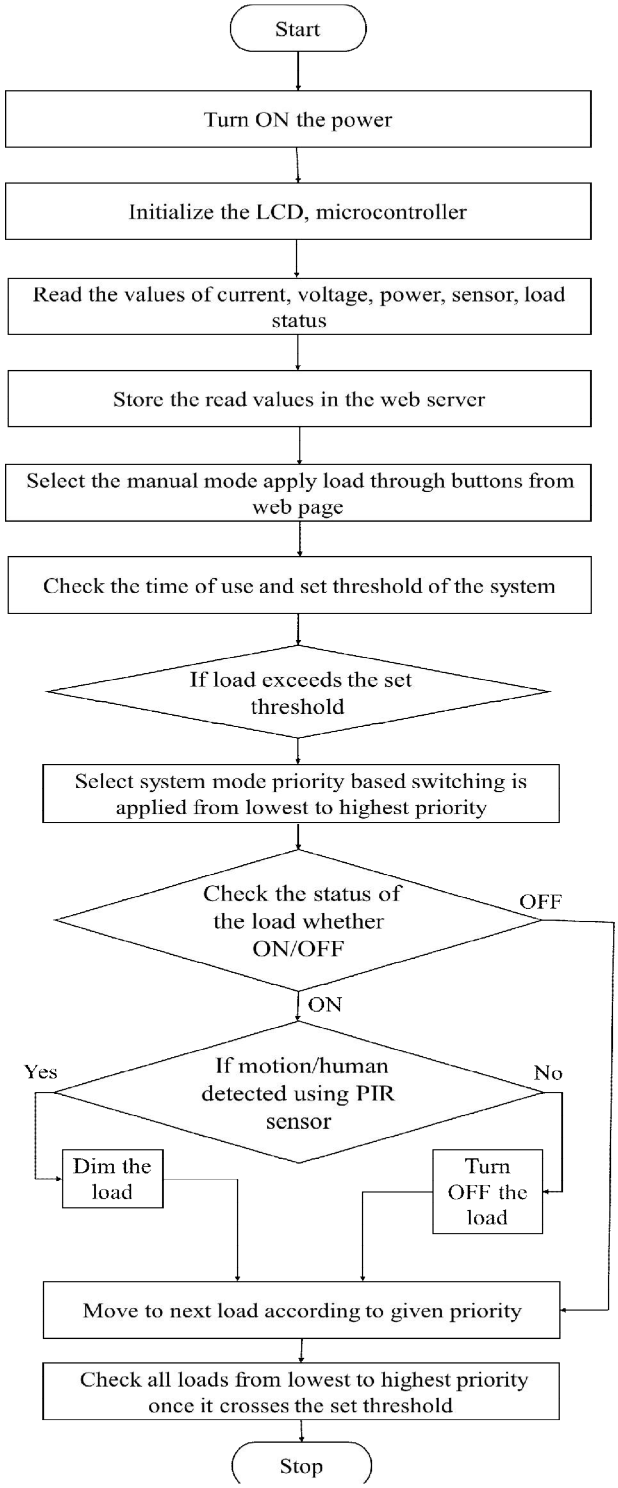

Figure 3: Flowchart of proposed system

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V. RESULTS

Manual Mode:
In manual mode we apply loads using buttons on the GUI we have applied 400W load by switching ON the loads for the individual room manually.

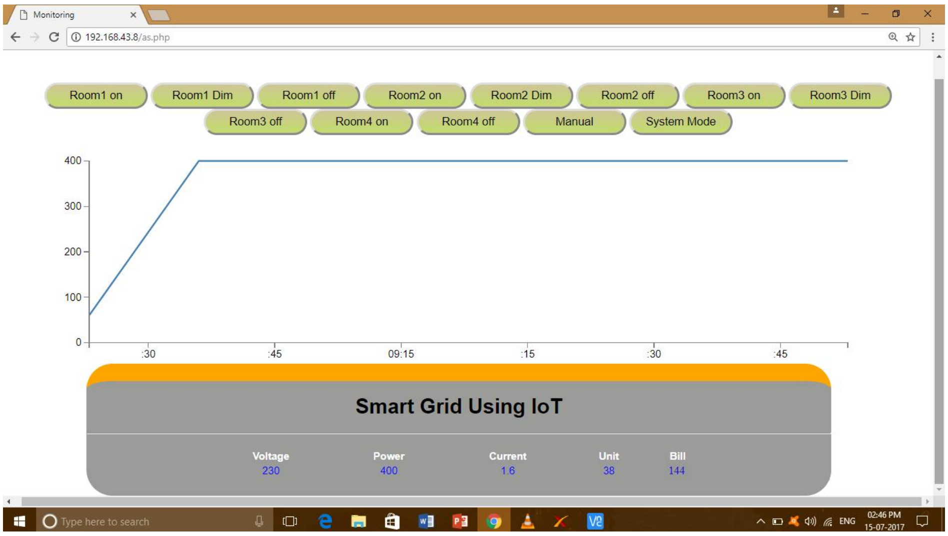

Figure 4: Snapshot of the manual mode with high load

System in manual mode shows the graph of power vs time in high load condition where the power consumption is 400W, current 1.6A, voltage 230V, and unit used is 38 for which bill charge is 144. Here energy meter is down calibrated considering one pulse as one unit depending on the power consumption of the connected loads.

Table 1: Condition table for time of use and set threshold

Condition	Time of use	Peak	Set Threshold	Billing per unit
1	6am - 10am	High	100W	3
2	10am - 6pm	Medium	200W	3
3	6pm - 12am	High	100W	3
4	12am - 6am	Low	300W	3

System Mode:
For demo purpose we have applied 400W load by switching ON the loads for the individual room. After which we go into the system mode where it takes action depending on the set conditions. These high load condition can be brought back to nominal condition through smartness of the system using system mode which in turn saves the energy and cost of the system effectively reduces the human efforts and also energy and heavy cost can be saved by controlling the home appliances.

Condition 2:-
Time of use: 10am – 6pm, Peak: Medium, Set threshold: 200W, Billing per unit: 3
Figure 5 shows the graph of power vs time where system final output is 200W using system mode. As we apply system mode when it was high load of 400W it check the condition of time of use and set threshold. As threshold was of 200W when it crosses this threshold it checked all the loads using PIR sensors where it found that in room 1 and room 3 human was detected so it kept that load ON and remaining two rooms no human was detected so it turn OFF the

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respective loads bring the system to set threshold level. Billing for the system under this condition was 3 per unit where 59 unit were used for which bill charge is 177. We save 200W of power which was wasting.

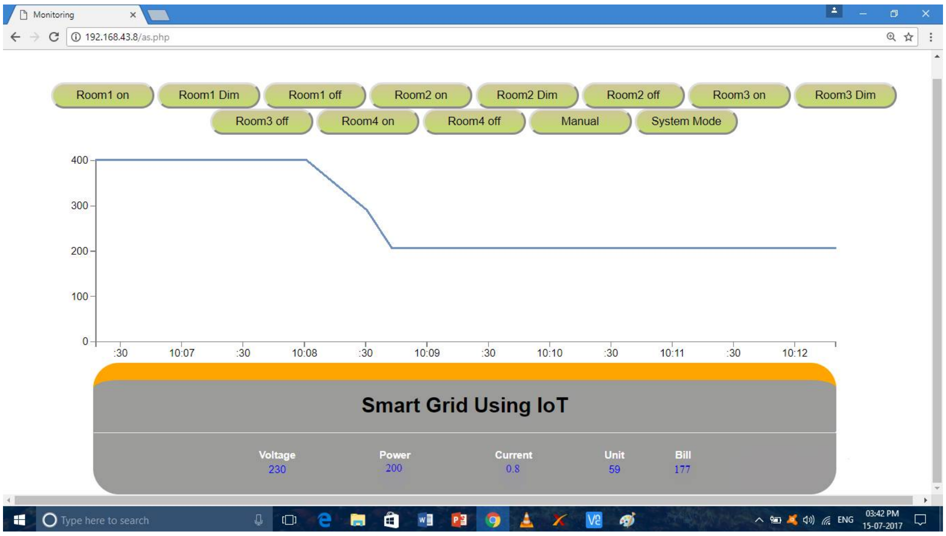

Figure 5: Snapshot of the output in system mode condition 2

Similarly for other conditions and different threshold we can save some power and energy cost.
For Total load of 400W:
With threshold of 100W, we can approximately save 300W of power and related energy cost.
With threshold of 200W, we can approximately save 200W of power and related energy cost.
With threshold of 300W, we can approximately save 100W of power and related energy cost.

VI. CONCLUSION AND FUTURE WORK

The proposed system, smart grid using IoT for monitoring and control of home automation is designed. The developed system effectively monitor and controls the loads connected to it. The developed system is robust and flexible in operation. It allows easy saving through meter reading, real time energy cost for the system, Load management in case of overload and heavy usage of power, greater data accuracy; improve billing speed and consumer service. Approximately we can save energy form 25% to 75% with different threshold in the given time of use. In this proposed system we trying to identify the possible areas in smart grid and metering, controlling that can be improved and proposed a new system which addresses them. A new smart grid and metering system was developed along with this research and tested in the real environment. The unique model designed to implement this system and different modes are used. But since the area of smart grids is very vast, more room is still available for further enhancements. As this is a prototype model design for the lights and fans loads. We can also extend this prototype system considering other home appliances. This system effectively reduces the human efforts and also energy can be saved by controlling the home appliances. This will give following outcome such as no load shading, extra light saved can be given to villages, MSEB can predict power generation, components life increases heating & blushing is avoided.

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