Experimenting Sensor-based Effective Energy Saving Module for Household Electricity Consumption

Rinku Chavda[a*], Sohil Pandya[b]

[a]*Research Scholar, Gujarat Technological University, Ahmedabad, Gujarat, India*
[b]*Department of Computer Applications, CMPICA, CHARUSAT, Charotar University of Science and Technology (CHARUSAT), CHARUSAT campus, Changa 388421, India*

Abstract

Modern technology gives better solutions to busy working people towards automation. Nowadays, houses, buildings, and organizations are equipped with a variety of appliances like computers, laptops, switches, doorbells, Ovens, Televisions, LED lighting, Water heaters, AC, etc. It becomes difficult to monitor all the electric equipment at a time. For example, sometimes if no one is present at home & some appliances remain on, it will consume electricity and generate unnecessary amounts to pay in electricity bills. Another scenario is Environmental effects on your power consumption. For example, based on temperature, humidity and light intensity of your surrounding atmosphere, automatic monitoring and controlling of appliances can be achieved with the help of Internet of Things (IOT). Based on the idea of monitoring and controlling appliances, authors have presented the Sensor based Electricity Saving Module.

Keywords: Internet of Things; Energy Saving; Light Sensor, Motion Sensor.

1. Introduction

Internet of Things (IoT) is a smart technology that interconnects each and every object (thing) through a network in one form or another and the main goal of IoT is to maximize the communication of hardware objects with the physical world and to convert the data collected by these objects into useful information without interacting with humans. The presence of IoT in the smart metering area has the potential to transform residential houses, homes and offices into management and controlling of energy, particularly in smart home solutions. Authors have presented a systematic methodology to incorporate Internet of Things based solutions into the home automation, considering both home electricity managing and controlling for various appliances. Various sensors such as motion sensor, temperature-humidity sensor, light sensors are helpful to get the information about the presence of the people in the house, what is the current temperature inside the house as well as how much the light intensity available naturally? Interfacing of sensors with Raspberry Pi 3 board, the managing and controlling of electric equipment i.e., turning ON or OFF can be implemented to achieve the goal of saving electricity and it also helps in managing the monthly budget of consumers in terms of finance. The rest of this paper is systematized as follows. Section 2 examines the work related to managing and controlling the household devices. Section 3 describes required equipment and its hardware interfacing for implementing Electricity Saving Module, and Section 4 presents methodology used for decision making of electric equipment using sensors. Section 5 represents experimental results. Finally, Section 6 concludes with major outcome of proposed methodology.

2. Literature Survey

Several researchers have proposed different types of work based on Internet of Things for monitoring and controlling home or building appliances which are as follows. Many Researchers have proposed a system design which empowers users to remotely monitor and control home devices and feature of online bill generation, view different type of data analytics which shown monthly power consumption of house, annual power consumption of community, state and country were also proposed with the help of mobile application [1]. Arduino based system has been proposed to optimize power of home appliances that can be monitored and controlled with the help of a temperature sensor, Wi-Fi module and web application [6]. Author has presented the system of a home administration and security framework utilizing Arduino and Internet of Things innovation for ongoing home security checking and for remotely controlling the home machines and assurance from flame mishaps with quick arrangements [2]. With the idea of information sharing of smart devices using IoT [10] have proposed a home model to demonstrate an energy efficient IOT based smart home to monitor and control smart devices using motion sensor and controls the kitchen area to monitor HVAC system. Author intended to provide how Internet of Things is useful in electricity competence applications in a view of its mechanical and industry impacts and what are the opportunities and risks for the diverse promote players [4]. Researchers have proposed a smart home control system using a coordinator based on ZigBee networking [5]. An IoT framework with smart

*Rinku Chavda
E-mail address: rinku.chavda.12@gmail.com

location-based automated and networked energy control proposed in [7], which uses Smartphone platform and cloud-computing technologies to enable multi-scale energy proportionality including building-, user-, and organizational-level energy proportionality. A structure plan of building electricity monitoring and investigation based on the Internet of things, which has some enlightening in building electricity consumption added to realize real-time monitoring and controlling, and improve the electricity saving of intellectual building [11].

3. Required Equipments and its Hardware interfacing

While implementing the Electricity saving module, various sensors have been used to get the information such as presence of natural light in room or house, temperature, presence of humans in room and different types of jumper wires to connect said sensors with the programming board. Detailing of the sensors such as purpose of sensor and board for reading sensor values and performing decision making of turning ON/OFF of equipments has been listed in Table 1. Hardware Interfacing of Raspberry Pi 3 with Sensors and LEDs using jumper wires were shown in fig. 1 as well as fig. 2 represents detailed connection of Raspberry Pi 3 GPIO pins with sensors.

Table 1. List of Equipments used in Electricity Saving Module

Sr. No.	Name of Equipment	Purpose
1	Raspberry Pi Model 3	Program/Logic building related to used sensors
2	DHT11 Sensor	Measuring Temperature and Humidity in the Room
3	Motion Sensor	Detecting presence of Person in the Room
4	Light Sensor Module	Measuring light intensity in the Room
5	5 LEDs	Represents One AC, 3 Lights and One Fan which are available in the Room
6	Jumper Wires	Connect various Sensors and LEDs to Raspberry Pi 3 GPIO Pins
7	Breadboard	Used to build a circuit to demonstrate its action

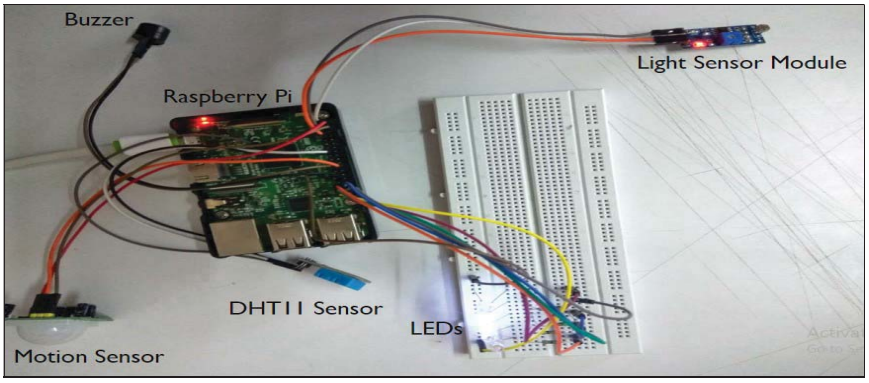

Fig. 1. Hardware representation of electricity saving module.

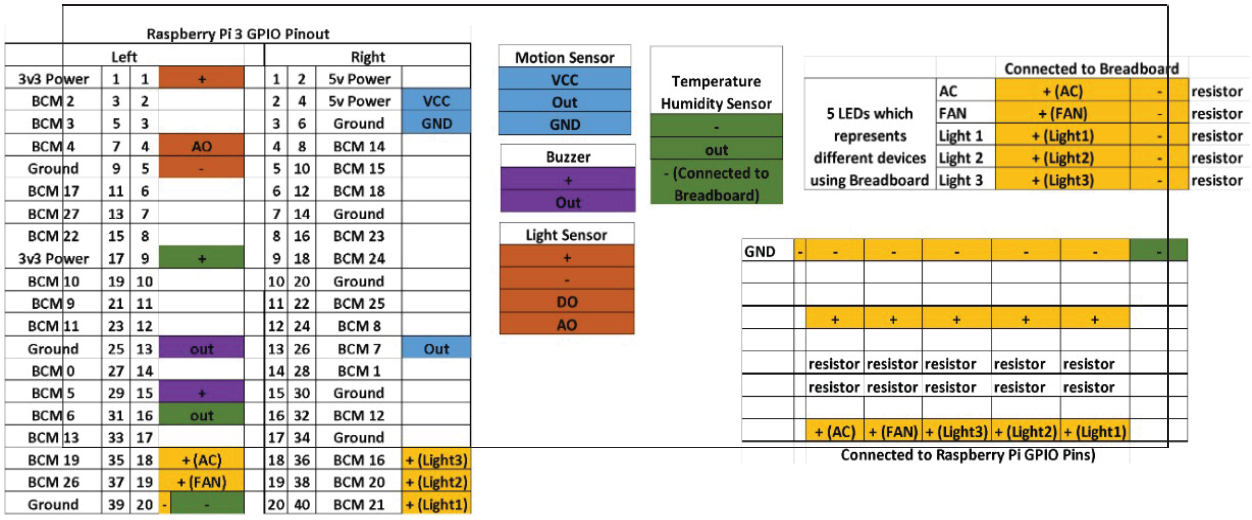

Fig. 2. Detailing of Raspberry Pi 3 GPIO pins with sensors.

4. Methodology for implementation of Electricity saving using IoT

In this section, Methodology to implement electricity saving module using Internet of Things have been discussed. The sensors periodically perform sensing and send (wirelessly or wired) sensed data to the Raspberry Pi 3. While reading the values of sensors, some threshold value has been fixed (Section 4.2) which will help to take decision regarding when to turn ON or OFF of electric equipment i.e., Lights in room, Fan, AC (discussed in section 4.3) as well as calculation of consumption with and without sensors (discussed in section 4.4).

4.1 Understanding of Sensors with respect to Electricity Saving Module

- *Motion Sensor:* Using the Motion Sensor, it is possible to check whether the Person is present or not in the Room. If a Person is not present in the Room for more than 5 minutes and he/she forgot to turn off all the ON devices of the Room, the program will automatically turn OFF all the ON devices which help us to save our power consumption. As soon as the Person gets into the Room, the sensor will detect "Person is back in the Room", then the program will turn ON all the devices as per the previous state when he/she left the Room.
- *DHT11 Sensor:* With the help of a Temperature and Humidity sensor, we can measure temperature and humidity in the Room, and based on the recorded data, the program will switch ON/OFF AC and FAN which leads to save power consumption.
- *Light Sensor Module:* With the help of the Light Sensor module, it becomes easy to get light intensity in the Room, and based on the recorded intensity, it will switch ON/OFF Lights which are in the Room.

4.2 Threshold values of Sensor readings

How to make decisions regarding the turning ON and OFF of electric equipment based on the sensor values? To get the answer of said question, some limit value or threshold values need to be finalized which will help to achieve efficiency of consumption. Threshold values of each sensor have been set as per the need of light intensity in room, cooling required in room, person is not present in room which were listed in table 2 as following.

Table 2. List of Sensors with Threshold values

Sensors	Threshold Values
Temperature and Humidity level	tempThreshold1 = 26, tempThreshold2 = 25, tempThreshold3 = 22 humidityThreshold1 = 60, humidityThreshold2 = 45
Light Intensity	lightThreshold1 = 100, lightThreshold2 = 200, lightThreshold2 = 300
Time Duration	timeThreshold1 = 5 minutes timeThreshold2 = after few minutes delayThreshold1 = 1 minute

4.3 Algorithm: Decision making to turn ON/OFF the Electric equipments based on threshold values

1. START
2. Turn **ON** Required devices suggested by Person
3. Repeat while **True**
   a. Store device status into database
   b. Read **Temperature** and **Humidity** Data
      IF (**Temperature** level is greater than tempThreshold[1] and **Humidity** level is less than humidityThreshold[1])
      THEN Turn **ON AC** and **OFF FAN**
      Else IF (**Temperature** level is less than tempThreshold[2] and **Humidity** is less than humidityThreshold[2]) or (**Temperature** level is less tempThreshold[3] and **Humidity** level is greater than humidityThreshold[2])
      THEN Turn **OFF AC** and **FAN**
      ELSE Turn **OFF AC** and **ON FAN**
   c. Read Light Intensity Data
      IF **Intensity of Light** is greater than lightThreshold[1]
      THEN Turn **ON All the LIGHTS**
      ELSE IF **Intensity of Light** is between lightThreshold[1] and lightThreshold[2]

THEN Turn **ON Two Lights** which consumes less power
ELSE IF **Intensity of Light** is between lightThreshold[2] and lightThreshold[3]
THEN Turn **ON One Light** which consumes less power
ELSE Turn **OFF all the LIGHTS**

d. Read Human Presence Data
IF **No ONE is present** in the ROOM
IF No One is present in the ROOM for **more than** timeThreshold[1]
THEN Turn **OFF ALL** the devices which are ON
Store the status i.e., OFF of ALL the devices into database
ELSE IF **Someone is present** in the ROOM
THEN Turn **ON the devices based on the Sensor data**
Store the status of turned ON devices into database
ELSE IF **Someone Come back** in the ROOM timeThreshold[2]
THEN Turn **ON the devices based on the previously stored status of Devices**

e. Time Delay for delayThreshold[1].

4. STOP

4.4 Algorithm: Calculate Electricity Consumption and find difference with and without help of IoT

1. START
2. **DEFINE Watts/Hour** for each Device.
3. **PERFOM** following steps for both types of Data i.e., Consumption with and without using IOT
   3.1. **Fetc4h** total usage of ALL Device data in minutes.
   3.2. **CALCULATE** power consumption for each device.
   3.3. **CALCULATE** total power consumption of user.
   3.4. **PRINT** power consumption of each device
   3.5. **PRINT** total power consumption of user.
4. **FIND** "difference of total power consumption of user" for both the type of Data i.e., Consumption with and without using IOT.
5. **PRINT** "Electricity Saving using IOT in KWs for recorded Time Period".
6. STOP

id	datetime	ac	light1	light2	light3	fan	light_intensity	temp	humidity
2856	2018-12-22 15:35:10	0	1	1	1	1	134	21.0	52.0
2857	2018-12-22 15:36:10	0	1	1	1	1	133	21.0	51.0
2858	2018-12-22 15:37:11	0	1	1	1	1	133	21.0	52.0
2859	2018-12-22 15:38:12	0	1	1	1	1	126	21.0	51.0
2860	2018-12-22 15:39:14	0	1	1	1	1	129	21.0	51.0
2861	2018-12-22 15:40:16	0	1	1	1	1	121	21.0	52.0
2862	2018-12-22 15:41:17	0	1	1	1	1	134	21.0	52.0
2863	2018-12-22 15:42:19	0	1	1	1	1	133	21.0	52.0
2864	2018-12-22 15:43:21	0	1	1	1	1	139	21.0	52.0
2865	2018-12-22 15:44:23	0	1	1	1	1	137	21.0	52.0
2866	2018-12-22 15:45:25	0	1	1	1	1	138	21.0	52.0
2867	2018-12-22 15:46:27	0	1	1	1	1	131	21.0	51.0
2868	2018-12-22 15:47:29	0	1	1	1	1	133	21.0	51.0
2869	2018-12-22 15:48:31	0	1	1	1	1	119	21.0	51.0
2870	2018-12-22 15:49:33	0	1	1	1	1	127	21.0	51.0
2871	2018-12-22 15:50:35	0	1	1	1	1	123	21.0	51.0
2872	2018-12-22 15:51:37	0	1	1	1	1	132	21.0	51.0
2873	2018-12-22 15:52:39	0	1	1	1	1	133	21.0	51.0
2874	2018-12-22 15:53:40	0	1	1	1	1	135	21.0	51.0
2875	2018-12-22 15:54:42	0	1	1	1	1	134	21.0	51.0
2876	2018-12-22 15:55:44	0	1	1	1	1	117	21.0	51.0
2877	2018-12-22 15:56:46	0	1	1	1	1	133	21.0	51.0
2878	2018-12-22 15:57:48	0	1	1	1	1	130	21.0	51.0
2879	2018-12-22 15:58:50	0	1	1	1	1	130	21.0	51.0
2880	2018-12-22 15:59:52	0	1	1	1	1	126	21.0	51.0
2881	2018-12-22 16:00:54	0	1	1	1	1	121	21.0	51.0

Fig. 3. (a) Represents Usage of AC, FAN and Lights without Sensors.

id	datetime	ac	light1	light2	light3	fan	light_intensity	temp	humidity
3025	2018-12-22 15:35:10	0	0	1	1	0	134	21.0	52.0
3026	2018-12-22 15:36:10	0	0	1	1	0	133	21.0	51.0
3027	2018-12-22 15:37:11	0	0	1	1	0	133	21.0	52.0
3028	2018-12-22 15:38:12	0	0	0	0	0	126	21.0	51.0
3029	2018-12-22 15:39:14	0	0	0	0	0	129	21.0	51.0
3030	2018-12-22 15:40:16	0	0	0	0	0	121	21.0	52.0
3031	2018-12-22 15:41:17	0	0	0	0	0	134	21.0	52.0
3032	2018-12-22 15:42:19	0	0	0	0	0	133	21.0	52.0
3033	2018-12-22 15:43:21	0	0	0	0	0	139	21.0	52.0
3034	2018-12-22 15:44:23	0	0	0	0	0	137	21.0	52.0
3035	2018-12-22 15:45:25	0	0	0	0	0	138	21.0	52.0
3036	2018-12-22 15:46:27	0	0	0	0	0	131	21.0	51.0
3037	2018-12-22 15:47:29	0	0	0	0	0	133	21.0	51.0
3038	2018-12-22 15:48:31	0	0	0	0	0	119	21.0	51.0
3039	2018-12-22 15:49:33	0	0	0	0	0	127	21.0	51.0
3040	2018-12-22 15:50:35	0	0	0	0	0	123	21.0	51.0
3041	2018-12-22 15:51:37	0	0	0	0	0	132	21.0	51.0
3042	2018-12-22 15:52:39	0	0	0	0	0	133	21.0	51.0
3043	2018-12-22 15:53:41	0	0	0	0	0	135	21.0	51.0
3044	2018-12-22 15:54:42	0	0	0	0	0	134	21.0	51.0
3045	2018-12-22 15:55:44	0	0	0	0	0	117	21.0	51.0
3046	2018-12-22 15:56:46	0	0	0	0	0	133	21.0	51.0
3047	2018-12-22 15:57:48	0	0	0	0	0	130	21.0	51.0
3048	2018-12-22 15:58:50	0	0	0	0	0	130	21.0	51.0
3049	2018-12-22 15:59:52	0	0	0	0	0	126	21.0	51.0
3050	2018-12-22 16:00:54	0	0	0	0	0	121	21.0	51.0

Fig. 3. (b) Represents Usage of AC, FAN and Lights with Sensors.

5. Results and Outcomes

The working of Electricity Saving Module represents the monitoring and analyzing consumption of electricity data phase. The collected data of sensors and state of electric equipment have been stored on cloud storage for calculating electricity consumption

with and without sensors. Figure 3(a) and (b) represents sensing data of used sensors with state of AC, FAN and Lights based on decision making of turning ON or OFF of the device.

Looking towards the consumption of electricity by households, it's necessary to answer the question i.e., what is the impact of IoT with respect to managing and controlling of electricity consumption? Information presented in table 3 concludes the overall impact of IoT i.e., use of sensors for controlling electric equipment.

1. Five electric equipment i.e., AC, FAN, 3 Lights were considered to get experimental results. Consumption of each equipment with and without sensors at every 1 minute interval has been stored in a database which was available on cloud i.e., shown in figure 3 (a) and (b).
2. While observing consumption results of AC that clearly indicates using the decision making with the help of various sensors have decreased the electricity consumption up to 98%, stated in table 3.
3. After implementing ESM, Electricity consumption of Light 1, Light 2, Light 3 and FAN also decreased by 80%, 40%, 49%, 60%, respectively and it affects the electricity bill amount of consumer.
4. Electric equipment wise detailed electricity consumption with and without sensors have been presented in table 4. It shows consumption in kW for approx. 11 hours and using ESM it saves 4.92 KWs.
5. Looking towards the equipment wise consumption using ESM, the consumption of AC, FAN, Lights 1-3 have been recorded as 0 due to absence of person in the room detected using Motion sensor as well as which lights to be kept ON, have been decided based on the Light intensity module for example, on 19 Feb. at 3pm and 4 pm as per the light intensity present in room, only two lights were to be kept ON. Same concept is extended for AC and based in DHT11 sensor, AC was ON at 3pm on 20 Feb. as per the rule mentioned in 4.3 section (algorithm)
6. Looking towards the reverse scenario of point no 4, i.e., consumption without using ESM, assuming the person has turned on all the electric equipment without knowing the actual need of them based on the natural light in the room as well as temperature in the room and remained ON even if the person was available in the room or not and graphical representation stating consumption-efficiency with and without ESM have been shown in figure 4(a) and (b)
7. From the experimental results mentioned in table 3, there were savings of approx. 18 kWs calculated as per the algorithm mentioned in 4.4 section for approx. 34 hours and it was achieved using the Electricity Saving Module which has decreased the financial burden of consumers.

Table 3. Electricity Consumption of Electric Equipment with and without Sensors

Electric Equipment	Consumption Without IoT	Consumption With IoT	Difference	Decreased in Electricity (%)
AC	17.28	0.18	17.1	98.958333
Light 1	0.4727	0.0889	0.3838	81.193146
Light 2	0.3039	0.1797	0.1242	40.868707
Light 3	0.3032	0.1539	0.1493	49.241425
FAN	0.389	0.1553	0.2337	60.077121
Total Consumption	18.7488 kW	0.7578 kW	17.991	95.958141
Electricity Saving using IoT for 33 Hours 47 minutes is 17.9910 kW				

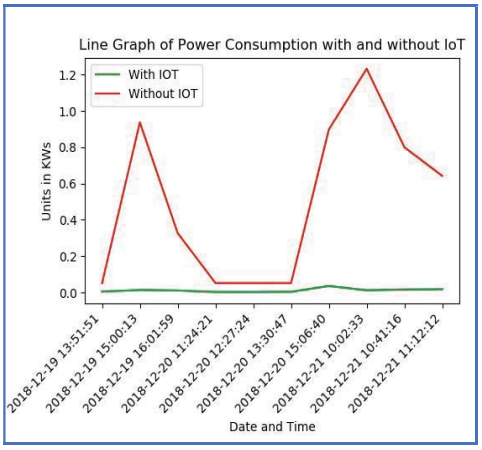

Fig. 4. (a) Electricity Consumption at Interval of 1 Hour.

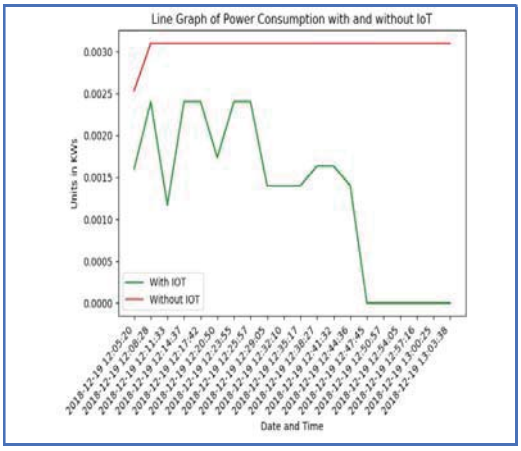

Fig. 4. (b) Electricity consumption at Interval of 3 minutes.

Table 4. Comparison of devices wise Electricity Consumption with and without IOT

		With IOT Electricity Consumption in KWs						Without IOT Electricity Consumption in KWs						Difference of Power Consumption
Date	Time	Total	AC	Light1	Light 2	Light 3	Fan	Total	AC	Light1	Light 2	Light 3	Fan	
19-12-2018	13:51:51	0	0	0	0	0	0	0.05	0	0.01	0.01	0.01	0.02	0.04
19-12-2018	15:00:13	0.02	0	0	0.01	0.01	0	0.94	0.9	0.01	0.01	0.01	0.01	0.93
19-12-2018	16:01:59	0.02	0	0	0.01	0.01	0	0.33	0.28	0.01	0.01	0.01	0.02	0.32
20-12-2018	11:24:21	0	0	0	0	0	0	0.05	0	0.01	0.01	0.01	0.02	0.05
20-12-2018	12:27:24	0	0	0	0	0	0	0.05	0	0.01	0.01	0.01	0.02	0.05
20-12-2018	13:30:47	0	0	0	0	0	0	0.05	0	0.01	0.01	0.01	0.02	0.05
20-12-2018	15:06:40	0.04	0.02	0	0.01	0.01	0	0.9	0.86	0.01	0.01	0.01	0.01	0.86
21-12-2018	10:02:33	0.02	0	0	0.01	0.01	0	1.23	1.2	0.01	0.01	0.01	0	1.22
21-12-2018	10:41:16	0.02	0	0	0.01	0.01	0	0.8	0.76	0.01	0.01	0.01	0.01	0.78
21-12-2018	11:12:12	0.02	0	0	0.01	0.01	0	0.64	0.6	0.01	0.01	0.01	0.01	0.62
												For ≈11 Hours		4.92 KWs

6. Conclusion

This paper addresses the idea that the residential buildings would shift themselves toward modern households i.e., automated decision making of turning ON or OFF of Electric equipment. In this paper, an Electricity Saving Module has been proposed, which ensures an electricity-efficient utilization of household resources. By applying the concept of IoT to automate ON/OFF of household equipment, based on experimental results it can be concluded that the presence of a person in room/house, temperature of house, natural light available in room detected using IoT based sensors plays an effective role while calculating the electricity bills which will help the consumer to manage his/her monthly finance.

References

1. Al-Ali, A., Zualkernan, I., Rashid, M., Gupta, R., Alikarar, M., 2017. A smart home energy management system using IoT and big data analytics approach. IEEE Transactions on Consumer Electronics, 63(4), p. 426-434.
2. Bommana, A. 2017. IoT based Monitoring and Control System for Home Automation using Prediction Algorithms. IJARCCE, Vol. 6, Issue 6, p. 70-73.
3. Dangar, B., Joshi, S. 2015. Electricity theft detection techniques for metered power consumer in GUVNL, GUJARAT, INDIA. Clemson University Power Systems Conference (PSC), p. 1-6.
4. Jammes, F. 2016. Internet of Things in Energy Efficiency: The Internet of Things (Ubiquity Symposium). Ubiquity, p. 1-8.
5. Khan, M., Silva, B., Han, K. 2016. Internet of Things Based Energy Aware Smart Home Control System. IEEE Access, 4, p. 7556-7566.
6. M. Ashok, P. Suresh, Varma, M. 2017. IoT based Monitoring and Control System for Home Automation. International Journal of Engineering Technology Science and Research, Volume 4, p. 413-418.
7. Pan, J., Jain, R., Paul, S., Vu, T., Saifullah, A., Sha, M. 2015. An Internet of Things Framework for Smart Energy in Buildings: Designs, Prototype, and Experiments. IEEE Internet of Things Journal, 2(6), p. 527-537.
8. Pavithra, D., Balakrishnan, R. 2015. IoT based monitoring and control system for home automation. 2015 Global Conference on Communication Technologies (GCCT), p. 169-173.
9. Sahoo, S., Nikovski, D., Muso, T., Tsuru, K. 2015. Electricity theft detection using smart meter data. 2015 IEEE Power Energy Society Innovative Smart Grid Technologies Conference (ISGT), p. 1-5.
10. Salman, L., Salman, S., Jahangirian, S., Abraham, M., German, F., Blair, C., Krenz, P. 2016. Energy efficient IoT-based smart home. 2016 IEEE 3rd World Forum on Internet of Things (WF-IoT), p. 526-529.
11. Wei, C., Li, Y. 2011. 2011. Design of energy consumption monitoring and energy-saving management system of intelligent building based on the Internet of things. International Conference on Electronics, Communications and Control (ICECC), p. 3650-3652.
12. https://www.healthandsafetyatwork.com/workplace-lighting/making-light-work
13. http://www.hse.gov.uk/pUbns/priced/l24.pdf