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IoT Based Smart Energy Meter for Smart Usage of Electricity

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Abstract

In this paper we deal with the measurement of individual power consumption of the appliances using MCU and updating the information on IOT cloud using a Wi-Fi module. Over the last few decades the consumption for electricity has increased exponentially. The method that can rig today's drastically growing energy issue is by downsizing household energy utilization. This has elevated focus for the need of precision and economic methods of power measurement methods. The aim of building this energy management system is to optimize as well as reduce extravagant consumption. Therefore, in the proposed model we provide the users a web portal which is available over desktop and mobile platforms and serves as an energy management system through which they can access details of real time energy consumption in their day to day life. We have made use of Arduino Uno REV3 microcontroller which is interfaced with the energy meter.

Keywords: *Energy management System, IOT, Arduino Uno REV3*

1. Introduction

In recent years the utilization of power has risen exponentially over time and population. Electrical energy consumption in the city's households has increased rapidly paving a need for an accurate and efficient method of power measurement which can give a fair understanding of the user's electricity utilization behaviour thus allowing them to have a transparent perspective of consumption and also acknowledging ways to reduce the additional usages in their day to day expenditure. Smart meters are a proven vital source for detailed feedback regarding energy use. Consumption information for a specific locality area offers sensitive data for managing electrical charges while reducing blackouts. For companies it will eliminate manual monthly meter readings, enabling dynamic pricing and optimizing the profit with existing resources.

Our model helps individuals to monitor electricity utilization for the individual appliances in a structured as well as in a systematic way and also avoid loss and theft of it, since our proposed system points out the units consumed by individual appliances as well as total electricity usage status. This informatics for a particular user is visible on an online portal. This allows the user to get live updates regarding the expenditure of electricity utilization. Consumptions for each appliance that is connected to the smart energy meter will be tracked down and the analytics performed over dashboard provides a functional control which can further be managed by user based on need.

Due to the new energy sources the smart meter must go along with the infrastructures that use them. The Smart electricity meters are replacing conventional meters worldwide. Smart metering systems automatically collect electricity consumption data, which generates accurate billing without sending workers to customer places to manually read the meters. SMAS uses a relational database management system which is an open source tool and helps to analyze the data [2]. With the speedy advances in wireless communication technology, new changes can be made to reduce manual effort by using a microcontroller. The traditional reading of manual meters is not appropriate for prolong operating purposes, since it utilizes considerable amount human resources. At present electricity utilization among the household is growing drastically, which makes it a difficult task in managing and retaining the power according to rising demands. Wireless communications have brought new perspective

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towards speedy sharing, safe and precise interchange of information. Therefore, it is easy to get the electricity bill faster and easier and we can do that on our devices [10]. The goal of this paper is to provide accurate data and reduce their power consumption. For superior billing and metering schemes smart energy meters are used. The use of GSM Short Message Service (SMS) module with Arduino provides automated computerized function for meter reading. This contributes to an advantage of advance reading and prevents errors in metering reading service among conventional meters. The energy meter proposed comes with an embedded controller which is exclusively used to exchange data regarding power utilization, bill generation, and providing secured services for GSM network available over mobiles. The data available over this service are fed and incorporated into current energy management systems available over power companies to provide committed service to customers with minimal use of man power [3]. A smart energy meter validates communication protocols for security purposes, electronic display interface and other functionalities. A smart meter must be capable of monitoring active power consumption. This also records current and voltage flow, reactive power, maximum power demand, frequency, power factor and other real-time information. The energy meter monitors the current and voltage, and calculates active power and is used to maximize the efficiency of electricity usage and show the energy used and the electricity bill to be charged [4].

The paper is structured as follows. Section II apportions with the related work. Section III contains the detailed methodology of the proposed system. Section IV describes the Results and Discussion. Section V concludes the research work with future scope.

2. Related Work

Increasingly, smart meters replace traditional electric meter. It delivers a range of smart functions including the ability to notify consumers about their energy usage through an online portal. They have access to read live status and collect monthly bills through electronic mediums, thereby removing the need for staff to visit homes to read the meter. In our proposed system we have used an IOT and web service, which delivers the meter reading straight from the consumer electricity board. These meters inform real time energy usage and make the city smart, connecting all devices under a centralized system to interact with each other by the help of IOT. Our proposed system will calculate the power consumption collectively as well for individual appliances. This paper misses out in providing web portals which will be covered in the proposed system [1]. Electricity service providers are sometimes in loss due to the inappropriate usage of power, bills sometimes are not paid and the practice of stealing power. Many feasible solutions are offered for this loss but some are strong enough to sort this problem out in the likes of Smart Home Automation, Energy Management System and Smart meter. India planned to develop advanced metering infrastructure but it's yet to be developed in developing countries. Our proposed system will generate profit economically keeping the above points. Moreover, it hasn't focused on the individual equipment's power consumption, which we have implemented in order to make it more feasible. In short, a consumer will have a clear idea of all the equipment consumption, and it will further help the consumer to save electricity bills [5]. As electricity consumption prediction plays an important role in making better decisions for cost and energy efficiency, our proposed system will predict the electricity expenditure of each house. Analysis will be done on the consumption data to extract the idea of power utilization behaviour. New methods of electricity consumption estimation would be applied in order to see utilization of electricity in houses. Out recommended model provides a filter option, enabling the consumer to filter out the electricity consumption for a particular span of time [6].

Automatic meter reading will help to get the meter readings anytime, without any requirement of meter reading person, who visits each household to see the power being consumed every time. Microcontroller is used here for monitoring purposes. Electricity providers will look after the customer activities in case if any illegal activities are done by the consumer. If they are found guilty, electricity will be cut off just by sending a message. A customer can see the live update of the power consumption from anywhere. In our model, we have provided the utilization in graphical as well as in numerical format for the household consumption which comes to rescue for making the visualization easier [7]. This proposed system focuses on power scheduling - based communication for the household devices and gives real time bills too. It manages two kinds of devices one which consumes power as it wants, other which can be switched on or off as desired. It uses a device scheduling approach to do so [8]. Current challenges which people face today are the electricity supply-demand gap. Use of smart meters, smart Grid and smart monitoring can be handy. In this paper, it has been discussed about all this equipment and the data flow in the meter which is presently utilized by the power supplier [9].

In this paper we are going to propose a model that helps individuals to monitor electricity utilization for the individual appliances in a structured as well as in a systematic way, since our proposed system points out the units consumed by individual appliances as well as total electricity usage status.

3. Methodology

Our model aims to acknowledge smart usage of electricity to users, thus enabling individuals to track down their day to day usage, hence allowing users to check live information of the individual appliances' energy consumption (in kWh), which can be accessed through an online portal available over desktop and mobile platforms. IoT is the key technology used here for the deployment of this model.

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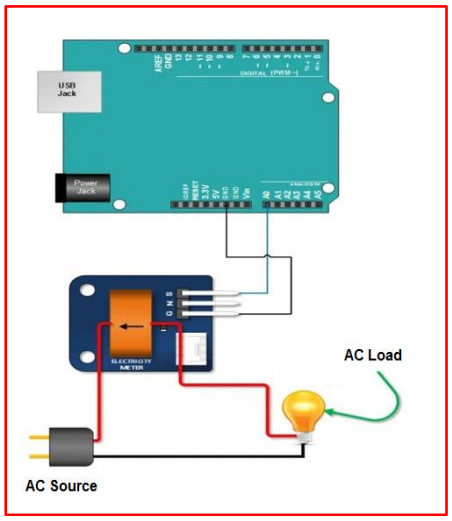

Figure 1: Energy Meter connected to Arduino Uno REV3.

Our proposed system becomes more reliable and accurate, by using the ZMCT current sensor which is a PCB mount current transformer, which helps to track the energy consumed by each individual appliance, furthermore it's connected to the MCU, that helps in transferring data to the cloud storage, where data is made available to users through the web service. The overall system is automated which makes it more convenient, transparent and gives functional control to individuals to keep track of their real-time day to day electricity consumption. As shown in Fig.1. Our proposed system consists of an energy meter which is connected to the Arduino Uno REV3. It is an ATmega328P based microcontroller module, with 14 digital input/output pins. Microcontroller is interfaced ESP8266 Wi-Fi module which is competent to host application from another device processor, making it simpler for the consumer to access their appliance usage over the internet. Additionally, to monitor individual consumption, multiple current sensors are adhered to the microcontroller.

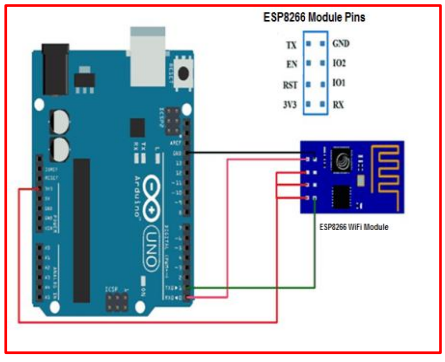

Figure 2: Arduino Uno REV3 connected to Wi-Fi module.

Fig.2 shows the ESP8266 Wi-Fi Module attached to the Arduino Uno REV3 which is a self-supporting System on a chip which is interspersed with TCP/IP protocols, which in return provides access to network over Wi-Fi through any MCU. Every ESP8266 Wi-Fi module is pre-programmed with a firmware collection of AT commands, making it ready to use just by plugging it with microcontroller unit.

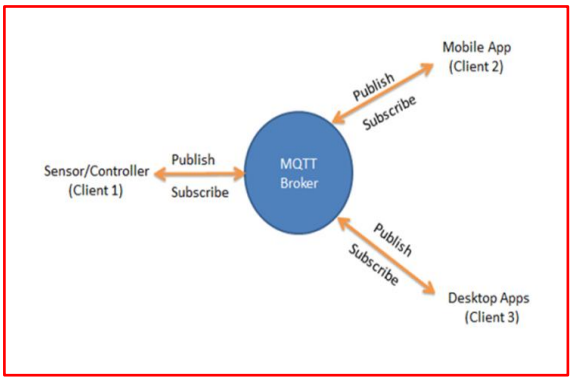

Figure 3: MQTT Architecture.

We are using MQTT protocol to transfer user's consumption data from MCU to cloud against the device and respective user ID. We have preferred MQTT for communication between IOT and cloud because it is more advanced than other protocols available over IOT. MQTT is a Message Queuing Telemetry Transport protocol. It is an easy and lightweight communication protocol built for restricted devices and low bandwidth, high latency or unstable networks. The design principles are intended to reduce the requirements for network bandwidth and system resources while also seeking to enhance reliability providing an assurance regarding the delivery of the messages from respective brokers to the corresponding clients. The key point of contact is the MQTT broker as shown in Fig.3.

The broker is responsible for forwarding complete messages among the senders and respective receivers. Each client who forwards an information to broker consists a subject in the message. The subject includes the broker's routing information. The client who intends to accept messages antes up to a specific subject, and the broker transmits all messages to respective clients who have subscribed with the corresponding subject. This system allows for exceedingly scalable solutions without having dependency or data consumer and producers.

The current sensor is mounted in front of the load, the current sensor will give the microcontroller a signal when the load is set to turn on and a code written in embedded C reads this signal and transforms it into meaningful information.

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Figure 4: Current sensor

Our model uses a ZMCT high precision PCB mount current transformer shown in Fig.4. which converts a high primary current into a lower secondary current. This module makes it easy to monitor AC mains current up to 5 Amps. We use the ZMCT current sensor since it is the best option which works well with the Arduino and the ESP8266 open source platform. ZMCT current sensor is a PCB mount current transformer with 1000:1 turn ratio. For higher current measurements we can use a PBT terminal and connect any wired current transformer up to 100 Amps.

Fig.5. shows our proposed model consists of a web service which runs on a centralized server. The data collected from an individual's house is sent to this web service hence the data is stored in cloud storage (remote database) against the respective key and respective device ID. In order to access the user's data, the user makes a request for the data through RESTful web service.

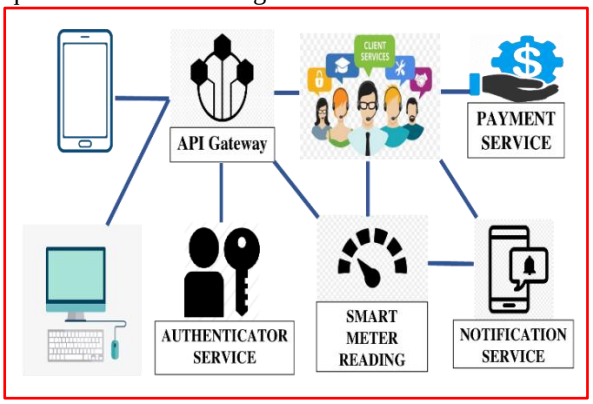

Figure 5: Modules for the backend services

The requested data is achieved through API calls made over respective end points. The requested data is sent as a response from the server; thus, response formatters are used over original API response hence transformed to the same format for which an individual has requested for, furthermore this allows the user to perform analytics since it presents the data in numeric and visual formats. Users having access to their real time energy consumption, our system facilitates them to visualize their usage patterns in graphical format. Moreover, the user can set the alert messages on-which the system gives the user a specific notification when the consumption jumps the specified threshold. Visualizing the consumption data in a graphical format will acknowledge the users about their consumption behavior thus enabling users to have a transparent perspective of the usage and reduce unnecessary consumption of electricity.

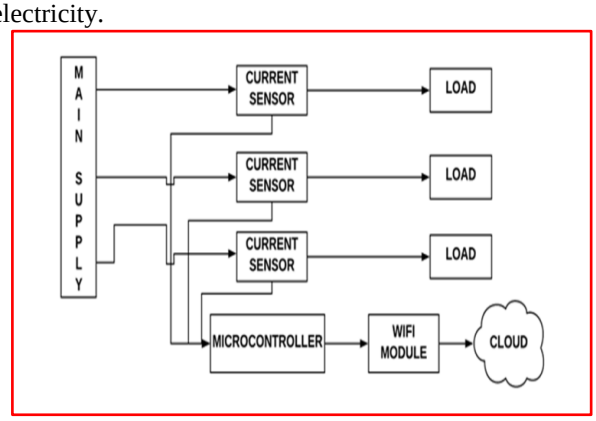

Figure 6: Block diagram of working model.

Fig.6. shows us the block diagram of our proposed model. In figure shown above, the current sensors are present in front of the load. These current sensors are interfaced to the Arduino REV3 microcontroller. The MCU is also interfaced with ESP8266 Wi-Fi module which is used to send and receive information from the cloud. When a load is turned ON the current sensor present in front of the load detects this and sends a signal to the microcontroller. This signal is read using embedded C and converted to useful information and sent to the cloud using the Wi Fi module.

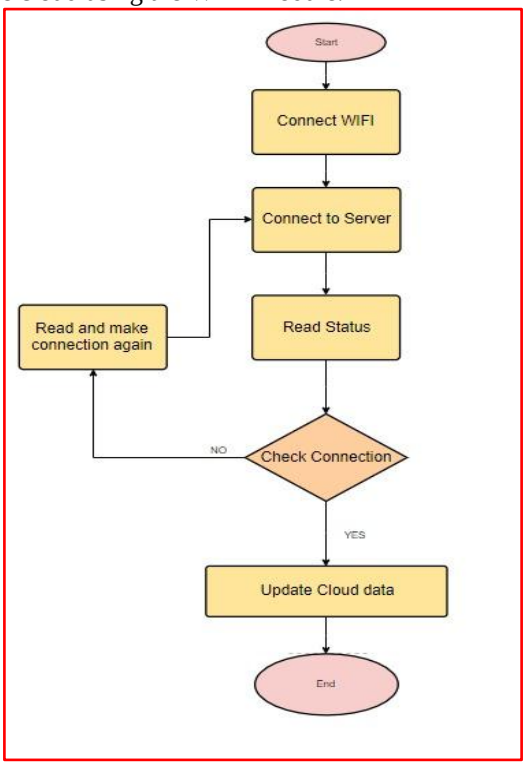

Figure 7: Flowchart of proposed model.

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Fig.7. depicts the flowchart of the proposed model, which is interfaced with an Arduino Uno REV3. This MCU is also attached to ESP8266 Wi-Fi module that is used for cloud data transfer and storage. The Wi-Fi module initially checks and establishes internet connection, and then connects to the server. When the server and MCU connection is established, data is transferred over cloud. This process continues to repeat itself until there is no power supply from the main source.

4. Results and Discussion

Our proposed work consists of the power supply section which includes transformer, full wave bridge rectifier filter and voltage regulator (from left to right) which is solely responsible for power supply to the loads thus acts as an energy meter. Fig.8. shows the experimental setup for the proposed model. The experiment has been carried out by interfacing ESP8266 Wi-Fi module and power supply to the Atmega328 microcontroller, followed by ZMCT high precision PCB mount current transformer. The circuit has been first designed and is being simulated using MATLAB/Simulink and required consumption data for individual appliances are logged in csv format.

The Arduino Uno REV3 microcontroller is connected to power supply section (energy meter) as well as to Wi-Fi module to process the data received from current sensors and send data over remote databases using MQTT protocol

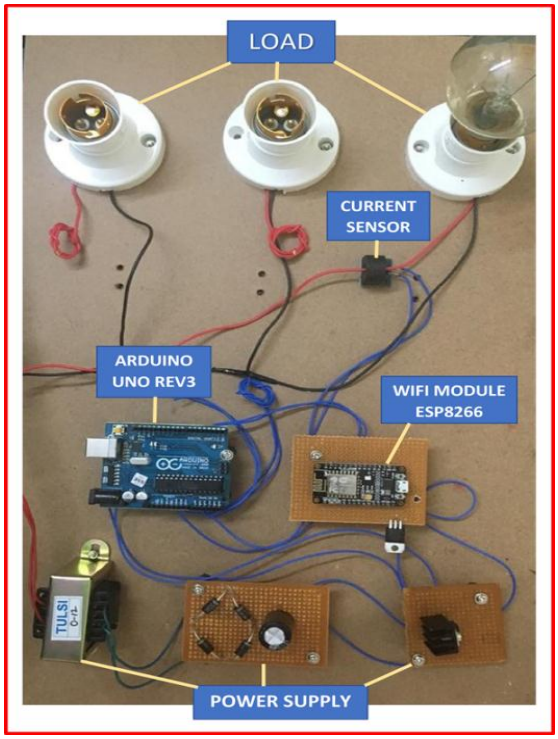
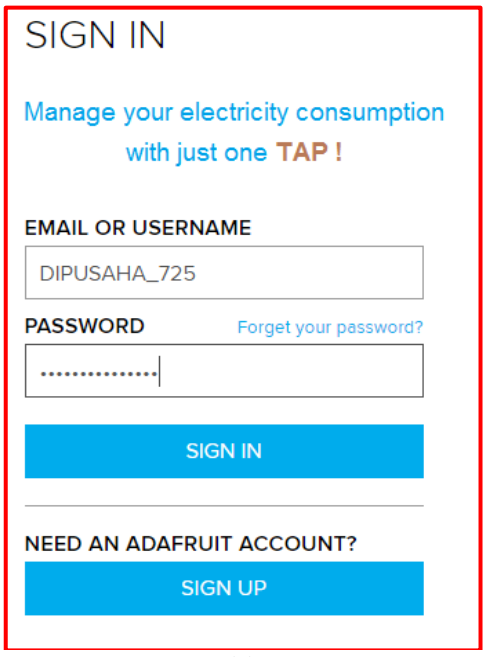


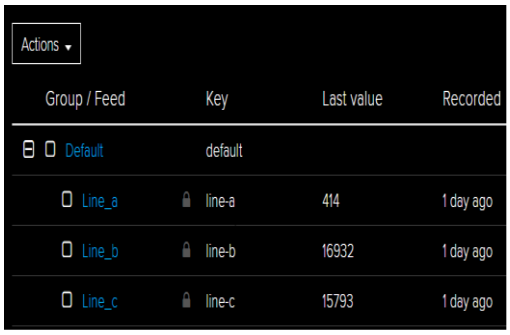
Figure 8: Experimental setup of proposed work.

against the respective userID and deviceID, current sensors are connected with the loads, with a aim to determine collective and individual appliances usage. In our proposed system we have made use of ESP8266 Wi-Fi module, this unit can function as a hotspot (access points can be created) and can also act as a station, so data can be easily uploaded and retrieved whenever required. This links to the internet and makes use of the MQTT protocol (publisher/subscriber model) in order to transfer data to cloud.

Current Sensors are mounted before their respective load, which detects and transforms current to an output voltage which is readily measureable and is proportional to the current along the measured path. Once load is set to ON state, the current sensor sends a signal to the microcontroller on which the microcontroller converts this into Milliampere (mA) using embedded C and uploads it to the remote database. The User can view their usage static through an online portal available over desktop and mobile platforms. The user can log into their account using their unique login id and password. Once logged in, they can view the energy consumed by the appliances in their house. They can also track the amount of energy used by individual appliances using our web service.



(a)



(b)

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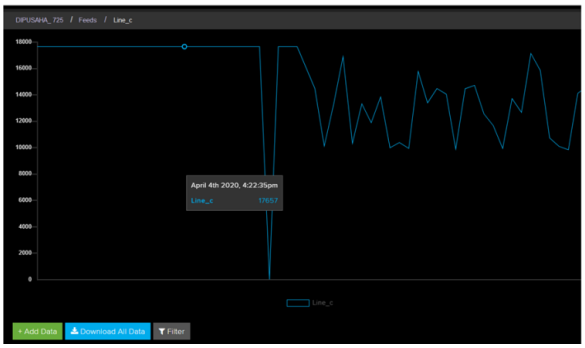
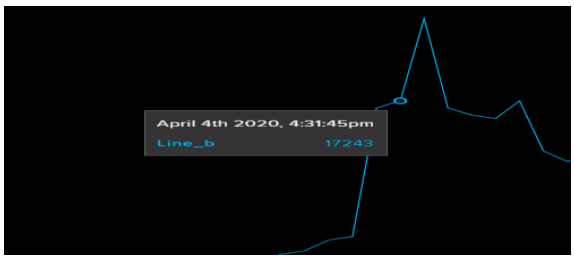
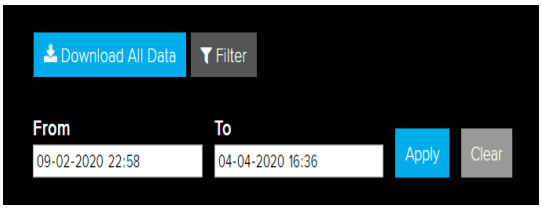


(c)



(d)



(e)

Created at	Value (mA)
2020/04/04 4:44:56pm	414
2020/04/04 4:36:09pm	396
2020/04/04 4:35:51pm	396
2020/04/04 4:35:33pm	396
2020/04/04 4:35:15pm	396
2020/04/04 4:34:57pm	396
2020/04/04 4:34:39pm	396
2020/04/04 4:34:21pm	396
2020/04/04 4:34:03pm	396
2020/04/04 4:33:45pm	396
2020/04/04 4:33:27pm	396
2020/04/04 4:33:09pm	396
2020/04/04 4:32:51pm	396

(f)

Figure 9: Output screens of Application.

The web portal consists of a login page as depicted in Fig.9a.where user enters the credentials (username and password). Furthermore, the backend service of the web portal does authentication for the user. After successful authentication the user is authorized to see their personal dashboard. Thus, user can check the electricity utilization of the devices connected and registered as shown in Fig.9b. We have three loads whose individual consumption has been depicted in the dashboard corresponding to the last usage. On choosing a particularload, the user gets a graphical representation of the energy consumed by that particular appliance as shown in Fig.9c. and Fig.9d. The graph is plotted based on time versus usage in milliamps. This helps the user visualize their data in a more detailed manner. The user consumption logged in csv and JSON format are available over respective API endpoints. The filter feature in the dashboard allows the user to see the consumption data for a specific time period as shown in Fig.9e by passing the two time segments. The filter tab uses the JSON to show the specific consumption for a particular time segment. Each entry log in this file is made every 18 seconds as seen in Fig.9f.

5. Conclusion

We made an effort to build an IOT based smart meter, which acknowledges and enables users to keep a track of the real time energy consumption of the appliances. The overall system is automated which makes it more convenient, transparent and gives functional control to an individual to keep track of his day to day consumption in real life. Individuals can see the usage graphically in the dashboard after successful authentication. This enables the users to perform analysis over their day to day consumption and paves a way to reduce the extravagant use of electricity.

Recommendation model regarding the smart usage of electricity, which gives guidance to users about the appropriate utilization of electricity based on the respective conditions, audio notification can be added in future which can turn off the load from remote locations and a module to keep a track for loss and theft detection can also be substituted in future scope.

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