Information Technology
&
Digital World

Low Cost Prepaid Energy Meter

B. Bhuvaneshwari[1], C. Subha Priyadharshini[2], S. Abisheak[3], N. G. Dhaswanth[4], M. Venkat Ramanan[5], S. Hariharan[6]

Department of Electronics and Communication Engineering, Coimbatore Institute of Technology (Affiliated to Anna University), Coimbatore, India

E-mail: [1]bbhuvaneswari@cit.edu.in, [2]subhapriyadharshini@cit.edu.in, [3]1904063ece@cit.edu.in, [4]1904074ece@cit.edu.in, [5]1904121ece@cit.edu.in, [6]2004206ece@cit.edu.in

Abstract

Many industries require a certain amount of electrical power. Prepaid metering, with its unique performance in the Internet of Things (IoT), tends to be an efficient power management system by providing cost-effective prepaid electricity services to the industrial sector. Errors can occur at any stage of the energy billing process, including errors in electromechanical meters, human errors during meter reading, and errors in processing paid and unpaid bills. A prepaid energy meter is the solution to these problems. In this work, prepaid energy meters were developed to reduce energy consumption in the industry. The introduction of this prepaid meter will contribute to improving energy management, saving energy, and eliminating fraudulent billing. Automated billing systems track consumption in real time, eliminating the possibility of fraudulent billing and consumption disputes. A prepaid energy meter was developed using current and voltage sensors, and the energy meter was tested with a load connected to a 220 V power supply. Energy meters are connected to the cloud to create a user alert system.

Keywords: Prepaid energy meter, IoT, energy management, automated billing system, alert system

1. Introduction

One of mankind's greatest discoveries is electricity. In the modern world, misuse of energy causes losses to public works. Losses in the power energy sector are divided into two groups: technical losses and administrative losses. Loss of technical performance is caused by the functional trend of equipment used from power plants to distribution stations. Non-technical losses occur due to lack of regular work intervention. These losses are higher in developing countries like India. In industrial sectors, users must pay for electricity even if

they do not use it, resulting in a regular loss. In this digital world, the prepaid energy meter is a revolutionary idea. This concept is not only useful for electricity management, but it also has the potential to prevent electricity theft and misuse. The Prepaid Energy Meter (PEM) concept is similar to that of prepaid mobile systems, since it is recharged and spent accordingly.

The user is provided with an account on the website and can use it to supplement it. The prepaid module has an LCD display that allows users to track how much energy has been used and how much is left. When the remaining energy falls below a certain value, user will be notified by SMS to top up account. The energy meter cuts power to the load when the remaining energy falls below the threshold. Once the meter charges above the threshold level, the load is restored and supplied. Through the website created, the system can track user information and update the server automatically. The designed concept attempts to address issues with the current systems, such as theft prevention, simple consumption monitoring, and avoiding the provider's set remuneration in the industrial current.Related Work

Md Redwanul Islam et al. 2019 [1], proposed the idea of implementing a real-time low-cost energy meter monitoring system by developing an Android Application on the basis of IoT. In this model, an IoT-based power meter monitoring system with an Android application is proposed to reduce the manual work for measuring power units and make users worry about excessive power consumption. An Arduino Uno and an optical sensor are used to get the pulses of the electricity meter. The system is readable and reliable. Data stored in the cloud is very important for future energy meter data mining.

S. Elakshumi et al. 2017 [2], presented an idea of load analysis of smart meters using server-based network in their paper "A server-based load analysis of smart meter systems". All sports facilities and customary areas are equipped with sensible energy meters. Servers are maintained at the institution level. To facilitate two-way communication between the server and the consumer's meter, data is transmitted over the facility's line using line modems or adapters. Energy consumption is calculated using a "meter constant" and this data is delivered to the server in meters.

Darshan N et al. 2015 [3], presented an idea of Microcontroller based design and implementation of energy meter using IoT and PLC concept in their paper on "IoT Based Electricity Energy Meter Reading, Theft Detection and Disconnection using PLC modem and Power optimization" which eliminates the human involvement in electricity maintenance.

Customers need to purchase the power they need on time, and the remote server often turns off power transmission automatically if they fail to pay. Wi-Fi units are used to perform IoT operations by sending energy meter data to web content accessible by IP address.

Shivam Roy et al. [4] developed an IoT Based Prepaid Energy Meter. A prepaid energy meter concept that automatically detects the energy consumed in the home and disconnects the load line when the first input threshold is reached. The automatic meter reading system sends data to the server via SMS. However, IOT-based energy meters regularly upload their readings to a central public server over GPRS. GPRS is cheaper than SMS and very easy to use with frequent updates. There is no need for a person to go to each house at the beginning of each month and check the readings.

2. Proposed Work

Fig 1 represents the block diagram of the proposed system. The prepaid Energy Meter mainly consists of ESP32 microcontroller which is used to process the values. Current sensor and Voltage Sensor gives the current and voltage readings which are processed in ESP32 and the Power reading is calculated in KWh. Relay unit is used to cut off the power supply when user exhausts the purchased power. Database is used to store the power readings. LCD is used to display the power readings. HTTP Protocol is used for message transfer between ESP32 and cloud and also for User alert system.
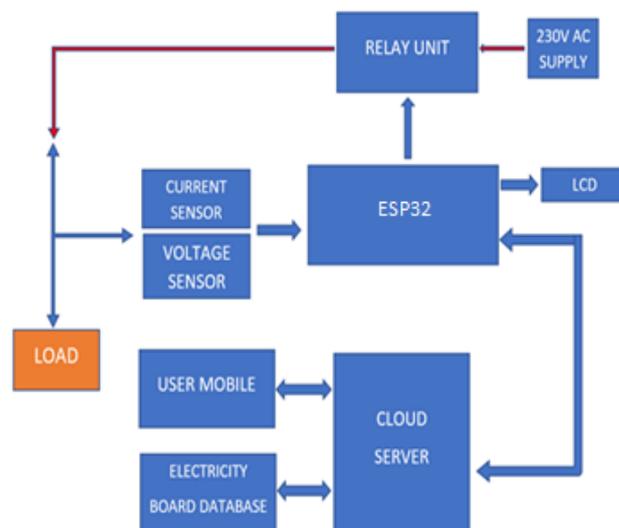

Figure 1. Proposed Prepaid Energy Meter

ESP32 is a 32-bit Silica Xtensa LX6 microprocessor with built-in Wi-Fi and Bluetooth. ESP32 has more features than ESP8266. ZMPT101B is a great option to measure

AC voltage on Arduino/ESP32/Raspberry Pi like open-source platform. ZMPT101B is a high precision voltage converter. The ACS712 current sensor is designed for easy use with microcontrollers such as ESP32. These sensors are supported by the Allegro ACS712ELC chip. The I2C LCD is a 16x2 LCD screen with an I2C interface. It shows 16x2 characters in two lines, white characters on a blue background. LCD displays are easy to project, especially with an ESP32, but they're also very complicated to solder. A relay is a switch that opens and closes a circuit electronically and electromechanically. The opening and closing of the opening and closing contacts in the electronic circuit are controlled by relays. The Arduino integrated development environment (or Arduino software (IDE)) includes a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and numerous menus.

Figure 2 shows the Hardware setup of Prepaid Energy Meter. The voltage and current consumption are measured by using voltage and current sensor. The sensors are connected to ESP32. The ground pin of ESP32 is connected to the grounds of current sensor, voltage sensor and relay. The V_{dd} pin of ESP32 is connected to the positive terminals of sensors and relay. The current sensor output is connected to pin 34 of ESP32 and the voltage sensor output is connected to pin 35 of ESP32 respectively. The I2C LCD's SDA (Serial Data) is connected to GPIO 21 and SCL (Serial Clock) is connected to GPIO 22 of ESP32 respectively.
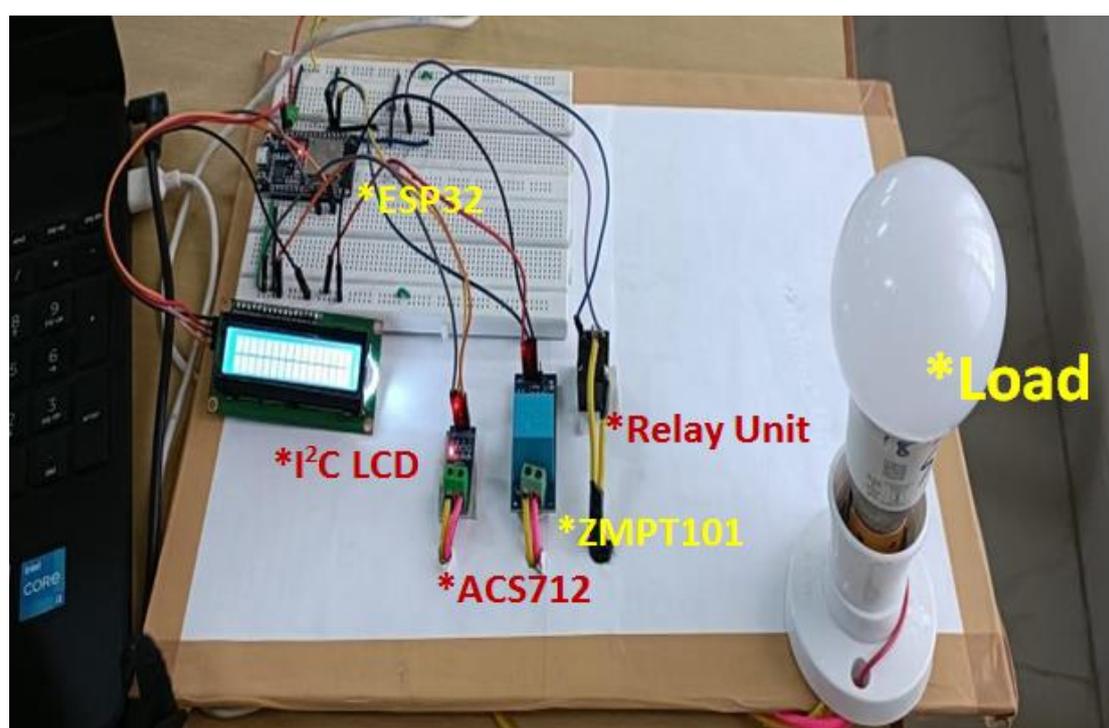
Figure 2. Hardware Setup

3. Results and Discussion

The entire model is controlled by Esp32 module. The input 230V power supply is introduced through the relay unit to the current and voltage sensors. The current and voltage sensors act as an energy meter, the input is monitored by Esp32 module, and correspondingly load is given via current and voltage sensor. Based on the load consumption, energy meter reading is calculated by the Esp32 based on the program implemented on it. Power consumed is displayed on the LCD display.

$$\text{Real Power} = \text{Voltage Ratio} * \text{Current Ratio} * \frac{\text{Sum of Power Readings}}{\text{Number of Samples}} \quad (1)$$

Esp32module is coded for prepaid meter in such a way that consumer can recharge the meter for the id provided by the provider. Based on the units that consumer required can pay and get it. later based on the consumption the units that consumer purchased will be reducing, once the purchased units are over the consumer will get acknowledged that the purchased units are over, if consumer Recharges again the supply will continue, else relay will cut-off the current supply to the consumer.

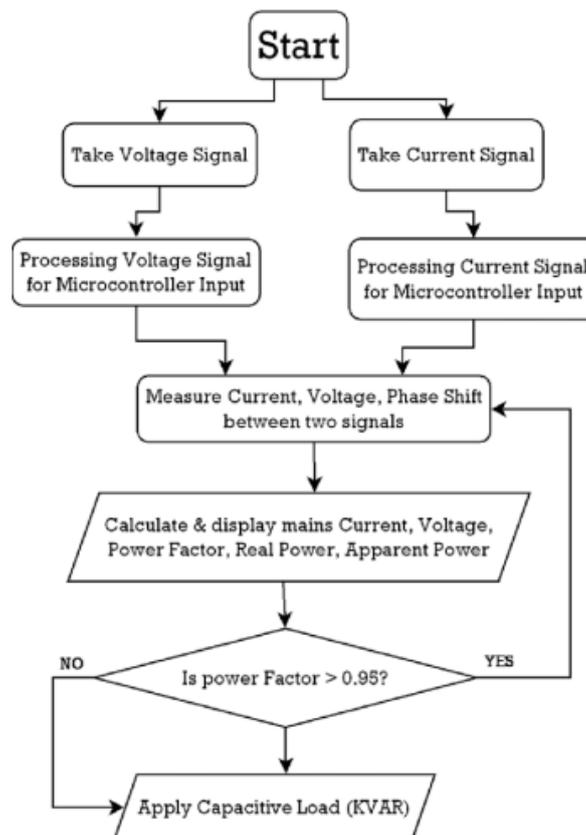$$\text{Apparent Power} = V_{\text{RMS}} * I_{\text{RMS}} \quad (2)$$

Figure 3. Power Calculation

ESP32 gets the Current and voltage reading from the current sensor and voltage sensor. These values are converted to the V_{rms} value and KWh and are continuously pushed to Cloud using Google App Script. In google sheets (cloud) the values of V_{rms} and KWh are processed.The Google sheet contains column like Date, V_{rms}, KWh, Id, Account, Last Kwh, Pre-KWh, Remaining and Relay Condition. Date column contains the timestamp details of when the readings are noted. V_{rms} and KWh contains the reading value from ESP32. From these values Previous KWh value is calculated.

The power factor and instantaneous power can be calculated using,

$$\text{Power Factor} = \frac{\text{Real Power}}{\text{Apparent Power}} \quad (3)$$

$$\text{Instantaneous Power} = \text{Phase Shifted Voltage} * \text{Filtered Current Value} \quad (4)$$

Figure 4. Google Sheet Database

From the Web the recharge value is obtained and stored in Account column. Remaining value is calculated from the account column and Pre-KWh and stored. From this the relay condition is found whether 0 or 1. The remaining value is sent to ESP32 using Google App Script. If the remaining value is less than zero relay stops the current flow. Once the user recharges, electricity will be provided.

The hourly power consumption can be monitored by the consumer through the mobile application developed, each and every database like (units consumed, units recharged) will be sent to the Electricity supplier. Figure 4 shows the Database of the hourly consumption. A web page has been created as shown in Figure 6 to collect the recharge details like Id, Name, Phone number, Power required in Kwh from the user using HTML, CSS and Java Script as shown in Figure 7.
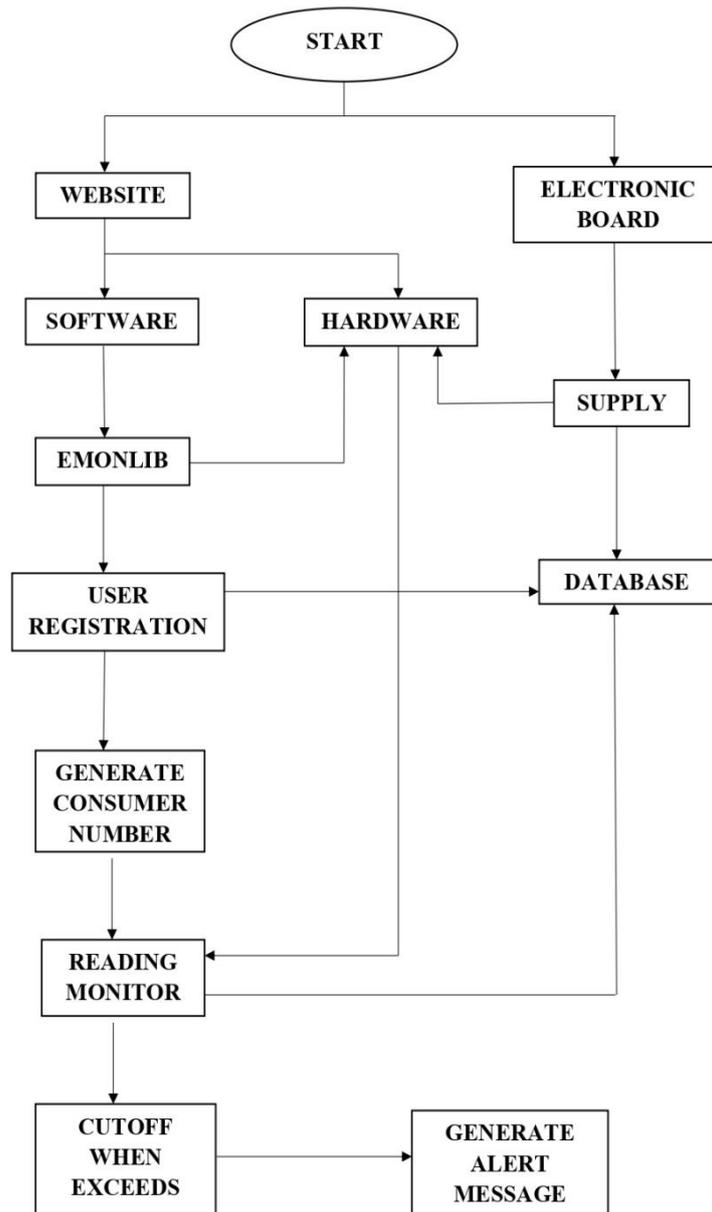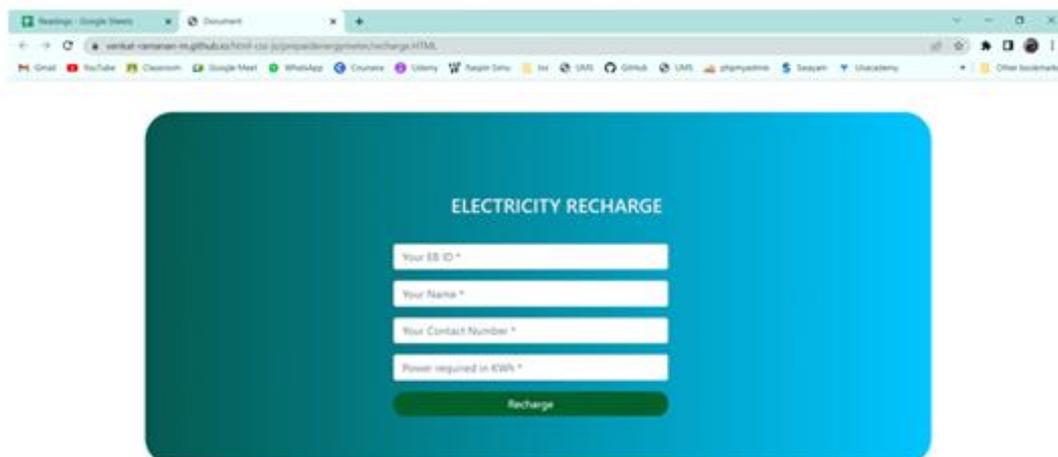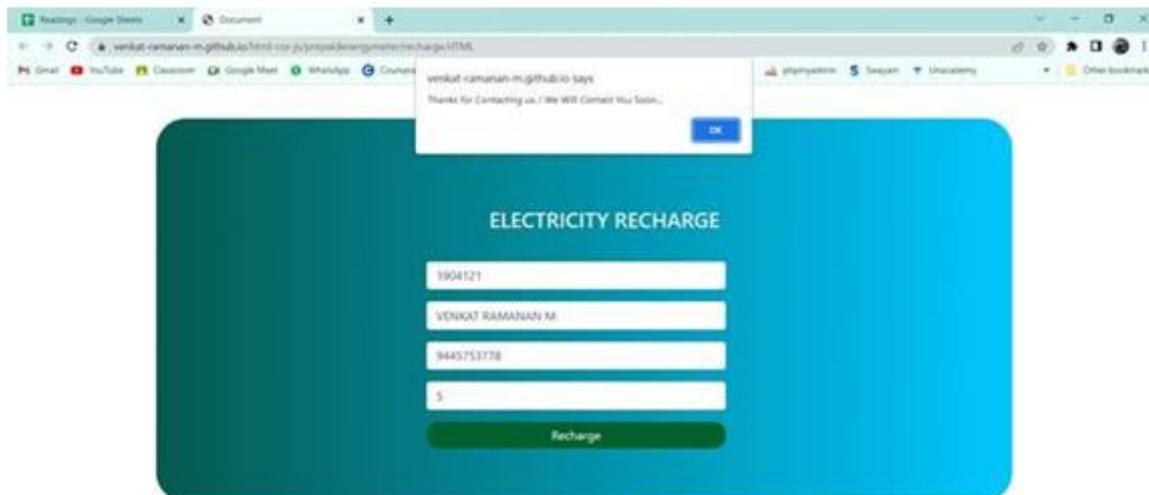
Figure 5. Working of Energy Meter


Figure 6. Web Page

Figure 7. User Detail

Once the user fills the web page requirement the data will be sent to Google Sheets where it will be processed. The power supply will be activated when the consumer recharges for the unit that consumer requires as shown in Figure 8. When the User is crossing certain power like 50% of recharged power an alert message will be sent stating that limit has been crossed recharge soon and when recharged power is completely exhausted an alert message will be sent stating Power is cutoff and to recharge immediately to get back electricity and the relay unit will cutoff the power supply as shown in Figure 8 and Figure 9.

The sum of the power readings can be calculated using,

$$\text{Sum of Power Readings} = \text{Sum of Power Readings} + \text{Instantaneous Power} \quad (5)$$
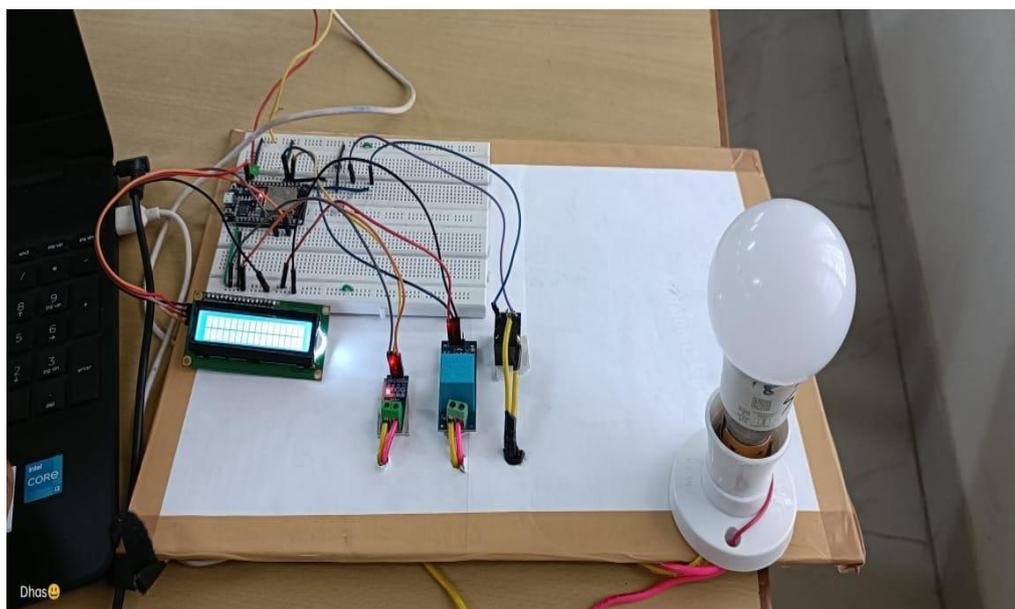
Figure 8. Current Cutoff when out of balance
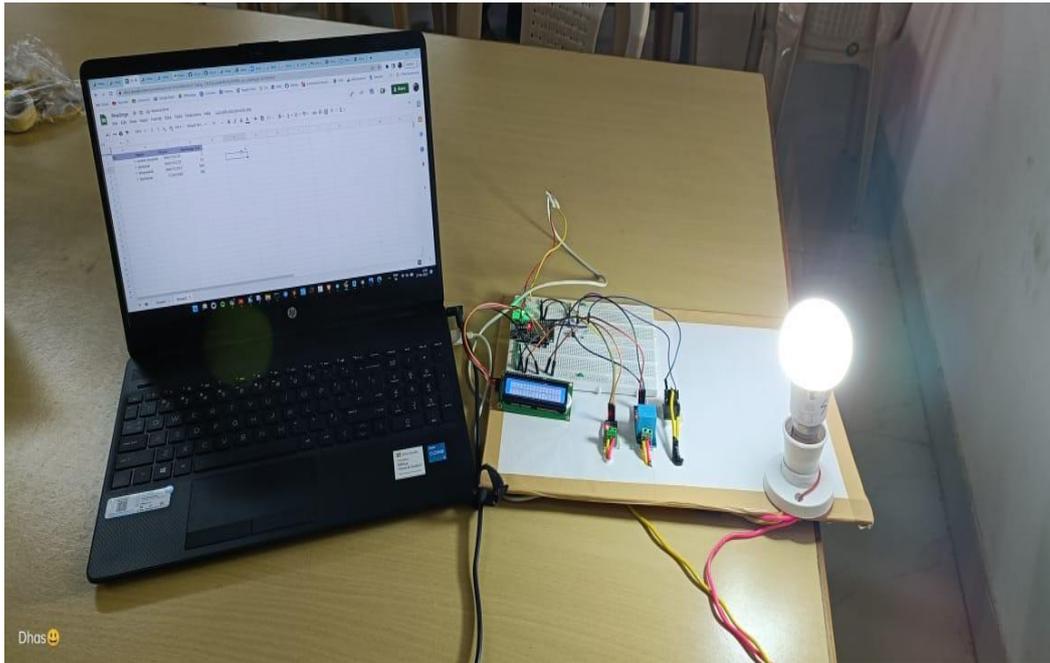
Figure 9. Output driven when recharged
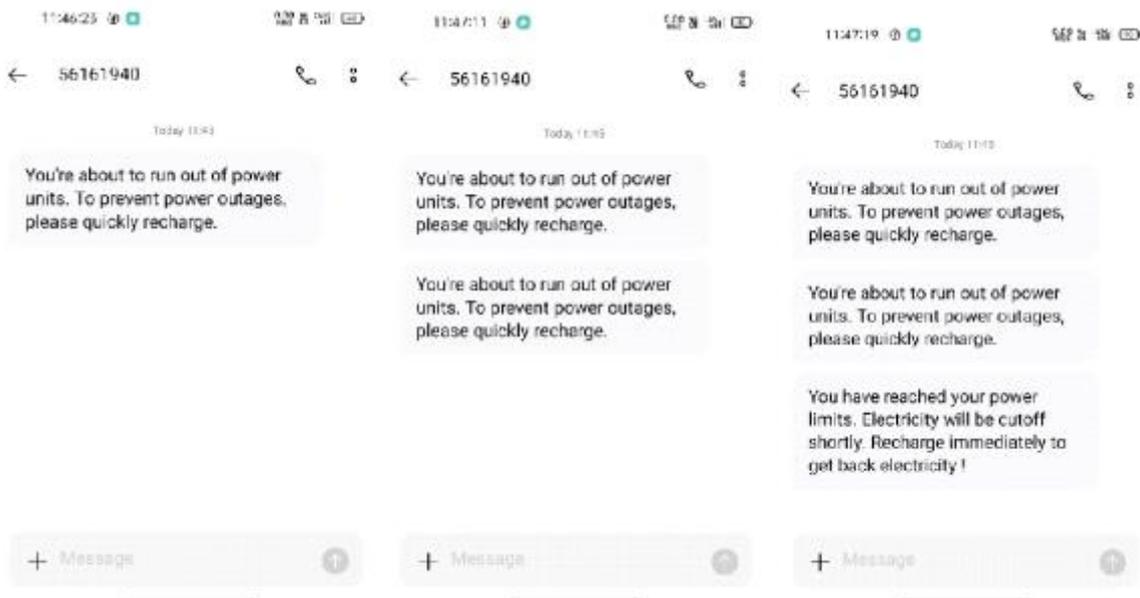
Figure 10. User Alert

4. Conclusion

An IOT-based intelligent energy meter that calculates power consumption, displays it on the LCD, uploads it to the cloud, and processes consumer data has been achieved. The energy meter proposed and created in this work saves time in billing, bookkeeping, and unnecessary travel. It provides an accurate record of the number of units driven and alerts the user when the charge is low. A relay cuts power as soon as the available credits are

exhausted. Reduce manual effort to perform energy meter readings in a cost-effective manner. Diversity of services will be a key competitive factor to improve market share in the current electricity market. Better than traditional meters, prepaid meters can help electric utilities differentiate themselves and offer value-added services to their users. Customers can be encouraged to voluntarily deploy prepaid meters. System can also offer rate or non-tariff incentives to users who have prepaid electricity rate changes.

The proposed system reduces consumer distress and allows users to worry about excessive power consumption and broken appliances in their homes. With this system, customers can easily check the total units and total electricity charges. The system is readable and reliable. Data stored in the cloud is very important for future energy meter data mining.

In the future, the design and implementation of the product will be improved to provide more reliable performance. New features can be added to developed products to provide global connectivity. Each user is given a smart card that can be used to refill RFID tags and meters in different ranges (Rs 50, Rs 100, Rs 200, etc.). In preparation for subsequent charging, consumers can check their balance on the LCD attached to the module. Automatic identification technologies such as radio frequency identification (RFID) rely on gadgets called RFID tags or transponders to store and remotely retrieve data. An RFID reader and an RFID tag must cooperate work to some degree in order for the technology to work.

References

[1] Dineshkumar.K, "Development of ARM Processor based Electricity Theft Control System using GSM Network", International Conference on Circuit, Power and Computing Technologies,2015.

[2] S. Elakshumi and A. Ponraj, "A server-based load analysis of smart meter systems," International Conference on Nextgen Electronic Technologies: Silicon to Software (ICNETS2), 2017.

[3] Islam, Md Sajedul, and Md Sadequr Rahman Bhuiyan. "Design and implementation of remotely located energy meter monitoring with load control and mobile billing system through GSM." Electrical, Computer and Communication Engineering (ECCE), International Conference on IEEE, 2017.

[4] Khairy Sayed1 , Farid Naguib Abdelbar2 , Emad Elzohri3 , Allam Ahmed4, "Design And Implementation Of Iot Based Digital Energy Meter For Remote Monitoring",

International Journal for Trends In Engineering & Technology Volume 14 Issue 1 – June 2016 - Issn: 2349–9303

[5] ShubhamM.Kirdat1 . Anup A. Kawade2 . Bharat B.Jadhav3 . Prof. Sandeep. N. Yadav, "A Review on Prepaid Energy Meter Using Arduino and GSM Technology" ,International Journal of Research in Advent Technology (IJRAT) (E-ISSN: 2321-9637) Special Issue National Conference "CONVERGENCE 2017", 09th April 2017.

[6] Vinayak Rangrao patil; Manoj D. Patil;Anupam Tanaji Khude, " Iot based Prepaid Energy Meter" , 5th International Conference on Devices, Circuits and Systems (ICDCS), 2020

[7] Sagar Rathee;Aayush Goyal;Anup Shukla, " Designing Prepaid Smart Energy Meter and Deployment in a Network" , IEEE 4th Information Technology , Networking, Electronic and Automation Control Conference(ITNEC), 2020

[8] Allah Wasaya;Sarib Malik;Muhammad Zaigham Abbas;Hamza Shahid, "An Approach Towards Prepaid meter System using PowerStudio SCADA", 4th International Conference on Energy Conservation and Efficiency (ICECE), 2021

[9] Nabil Mohammad;Anomadarshi Barua;Muhammad Abdullah Arafat, "A smart prepaid energy metering system to control electricity theft" , International Conference on Power, Energy and Control (ICPEC), 2013

[10] Golam Mostafa, "Development of a single phase prepaid Electrical Energy Meter using 89S8252 microcontroller architecture", International Conference on Advances in Electrical Engineering (ICAEE), 2015

[11] B Rahul Rajesh;S Mohan Kumar;Nayab Z Sharief;Sourabh Kothari;K Ezhilarasan, "IoT based automatic energy metering system with prepaid/postpaid configurability" , International Conference On Smart Technologies For Smart Nation (SmartTechCon), 2017

[12] Muhammad Nafees, " RFID based prepaid energy meter and home automation with reporting", 23rd International Conference on Automation and Computing (ICAC), 2017

[13] Au Thien Wan; Suresh Sankaranarayanan; Siti Nurafifah Binti Sait, " Smart agent based prepaid wireless energy meter". International Conference on Cloud Computing and Internet of Things, 2014

[14] P Rahul Reddy ; Rajashekhar Kammanaboina ; Dumpa Prasad;Prabhakara Rao Kapula;Asisa Kumar Panigrahy. "Implementation of Smart Energy Meter through Prepaid Transaction using IoT", International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT), 2021

Author's biography

B. Bhuvaneshwari is currently working as an Assistant Professor in the Department of Electronics and Communication Engineering, Coimbatore Institute of Technology, Coimbatore, India. Prior to her appointment at CIT, she was working as lecturer in SRM University, Chennai. She received her undergraduate degree from Thiagarajar College of Engineering, Madurai and postgraduate degree from Government College of Technology, Coimbatore. She obtained her Ph.D in Certain Investigations of 3D Reconstruction using Passive and Active methods from Anna University, Chennai. Her areas of Interests include signal & image processing and computer vision. She has published papers on Image Processing, and computer vision in IEEE and IOS press journals (all Scopus/SCI indexed). To her credit she holds an Australian Patent in her domain. She has delivered guest lectures in the application field of Image processing and computer vision.

C. Subha Priyadharshini is currently working as an Assistant Professor in the Department of Electronics and Communication Engineering, Coimbatore Institute of Technology, Coimbatore, India. She received her undergraduate degree from Velammal Engineering College, Chennai, and postgraduate degree in the field of Communication Systems at College of Engineering, Guindy. She lectures in Digital communicaton, Satellite and Optical communication. Her areas of interests include Visible Light Communication and Wireless Communication. To her credit she holds an Australian Patent in her domain.

S. Abisheak is currently an undergraduate student at Department of Electronics and Communication Engineering, Coimbatore Institute of Technology, Coimbatore, India. His area of interest includes IoT and wireless communication.

N. G. Dhaswanth pursuing his undergraduate in Electronics and Communication Engineering at Coimbatore Institute of Technology, Coimbatore, India. His area of interest includes wireless sensor network and IoT.

M. Venkat Ramanan is doing his undergraduate degree course in the Department of Electronics and Communication Engineering, Coimbatore Institute of Technology, Coimbatore, India. His area of interest includes data communication and wireless networks.

S. Hariharan is currently an undergraduate student at Department of Electronics and Communication Engineering, Coimbatore Institute of Technology, Coimbatore, India. His area of interest includes IoT devices and sensor communication.