As per UGC guidelines an electronic bar code is provided to secure your paper

International Journal for Modern Trends in Science and Technology
Volume 11, Issue 09, pages 194-203.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol11issue09.html
DOI: https://doi.org/10.5281/zenodo.18124631

Design and Implementation of Prepaid Energy Meter Using IoT and GSM Technology

Dr. K.V.R.B Prasad | K. Gopi | C. Ajith Kumar | A.Malleswari | N.Vinod Kumar

Department of Electrical and Electronics Engineering, Chadalawada Ramanamma Engineering College, Andhra Pradesh, India.

To Cite this Article
Dr. K.V.R.B Prasad, K. Gopi, C. Ajith Kumar, A.Malleswari & N.Vinod Kumar (2025). Performance Analysis of DVR and STATCOM for Power Quality Improvement in Grid-Connected Solar Systems. International Journal for Modern Trends in Science and Technology, 11(09), 194-203. https://doi.org/10.5281/zenodo.18124631

Article Info
Received: 02 September 2025; Accepted: 28 September 2025.; Published: 30 September 2025.

KEYWORDS

Prepaid Energy Meter, Internet of Things (IoT), GSM Technology, Smart Energy Management, ESP32 Microcontroller, Energy Monitoring, SMS Notification, Cloud-Based Monitoring, Load Management, Peak Load Control, Home Automation, Smart Metering

ABSTRACT

The purpose of this study is to design and test a novel charging method for Electric Vehicles (EVs) by means of a bridgeless power factor correction (PFC) stage followed by a bidirectional dual active bridge (DAB) converter which is capable of bidirectional energy exchange between the grid and the EV battery, in addition to achieving near unity power factor, low conduction losses and low input current distortion at the same time. Using MATLAB based simulation we will also be able to test the efficiency and ability of the system to meet the required power quality standards (IEC 61000-3-2 and IEEE 519). The bridgeless PFC configuration reduces conduction loss in comparison with the traditional diode rectifier and has the capability of near unity power factor operation. The use of a digital PFC controller enabled us to create an input current that closely follows the waveform of the grid voltage, thus enabling us to comply with the international power quality standards mentioned above. In addition to the PFC stage the bidirectional DAB stage provides galvanic isolation and enables us to have both grid to vehicle (G2V) and vehicle to grid (V2G) power exchange capabilities. The DAB stage is controlled using phase shift modulation to enable both soft and efficient switching operation. We will also be testing all performance characteristics of the system using MATLAB simulation, specifically: DC link voltage regulation, input current distortion, and charging profile accuracy. The results from our simulations confirm that the system operates stably under variable load conditions while providing high efficiency and low harmonic distortion levels. The system is a simulated model and was not implemented as a physical prototype. Our simulation results demonstrate the feasibility of the system for future smart charging stations and grid connected electric vehicle infrastructure. The modular nature of the design and the scalable

architecture combined with the systems ability to meet the required power quality standards makes it a good candidate for future generations of electric vehicles.

1. INTRODUCTION

The need for the creation of more efficient billing and monitoring systems in residential and commercial infrastructure has resulted from the significant increase in global energy demand and increased use of electricity in all types of electrical loads. Most conventional post-paid energy meters require manual readings and billing, which can cause several problems including, but not limited to, incorrect readings, delayed billing, loss of revenue due to "energy theft," and a lack of information regarding energy consumption in real time by consumers. These issues result in less transparency in billing and create operational challenges for utility providers. Pre-paid metering systems have been introduced as an effective way to manage energy, since the consumer pays for the energy before they consume it, and the meter deducts the amount of energy consumed from the available funds in their account [2] . This approach promotes the most cost-effective use of energy, improves the efficiency of collecting payments from consumers, and prevents disputes between the consumers and the providers of energy [3] . As smart grid technologies continue to evolve, energy metering has progressed from simple electromechanical meters to sophisticated digital and wireless metering systems that are capable of providing real-time monitoring and automated control [4] . The development of the Internet of Things (IoT), has significantly contributed to the evolution of smart energy metering, and allows for seamless connectivity between the meters, the cloud server and the users' interfaces [5] . Through IoT-prepaid meters, users are able to monitor their energy consumption remotely, replenish funds through mobile apps, and view real-time reports of their remaining balance and historical usage patterns [6] . Additionally, the inclusion of GSM communications offers another level of communication, enabling data transfer and notifications to be received by the users in locations where there may be no Internet connection [7] . Users are notified through SMS of low-balance warning messages, tamper messages, power outages, and confirmation of recharge, thus improving both the reliability of the system and the involvement of users [8]. Research studies recently conducted have demonstrated that smart energy meters utilize sensor-based measurements employing voltage and current sensors to measure power, energy, and power factors more accurately than traditional methods [9] . Various types of microcontrollers including Arduino, ESP8266, and Raspberry Pi have been used extensively in smart energy metering applications. The ESP32 microcontroller however presents a more efficient option compared to other options due to the built-in Wi-Fi capabilities, dual core processing speed, and low power consumption, thus making it an ideal solution for real-time IoT applications [10] [11] . The addition of sub-meters to validate the measured values, increases the accuracy of the measured values and provides reliable energy auditing [12] . Smart metering, home automation, and peak load management are emerging research fields, and seek to decrease the burden of excess load during peak hours and to ensure grid stability [13] . Relay-based load control permits the selective shutdown of non-essential loads either during periods of high demand, or when a user's available balance falls to zero [14] . A four channel relay module provides versatility for controlling multiple loads and allows the user to prioritize the appliances based on energy consumption [15] . A DC-DC buck converter is implemented to provide stable voltage regulation for the microcontroller and GSM modules, preventing damage caused by voltage fluctuations and brownout conditions [16] . Local audible warnings provided by a buzzer notify the user of low-balance, overloading, and tampering events [17] . A smart prepaid energy meter utilizing IoT and GSM technologies is presented in this project using the ESP32 microcontroller, GSM module, voltage and current sensors, sub-meter, relay-based automation, LCD-I2C display, and cloud monitoring interface [18] - [19] . The system continually monitors and calculates the voltage, current, power, and energy consumption, and displays the calculated values locally on a 16x2 LCD. Simultaneously, the calculated values are uploaded to an online database for users to access through an Android application [20] . Once the user has depleted their available credits, the system automatically disconnects the load via relay control and sends an SMS notification to the user of the depletion of credits. The proposed system resolves the limitations associated with traditional metering by providing transparency, remote access, automatic billing, and effective energy usage, and is therefore an important contribution to the implementation of modern smart grid architectures [21] . The development of such a system not only provides users with real-time control and awareness of their energy usage, but also provides utility providers with lower labor costs, fewer uncollected bills, better identification of power theft, and enhanced load management strategies. Therefore, prepaid smart energy metering is regarded as a promising technology for future generation energy distribution networks.

2. SYSTEM CONFIGURATION

The configuration of this system is built around an ESP32 microcontroller that will be acting as the main unit of the system for processing data, controlling and communicating. The ESP32 is also interfaced with a voltage sensor, current sensor and sub-meter to measure and track electrical data and ultimately calculate the energy consumption in terms of units. The ESP32 can communicate with a 16x2 LCD display connected using I²C to the ESP32 in order to show the user in real time their voltage reading, current reading, amount of units they have used and how much money they have left as depicted by Figure.1. A 4 channel relay module will be used to control and monitor the user's AC loads, allowing the user to effectively manage peak loads and automatically disconnect power to the user's account once the prepaid balance has been depleted. For wireless communication and user notifications, a GSM module is integrated into the system to allow for the sending of SMS alerts to the user when their prepaid balance becomes low, or when a recharge occurs, or if there are any power outages that cause the power to cut off. A buzzer is also provided to give the user audible signals when critical conditions occur. All the devices in the system are powered via a DC to DC buck converter providing a constant and regulated DC voltage to all the electronic components in the system. This configuration allows for both an efficient way of monitoring the user's prepaid energy usage and sending the user remote notifications, while providing the user with intelligent control over their connected loads.

3. DESIGN AND IMPLEMENTATION OF PROPOSED SYSTEM

The configuration of this system is built around an ESP32 microcontroller that will be acting as the main unit of the system for processing data, controlling and communicating. The ESP32 is also interfaced with a voltage sensor, current sensor and sub-meter to measure and track electrical data and ultimately calculate the energy consumption in terms of units. The ESP32 can communicate with a 16x2 LCD display connected using I²C to the ESP32 in order to show the user in real time their voltage reading, current reading, amount of units they have used and how much money they have left as depicted by Figure.1. A 4 channel relay module will be used to control and monitor the user's AC loads, allowing the user to effectively manage peak loads and automatically disconnect power to the user's account once the prepaid balance has been depleted. For wireless communication and user notifications, a GSM module is integrated into the system to allow for the sending of SMS alerts to the user when their prepaid balance becomes low, or when a recharge occurs, or if there are any power outages that cause the power to cut off. A buzzer is also provided to give the user audible signals when critical conditions occur. All the devices in the system are powered via a DC to DC buck converter providing a constant and regulated DC voltage to all the electronic components in the system. This configuration allows for both an efficient way of monitoring the user's prepaid energy usage and sending the user remote notifications, while providing the user with intelligent control over their connected loads.

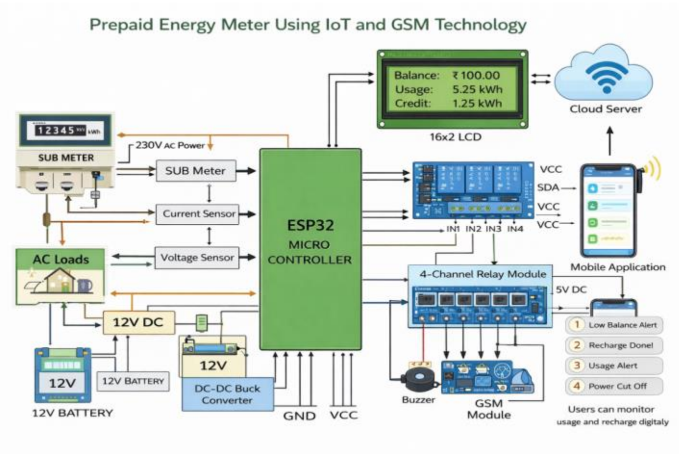


Fig.1 proposed system configuration

4. WORKING OPERATION BASED ON FLOWCHART

This prepaid meter is designed to measure electric energy (by means of the sensors) and to manage the amount of money a consumer spends on electricity (with respect to a given prepaid credit). As indicated in Figure.1, the voltage and current sensors provide continuous measurements of voltage and current supplied to a load; the sub-meter also continuously measures the amount of energy consumed. The ESP32 processor processes the analog readings provided by the sensors to determine the instantaneous rate of energy consumption. Each time a predetermined unit of energy is consumed, it is subtracted from the remaining prepaid balance in the system. Information regarding the amount of energy that has been consumed and the amount of prepaid balance remaining is communicated to a local display (a 16×2 LCD) using an I²C communication link. At the same time, this same information is sent to a cloud-based database for remote access using IoT technology, where it can be accessed remotely by a user with a smart phone app. The GSM module also sends SMS messages to users indicating low account balances, successful recharge transactions, high consumption levels (overload), and the automatic disconnection of the power supply. A 4-channel relay module allows users to control the status of up to four loads and to perform peak load management. Specifically, if the consumption level of the loads exceeds predefined limits or if the prepaid account balance reaches zero, the relay module will automatically turn off the lowest priority loads. All other components of the system receive their operating power from a DC-to-DC buck converter that regulates the output voltage. An audible warning buzzer is activated at critical times. This coordinated action enables the system to accurately track the consumption of prepaid energy, to intelligently manage the status of connected loads, and to notify consumers of various system-related events.

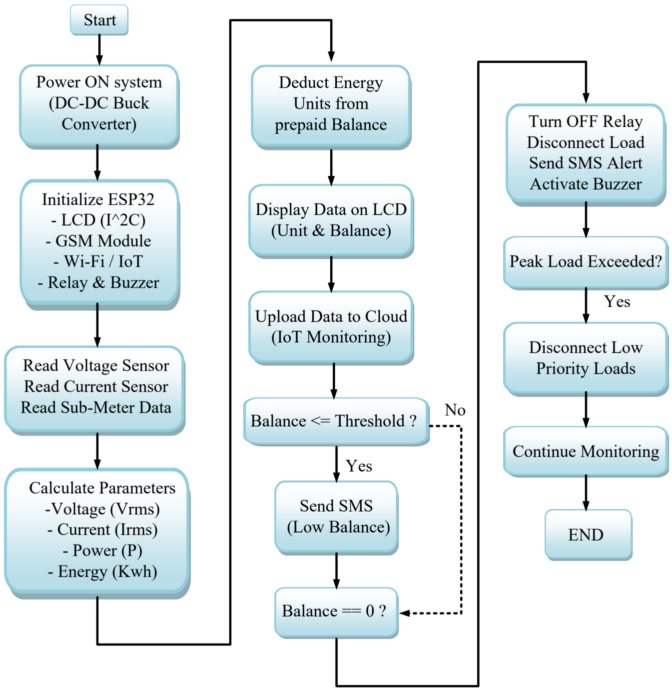


Fig.2 Flow chart of proposed system working and operation

A. ESP32 Microcontroller

The ESP32 microprocessor is the central control/computation unit of the prepaid energy meter. Using its onboard ADC (Analog-to-Digital Converter), it samples the analog signals from the voltage and current sensors; the sampled values are then processed using digital signal processing to calculate electrical parameters such as RMS voltage, RMS current, real power, apparent power, power factor, and total energy consumed. In addition to calculating these electrical parameters, the ESP32 tracks the prepaid account balance of the user by subtracting the consumed energy over time. Also, the ESP32 manages the relay module that is used to switch loads on/off, communicates with the GSM module using the UART communication protocol to send SMS alerts to users, and transmits energy consumption data to a cloud server via its built-in WiFi connection for remote monitoring of the system and mobile app access.

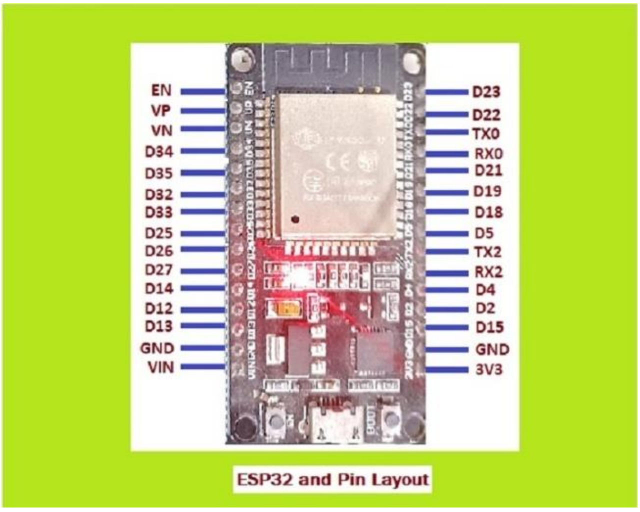


Fig.3 ESP32 and its Pin Description

2. Voltage Sensor

The voltage sensor is connected to the AC supply through an appropriate potential divider or isolation transformer as shown in Figure.4. It steps down the high AC voltage to a low-level signal suitable for the ESP32 ADC input. The instantaneous voltage signal v(t) is sampled and used to compute the RMS voltage:

$$V_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} v_i^2} \quad (1)$$

Where v_i represents the sampled voltage values and N is the number of samples per cycle. Accurate voltage measurement is critical for calculating real power and detecting abnormal voltage conditions.

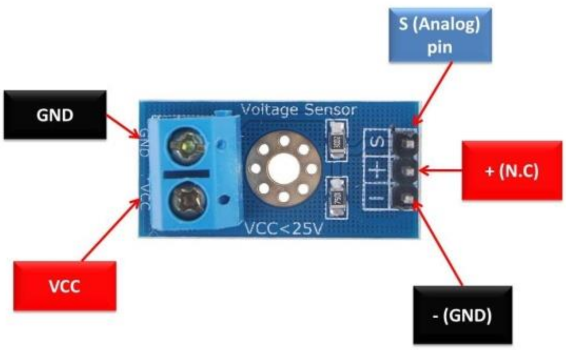


Fig.4 Voltage Sensor Module

3. Current Sensor

The current sensor measures the load current flowing through the system. Sensors such as CTs or Hall-effect sensors generate a proportional low-level output voltage corresponding to the load current as shown in Figure.5. The RMS current is computed using:

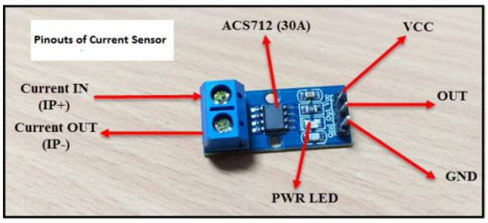


Fig.5 Current Sensor Module

$$V_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} i_i^2} \quad (2)$$

Where i_i represents sampled current values. This data is synchronized with voltage samples to calculate instantaneous and average power

4. Power and Power Factor Calculation

The instantaneous power is calculated by multiplying sampled voltage and current values:

$$p(t) = v(t) \times i(t) \quad (3)$$

The average real power P is obtained by averaging instantaneous power over a time window:

$$P = \frac{1}{N}\sum_{i=1}^{N} v_i \times i_i \quad (4)$$

The apparent power S is given by:

$$S = V_{rms} \times I_{rms} \quad (5)$$

The power factor (PF) is calculated as:

$$PF = \frac{P}{S} \quad (6)$$

These parameters allow the system to accurately evaluate energy consumption and efficiency.

5. Energy Consumption and Prepaid Credit Management

Energy consumption is obtained by integrating power over time:

$$E = \int P(t)\, dt$$

$$E = \int P(t)dt \quad (7)$$

In digital implementation, this is approximated as:

$$E = \sum_{k=1}^{M} P_k \times \Delta t \quad (8)$$

Where Δt is the sampling interval. The energy value is converted into billing units (kWh), and the corresponding cost or units are deducted from the prepaid balance stored in the ESP32 memory.

6. Sub-Meter

the sub-meter independently and reliably measures the electrical energy usage that it supplies the data used to create the accurate bills; it produces pulse outputs with each pulse representing a specific quantity of energy (e.g., 1000 pulses = 1kWh) as shown in figure 6; these pulse signals are fed into the ESP32's interrupt capable pins to enable pulse counting at extremely high loads without losing any pulses; each incoming pulse is detected through an interrupt service routine (ISR);

based on this ISR, the ESP32 increments a pulse counter; the total energy consumed is determined by calculating the accumulated pulse counter value to determine energy units, through a pre-determined calibration factor. the total energy usage is therefore calculated as:

$$Energy\ (Kwh) = \frac{Total\ Pulse\ Count}{Pulses\ per\ Kwh}$$

The ESP32 microprocessor is the main processing/computational component of the prepaid energy meter. It samples the analog signals from the voltage and current sensors through its onboard Analog-to-Digital converter (ADC); the sampled signals are then processed using digital signal processing to compute electrical parameters including but not limited to the root mean square (rms) of both voltage and current, the rms of both voltage and current, real power, apparent power, power factor, and the total amount of energy consumed. The ESP32 also monitors the prepaid account balance of each user by subtracting the amount of energy consumed at different times. In addition, the ESP32 controls the relay module which turns loads off/on, uses UART communication to communicate with the GSM module in order to send SMS alerts to users when their load has been switched off due to a low prepaid account balance or other alarm conditions, and utilizes the built-in WiFi capabilities of the ESP32 to transmit energy consumption information to a cloud-based server to allow for remote monitoring of the system and user access to the system through a mobile application.

Fig.6 Smart Prepaid Energy Meter

$$E_{sub} = N_p \times k \qquad (9)$$

where Np is the number of pulses counted and k is the energy constant (e.g., pulses per kWh). This ensures measurement accuracy and helps in detecting tampering or discrepancies.

7. 16×2 LCD Display with I²C Interface

The 16×2 LCD display shows real-time electrical parameters such as voltage, current, energy consumption, and remaining prepaid balance as shown in Figure.7. The I²C interface uses two communication lines SDA and SCL to transmit data from the ESP32, minimizing pin usage and simplifying system wiring. The display is periodically updated with processed values.

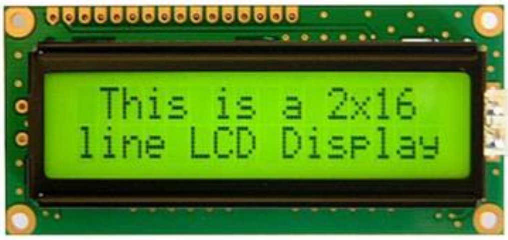


Fig.7 16×2 LCD Display

8. 4-Channel Relay Module

The relay module enables switching and control of multiple electrical loads. The ESP32 controls each relay based on prepaid balance and peak load conditions as shown in Figure.8. When the total power exceeds the preset threshold Pmax, low-priority loads are disconnected:

Fig.8 Relay Module

$$If\ P > P_{max} \Rightarrow\ Load\ shedding\ initiated$$

Similarly, when the prepaid balance reaches zero, the relay controlling the main load is turned OFF automatically.

9. GSM Module

The GSM module provides cellular communication for sending SMS alerts to the consumer. The ESP32 sends AT commands via UART to trigger SMS notifications as shown in Figure.8. Alerts include low balance warning, recharge confirmation, overload detection, and power cutoff information. This ensures reliable communication even in the absence of internet connectivity.

Fig.9 GSM module interfacing

10. DC-to-DC Buck Converter

The DC-to-DC buck converter steps down the input voltage to regulated levels suitable for different components such as the ESP32, GSM module, sensors, and relay module. The output voltage Vo of the buck converter is related to the duty cycle D by:

$V_o = D \times V_{in}$ (10)

Stable voltage regulation ensures reliable system operation and protects sensitive electronic components.

11. Buzzer

The buzzer provides audible alerts for critical events such as low prepaid balance, overload conditions, and power disconnection as shown in Figure.10. The ESP32 activates the buzzer using digital or PWM signals, enhancing user awareness and safety.

Fig.10 piezo Buzzer

IV. Database and Android Communication

The new Smart Meter with IoT capabilities can send/receive data via the Internet to enable real-time monitoring and control. Internet capability will allow for home automation and remote load management, both necessary features of this smart meter. The proposed system includes an Android app to allow users to see their current energy usage, remaining prepaid balance, recharge units, and turn on/off connected loads. To provide a continuous flow of data between the hardware and the mobile app, the system uses a Firebase cloud database to store and manage all relevant data (sensor readings, energy consumption data, relay statuses, etc.) The ESP32 microcontroller sends real-time sensor readings, energy consumption, relay status, and current balance info to the Firebase database via Wi-Fi capabilities. The Android app receives these same values from the database and shows them to the user in real time. Each time the user makes a request through the app (recharge unit, switch load), the updated values are sent back to the database; the ESP32 is always checking the database and updating how it operates accordingly so that there is continuous communication between the hardware and the Android app.

5. UNIT MEASUREMENT AND PREPAID BILLING OPERATION

The optocoupler detects the LED pulse output of the conventional smart prepaid energy meter for use as an input for the ESP32 microprocessor. The optocoupler provides the electrical isolation and converts the LED blink into a digital pulse which can be further processed by the ESP32. The ESP32 counts the pulses to measure the energy usage. Thirty-two LED pulses represent one unit of the energy usage within the implemented system. The system calculates and updates the energy usage units continuously and stores them in both the local system memory and the cloud based database. The amount of money billed per unit is set by the user via the Android application and then stored in the Firebase database. The number of units that have been credited to the customer's account are determined using equation (1).

$$Credited\ Units = \frac{Entered\ Amount}{Price\ per\ Unit}$$

The energy consumed per LED blink is calculated using Equation (2):

$$Units\ per\ Blink = \frac{1\ Unit}{32\ Blinks} = 0.03125\ Units$$

At all times, the ESP32 continually measures the amount of consumption (units) against the amount of credit (units). The ESP32 will activate a relay module which connects to and supplies power to the attached load when there is credited unit(s) remaining. Consumption is then logged as "units consumed" while crediting is logged as "unit(s) credited" until all credited units have been utilized. At that point the ESP32 de-activates the relay module which disconnects the load and notifies the user via both the GSM module and Android app; thus ensuring accurate pre-paid billing, preventing excessive consumption and providing the user with transparent information regarding their consumption.

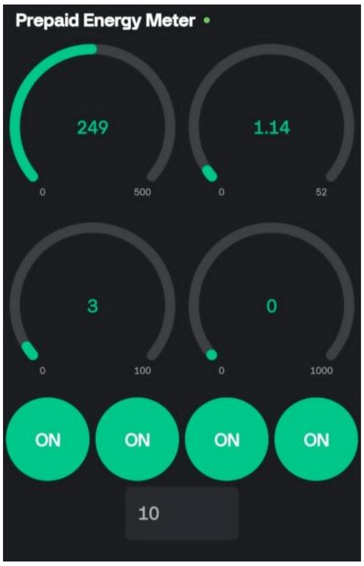
6. RESULTS AND DISCUSSION

The system's capability for real-time monitoring, prepaid billing, home automation, and peak load management was evaluated by implementing and testing the proposed system using IoT and GSM technologies. Upon activation of the hardware kit, the LCD display will show whether GSM initialization was successful, thus showing communication was established between the GSM module and the ESP32. Upon successful initialization of the GSM module, the LCD will prompt the user to make a missed call to the saved mobile number on the SIM card in the GSM module. This process confirms the user's identity and secures their registration. Upon receiving the missed call from the user, the user's mobile number will be displayed on the LCD, and the user will receive a confirmation SMS that their mobile number was successfully registered with the system. After successful GSM registration, the user's Wi-Fi credentials (i.e., SSID and password) will be programmed into the ESP32 via the Arduino IDE, compiled, and uploaded to the controller. With successful completion of this process, the system will begin to transmit real-time data, and allow for the continuous measurement of voltage, current, the units of electricity consumed, and the remaining prepaid balance. The Blynk IoT app serves as the main user interface for the user to monitor and control the system remotely. The app uses visual indicators to present the electrical parameters measured by the system including voltage, current, the units of electricity consumed, and the amount of the prepaid balance. Additionally, the app includes toggle buttons to turn ON/OFF each of the four loads connected to the system, and an input field for users to recharge their prepaid account. Testing revealed that the system could correctly measure and display various values during normal operation, such as 249V voltage, 1.14A current, and the remaining units of electricity, thereby demonstrating that both the sensors measuring these parameters were functioning properly and the data measured by the sensors was being transmitted properly to the mobile app. Additionally, testing demonstrated that remote load switching via the Blynk app was very fast and reliable.Data visualization based upon the system's parameters was confirmed using the ThingSpeak platform, which successfully captured and graphically presented the system's parameters over time. Data from the four fields of data collected were plotted on the graphs, with Field 1 representing the fluctuation of the system's voltage, Field 2 representing the fluctuation of the system's current, Field 3 representing the units of electricity consumed by the system, and Field 4 representing the remaining prepaid balance. The plots showed continuous real-time updates with respect to time, thereby verifying that the system's IoT components were transmitting data to the cloud effectively, and that the system's components were integrated with the cloud effectively. Testing of the system's prepaid billing feature was accomplished by charging the system via the Android app. The amount entered into the app was converted to units of electricity by dividing the amount by the predefined tariff rate of ₹5/unit. During testing, the tariff rate was defined as ₹5/unit. As long as there were credited units available, the relay module would energize and supply power to the connected loads. As the amount of energy consumed by the loads increased, so did the amount of units of electricity consumed by the loads, while the amount of credited units available decreased. When the amount of the prepaid balance fell to zero, the system would automatically disconnect all loads and display a "No Balance" message, thereby verifying that the system was functioning properly to prevent unauthorized use of the loads. Additionally, testing of the system's home automation and peak load management features was performed. The maximum load capacity of the system was limited to 2A, with 1.2A assigned to light loads and 0.8A assigned to power loads. During peak usage, when the current to the light loads exceeded the predetermined threshold, the system would automatically disconnect the power loads to limit the overall demand of the system as illustrated in Figure.9. Additionally, if an abnormal condition occurred in regards to the load, the system would indicate theft by displaying a message on the LCD, and send notifications to the user. At the end of the peak hours, the loads would automatically reconnect to the system without requiring any user interaction. Overall, the test results demonstrate that the proposed system functions properly and reliably. The combination of GSM technology for user authentication and notification, IoT technology for real-time monitoring, cloud visualization for data analysis, prepaid billing, home automation, and peak load management demonstrates the effectiveness of the system. The developed hardware provides a functional, scalable, and user-friendly solution for modern smart energy management in residential and small commercial applications.

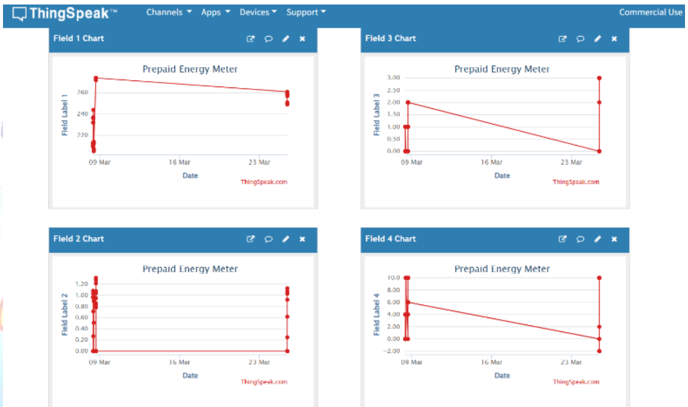
(a)

(b)

(c)



(d)



(e)

Fig.9 a-e Results of Final Hardware of the Proposed Energy Meter System

7. CONCLUSION

A smart prepaid energy meter was built using IoT and GSM technologies in this research to allow for real time monitoring of your energy usage, automated billing and smart load switching. An ESP32 micro controller is used to accurately read voltage, current, power and energy usage. Energy readings are shown on a local lcd display and also sent to both a cloud server and android app so that users can view their energy usage as well as the remaining balance at any given moment. Low balance and recharge confirmations will be sent via gsm to users regardless of their internet connection status. Additionally, gsm provides a reliable means of sending messages to customers regarding automatic power disconnections due to low balance, as well as messages to inform customers of successful recharge operations. A prepayment billing system will deduct consumed energy units from the user's available credits thereby eliminating the need for manual meter readings and decreasing billing errors. Users will have the option to disconnect un-needed electrical appliances when there is insufficient credits or during high peak demand hours utilizing relay-based load switching. This meter system was successfully tested and has provided a stable operating environment, accurate measurements and effective load management. The proposed smart prepaid energy meter increases billing clarity, promotes responsible energy use and decreases the workload of utility companies. Therefore, it represents a cost-effective and practical means of achieving smart energy management in both residential and commercial environments.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Bint Faheem, J. Energy crisis in Pakistan. IRA-Int. J. Technol. Eng. 2016, 3, 1–16.

[2] Ren, D.; Li, H.; Ji, Y. Home energy management system for the residential load control based on the price prediction. In Proceedings of the 2011 IEEE Online Conference on Green Communications, GreenCom'11, Piscataway, NJ, USA, 26–29 September 2011; pp. 1–6.

[3] Balasubramaniam, P.M.; Prabha, S.U. Power quality issues, solutions and standards: A technology review. J. Appl. Sci. Eng. 2015, 18, 371–380.

[4] Barman, B.K.; Yadav, S.N.; Kumar, S.; Gope, S. IOT Based Smart Energy Meter for Efficient Energy Utilization in Smart Grid. In Proceedings of the 2018 2nd International Conference on Power, Energy and Environment: Towards Smart Technology (ICEPE), Shillong, India, 1–2 June 2018.

[5] Talwar, P.D.; Kulkarni, S.B. IoT based energy meter reading. Int. J. Recent Trends Eng. Res. 2016, 2, 586–591.

[6] Gavhane, V.V. IoT based Energy Meter with Smart Monitoring of Home Appliances. In Proceedings of the 2021 6th International Conference for Convergence in Technology (I2CT), Maharashtra, India, 2–4 April 2021; pp. 1–5.

[7] Al-Kuwari, M. Smart-Home Automation Using IoT-Based Sensing; Electrical Engineering Department, College of Engineering, Qatar University: Doha, Qatar, 2020; pp. 1–6.

[8] Nurfadilah, M.F. Energy Saving Management with Suggestion. In Proceedings of the 2020 6th International Conference on Interactive Digital Media (ICIDM), Bandung, Indonesia, 14–15 December 2020; pp. 1–5.

[9] Patil, V.R.; Patil, M.D.; Khude, A.T. IoT Based Prepaid Energy Meter. In Proceedings of the 2020 5th International Conference on

[10] L. Lakatos, G. Hevessy, and J. Kovács, "Advantages and Disadvantages of Solar Energy and Wind Power Utilization," Publisher: Routledge Informa Ltd Registered in England and Wales Registered Number: 1072954.

[11] Ankit Kekre, Suresh K. Gawre," Solar Photovoltaic Remote Monitoring System Using IoT", Proceeding International conference on Recent Innovations is Signal Processing and Embedded Systems (RISE -2017) 27-29 October,2017.

[12] Rolf Arne Kjellby, Thor Eirik Johnsrud, Svein Erik Loetveit,Linga Reddy Cenkeramaddi,Mohamed Hamid and Baltasar Beferull-Lozano, "Self-Powered IoT Device for Indoor Applications", 2018 31th International Conference on VLSI Design and 2018 17th International Conference on Embedded Systems.

[13] https://components101.com/development-boards/nodemcu-esp8266- pinout-features-and-datasheet

[14] Aygegül Tagçjollu, Onur Tagkjn and Ali Vardar," A Power Case Study for Monocrystalline and Polycrystalline Solar Panels in Bursa City, Turkey", Hindawi Publishing Corporation International Journal of Photoenergy [Volume 2016, Article ID 7324138].

[15] Osaretin C.A., Edeko F.O, "Design and Implementation of a Solar Charge Controller with Variable output." Journal of Electrical and Electronic Engineering [Vol 12, No 2, ISSN 1118 – 5058, November 2015].

[16] Homera Durani, Mitul Sheth, Madhuri Vaghasia, Shyam Kotech, "Smart Automated Home Application using IoT with Blynk App", Proceedings of the 2nd International Conference on Inventive Communication and Computational Technologies (ICICCT 2018) IEEE Xplore Compliant – Part Number: [CFP18BAC-ART; ISBN:978-1-5386- 1974-2].

[17] Soham Adhya , Dipak Saha , Abhijit Das , Joydip Jana , Hiranmay Saha, "An IoT Based Smart Solar Photovoltaic Remote Monitoring and Control unit", 2016 2nd International Conference on Control, Instrumentation, Energy & Communication (CIEC).

[18] Dr. M.Mahalakshmi, Dr.S.P.Rajaram, S.Priyanka, R.Rajapriya, "Distant Monitoring And Controlling Of Solar Driven Irrigation System Through IoT", 2018 National Power Engineering Conference (NPEC).

[19] Oran Chieochan,Anukit Saokaew, Ekkarat Boonchieng," Internet of things (IoT) for smart solar energy: A case study of the smart farm at Maejo University", 2017 International Conference on Control, Automation and Information Sciences (ICCAIS) October 31-November 3, 2017, Chiang Mai,Thailand.

[20] Mubashir Ali, Mahnoor Khalid Paracha," An IoT Based Approach For Monitoring Solar Power Consumption With Adafruit Cloud" International Journal Of Engineering Applied Sciences And Technology, 2020,[Vol. 4, Issue 9, ISSN No. 2455-2143, Pages 335-341].

[21] Nallapaneni Manoj Kumar, Karthik Atluri, Sriteja Palaparthi," Internet of Things (IoT) in Photovoltaic Systems", 2018 National Power Engineering Conference (NPEC).