Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 7, June. 2026
Paper Id: – IJ2026V6I7 -17 A-F
ISSN 2582-6026

IOT-BASED SMART ENERGY MONITORING AND THEFT DETECTION SYSTEM

[1]Vijaya Pravin Kshirsagar, [2]Avhad Savita Bhaskar, [3]Solase Laxmi Gorakh, [4]Hatkar Vrushali Kishor, [5]Tejasvini popat Jadhav, [6]Prof. C. K. Shejwal

[1]UG Scholar, Electrical Dept., SND College of Engineering and research center,Yeola
[2]UG Scholar, Electrical Dept., SND College of Engineering and research center, Yeola
[3]UG Scholar, Electrical Dept., SND College of Engineering and research center, Yeola
[4]UG Scholar, Electrical Dept., SND College of Engineering and research center, Yeola
[5]UG Scholar, Electrical Dept., SND College of Engineering and research center, Yeola
[6]Asst. Prof. Electrical Dept. ., SND College of Engineering and research center, Yeola

ABSTRACT - This research introduces a novel IoT-integrated smart energy meter that can identify energy theft on its own and track power use in real time. The solution uses cloud platforms (Blynk/Thingspeak) and microcontrollers like Arduino or ESP32 to avoid manual meter reading problems and give customers clear use statistics. The inbuilt theft detection algorithm promptly notifies authorities and initiates a remote power cutoff via relay when it detects unauthorized tapping by comparing input and output currents.

I. INTRODUCTION

1.1 Overview of Electrical Energy Management

One of the most crucial resources for the advancement of contemporary society is electrical energy. Electricity is essential to nearly every facet of human existence, including household tasks, industrial production, agricultural operations, healthcare services, educational institutions, transportation networks, and communication systems. The world's need for electrical energy has dramatically expanded due to industrialization, population expansion, and technological breakthroughs. As a result, government organizations and utility companies now face significant obstacles in the effective production, transmission, distribution, monitoring, and use of electricity.

The main components of conventional power metering systems are electromechanical or electrical energy meters that require manual reading by authorized personnel. In these conventional systems, electricity board employees visit consumer premises periodically to record energy consumption and prepare bills. Although this method has been widely adopted for many years, it suffers from numerous limitations, such as human errors during meter reading, delayed bill generation, inaccurate billing, high labor costs, and inefficient energy management. Moreover, the conventional postpaid billing system allows consumers to pay only after utilizing electrical energy, which often results in delayed payments and increased financial burden on electricity distribution companies. Power theft is a major issue with current electrical distribution networks. The unlawful use of electrical energy by unauthorized connections, meter tampering, meter bypassing, or direct tapping from distribution lines is referred to as electricity theft. Power theft negatively impacts the stability and dependability of the power distribution network and results in significant financial losses for utility companies. Numerous studies indicate that a significant portion of all power outages in many developing nations are caused by electricity theft. Thus, the development of intelligent, automated, and secure energy metering systems that can minimize energy losses while guaranteeing precise billing and effective power control is imperative.

1.2 Need for GSM-Based Prepaid Electricity Metering System

The existing electricity billing system faces several operational and technical challenges. Manual meter reading requires a large workforce, leading to increased operational expenses for electricity boards. In remote areas, meter reading becomes even more difficult due to geographical constraints and accessibility issues. Furthermore, errors introduced during manual data collection may result in incorrect billing, causing dissatisfaction among consumers. Delayed payment of electricity bills is another major concern for utility providers. Since traditional systems operate on a postpaid basis, consumers may fail to pay bills on time, resulting in revenue losses and additional efforts for bill collection. In many cases, electricity supply has to be disconnected manually, which further increases operational costs.

One of the most important problems affecting energy distribution networks globally is power theft. In addition to lowering income, illegal electricity use leads to serious technical issues such overloading, voltage swings, and declining power quality. Because unlawful actions are frequently hidden from utility officials, it is very difficult to detect power theft using traditional methods. The suggested GSM-based prepaid electrical energy meter offers a clever and practical way to get around these restrictions. By ensuring that customers recharge their accounts prior to consuming power, the prepaid approach eliminates problems associated with late payments and delinquent bills. GSM technology integration allows for remote communication between consumers and utility providers through Short Message Service (SMS). Automatic notifications regarding low balance, recharge status, energy consumption, and theft detection can be transmitted instantly without requiring physical intervention.

II. LITERATURE REVIEW

2.1 Literature Review

S. Vivek and M. Ramya (2018) proposed a GSM-based prepaid energy meter system for automatic billing applications. The system utilized a microcontroller and GSM communication to monitor energy consumption and transmit billing information to consumers. The authors concluded that the proposed system effectively reduced manual meter reading and improved billing accuracy. However, the system lacked advanced power theft detection capabilities.

P. S. Kulkarni et al. (2019) developed a smart prepaid energy meter using GSM technology and RFID recharge mechanisms. The proposed system enabled consumers to recharge electricity credits using RFID cards. The study demonstrated improved consumer awareness regarding electricity consumption. However, the system did not incorporate remote monitoring or IoT

A. Kumar and R. Singh (2020) presented an IoT-based smart energy meter for real-time electricity monitoring. The system used wireless communication to upload energy consumption data to cloud servers. Consumers could monitor energy usage remotely using mobile applications. Although the system provided real-time monitoring, it did not include automatic theft detection functionality.

M. Ahmed and S. Khan (2018) proposed a GSM-based automatic energy billing system that automatically generated electricity bills and sent SMS notifications to consumers. The system minimized billing errors and reduced manual intervention. However, the proposed system was unable to disconnect the supply automatically when bills remained unpaid.

R. Patel et al. (2021) designed a smart electricity meter with power theft detection using current sensing techniques. The system continuously monitored current variations to identify unauthorized electricity usage. Experimental results demonstrated effective theft detection under various operating conditions. Nevertheless, GSM communication was not integrated into the system.

J. Thomas and K. Joseph (2019) developed a prepaid energy meter using an embedded microcontroller and relay control mechanism. The relay automatically disconnected the electrical supply whenever the balance became insufficient. The authors reported improved revenue collection efficiency. However, the system lacked communication capabilities for sending

B. Sharma and N. Gupta (2020) proposed a wireless smart metering system using GSM and ZigBee technologies. The system enabled remote meter reading and automatic bill generation. Although the system improved operational efficiency, the complexity and implementation cost were relatively high.

S. Das et al. (2021) introduced an intelligent electricity monitoring system integrated with GSM and IoT technologies. The system continuously monitored electrical parameters and provided remote access to users. The proposed system offered enhanced energy management; however, theft prevention mechanisms were limited.

K. Reddy and V. Rao (2022) developed a smart prepaid energy meter with automatic billing and load control features. The system provided automatic supply disconnection during low balance conditions and transmitted alerts using GSM communication. The study highlighted significant improvements in billing efficiency but suggested further enhancements for advanced theft detection and cloud integration.

III. OBJECTIVES

The primary objectives -

1. To create a prepaid electrical energy meter based on GSM technology.
2. To put in place automated electricity billing.
3. To keep an eye on power factor, voltage, current, and frequency.
4. To precisely determine energy usage in real time.
5. To provide customers prepaid power use options.
6. To use GSM technology to deliver SMS notifications about low balances and billing details.
7. To cut off the power supply automatically when the prepaid balance drops to zero.
8. To identify power theft and unapproved electricity use.
9. To increase utility providers' efficiency in collecting revenue.
10. To lower operating costs and manual intervention.
11. To raise consumer awareness of power usage.To develop a reliable and cost-effective smart energy management system.

IV. METHODOLOGY

An ESP32 microcontroller, a GSM communication module, circuitry for measuring voltage and current, an LCD display, and a relay control mechanism are all integrated into the suggested technique. To determine the amount of electrical energy used, the system continually analyzes electrical characteristics including voltage, current, frequency, and power factor. The available prepaid balance is automatically updated based on the observed energy use. Customers replenish power credits ahead of time under the prepaid basis of the system. The appropriate amount is automatically subtracted from the available balance when power is used. SMS messages on low balance, recharge status, billing details, and power theft alarms are sent by the GSM module. A relay circuit immediately cuts off the electrical supply if the balance drops to zero or power theft is discovered.

4.1 Proposed Methodology

The methodology adopted for the proposed system consists of the following major stages:

Step 1: Initialization of System

Initially, the ESP32 microcontroller initializes all connected peripherals such as LCD display, GSM module, sensors, relay unit, and communication interfaces. After initialization, the system verifies the operational status of all modules.

Step 2: Measurement of Electrical Parameters

The voltage measurement circuit continuously measures the AC supply voltage. Similarly, the current transformer continuously senses the load current. The frequency measurement and power factor measurement circuits monitor additional electrical parameters required for accurate energy computation.

Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 7, June. 2026
Paper Id: – IJ2026V6I7 -17 A-F
ISSN 2582-6026

Step 3: Energy Consumption Calculation

The measured voltage and current values are processed by the ESP32 microcontroller to calculate electrical power. The energy consumed by the connected load is determined continuously using mathematical equations.

Step 4: Prepaid Balance Management

The available prepaid balance is stored within the microcontroller memory. Whenever electrical energy is consumed, the corresponding cost is automatically deducted from the available balance.

4.2 The flowchart

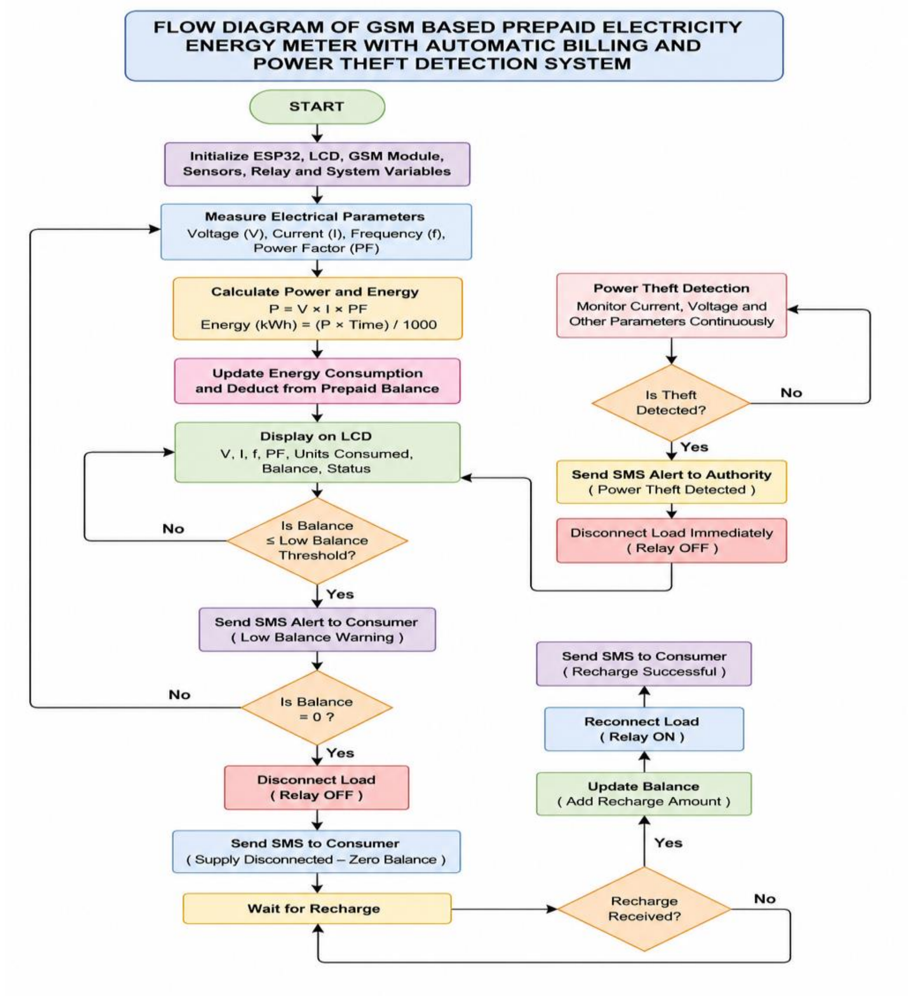

Fig 1- The Flowchart

Innovative Journal for Opportunities and Development in Science & Technology,
Volume 6, Issue 7, June. 2026
Paper Id: – IJ2026V6I7 -17 A-F
ISSN 2582-6026

V. SIMULATION RESULT

5.1 Introduction

Simulation plays a vital role in validating the performance and functionality of the proposed system before practical implementation. It provides an effective platform for analyzing the behavior of the system under different operating conditions. The simulation study helps in verifying the correctness of the designed circuitry, control algorithms, and communication mechanisms.

5.2 Simulation Environment

The simulation and software implementation of the proposed system were carried out using the following tools:

Sr. No.	Software Tool	Purpose
1	Proteus Design Suite	Circuit simulation
2	Arduino IDE	Embedded program development
3	Embedded C	Software coding
4	Serial Monitor	Data monitoring and debugging

5.3 Simulation Setup

The complete simulation model consists of the following sections:

- ESP32/Microcontroller Unit
- Voltage Measurement Circuit
- Current Measurement Circuit
- LCD Display Module
- GSM Communication Module

The simulation setup continuously monitors electrical parameters and updates the prepaid balance according to energy consumption.

5.4 Case 1: System Initialization

Initially, when power is supplied to the system, all hardware peripherals are initialized by the ESP32 microcontroller.

Observations

- LCD displays welcome message.
- GSM module establishes network connection.
- Sensors are initialized successfully.
- Relay remains in ON state if sufficient balance exists.
- Initial prepaid balance is displayed.

Result

The system initializes successfully without any errors and enters normal operating mode.

VI. CONCLUSION

The created system continually monitors critical electrical characteristics including voltage, current, frequency, and power factor using an ESP32 microcontroller as the central processing unit. The technology precisely determines the amount of electrical energy used and automatically changes the prepaid balance based on these criteria. While guaranteeing prompt revenue collection for electricity distribution firms, the introduction of a prepaid billing system encourages customers to use electrical energy effectively. Utility authorities and customers may communicate wirelessly thanks to the incorporation of the SIM800L GSM module. SMS messages about low balance situations, recharge confirmation, electricity billing details, and power theft alarms are all successfully sent by the system. This real-time communication feature lowers the requirement for manual intervention and greatly raises customer awareness.

Automatic power theft detection is a key component of the suggested solution. In order to detect unlawful power consumption, the system continually analyzes electrical conditions. The system instantly sends an alarm message and uses a relay mechanism to cut off the electrical supply once a theft circumstance is recognized. This feature improves the security of the power distribution network and reduces monetary losses brought on by illicit electricity use. When the prepaid balance drops to zero, the relay control section automatically disconnects the supply and reconnects it upon a successful recharge. This automation increases operational efficiency and lowers the need for human labor.

The results of the simulation and experiment show that the suggested system functions well in a range of operational scenarios. The technology offers precise energy measurement, automatic billing, effective theft detection, reliable GSM communication, and efficient load control. Therefore, the proposed GSM-based prepaid electricity energy meter offers a cost-effective, secure, and user-friendly solution for smart energy management applications.

REFERENCES

1. Carlos Robles Algarín , John Taborda Giraldo and Omar Rodríguez Álvarez, ”Fuzzy Logic Based MPPT Controller for a PV System” ,www.mdpi.com / journal / energies 2017
2. B.Krishna Naick, T.K.Chatterjee, “K.Chatterjee “Fuzzy Logic Controller based PV System Connected in Standalone and Grid Connected Mode of Operation with Variation of Load”, International Journal Of Renewable Energy Research
B.K. Naick et al., Vol.7, No.1, 2017
3. Dinut-Lucian Popa, Marian-Stefan Nicolae, Petre-Marian Nicalea and Marius Popescu, “Design and simulation of 10MW power plant using MATLAB and Simulink”. IEEE international power conference, 2016
4. Pravinkumar chandran, Vishnukumar Murugesan, “a solar power production system using MPPT with grid synchronization for Distributed Power production and distribution” , International journal of electrical and electronics Engineering Reserch (IJEER), Vol-4,Issue 1, PP-133-132, Feb 2014
5. Govind Anil, Nirmal Murugan, Mufeed Ubaid “PI Controller based MPPT for a PV System” IOSR Journal of Electrical and Electronics Engineering”, (IOSR-JEEE), Volume 6, Issue 5 (Jul. - Aug. 2013), PP 10-15
6. R.-L. Lin, C. Hong-Zhi, “MPPT photovoltaic wide load-range ZVS phase-shift full-bridge charger with DC-link current regulation“, 2012 IEEE Industry Applications Society Annual Meeting (IAS), pp.1-8, 7-11 Oct. 2012
7. M.I. Hossain, S.A. Khan, M. Shafiullah, M.J. Hossain, “Design and implementation of MPPT controlled grid connected photovoltaic system“, 2011 IEEE Symposium on Computers & Informatics (ISCI), pp. 284-289, 20-23 March 2011
8. M. A. G. de Brito, L. P. Sampaio, G. Luigi, G. A. e Melo and C. A. Canesin, “Comparative analysis of MPPT techniques for PV applications“, 2011 Int. Conf. on Clean Electrical Power (ICCEP), Ischia, pp. 99-104, 2011
9. J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galvan, R. C. P. Guisado, Ma. A. M. Prats, J. I. Leon, N. Moreno-Alfonso, “Power Electronic Systems for the Grid Integration of Renewable Energy Sources: A Survey”, IEEE Trans. on Ind. Electr., Vol. 53, Issue 4, June 2006, pp. 1002 – 1016