International Journal of Scientific Research and Engineering Development-– Volume 9 Issue 1, Jan-Feb 2026
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Smart Energy Monitoring and Safety System

[1]Mr. Shubham S. Nimbekar, [2]Babali R. Chakole, [3]Ashwini B. Malewar, [4]Samruddhi P. Hinge, [5]Tushar V. Wanjari, [6]Gaurav R. Panchbudhe

[1]Assistant Professor, Department of Electrical Engineering, Kavikulguru Institute of Technology & Science, Ramtek, Nagpur, Maharashtra, India-441106,

[2]B.Tech. Scholar, Department of Electrical Engineering, Kavikulguru Institute of Technology & Science, Ramtek, Nagpur, Maharashtra, India-441106,

[3]B.Tech. Scholar, Department of Electrical Engineering, Kavikulguru Institute of Technology & Science, Ramtek, Nagpur, Maharashtra, India-441106,

[4]B.Tech. Scholar, Department of Electrical Engineering, Kavikulguru Institute of Technology & Science, Ramtek, Nagpur, Maharashtra, India-441106,

[5]B.Tech. Scholar, Department of Electrical Engineering, Kavikulguru Institute of Technology & Science, Ramtek, Nagpur, Maharashtra, India-441106,

[6]B.Tech. Scholar, Department of Electrical Engineering, Kavikulguru Institute of Technology & Science, Ramtek, Nagpur, Maharashtra, India-441106

Abstract:

Whether it's in our homes or small businesses, we rely on electricity for almost everything, but issues like voltage drops and power surges can easily ruin expensive appliances if they aren't handled properly. To address these issues, we developed a Smart Energy Monitoring and Safety System that acts as a digital guard for the power supply. It works by monitoring voltage and current levels in real-time and is also programmed to automatically disconnect the power the moment it detects a rise or a dangerous dip in voltage. This system not only improves safety but also helps users become more aware of their energy usage patterns. The system reduces traditional dependencies by adding automation and intelligence to the electrical setup. To make it a real-world product, the system features a built-in LCD screen that gives live updates on energy statistics to get the latest update about the system's health. By using cost-effective components, this setup provides an easy, low-cost way to automate electrical safety, protect equipment, and cut down on the need for manual supervision.

Keywords — ***Smart Energy Monitoring, Voltage Drop Protection, LCD Display System, Voltage Sensing, Electrical Safety System.***

I. INTRODUCTION

Electricity became an essential part of life as it is powering homes, offices, small-scale and large-scale industries. However, problems such as voltage fluctuations, overload and sudden changes in demand can damage appliances and reduce system reliability. This will not only affect the performance but may also create safety risks if not handled properly. Traditional protection devices, such as fuse circuit breakers, provide basic safety, but they do not continuously monitor electrical conditions. When these problems are identified, some of the appliances are already damaged. With the rapid use of sensing electronic devices, there is a need to switch for smarter system that can monitor electrical parameters in real time and respond immediately or give a warning to an unsafe condition.

The proposed idea, Smart Energy Monitoring and Safety System, is designed to meet the given requirements. It continuously measures voltage and current, compares them with safe limits and disconnects the load automatically during undervoltage situations. An LCD display provides live system information, making monitoring simple

and user-friendly. This system offers a practical and cost-effective approach to improve electrical safety.

II. System Overview

The Smart Energy Monitoring and Safety System is a solution developed to monitor electric current and control AC loads safely using an ESP32 microcontroller. It works by integrating power conversion, sensing, processing, protection and user display units into a single compact setup to ensure reliable operation under normal and abnormal conditions.

The system gets power from a 230V AC mains supply, which is stepped down to 12V AC using a step-down transformer, and this reduced voltage is converted into DC through a bridge rectifier and regulated using a 7805voltage regulator to provide a stable power supply for the ESP32 microcontroller and the 16×2 LCD. This ensures the consistent operation of all low-power electronic components.

Load Current is tracked using a Current Transformer (CT), which is used to detect the current flowing through the AC load and produces a small proportional signal. This signal is then rectified and sent to the ESP32 for further processing. After receiving the current values, the ESP32 continuously checks whether the system is operating under safe conditions or not.

For protecting and controlling the load, ESP32 sends a control signal to the BC547 transistor, which helps in driving the relay. This relay ensures that proper electrical isolation is maintained between the low-power control circuit and the high-voltage AC load. A buzzer is provided to alert the user during an abnormal and sudden rise or dip in voltage. Simultaneously, the LCDs provide real-time current readings along with the system status, making it easy for the user to monitor the operation.

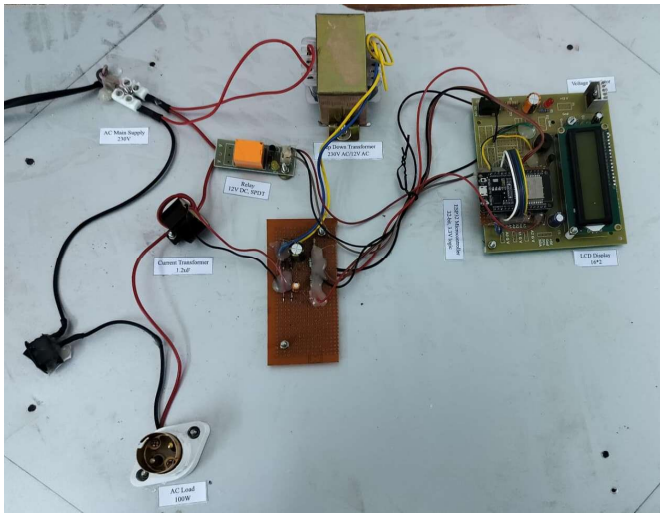

Fig. 1 Hardware of the device

III. Working Flow

When the main power supply is turned ON, the step-down transformer reduces the 230V AC input voltage to a lower voltage suitable for the given circuit to use safely. This low AC voltage is then converted into DC using a bridge rectifier and regulated to a stable level with the help of a voltage regulator. The regulated DC power is supplied to the ESP32 microcontroller and LCD Display to power the system.

Once power is supplied to all the components, the current transformer starts continuously sensing the amount of current flowing through the AC load. It produces a small proportional signal which is then converted into a suitable DC form and given as input to the ESP32 for analysis. This microcontroller continuously reads and processes the data and displays the updated information on the LCD in real time.

During normal operating conditions, the relay remains activated, allowing the AC load to function properly without any interruption. However, if the sensed current goes beyond the preset safe limit or any abnormal condition is detected, the ESP32 immediately sends a signal to the transistor to turn OFF the relay. Due to this action, the load is disconnected to prevent possible damage and simultaneously buzzer gives an alert to indicate that a fault has occurred.

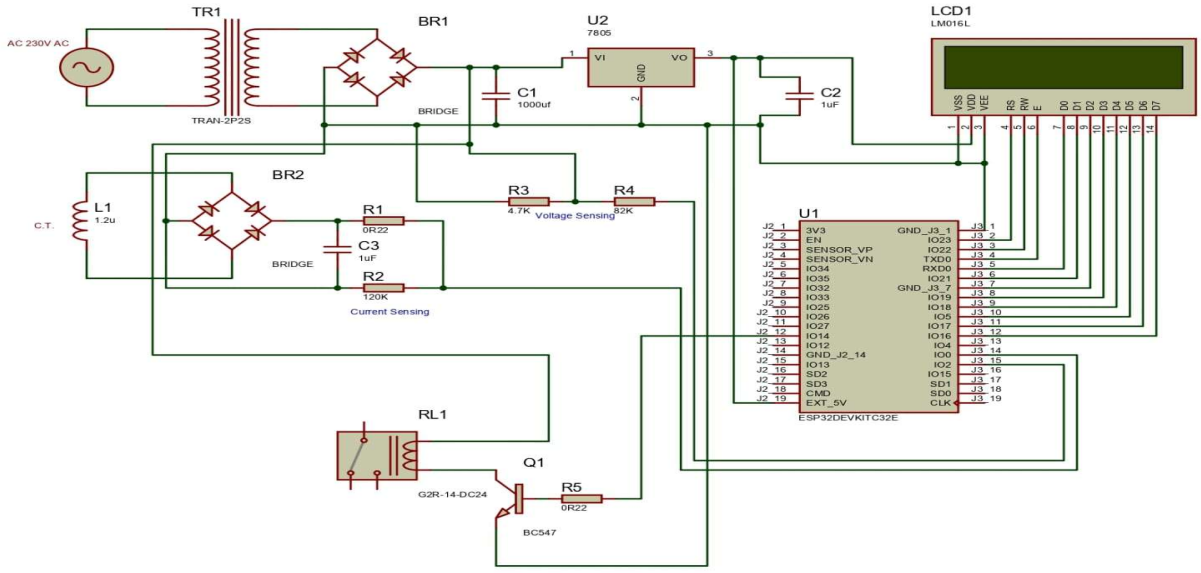

Fig. 2 Schematic circuit diagram of the device

IV. RESULT

The system of Smart Energy Monitoring and Safety System was tested under different operating conditions to evaluate its performance. During normal circumstances, the system successfully displayed real-time parameters on the LCD. The voltage and current values were continuously updated, giving real-time energy consumption of the connected AC load. The figure below represents a bulb that is glowing, which indicates that the voltage and current are within safe limits.

Fig. 3 Normal Operating Condition of Current and Voltage

However, when voltage fluctuations were introduced, and voltage exceeded the safe limit, the system responded immediately by giving a buzzer alarm, and the ESP32 detected the abnormal condition and deactivated the relay, leading to automatic disconnection of the AC load. This confirms that the system works effectively under different conditions.

As shown in the figure below of LCD display of the system displays real-time energy consumption of the connected load.

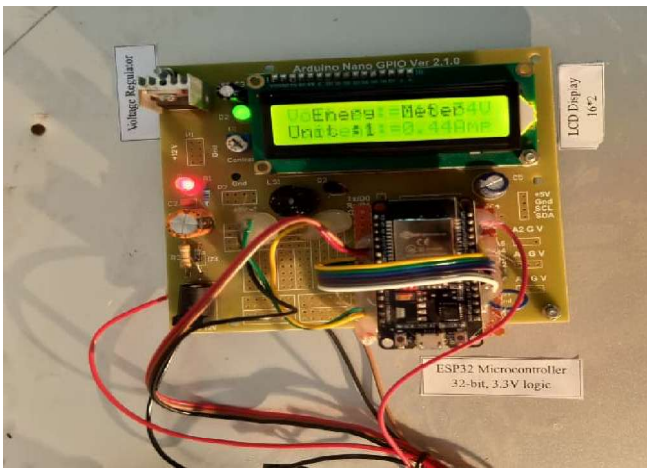

Fig. 4 LCD Displaying Load Consumption

Figure 5 shows instantaneous voltage and current values (approximately 221–222 V and 0.44 A),

which are changing during each operation, and the same value is updated on the LCD.

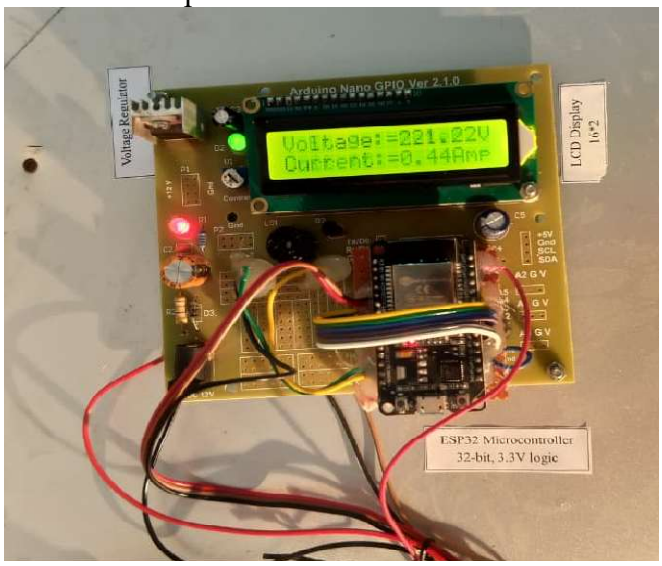

Fig. 5 LCD displaying voltage and current values

The system is tested under different condition such as when the voltage is above or below the safe limits, the system is off, and the display is shown on the LCD. This shows that the ESP32 correctly detects an abnormal condition and disconnects the load. This ensures that the protection mechanism functions correctly under different conditions

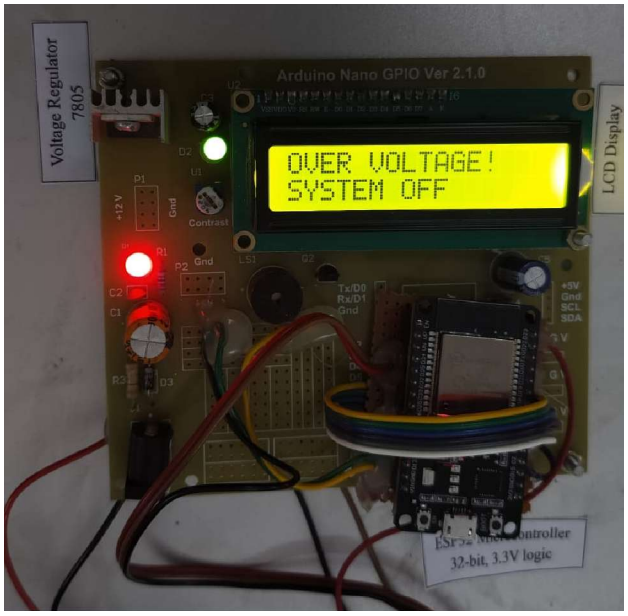

Fig. 6 LCD displaying system off on overvoltage condition

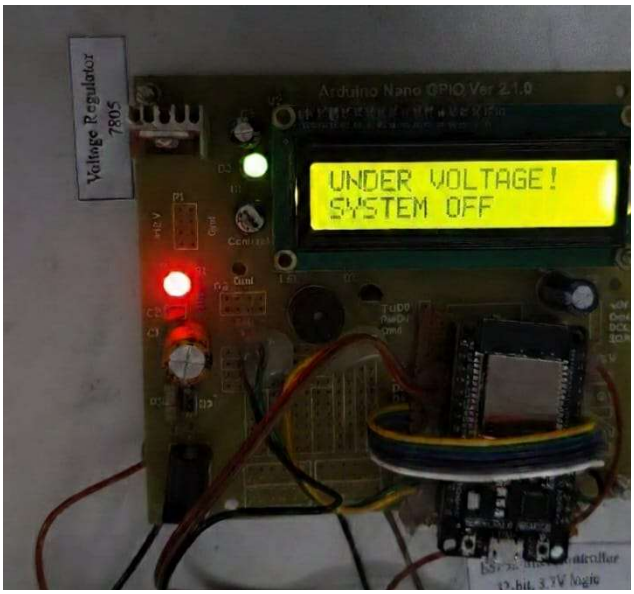

Fig. 6 LCD displaying system off on undervoltage condition

V. CONCLUSIONS

The proposed system, Smart Energy Monitoring and Safety System, is primarily designed to monitor load current, voltage fluctuations, and protect the electrical appliances from getting damaged due to a sudden rise or dip in voltage. The system used an ESP32 microcontroller to continuously monitor and track current levels and automatically disconnect the load when undesirable conditions are detected.

LCD is used to display real-time values and system status, and also makes it user-friendly by providing a buzzer that gives an immediate alert during fault conditions. Use of simple and low-cost components makes the system easy to implement and a reliable and valuable product for residential and small-scale applications.

Key Benefits

- It provides continuous monitoring of voltage fluctuation to ensure safe operation.
- It automatically disconnects the AC load during abnormal conditions, reducing the risk of damage.
- It improves user awareness by displaying real-time status and current values on the LCD screen.

- It offers an audible alert, i.e. buzzer, helping users quickly identify fault conditions.
- It uses easily available and low-cost components, making it economical and easy to implement.
- It reduces the need for manual supervision and enhances overall electrical safety.

Future Scope

- Wireless communication features such as Wi-fi or IoT integration can be added for remote monitoring.
- Data logging functionality can be implemented to analyse energy usage over time.
- A mobile or web application can be developed to display system status and alerts via notification.
- This system can be enhanced to support multiple loads and high power ratings for industrial use.

REFERENCES

[1] A. Q. Mohammed, Z. H. D. ALBadri, I. M. Jawad, and I. R. N. ALRubeei, "Using IoT applications for detection of the overvoltage and undervoltage in electrical systems," *Sustainable Engineering and Innovation*, vol. 7, no. 1, pp. 41–50, 2025.

[2] A. Kumar, A. Maurya, T. P. Pandey, R. Yadav, and L. Singh, "Design and implementation of an Arduino-based over/under voltage protection system for domestic applications," *International Journal for Research in Applied Science & Engineering Technology*, vol. 13, no. 5, May 2025.

[3] G. Parshuram, P. V. Reddy, B. M. Sahith, and R. Prabhakar, "Overload protection system for home appliances using Arduino," *International Journal for Recent Developments in Science & Technology*, vol. 9, no. 4, Apr. 2025.

[4] K. R. Sonar, A. Sonkusare, A. Bhandarkar, G. Bhimte, K. Dhoke, and S. Maskar, "Real time energy monitoring using energy meter," *International Journal of Scientific Research and Engineering Development*, vol. 8, no. 2, Apr. 2025.

[5] S. Y. Sayais, S. Rajput, S. Patil, V. Nikumbh, G. Shisode, and Manikam, "Overvoltage and undervoltage load protection system using Arduino Uno," *International Research Journal of Engineering and Technology*, vol. 11, no. 11, Nov. 2024.

[6] G. K. M, S. M. V, S. G. D, and T. R, "Energy monitoring device using Arduino," *International Journal for Research in Applied Science & Engineering Technology*, vol. 1, no. 7, Jul. 2023.

[7] A. Patra, T. Shrivastava, S. Soni, and R. Damor, "Implementation of overvoltage and undervoltage protection," *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, vol. 9, no. 6, June 2021.

[8] *K. Ragul, M. Mukul, P. Vijay, and P. Rajkumar, "Design and implementation of smart energy meter using IoT," International Research Journal of Engineering and Technology, vol. 7, no. 4, Apr. 2020.*

[9] R. S. Hariharan, R. Agarwal, M. Kandamuru, and H. A. Gaffar, "Energy consumption monitoring in smart home system," in *IOP Conference Series: Materials Science and Engineering*, AICERA, 2020.

[10] N. Batra and M. Chawla, "Design and implementation of smart energy meter using Internet of Things (IoT)," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 9, no. 5, May 2020.

