



A MICROCONTROLLER BASED SMART ENERGY METER WITH ANTI-TAMPERING FEATURES

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Abstract: The idea of the Microcontroller-Based Smart Energy Meter with Anti-Tampering is to create a device that allows people to monitor their electricity consumption accurately and conveniently while also improving the security of the meter. The PZEM-004T sensor was used to measure the electrical parameters, including voltage, current, power, energy, frequency, and power factor, which were acquired by the ESP32 microcontroller and displayed on the OLED display. An IR sensor was used to detect any unauthorized tampering and, when triggered, the ESP32 microcontroller sounded a buzzer alarm and controlled the relay and solenoid lock. The presented system was designed to reduce the effort required for meter reading and provide information about the energy consumption in real-time while also featuring a basic level of protection from tampering. This document has been created for research and educational purposes to illustrate the work of a microcontroller-based intelligent energy meter with anti-tampering features. It does not promote or endorse any specific product or company. Any trademarks or brands mentioned are the property of their respective owners.

Keywords: Smart Energy Meter, ESP32, PZEM-004T, Energy Monitoring, Anti-Tampering, IR Sensor, OLED Display, Relay, Solenoid Lock, IoT

I. INTRODUCTION

Electricity has become an integral part of our lives, and therefore, its accurate measurement is of paramount importance. Conventional energy meters provide limited information regarding the electricity consumption of any load. Manual reading of conventional meters may consume a lot of time and may result in errors in the data collection process. With the rising use of electrical and electronic devices, there is an immediate need for developing accurate and reliable energy meters that are efficient and provide the necessary information. In this project, a microcontroller-based smart energy meter with anti-tampering features has been proposed.

The system is designed to overcome the limitations of conventional energy meters. The system has been designed around a PZEM 004T sensor and an ESP32 microcontroller. The sensor provides a means of getting various parameters including voltage, current, power, energy, frequency, and power factor. For energy data collection and other purposes, the ESP32 reads and interprets the information provided by the PZEM-004T sensor and displays the data on an OLED screen. Thus, the system provides an easy way of determining various parameters. Notably, the proposed system has an anti-tampering feature that enhances the security of the system. Tampering with electric meters may cause malfunctioning of the system and provide incorrect data concerning the energy consumption of a load. An infrared sensor has been used to detect any form of interference with the system. In case of malfunctioning, the ESP32 will detect the problem and activate the buzzer to notify the user of the problem. The proposed system also incorporates a relay and solenoid lock to offer an enhanced form of security.

The ESP32 microcontroller can be programmed to operate the relay and solenoid lock to ensure that the system is safe. The proposed smart energy meter is an innovative system that can be used to monitor the consumption of electrical energy in real-time. The system can also be used to provide alarm systems in case of any interference with the system. The system offers advanced features including load control, display, and data collection. Due to the use of an ESP32 microcontroller, the smart meter can be integrated with other features including communication and internet of things (IoT) in the future. Overall, the proposed system is a

reliable and cheap method of monitoring and controlling electrical appliances.

II. AIMS & OBJECTIVES

Aim

The main aim of this project is to design and develop a microcontroller-based smart energy meter with anti-tampering features that measures electrical energy consumption, monitors meter operating conditions, detects possible tampering activities, and provides alerts to improve the accuracy, reliability, and security of electricity usage monitoring.

Objectives

- To measure electrical parameters such as voltage, current, and power consumption using suitable sensors and measurement circuits.

- To calculate the electrical energy consumed by a user in kilowatt-hours (kWh).
- To use a microcontroller to process sensor data and manage the overall operation of the energy meter.
- To detect possible meter tampering, including unauthorized access, magnetic interference, and abnormal electrical connections, using appropriate detection methods.
- To identify unusual energy consumption patterns that may indicate suspicious activity or a meter malfunction.
- To display real-time

III. LITERATURE SURVEY

1. **Development of Conventional Energy Meters:** Traditional energy meters were primarily designed to only record the total amount of electricity consumed by the user. These are simple and commonly used, but generally do not provide much information about the current electrical conditions. Meter readings often have to be collected manually which can require additional time and possible human errors. These issues created the need for electronic systems that could offer multiple measurements. detailed
2. **Microcontroller-Based and Reliable Energy Energy Monitoring:** Introduction of microcontrollers allowed for the development of energy meters capable of continuously measuring and processing electrical parameters. Systems of this type are able to obtain values such as voltage, current, power, and energy consumption through appropriate sensors. Microcontroller units can then process these measurements and display the results on an LCD or OLED screen, increasing ease of understanding of energy information. Additionally, this approach offers flexibility in incorporating automated control and protection mechanisms to the energy meter.
3. **Smart and IoT-Based Energy Metering:** Modern energy monitoring systems have been increasingly incorporating communication and IoT technologies. Microcontroller units with wireless capabilities can transmit energy data to mobile applications or cloud platforms, enabling users to monitor consumption remotely without requiring physical visit to the meter. Furthermore, these systems can facilitate improved energy-management practices by providing real-time information of consumption. The ESP32 is particularly well-suited for such applications which involve processing as well as built-in wireless communication.
4. **Anti-Tampering and Meter Security:** Another important area of development for smart metering systems is the detection of unauthorized interference. Various systems utilize sensor and monitoring techniques to detect conditions such as opening of the meter, physical interference, abnormal current flows, magnetic influences, or other suspicious activity. Upon detection of a unusual condition, the system can trigger an alarm or communicate the event to a monitoring unit. Such security features allow for improving the reliability of energy measurement and facilitating easier identification of unauthorized interference.
5. **Integrated Smart Energy Meter with Protection:** Recent approaches have been focusing on achieving multiple functions such as measurement, monitoring, display, and security in a compact system. The proposed project follows this concept by incorporating the PZEM-004T energy sensor, ESP32 microcontroller, OLED display, IR sensor, buzzer, relay, and solenoid lock. The PZEM004T provides electrical measurements while the ESP32 processes the data and manages the display as well as protection mechanisms. The IR sensor offers an additional way for detecting physical interference, and the buzzer, relay, and solenoid set-up provides warning and protective functionality. The integrated design demonstrates how conventional energy measurement can be integrated into a smart control and anti-tampering system.

IV. METHODOLOGY

The above Picture of Microcontroller Based Smart Energy Meter with Anti Tampering Features is proposed by combining the measurement of the energy meter, its monitoring, detecting, and protecting from any interference. The methodology starts by sensing the voltage of the electrical supply, processing of the information about the power supply using ESP32, displaying the results, and taking necessary actions in case of any illegal attempts.

1. Power Supply and Regulation

The system uses 230 V AC mains as an input voltage. An SMPS is used to step down the voltage coming from the mains to a stable low DC voltage needed for the proper functioning of all electronics. A 7805 voltage regulator is employed in the circuit to deliver a stable 5 V to the circuit components which require it. Capacitors are used to filter and smooth the pulsating voltage from the power supply to ensure stable operation of the controller and all sensors.

2. Measurement of Electrical Parameters

The PZEM-004T sensor is connected to the mains and load to calculate the necessary information about the electricity consumption. This sensor continuously calculates voltage, current, power, energy, frequency, and power factor of the electricity being consumed. The resulting values are transferred to the ESP32 microcontroller via the sensor's serial TX/RX pin.

3. Processing Using ESP32

The ESP32 microcontroller is the main processing unit for the entire system. It takes all the information transferred from the PZEM-004T sensor to process based on the set instructions. It constantly checks the received signal from the IR sensor to see if there was any illegal interaction with the meter.

4. Display of Energy Data

An OLED display is used to present the calculated values from the PZEM-004T sensor to the user. The display notifies the user about all the voltage, current, power, and total electricity being consumed and indicates whether the system functions correctly or a tamper has been detected.

5. Tamper Detection

An IR sensor is used as a tool to detect any illegal attempts of stealing electricity by monitoring the protected area. Once the sensor detects any illegal interference with the meter, it will send a signal to the ESP32 microcontroller indicating the tamper. Then the controller will activate the set alarm or protective function based on the received signal.

6. Alarm and Protective Action

In case of tampering attempts detected by the IR sensor, the ESP32 microcontroller will activate the buzzer through the transistor driver to alert the owner or administrator. On the other hand, the controller can also operate the relay and solenoid lock according to the set rules in the system to either lock or disconnect the load from the circuit. The solenoid lock physically locks or unlocks the protected area while the relay switches or isolates the load in case of tampering.

7. Overall System Operation

The whole system works as long as the load is connected to the electricity supply. The PZEM-004T sensor calculates the values related to the power supply while the ESP32 processes the information and displays it on the OLED screen. At the same time, the IR sensor monitors the protected area looking for any tamper. If everything works correctly, the microcontroller lets the user know about the current status of the meter. However, if a tamper is detected, the ESP32 will activate the set buzzer alarm and the relay/solenoid protective mechanism.

Overall Working Flow

230 V AC Supply → SMPS → 7805 Regulator → PZEM004T → ESP32 → OLED Display IR Sensor → ESP32 → Buzzer + Relay → Solenoid Lock

Thus, the methodology combines automatic energy measurement, continuous monitoring, tamper detection, alarm generation, and physical protection in one microcontroller-based smart energy meter.

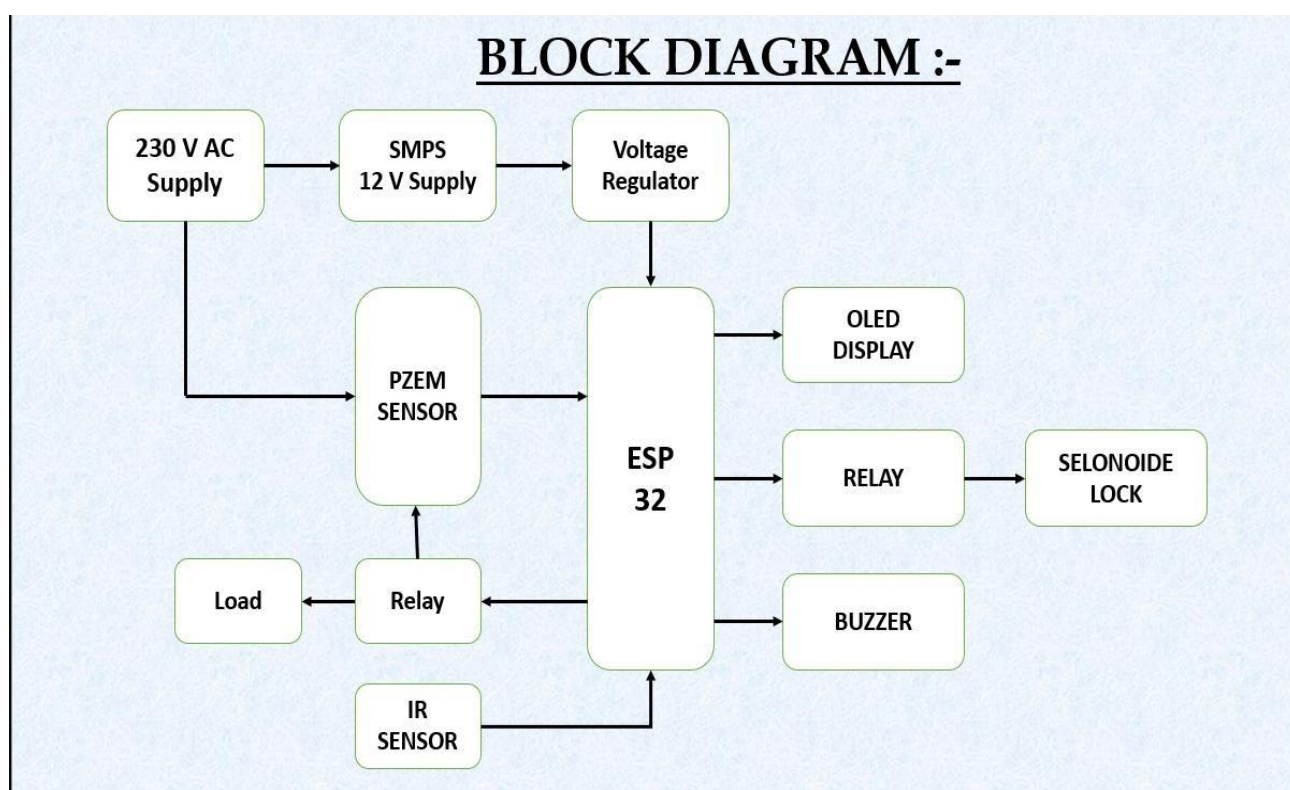
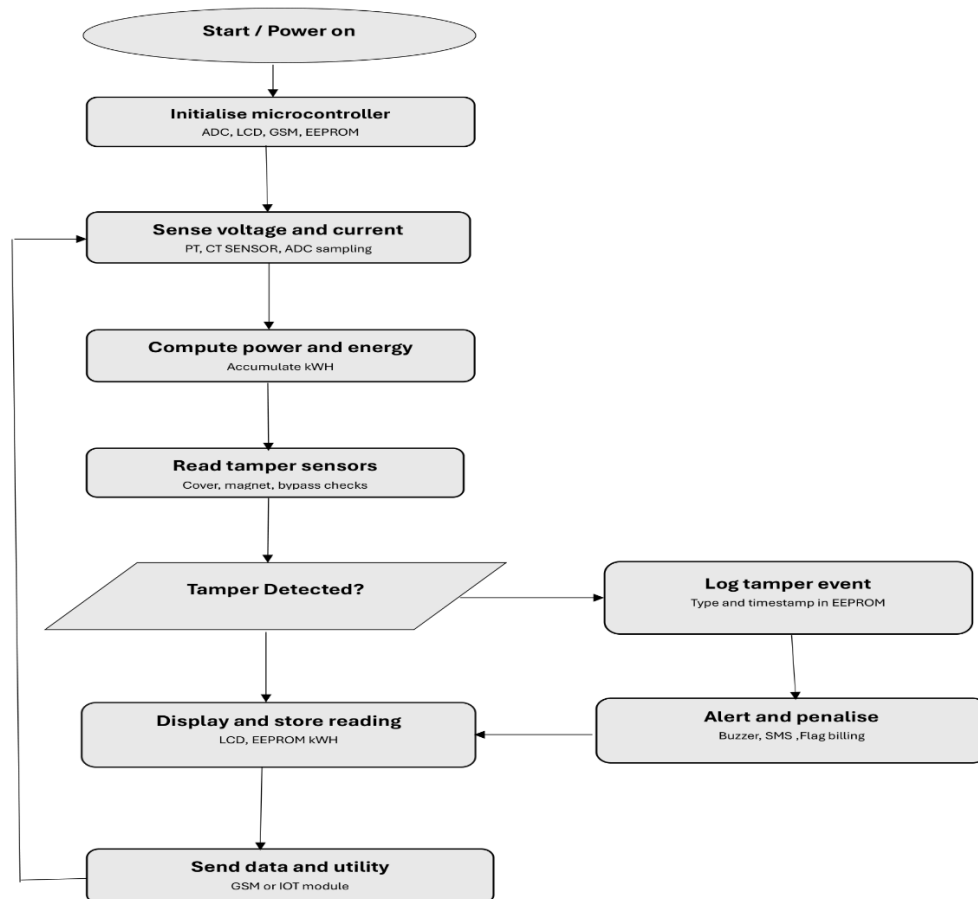


Figure 1: block diagram of the proposed system



Flowchart: microcontroller based smart energy meter with anti-tampering

Figure 2: flowchart of the proposed system

V. RESULTS AND DISCUSSION

The proposed microcontroller-based smart energy meter with anti-tampering features is designed to monitor electrical energy consumption and identify possible unauthorized interference with the metering system. The microcontroller processes the data received from the measurement sensors and calculates the corresponding energy consumption. The readings can be displayed on an LCD or OLED screen, allowing users to observe electricity usage conveniently.

The anti-tampering mechanism is intended to identify suspicious conditions, such as unauthorized access to the meter, magnetic interference, and abnormal electrical connections, depending on the detection techniques implemented in the system. When a supported tampering condition is detected, the system can generate an alert through a buzzer or indicator. If a communication module is incorporated, the detected event and energy consumption information can also be transmitted to a remote monitoring platform.

The proposed system offers the potential to improve the monitoring of electricity consumption by reducing dependence on manual meter reading and enabling timely identification of suspicious activities. The integration of energy measurement, microcontroller-based processing, and tampering detection provides a practical approach to improving the security and convenience of electricity metering.

The accuracy of energy measurement and the effectiveness of tampering detection should be evaluated through experimental testing. Suitable tests include comparing meter readings with a reference energy meter, checking the response to different electrical loads, and verifying the detection of each supported tampering condition. Quantitative performance values should be included after testing the actual prototype.

VI. CONCLUSION

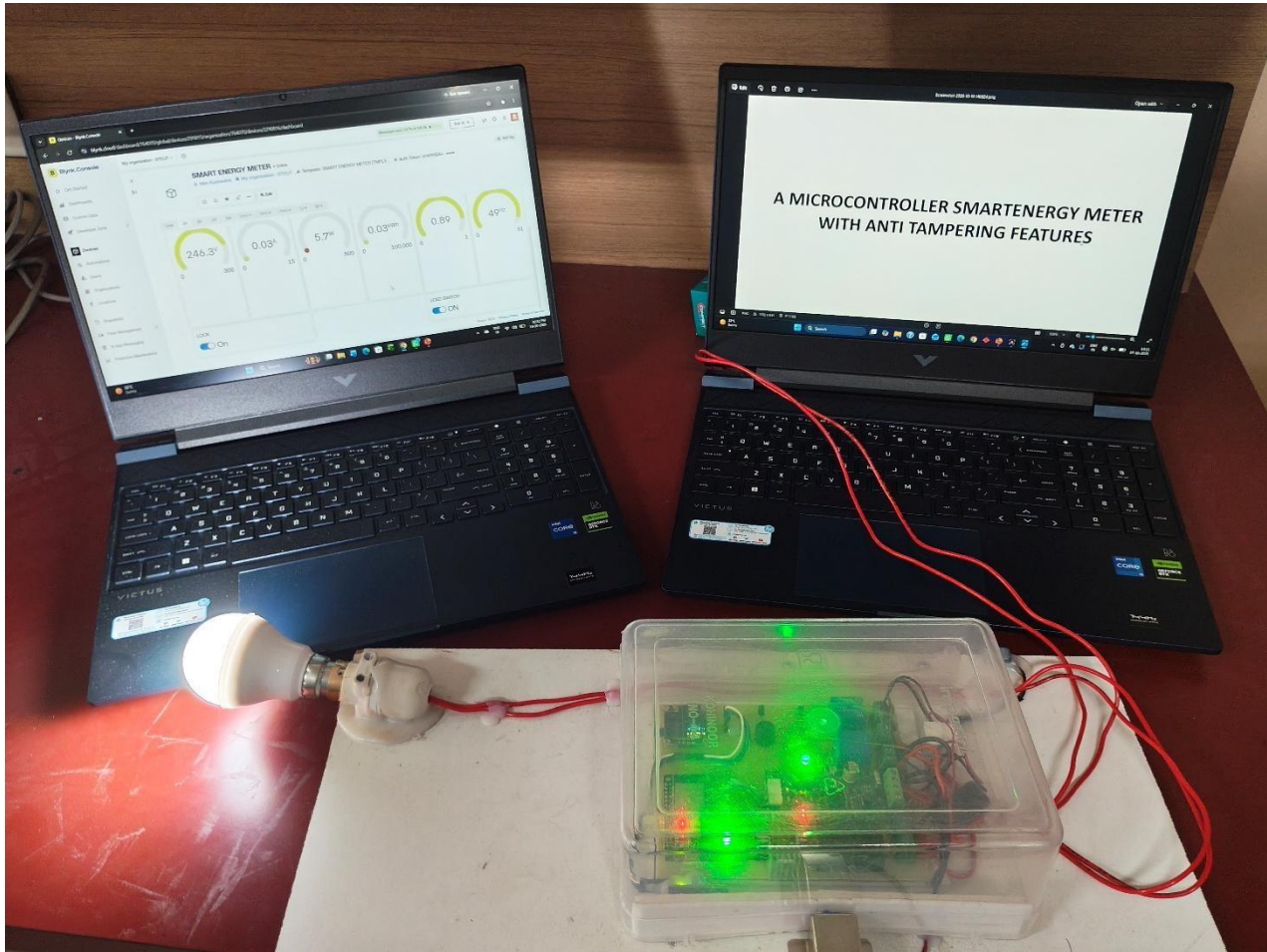
This research presents a microcontroller-based smart energy meter with anti-tampering features for improved electricity consumption monitoring and meter security. The proposed design combines electrical parameter measurement, energy calculation, microcontroller-based data processing, and tampering detection within a single system. Depending on the implemented hardware, the system can also provide local alerts and remote transmission of energy readings and suspicious-event information.

The integration of these functions can help users monitor electricity consumption more conveniently while assisting electricity providers in identifying potential meter interference and irregularities. Automated monitoring can also reduce the need for frequent manual readings and support more efficient energy management.

The effectiveness of the proposed system depends on the accuracy of the measurement circuit, the reliability of the tampering detection methods, and the quality of the communication infrastructure. Therefore, experimental validation is necessary before making claims about measurement accuracy, detection performance, or cost savings.

Future development may include cloud-based data storage, mobile application integration, improved tampering classification, encrypted communication, and advanced analysis of energy consumption patterns. These enhancements could make the system more reliable, secure, and suitable for practical electricity monitoring applications.

PROJECT MODEL



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