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IOT BASED SMART ENERGY METER FOR POWER MONITORING SYSTEM USING ESP8266

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***Abstract*— Energy saving is the most important and challenging issue. Smart power meter is used in domestic electric power distribution system. The integration of the Node-MCU, PZEM sensor, Relay and provides the system as Smart Power Monitoring system. Smart power meter provides data for optimization and reduce the power consumption. This system communicates with embedded controller and ESP8266 module to transmit the data. Domestic consumers get benefited through this system.**

Keywords—Energy, NodeMCU, Relay, Consumers

I. INTRODUCTION

IoT based smart energy meters can overcome the existing problems like reducing man power, energy monitoring, load management, etc. Smart energy meter works in a way such that it calculates the amount of energy used as well as controls it when it reaches specified limit. It is an advanced technology for reading and controlling the energy consumption. It is very useful in saving energy in efficient manner. We used NodeMCU and PZEM sensor in this model.

This NodeMCU is an open source IOT platform based on ESP8266 which can connect objects and let data transfer using the Wi-Fi protocol. PZEM-004T is an electronic module that functions to measure: Voltage, Current, Power, Frequency, Energy and Power Factors.

1.1 BACKGROUND OF THE WORK

An IoT-based smart energy meter is a device that measures and tracks energy use in residences, structures, or even entire communities. It is equipped with sensors that can gather information about energy usage and send it to a cloud database for improved data analytics. Voltage, current, and power usage data are all gathered by the smart meter. This information may be gathered constantly or at specified intervals, such as once every minute or hour. A cloud database receives the collected data via the internet. Wi-Fi, cellular, and Lora WAN are just a few examples of the wireless technologies that can be used to achieve this. The information is kept in a cloud database for analysis. The database may be hosted by the electric company.

1.2 SCOPE OF THE PROPOSED WORK

We found that the internet of things (IoT) has the potential to completely change how we monitor and control energy use. IoT can give real-time data on power usage, which may be used to spot inefficiencies and optimize operations, by putting sensors and actuators throughout the power system. In order to utilize iot for power monitoring to its maximum capacity, a number of issues must be resolved. These difficulties include:

- The need for a secure and reliable network to transmit data from sensors to the cloud.
- The need for scalable and efficient data storage and processing solutions.
- The need to develop algorithms for identifying and responding to anomalies in power usage.
- The goal of this project is to develop an IoT-based power monitoring system that addresses the challenges outlined above.

The system will be designed to:

- Collect real-time data on power usage from sensors deployed throughout the power grid.

- Transmit data securely and reliably to the cloud.
- Store and process data efficiently.
- Identify and respond to anomalies in power usage.

1.3 ADVANTAGES

• Real-time data on energy consumption is provided by Internet of Things-based smart energy meters, enabling utility providers and consumers to track usage trends and make wise energy management decisions.

•Users can access and control their energy use statistics remotely via cell phones or PCs. This allows them to control and alter their energy consumption, perhaps resulting in energy savings.

•Smart metres provide more precise measurements than standard metres. This ensures that customers are charged for the exact quantity of energy used, reducing arguments and mistakes.

1.4 DISADVANTAGES

•Smart metres gather specific information about energy consumption, which raises privacy issues regarding how this information is utilised, kept, and perhaps shared.

•Smart metres depend on connectivity and may be impacted by network or power outages. To guarantee consistent functioning, regular maintenance and updates are required.

• Smart metres, like any IoT device, are susceptible to hacking or unauthorised access, which might result in data breaches or even remote energy usage manipulation.

II. LITERATURE REVIEW

In 2017, C. Choi, et al. [1] proposes an effective energy monitoring system based on IoT. It will forecast users, energy demands. It mainly focuses on Lora technology, renewable energy generations etc. But its main drawback is, it does not discuss how the data is taken and how power is calculated.

Hiremath et al. [2] in 2017 made his research on IoT-based energy control and managing devices. They designed and implemented an energy meter which uses Arduino as its microcontroller. This system is used to measure the power consumed by electrical devices. Power consumption is monitored and is send to the server via Wi-Fi module. Web based application is used so that the user can monitor the consumption anywhere in the world. The researcher mainly focuses only on the tools used in the experiment. Measurement data and their details are not discussed in it.

Other scholars like Medina et al [3]. in 2018 conducted a study on IoT-based electrical energy consumption using Raspberry pi. This study was made in order to know how energy consumption can be controlled and monitored. An android application was used for displaying the data obtained. According to their studies analog input from the current sensor is connected to Arduino and is controlled by Raspberry pi. This data is then processed and stored in the database. Based on their results some systems are having high accuracy while some other devices are having low accuracy.

In 2019, Prasetyo et al. [4] researched Smart Home for monitoring and control of electrical energy. The research was taken place in Indonesia. The research aims to conduct the effectiveness of electricity usage by monitoring and controlling power using cloud-based IoT. The Smart Home design was built using several devices such as an Arduino microcontroller, Internet module, AC Voltmeter, Relay, LDR Sensor, and PIR Motion Sensor. The output of the research is still in the form of design, not yet at the stage of developing and implementing the tool.

A. Abbreviations and Acronyms

- PZEM- Part Zone Expansion Module
- NodeMCU- Node Microcontroller Unit

III.PROPOSED SYSTEM

We are living in a world where everything depends on Electricity. Simply we can say that electricity governs the world. Therefore, power consumption has become an essential criterion for every field. From the above literature surveys we can find that every researchers aims in developing new technologies for automating the household items, machineries, for finding power theft, for controlling the voltages etc., using smart meter, sensors, microcontrollers, along with Internet of Things. None of them concentrated on the huge cost of energy which we are paying. Sometimes we wonder by seeing the electricity bill as it may exceed our monthly budget. Efficient monitoring and controlling system is the only method to overcome this situation. The proposed system is one such method. Here we are controlling the loads according to our monthly tariff chosen with the help of sensors and relay. User can choose their own tariff in accordance with their monthly budget. If they need any extra power, then the user itself can edit their tariff. In such a way energy gets consumed by controlling unnecessary loads automatically and save money. Simply we can say that the proposed system is to create a user friendly system in order to monitor energy usage in real time. Data is collected by some electronic devices and is transmitted to the server using NodeMCU.

The main components required for the system are as follows:

1. PZEM sensor
2. Node MCU
3. Relay
4. LCD Display

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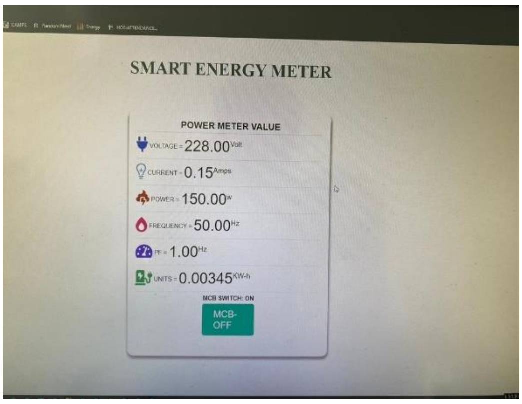
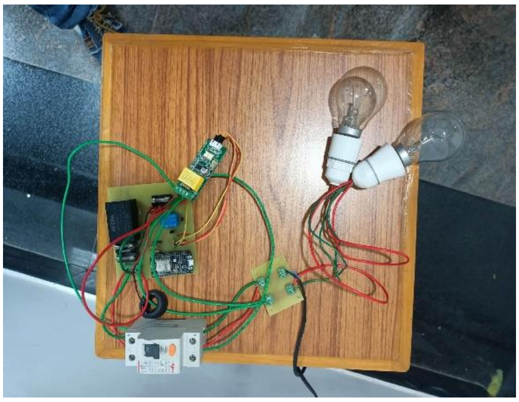




3.1 Objectives of the proposed work

The following might be characterized as the planned work's objectives for the "IoT-based Smart Energy Meter for Power Monitoring System" project in light of the results of the literature review:

•Design and implement a reliable IoT-based energy monitoring system:

Create a dependable and durable energy monitoring system that makes use of IoT technologies, considering the flaws and restrictions found in current systems from the literature survey.

•Increasing Data Precision and Accuracy:

Enhance the precision and accuracy of data collecting and processing related to power usage, solving issues with earlier systems.

•Confirm Real-Time Data Monitoring:

Put in place a real-time data monitoring tool to meet the demand for the most recent information on patterns and swings in power consumption.

•Adding Advanced Data Visualization:

Utilize cutting-edge data visualization techniques to outperform existing system visualizations by giving users simple-to-understand and insightful depictions of their energy usage trends

•Improved User-Friendliness:

Based on the insights gleaned from the literature review regarding user interface design principles, create a user-friendly web interface that is intuitive and accessible to users of different technical backgrounds.

•Putting in place Security Measures:

Address security issues found in earlier systems by integrating strong security mechanisms to safeguard user data and system integrity.

•Analyze sustainability and energy efficiency:

Analyze the system's energy efficiency and look into sustainable methods of energy consumption reduction in accordance with the environmental factors mentioned in the literature review.

•Ensure future integration and scalability:

In order to keep up with new developments in IoT applications for energy management, design the system with scalability in mind, enabling simple integration with future technologies and components.

•Carry out Extensive Testing and Validation:

Based on the flaws found in prior systems, carry out extensive testing and validation methods to make sure the system satisfies or exceeds performance standards and expectations.

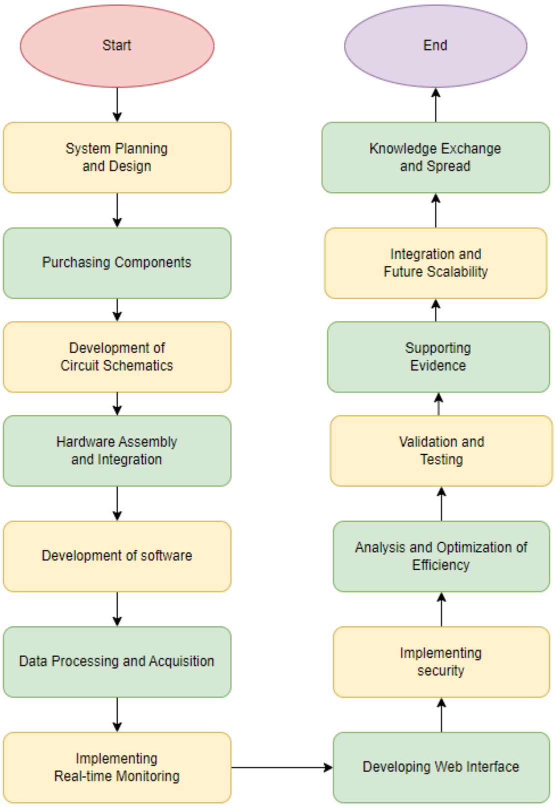
•Share and Document Knowledge:

To encourage knowledge sharing, replication, and additional research in the subject, create thorough documentation of the project that includes technical details, code documentation, and user manuals. These goals are developed from the knowledge gathered from the literature review, which revealed the advantages and disadvantages of current IoT-based energy monitoring systems. By focusing on these goals, a better and more inventive smart energy meter system will be created.

Figure 3.2.1- Synthetic procedure

•System Planning and Design

In this preliminary stage, the project is planned, and the needs of the system are established. Based on the project objectives and research findings, it entails defining the hardware



components (ESP8266, PZEM-004T module, CT coil, 5V relay, resistors, capacitors, MCB, LCD Display), software stack, and overall system design.

•Purchasing Components

All the hardware parts, sensors, and electronic components are acquired at this step. It guarantees that all the materials needed for the project's later phases are on hand.

•Development of Circuit Schematics

The precise schematic diagram of the electronic circuit must be created during this step. It entails creating power supply configurations as well as defining the connections between components and their locations on the circuit board.

• Hardware Assembly and Integration

The hardware parts are put together in accordance with the circuit design. The ESP8266, PZEM-004T module, CT coil, relay, resistors, capacitors, MCB, and LCD Display must all be physically connected during this phase.

•Development of software

The software stack is created, including the Arduino IDE for ESP8266 programming. Writing code makes it easier to collect data from sensors, process that data, and communicate with the web interface.

•Data Processing and Acquisition

The PZEM-004T module and CT coil's power consumption data are gathered using data collecting procedures. Accurate power usage estimates are filtered and computed using data processing methods

•Implementing Real-time Monitoring

Real-time monitoring capabilities for the system are put into practice.

Users can access real-time data on power consumption because to its ability to deliver continuous data refreshes.

•Developing Web Interface

The HTML-based web interface was developed to allow users to view and retrieve data on energy consumption. The development of interactive features, data presentation, and user authentication.

•Implementing security

To protect user data and the system, strong security measures have been included. This covers cyber threat defense, encryption, and authentication.

•Analysis and Optimization of Efficiency

The effectiveness and power usage of the system are assessed.

The application of optimization techniques increases energy efficiency.

•Validation and Testing

The system is put through rigorous testing procedures to make sure it is reliable, accurate, and functional. Different test scenarios are run, and the outcomes are recorded.

•Supporting Evidence

An extensive amount of documentation is produced, including user guides, technical specifications, project reports, and technical information. For users and potential developers, this documentation serves as a reference.

•Integration and Future Scalability

Future scalability and integration with developing technologies are considered. The system is built to support future upgrades and improvements.

•Knowledge Exchange and Spread

Presentations, articles, and conversations are used to disseminate knowledge and project findings. This section emphasizes how critical it is to inform the general public about the project's findings.

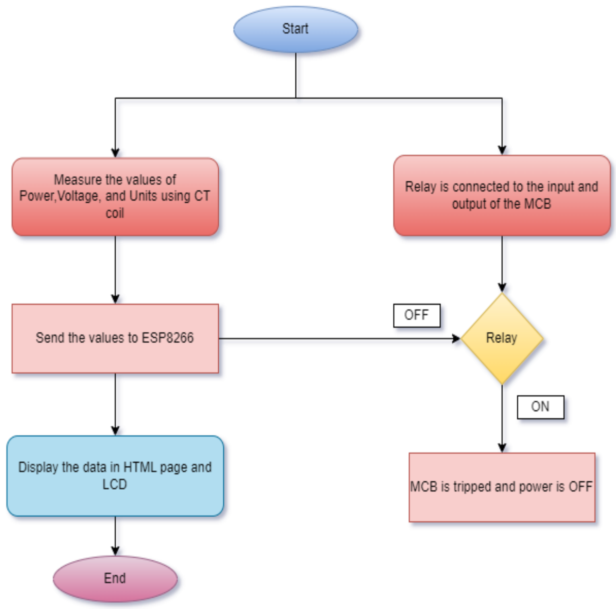


Figure 3.1.2-Flow diagram of the proposed work

The ESP8266-based open source IOT platform NodeMCU enables the connection of objects and Wi-Fi-based data transmission. To be used later, the sensor data will be sent to the cloud. Electronic PZEM-004T module measures voltage, current, power, frequency, energy, and power factor. The PZEM sensor, which estimates the units of power utilized, is connected to the Node-MCU, and a relay controls the MCB. We establish a cap on the amount of power that may be used, and when it is reached, relays activate and the MCB is switched off to cut off the electricity. Relay, when it detects and trips, will turn the MCB off.

3.3. Selection of Components:

•ESP8266:

The main microcontroller in the system is the ESP8266. In order to communicate with the web interface and cloud services, it connects to Wi-Fi networks. Data from sensors is gathered by the ESP8266 and sent to the web interface for analysis and visualization.

•PZEM-004T Module:

An essential part for measuring voltage and current is the PZEM-004T module.

Voltage, current, power, and energy usage are all precisely measured power metrics.

The module transmits vital information for power monitoring to the ESP8266 through a serial port.

•Current Transformer Coil (CT Coil):

The current flow in an electrical circuit is measured using a CT coil.

It reduces the strong AC current to a level that the PZEM-004T module can handle.

It adds to the calculation by measuring the current and power consumption.

•Relay 5V:

The 5V relay is used to remotely control electrical circuits or appliances.

Through the web interface, it enables the system to turn appliances on or off in response to user orders. By allowing for remote control, this part improves the system's functionality.

•Capacitors and resistors:

In the circuit design, capacitors and resistors are utilized for a variety of tasks.

Resistors can be used for current limiting, voltage division, and other circuit-specific tasks. For accurate sensor readings, capacitors can filter signals, lower noise, and regulate power supply voltage.

•Miniature circuit breakers, or MCBs

A safety feature in the electrical circuit, the MCB.

It safeguards against overcurrent and short-circuit situations for the system and any connected appliances. When a fault occurs, the MCB trips, disconnecting the circuit to prevent damage.

•LCD:

The LCD gives ongoing input to clients. It can show power utilization information, framework status, or other applicable data straightforwardly on the gadget. Clients can rapidly get to data without depending entirely on the web interface. These parts work as one to make an IoT-based Brilliant Energy Meter for Power Checking Framework. The ESP8266 goes about as the cerebrum of the framework, connecting with the PZEM-004T module and CT loop to gather power-related information. The 5V transfer empowers distant machine control. Resistors and capacitors aid circuit plan and steadiness, while the MCB guarantees security. The LCD show offers a neighbourhood interface for information access and perception. Together, these parts structure a complete energy checking arrangement, furnishing clients with significant experiences into their power utilization.

IV.WORKING

The Node-MCU is connected to PZEM sensor which calculates the units of power used and Relay controls the MCB. We set the limit of power consumed and if it reached the limit the relays turns on and switches the MCB off to stop the power supply. Relay will turn the MCB off when it detects that the supply and return current are not balanced.

The load wire is inserted inside the PZEM sensor which calculates the power used displays it in LCD. We can see the power consumed by using the HTML page, by copying the IP address and pasting it in the chrome browser. A static IP address is created for this. It displays the power consumed, current, and voltage etc., used. By using the mobile phone we can see the amount of power consumed in our home or work place and conserve the electricity accordingly.

4.1 HARDWARE PART:

The hardware part includes

- ESP8266 microcontroller
- Resistors
- PZEM-004T module and CT sensor
- Capacitor
- 5V relay module
- PCB board
- LCD Display
- MCB

4.2 MICROCONTROLLER PROGRAMMING:

The microcontroller we use here in ESP8266 which is programmed in Embedded C programming language. Arduino IDE is used for programming and uploading the code.

4.3 WEB PAGE CREATION:

When a visitor uses a web search engine to find a website, the first page they see is the home page. A home page can also serve as a presentation page to attract visitors. A site's need for a perfect home page configuration is often significant. By copying the IP address and inserting it into the Chrome browser, we can view the amount of energy used when using the HTML page. For this, a static IP address is generated. It shows the voltage, current, and power used, among other things.

4.4 PCB DESIGN:

A PCB board is designed using Kicad tool for connecting the components and compact design.

V.RESULT

Existing systems only concentrate on controlling energy theft, home automations, reducing man power, automatic meter reading using different technologies etc. Our proposed system is to conserve energy thereby reducing the bill amount by proper load management and by determining our own tariff. This is cost efficient than the existing models available in the market and is user friendly. Hence using this technology we can analyse the usage of power in our work place or at home and plan accordingly to save power. Similar projects like this usually use internet connection for transmission of data. The main advantage of our project is that we can see the data from the sensor without the use of internet connection. The budget is also low compared to other existing models. The usage of Node-MCU allows us to operate the Power meter even without the use of internet. Node-MCU connects through the local network which includes a Wi-Fi modem, mobile phone.

The implementation of IoT-based smart energy meters for monitoring systems is a significant advance in the field of energy management. This revolutionary solution gives real-time insights into energy consumption, enhances productivity, and promotes sustainability by combining the Internet of Things (IoT) and energy monitoring. The main objective of an IoT-based smart energy meter is to monitor and gauge electricity use in real-time. In contrast to conventional energy meters, which require human readings and offer limited information, smart meters give a thorough picture of energy consumption. Due to their sensor and communication capabilities, these meters may transmit data to a centralized server or cloud platform.

The capacity to deliver real-time data is one of the main benefits of IoT-based smart energy meters. This indicates that both consumers and utility suppliers have access to the most recent data regarding energy use. This gives people the power to choose their energy usage patterns with knowledge. They can pinpoint periods of peak usage, maximize tasks that consume a lot of energy, and eventually cut their electricity costs. On the other side, utility companies are better able to manage their resources, recognize and handle power outages in a more effective manner, and prepare for upcoming infrastructure changes. Smart energy meters also help to improve energy efficiency. These meters can identify anomalies or inefficient behaviour by tracking usage patterns. For instance, they might spot electrical system leaks or very energy-hungry gadgets. Consumers can be informed of this information and encouraged to take appropriate action. Sometimes the meters themselves can start automated processes, including turning off unnecessary gadgets during times of high demand.

The advantages go beyond particular households. IoT-based smart meters provide businesses and industries with granular insights into energy usage, enabling them to optimize operations. This not only lowers operating expenses but also lessens the carbon imprint. For instance, large industrial facilities can identify operations that use a lot of energy and deploy energy-efficient technology to reduce waste.

Additionally, smart energy meters are essential for sustainability initiatives. Considering the widespread worries about climate change and resource depletion, responsible energy use is essential.

By providing information on energy use and its effects on the environment, smart meters encourage environmentally friendly behaviour. This information can motivate people and companies to adopt environmentally friendly behaviour's, such as using renewable energy sources, cutting back on total usage, and switching to energy-efficient products. Another essential component of IoT-based smart energy meters is the capability to remotely monitor and manage energy consumption. Customers can see their energy usage data and make adjustments in real-time through smartphone apps or web portals. For example, they can arrange appliances to run during off-peak hours, change thermostats, or remotely switch off lights. This degree of control improves convenience while simultaneously promoting energy efficiency.

Implementing IoT-based smart meters requires careful consideration of security and privacy issues. The confidentiality of energy consumption data must be ensured, and illegal access must be prevented at all costs. Any smart metering system must have strong encryption and authentication procedures to protect sensitive data.

In conclusion, there are several benefits to the IoT technology's integration with smart meters for energy monitoring. By encouraging sensible energy consumption, these meters provide real-time data, improve energy efficiency, and support sustainability. They provide utility providers and customers with insightful information that improves resource management and lowers costs.

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