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SMART ENERGY METER MONITORING SYSTEM BASED ON IOT

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Abstract: -
This project describes a Smart Energy Meter Monitoring System that uses an Arduino microcontroller to continually monitor the voltage and current supply, compute power usage, and track energy consumption. The system also makes use of specialised current and voltage sensors. The technology calculates energy consumption costs precisely by using exact sensor measurements. A central database receives the gathered data with ease, guaranteeing real-time administration and storage. Data retrieval from the database is made easier by an intuitive web interface, which lets users keep an eye on their consumption habits and related expenses. This website helps to promote energy efficiency by giving consumers insightful information about how much electricity they use. Utility firms and managers can also use real-time data from the system to optimise energy distribution networks and analyse consumption patterns. The amalgamation of Arduino, voltage and current sensors, and database technologies yields an effective, expandable, and user-focused energy monitoring system. This Monitoring Smart Energy Meter. The system makes a substantial contribution to raising energy consumption awareness, encouraging wise decision-making, and improving general energy management techniques.

Keywords: energy efficiency, track energy consumption.

Introduction

Modern technology must now be integrated if we are to pursue a sustainable and efficient energy future. The Smart Energy Meter Monitoring System, a sophisticated system utilising Internet of Things (IoT) capabilities and cutting-edge sensors, such the ACS712 for current sensing and DC voltage sensors, is one such breakthrough creating waves in the energy sector[1].

This groundbreaking system goes beyond traditional energy metering by providing real-time and comprehensive insights into key parameters crucial for effective energy management[2]. By seamlessly calculating voltage, current, energy consumption, power usage, and associated costs, the Smart Energy Meter Monitoring System is a game-changer for both consumers and utility providers[3].

The core components of this system include the ACS712 current sensor and DC voltage sensors, working in harmony to capture accurate and precise data from the energy grid. These sensors play a pivotal role in enabling the system to measure electrical parameters with unparalleled accuracy, ensuring that users have access to reliable information for optimizing energy consumption[4].

This system's real-time data transmission to a centralised database is one of its main features. The Smart Energy Meter uses Internet of Things (IoT) connectivity to guarantee that consumers and utility providers have access to real-time data on energy consumption, facilitating resource allocation and proactive decision-making[5].

Dual display choices are provided by the system to improve user accessibility. First, the Meter has a specialised display unit built right into it that gives people on-site immediate access to pertinent data. Second, any internet-enabled device may be used for remote monitoring using an intuitive online interface, which enables users to watch trends in energy consumption, examine historical data, and make educated decisions about their energy usage[6].

Furthermore, the ability of the Smart Energy Meter Monitoring System to compute energy costs using real-time pricing models guarantees that customers are aware of the financial effects of their energy usage patterns. In addition to encouraging energy efficiency, this function gives users the ability to make decisions that take the environment and economy into account[7].

Overview

Specifically, the ACS712 for current sensing and DC voltage sensors, along with the power of Internet of Things (IoT) technology, combine to create the revolutionary Smart Energy Meter Monitoring System. By providing real-time insights into vital metrics including voltage, current, energy consumption, power usage, and related costs, this cutting-edge device completely reimagines standard energy metering. With an emphasis on efficiency and sustainability, this system seeks to transform energy management strategies for utility companies as well as customers.

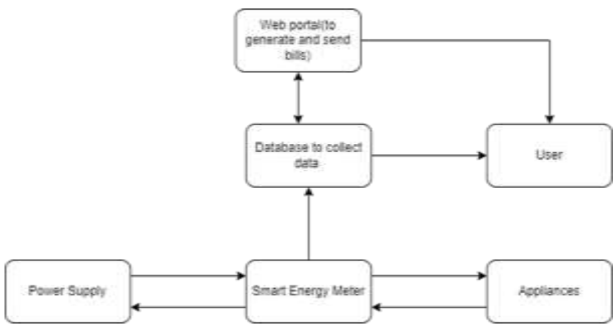
In order to obtain precise and reliable data from the energy grid, the Smart Energy Meter Monitoring System primarily uses the ACS712 current sensor and DC voltage sensors. By ensuring users have access to trustworthy information, this promotes the adoption of energy-efficient practices. When combined with IoT connection, the system's real-time data transmission to a centralised database allows consumers and utility suppliers to make decisions based on current information[8].

Key features include dual display options for user accessibility. A dedicated display unit integrated into the meter provides on-site users with instant access to relevant data, while a web interface allows remote monitoring from any internet-enabled device. This not only enhances user convenience but also facilitates proactive decision-making and resource allocation[9].

Moreover, the Smart Energy Meter Monitoring System calculates energy costs based on real-time pricing models, offering users a clear understanding of the financial implications of their energy consumption. By empowering users to make informed choices aligned with economic and environmental considerations, the system promotes energy efficiency and responsible energy consumption[10].

Proposed Methodology

The Smart Energy Meter Monitoring System employs a sophisticated methodology to seamlessly integrate IoT technology with advanced sensors such as ACS712 for DC current sensing, SCT-013 for AC current sensing, and ZMPT101b for AC voltage sensing. These sensors are connected to a microcontroller, facilitating the processing of raw data through calibrated algorithms for accurate measurements of voltage, current, power, energy consumption, and associated costs based on real-time pricing models.



The system ensures real-time communication with a centralized database via secure IoT protocols, utilizing robust databases like MySQL or MongoDB for efficient data storage. Users can access the system through a user-friendly web interface designed to display both real-time and historical energy data, complemented by an on-site display unit integrated into the meter for immediate access to key information[12][13][14].

Figure 2. Login page

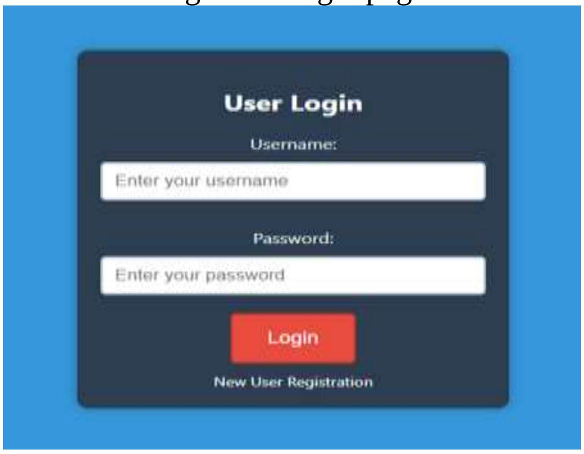


Figure 3. User login

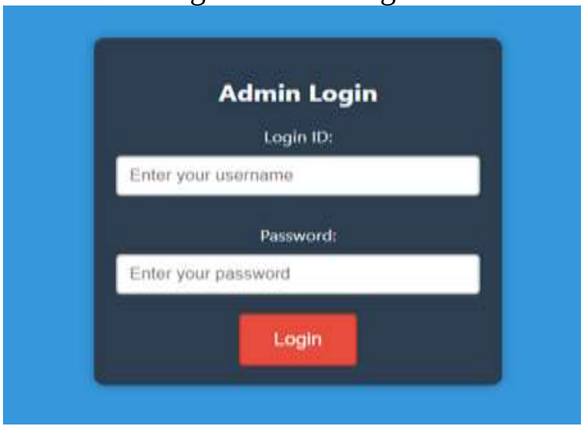


Figure 4. Admin login

Figure 5. User details page in admin portal

Admin features are incorporated, requiring secure login credentials and user role definitions to control data access and manipulation[15]. The system enables the admin to generate bills in PDF format, offering customization options for billing periods and formats. Additionally, a notification system

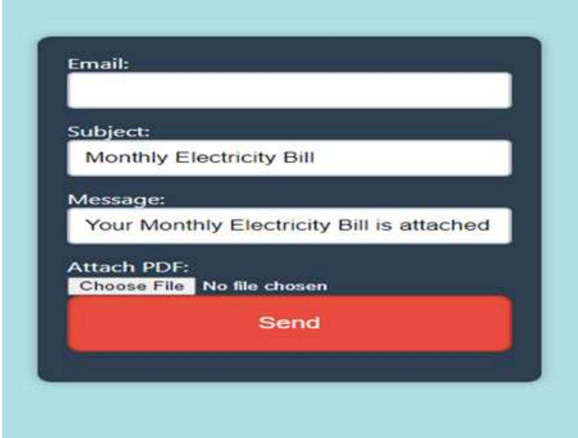


Figure 6. Email sending page

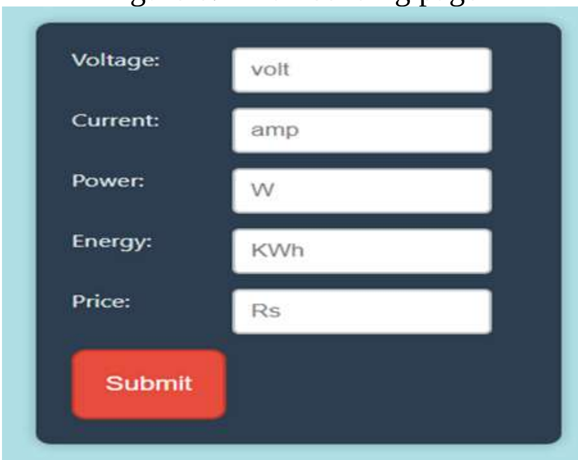


Figure 7. PDF Bill generation page

Monthly Electricity Bill			
Voltage	Current	Power	Energy
0	0	0	0
Price			

Figure 8. PDF of bill

is integrated, allowing the admin to send bills in the form of PDFs, SMS, or emails directly to consumers via the web server[16]. Security measures are implemented, incorporating data encryption protocols to safeguard both transmission and storage. Access controls are established to prevent unauthorized entry, ensuring the protection of sensitive user information and billing data. Rigorous testing and calibration of hardware components and software algorithms guarantee accuracy, and the deployment of the system includes proper installation and ongoing monitoring to track performance and promptly address any issues that may arise. This comprehensive approach positions the Smart Energy Meter Monitoring System as a robust and user-friendly solution for real-time energy management and billing[17][18].

Current Sensor ACS712: The ACS712 is a linear current sensor that uses the hall effect to measure current and outputs an analogue voltage that is proportionate to the current flowing through the sensor. There are various models with different current ranges available. The sensor provides precise and instantaneous readings of both AC and DC currents by integrating a Hall effect transducer with a precision amplifier. It is extensively utilised in many applications, including industrial automation, power supplies, and energy monitoring. Because of its non-intrusive design, current flow can be interrupted during integration, making it simple to integrate into present electrical systems.

Figure 9. ACS712 current sensor

SCT-013 Current Sensor:

Figure 10. SCT-013 Current Sensor

The SCT-013 is a non-invasive, split-core current transformer designed for AC current measurement. Its split-core design enables easy installation around existing conductors without the need for any electrical connections. The sensor employs a magnetic core, which induces a current in the secondary winding proportional to the current flowing through the primary conductor. The output is then processed to provide an analog signal or converted to a digital signal for use in various applications, including energy monitoring, smart meters, and power quality analysis. The SCT-013 is particularly valued for its simplicity and safety in retrofitting onto existing electrical systems for accurate AC current measurement.

ZMPT101B Voltage Sensor:

Figure 11. ZMPT101B voltage sensor

The ZMPT101B is a voltage sensor module that is commonly used for measuring AC voltage. It employs a capacitive voltage divider principle and includes a voltage transformer to provide galvanic isolation. The sensor generates an output proportional to the input AC voltage, making it suitable for applications such as voltage measurement in power systems, smart energy meters, and industrial control systems. Its compact design, ease of integration, and isolation features make the ZMPT101B a popular choice for monitoring and controlling AC voltage in diverse electronic applications.

0-25V DC Sensor:

Figure 12. DC voltage sensor

The 0-25V DC sensor is a generic term for sensors designed to measure direct current (DC) voltage in the range of 0 to 25 volts. These sensors typically consist of a voltage divider circuit or a precision amplifier to convert the input voltage into a readable signal. They are commonly used in electronics projects, power supply monitoring, and battery voltage measurement applications. These sensors may come in various forms, including modules or standalone components, providing a convenient and accurate means of measuring DC voltage within the specified range. Their versatility and ease of use make them valuable tools for projects requiring precise monitoring of low to moderate DC voltage levels.

Arduino Uno:

Figure 13. Arduino Uno

The Arduino Uno is a widely used open-source microcontroller board that serves as the heart of countless DIY electronics projects. Developed by the Arduino company, the Uno is based on the ATmega328P microcontroller. It features a user-friendly environment, both in terms of hardware and software, making it accessible to beginners and appealing to experienced developers alike.

The Arduino Uno includes digital and analog input/output pins that can be easily programmed through the Arduino Integrated Development Environment (IDE). It comes with built-in functionalities like timers, communication interfaces (UART, I2C, and SPI), and pulse-width modulation (PWM) outputs. The board is powered via a USB connection, and it can also be powered externally.

One of the key features of the Arduino Uno is its simplicity and versatility, allowing users to interface with a wide range of sensors, actuators, and other electronic components. Its open-source nature encourages a collaborative community, fostering the sharing of code and project ideas. The Arduino Uno has become a go-to choice for prototyping and creating interactive electronic projects, making it a fundamental tool for both hobbyists and professionals in the field of electronics and programming.

ESP32(Node MCU):

Figure 14. ESP32

The ESP32 stands out as a highly versatile microcontroller and system-on-chip (SoC) renowned in the realm of embedded electronics and Internet of Things (IoT) applications. Developed by Espressif Systems, this successor to the ESP8266 boasts a dual-core Tensilica Xtensa LX6 processor, offering enhanced processing power and multitasking capabilities. Notably, the ESP32 supports various wireless communication protocols, including Wi-Fi and Bluetooth, making it a preferred choice for IoT projects where connectivity is paramount. Its low-power design facilitates efficient operation in battery-powered devices, while a rich set of peripherals—ranging from GPIO pins to SPI and I2C—allows seamless interfacing with diverse sensors and actuators. The ESP32 also prioritizes security, incorporating features like hardware-accelerated encryption and secure boot. Additionally, it benefits from a robust development ecosystem with an active community, enabling developers to access a plethora of resources and libraries. Thanks to its affordability, widespread availability, and compatibility with popular integrated development environments like the Arduino IDE, the ESP32 has become a favored solution for hobbyists, makers, and professional developers across a spectrum of projects, from simple electronics to complex IoT applications[19][20].

Results
The implementation of the smart energy meter has yielded significant and promising results, marking a transformative impact on energy monitoring, consumption awareness, and management. Through the integration of a 0-25V DC voltage sensor and an ACS712 current sensor, the meter has demonstrated precise measurement capabilities, providing real-time data on both voltage and current consumption. The ESP32 connectivity has proven robust, enabling seamless communication between the meter and the dedicated web portal.

One notable outcome is the empowerment of end-users with comprehensive insights into their energy consumption patterns. The web portal's user-friendly interface allows individuals to monitor their energy usage efficiently, fostering a heightened awareness of consumption habits. The incorporation of advanced algorithms for calculating energy, power, and consumption prices has facilitated accurate billing, creating a transparent and accountable system for users.

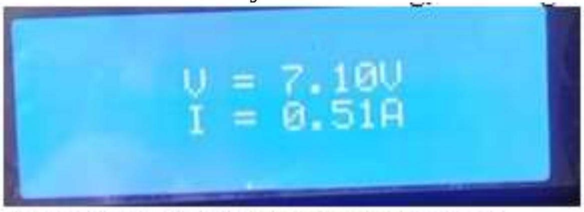


Figure 15. Voltage and Current measurement

Figure 16. Power and Energy Measurement

Figure 17. Price calculation

The administration features of the web portal have facilitated efficient bill generation and management. Admins can analyze aggregated data, generate bills, and initiate communication with users seamlessly. The incorporation of security measures ensures the integrity and confidentiality of the data, maintaining the trustworthiness of the system.

The overall impact of the smart energy meter has transcended individual user benefits, contributing to larger initiatives such as energy efficiency, sustainability, and grid management. The accurate and granular data collected by the meter can be leveraged for informed decision-making, paving the way for optimized energy distribution and consumption at a broader scale.

In conclusion, the results of the smart energy meter project underscore its efficacy in providing tangible benefits to end-users, administrators, and the broader energy ecosystem. The project's success not only lies in its technical functionality but also in its potential to catalyze positive shifts in energy consumption behaviors and contribute to a more sustainable and efficient energy landscape.

Applications

1. Real-time Monitoring and Alerts: - Manage energy use in real-time and notify users when their usage surpasses predetermined limits.

   - Notify users of any unexpected changes in voltage or current, as they could point to possible problems with the electrical system.

2. Historical Data Analysis: - Archive past data on the website so that administrators and users can examine patterns in energy usage over time.
   - To visualise patterns in the daily, weekly, or monthly energy usage, provide graphical representations and charts.

3. Energy Efficiency Suggestions: - Utilise the gathered information to provide users with tailored advice on how to maximise their energy use and cut expenses.
   - Offer advice on energy-saving devices or practices based on past usage trends.

4. Integration with Smart Home Systems: - Link your smart energy meter to well-known smart home services (like Google Home and Amazon Alexa) so that customers can use voice commands to monitor and regulate their energy usage.

5. Demand Response Integration: - Put in place a system that allows the grid operator or utility to send signals to lower energy use during times of peak demand.
   - Offer discounts or prizes to encourage users to take part in demand response programmes.

6. Integration of Renewable Energy: - Provide assistance in tracking and incorporating renewable energy resources, such solar or wind power plants.
   - Give consumers information about the proportion of energy they use that comes from renewable sources.

7. Integration of Energy Billing and Payment: - Extend the billing system to enable online payments via the web portal.
   - Integrate with different payment gateways to make transactions easy and safe.

8. Security and Access Control: - Put strong security measures in place to guard user information and guarantee safe communication between the web portal and the smart energy meter.
   - Give distinct users (admin, regular user) role-based access control to manage who can do what on the portal.

9. Mobile Application: - Create a mobile application that lets consumers pay bills, get alerts, and keep an eye on their energy usage while they're on the road.

10. Community and Social Features: - Provide a community forum on the website where users can exchange energy-saving advice and firsthand accounts.
    Incorporate social features, like leaderboards, to promote healthy competition among users and cut down on energy usage.

Future Scope

The future scope of your smart energy meter project is vast, with ongoing advancements in technology and increasing awareness of sustainable living. Here are some potential areas of growth and development:

1. Smart Grid Integration: - Work with utility providers to incorporate your smart energy meter into more comprehensive smart grid projects. Better energy management, fewer outages, and more grid efficiency can result from this.

2. Blockchain for Energy Transactions: Examine how blockchain technology can be integrated for safe and open energy transactions. Peer-to-peer energy trading may be made easier by this, and billing and payment transactions would have an unchangeable ledger.

3. Using machine learning algorithms to analyse past energy usage data and forecast future patterns is known as machine learning for predictive analytics. This could support users' and utility firms' decision-making about the distribution and consumption of energy.

4. Improvements in IoT and Sensor Technology: Keep abreast on developments in IoT devices and sensors. Your smart energy meter's accuracy and precision may be improved with more recent and precise sensors.

5. 5G Connectivity: - As 5G technology spreads, think about utilising its fast connectivity to improve the web portal's and the smart energy meter's communication. Faster data transfer and more rapid monitoring may result from this.

6. Edge Computing: - Instead of depending entirely on cloud services, investigate the possibilities of edge computing to process data locally on the device. By doing so, latency can be decreased and real-time monitoring capabilities enhanced.

7. Energy Harvesting Technologies: - Look into ways to complement or power the smart energy meter by using energy harvesting technologies, such as thermoelectric or piezoelectric devices. This may result in more self-sufficient and sustainable gadgets.

8. Integration with Smart Cities: Work with smart city programmes to provide an overall positive impact on urban sustainability. An urban environment that is more connected and effective can be achieved by integration with other smart systems, such as traffic control and smart lighting.

9. Augmented Reality (AR) Interfaces: - Create AR interfaces that provide users the immersive and interesting ability to see their energy usage in real-time. Users' comprehension and awareness of their energy use may be improved as a result.

10. Integration with Energy Storage: - Investigate integration with energy storage devices, like household batteries. By doing this, consumers may be able to store extra energy produced by renewable resources for use in times of high demand or low production.

11. International Standards and Interoperability: - Strive to implement and participate in international standards pertaining to energy management systems and smart meters. The scalability and general acceptance of your smart energy meter can be improved by interoperability with other devices and systems.

Your smart energy meter's long-term performance and relevance in the changing field of energy management will be largely dependent on its capacity to innovate continuously, adjust to new technologies, and prioritise sustainability.

Conclusion

In conclusion, the smart energy meter, with its integration of voltage and current sensors, ESP32 connectivity, and web portal capabilities, presents a robust foundation for sustainable energy management. As technology continues to advance, the future scope of this meter holds exciting possibilities. Collaborating with smart grid initiatives, integrating blockchain for transparent transactions, and harnessing the potential of machine learning for predictive analytics are promising avenues. Moreover, staying abreast of developments in 5G connectivity, edge computing, and energy harvesting technologies ensures the meter's adaptability to emerging trends. The prospect of contributing to smart city initiatives, implementing augmented reality interfaces, and incorporating energy storage solutions further underscores its potential impact on urban sustainability. Embracing global standards and fostering interoperability will be crucial for scalability and widespread adoption. As the smart energy meter evolves, its capacity to empower users, enhance energy efficiency, and contribute to a more sustainable future is poised to remain at the forefront of technological innovation in the energy management landscape.

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