An IoT Based Early Alert System to Monitor and Reduce Electrical Energy Consumption at Home in Smart Cities

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Abstract. The proposed IoT-based energy monitoring system is a powerful tool for managing and monitoring energy consumption in homes and small businesses. It is designed to measure the voltage and power consumed by appliances connected to it, providing users with real-time energy consumption data and a historical record of energy usage over time. Additionally, the system is equipped with features that enable remote access via a software application, allowing users to monitor their energy consumption and track their daily usage patterns to identify opportunities for energy savings. One of the most significant advantages of this system is its ability to turn off the appliances connected to it. Users can set up the system to turn off appliances when they are not in use, reducing energy consumption and lowering their electricity bills. The software application provides users with a comprehensive view of their energy consumption, allowing them to identify the appliances that consume the most energy and develop strategies to conserve energy. The application's data storage capabilities enable the safe and secure storage of energy consumption data, which can be accessed at any time. The appliance is a sophisticated energy monitoring system that operates by measuring the power and voltage consumption of appliances. It can be easily integrated into a home or small business network, and its data can be accessed remotely through the software application. With its powerful features, including real-time energy consumption monitoring, historical data tracking, and the ability to turn off connected appliances, this IoT-based energy monitoring system is an ideal choice for those looking to conserve energy and lower their energy bills.

Keywords: IoT-based energy monitoring system · voltage · power · remote access · energy consumption data · historical record · conserve energy · data storage · turn off appliances · real-time monitoring

1 Introduction

In recent years, energy management has become a critical issue in homes and small businesses due to the ever-increasing demand for energy and the need to conserve resources. With the advent of the Internet of Things (IoT), a new generation of energy monitoring systems has emerged, enabling consumers to monitor their energy consumption

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more efficiently and take steps to reduce their energy usage. The proposed IoT-based energy monitoring system aims to provide users with real-time monitoring of energy consumption and control over connected appliances, offering a simple and effective way to conserve energy [1].

The idea of monitoring energy consumption and controlling appliances remotely is not new. Several studies have been conducted on energy monitoring and conservation, and a variety of devices have been developed to help users manage their energy usage [2]. For instance, a study by Han et al. (2012) proposed a system that allows users to monitor energy consumption in real-time and control appliances remotely. The system used sensors and a cloud-based platform to provide users with real-time energy consumption data and offer suggestions for energy conservation [3]. The system consisted of sensors and smart plugs that could be used to turn off appliances when they were not in use, helping users reduce their energy consumption [4]. Similarly, a study by Tian et al. (2013) developed an energy monitoring system that could measure and analyze energy consumption in homes and small businesses.

The proposed IoT-based energy monitoring system builds on the work of previous studies and offers several innovative features that make it an ideal solution for homes and small businesses [5]. First, the system can measure voltage and power consumption accurately, providing users with a precise measurement of their energy usage. Second, the system is integrated with a software application that allows users to access real-time energy consumption data and historical records of energy usage [6]. This feature enables users to monitor their energy usage and identify opportunities for energy conservation. Third, the system has the ability to turn off connected appliances remotely, providing users with a convenient way to conserve energy and reduce their electricity bills [7].

Several studies have shown that energy monitoring systems can be effective in reducing energy consumption [8–10]. For example, a study by Jin et al. (2015) found that energy monitoring systems can help users reduce their energy consumption by up to 15%. Similarly, a study by Garg and Singh (2015) showed that energy monitoring systems can help users identify energy wastage and develop strategies for energy conservation. These studies highlight the importance of energy monitoring systems in promoting energy efficiency and reducing energy consumption.

The proposed IoT-based energy monitoring system offers several advantages over traditional energy monitoring systems. First, it provides real-time energy consumption data, enabling users to monitor their energy usage and identify areas for improvement. Second, the system can be controlled remotely, allowing users to turn off appliances and reduce energy consumption with ease. Third, the system is highly accurate and reliable, ensuring that users receive precise measurements of their energy usage. These advantages make the proposed system an ideal solution for homes and small businesses looking to conserve energy and reduce their electricity bills.

In conclusion, the proposed IoT-based energy monitoring system is a significant innovation that can help consumers manage their energy consumption more effectively. The system's innovative features, including real-time energy consumption monitoring, remote control of appliances, and accurate measurements of energy usage, make it an ideal solution for homes and small businesses. The system builds on the work of previous studies on energy monitoring and conservation and offers several advantages over

traditional energy monitoring systems. The next section will discuss the methodology used in developing the proposed system.

2 System Description

The power supply of 220 V is given to the step down transformer. It converts the high volt to low volt and the power supply of 12 V is given to the rectifier. Rectifier has 2 regulators, 7812 and 7805. 7812 is the regulator that is used for the power supply of 12 V for the relay. 7805 is used to provide power supply for the controller, WiFi Module and LCD Display. 2 Current sensors and 2 voltage sensors are connected with it. Voltage sensor is done by connecting the rectifier with the Potential transformer. Analog input is given to the Arduino board. The values are updated to the cloud and that can be accessed by software using the channel number. The values can be viewed on the software. Once the units reaches the threshold. With the relay the power is turned off.

2.1 Hardware Components

2.1.1 Microcontroller Arduino Uno

Arduino Uno is a popular microcontroller board that is widely used in energy monitoring devices for data acquisition, processing, and control. In energy monitoring systems, Arduino Uno is used as the main control unit that interfaces with different sensors and modules to collect data, analyze it, and provide control signals to different components.

By using Arduino Uno, energy monitoring devices can be customized and programmed to meet specific requirements, enabling the implementation of advanced monitoring and control algorithms. Arduino Uno is equipped with various input/output pins that can be used to interface with different sensors and modules, such as current and voltage sensors, WiFi modules, LCD displays, and relays (Fig. 1).

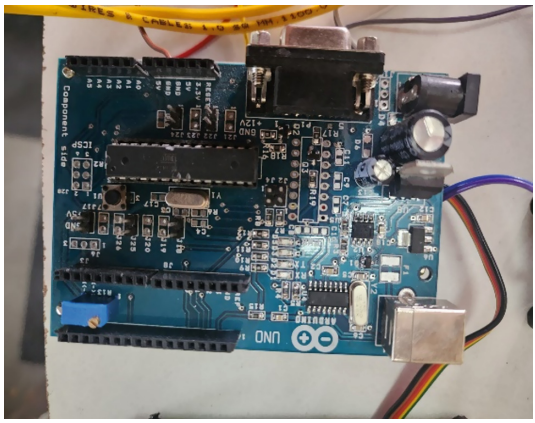

Fig. 1. Microcontroller Arduino Uno

2.1.2 Step Down Transformer

Step-down transformers can also be useful in energy monitoring devices, which measure and monitor the amount of electrical energy used by households, businesses, or other facilities. These devices typically use current transformers (CTs) or voltage transformers (VTs), which are types of step-down transformers, to reduce the voltage or current level of the AC power signal before it is measured. The current transformer reduces the current level of the AC signal, making it easier to measure accurately. Similarly, a voltage transformer can be used to measure the voltage level of the AC signal by reducing it to a lower, more manageable level.

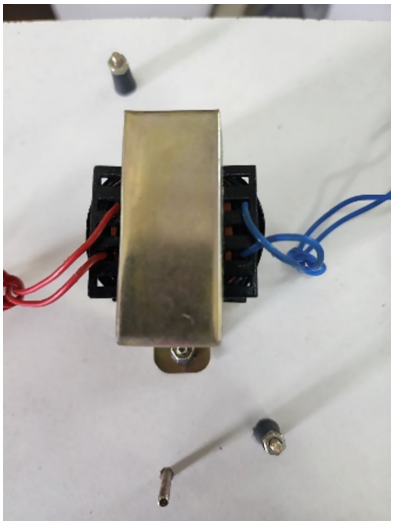

Fig. 2. Step Down Transformer

2.1.3 Current Sensor

Current sensors, also known as current transducers, are important components in energy monitoring devices used for measuring and monitoring electrical energy consumption. These devices measure the electrical current flowing through a conductor and convert it into an electrical signal that can be measured and analyzed. In energy monitoring devices, current sensors are typically used with a microcontroller or a similar electronic device that can process the signals from the sensor and calculate the amount of electrical energy being consumed by the load. By measuring the current flowing through a power line, current sensors can provide real-time information about the power consumption of devices, machines, or entire systems, which is essential for optimizing energy usage, identifying power-hungry appliances, or detecting energy waste and leaks. Current sensors are widely used in energy monitoring systems for various applications, such as monitoring the power consumption of HVAC systems, refrigeration systems, motors, pumps, and lighting systems in industrial, commercial, and residential settings (Fig. 3).

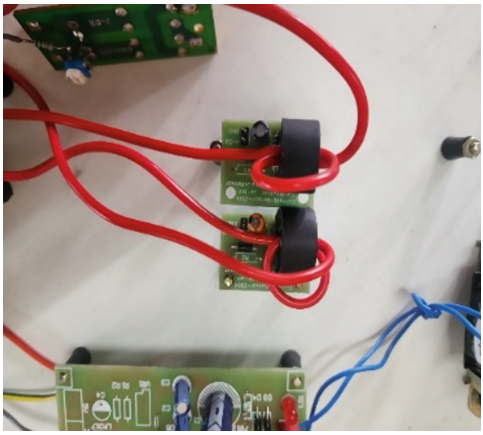

Fig. 3. Current Sensor

2.1.4 Voltage Sensor

Voltage sensors are important components in energy monitoring devices used for measuring and monitoring electrical energy consumption. These devices measure the electrical voltage level of a circuit and convert it into an electrical signal that can be measured and analyzed. In energy monitoring devices, voltage sensors are typically used in conjunction with current sensors to determine the amount of electrical energy being consumed by a load. By measuring both the current and voltage levels of a circuit, the power consumption of the load can be calculated in real-time. This information can be used to optimize energy usage, identify power-hungry appliances, or detect energy waste and leaks. Voltage sensors are essential components in energy monitoring devices that enable the accurate and precise measurement of electrical energy consumption, facilitating energy management and conservation efforts in various industries and applications.

2.1.5 Relay

Relays are important components in energy monitoring devices used for controlling the flow of electrical power to loads or circuits. In energy monitoring systems, relays are used to switch power on and off to the loads being monitored. Relays work by using an electromagnetic coil to open or close a set of contacts. When the coil is energized, the contacts close and power flows to the load. When the coil is de-energized, the contacts open, and power is disconnected from the load. In energy monitoring systems, relays are typically used to control the power supply to specific loads or circuits. For example, a relay can be used to switch off the power supply to a specific appliance during off-peak hours when energy consumption is high. This can help to reduce energy consumption and save costs. Relays can also be used to control the power supply to entire buildings or facilities (Fig. 4).

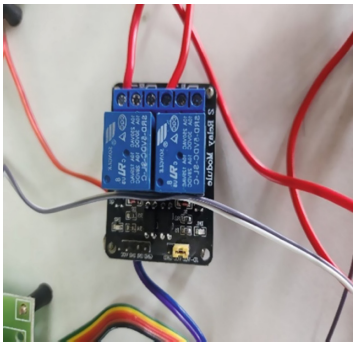

Fig. 4. Relay

3 Proposed System

- Hardware Components: The proposed system will include a set of hardware components such as sensors, microcontrollers, and relays to measure the voltage and power consumed by the appliances that are connected to the system. These components will be connected to a central hub that will communicate with the software application.
- Software Application: The system will include a software application that will be accessible from a mobile device or computer.
- Cloud Storage: The data collected by the sensors will be stored on a cloud-based platform. The cloud storage will allow for easy access to the data from anywhere in the world and ensure the data is not lost in case of a system failure.
- Data Analytics: The proposed system will incorporate data analytics to provide insights into energy consumption patterns. The data analytics will help users identify which appliances consume the most energy and at what time of day, enabling them to make more informed decisions about their energy consumption.
- Integration with Smart Home Devices: The proposed system can be integrated with smart home devices to provide a more seamless user experience.

3.1 Methodology

1. Identify the objectives and requirements:
   - Define the goals of your early alert system, such as reducing energy consumption, identifying abnormal usage patterns, or optimizing energy efficiency.
   - Determine the specific requirements, including the types of sensors, communication protocols, and alert mechanisms you want to incorporate.
2. Sensor selection:
   - Choose appropriate sensors to collect data on energy consumption. This can include smart energy meters, current sensors, temperature sensors, or occupancy sensors.
   - Ensure that the selected sensors are compatible with IoT platforms and can provide accurate and real-time data.

3. IoT platform and connectivity:
   - Select an IoT platform or framework that supports data collection, storage, and analysis. Examples include AWS IoT, Google Cloud IoT, or Microsoft Azure IoT.
   - Determine the connectivity options for your IoT devices, such as Wi-Fi, Bluetooth, or Zigbee, based on the range and scalability requirements.
4. Data collection and transmission:
   - Install and configure the selected sensors to collect energy consumption data at regular intervals.
   - Establish a secure and reliable communication channel between the sensors and the IoT platform for transmitting the data. Ensure encryption and authentication mechanisms are in place to protect the data.
5. Data storage and processing:
   - Set up a data storage system, such as a cloud database, to store the collected energy consumption data.
   - Implement data processing algorithms to analyze the data and identify patterns or anomalies in energy usage. This can involve statistical analysis, machine learning, or rule-based methods.

6 Alert generation and notification:
   - Define the criteria for triggering an alert based on predefined thresholds or abnormal usage patterns.
   - Implement an alert generation mechanism that can generate notifications when unusual energy consumption is detected.
   - Choose appropriate alert mechanisms, such as email notifications, SMS alerts, or mobile app notifications, to inform users about energy consumption anomalies.
7. User interface and visualization:
   - Develop a user-friendly interface, either a web or mobile application, to visualize energy consumption data and provide insights to users.
   - Display real-time energy consumption information, historical trends, and alerts in an easily understandable format, such as graphs or charts.
8. Testing and validation:
   - Conduct extensive testing of the entire system to ensure its reliability, accuracy, and responsiveness.
   - Validate the system's effectiveness in identifying abnormal energy consumption and generating timely alerts.
   - Gather user feedback and iterate on the system to improve its performance and usability.

9. Deployment and maintenance:
   - Deploy the system in the target environment, such as residential homes or apartments.
   - Monitor the system regularly to ensure it continues to function properly and provide accurate alerts.
   - Address any maintenance or upgrade needs, such as replacing faulty sensors or updating the software, to maintain the system's efficiency over time.

4 Circuit Implementation

See Fig. 5.

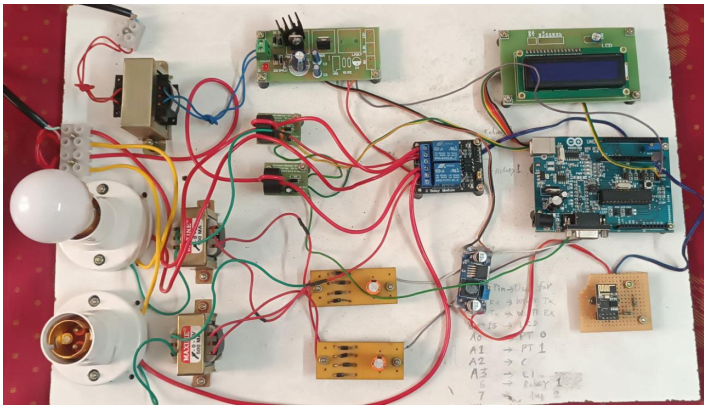

Fig. 5. Circuit of the Proposed System

5 Energy Consumption Graph

See Fig. 6.

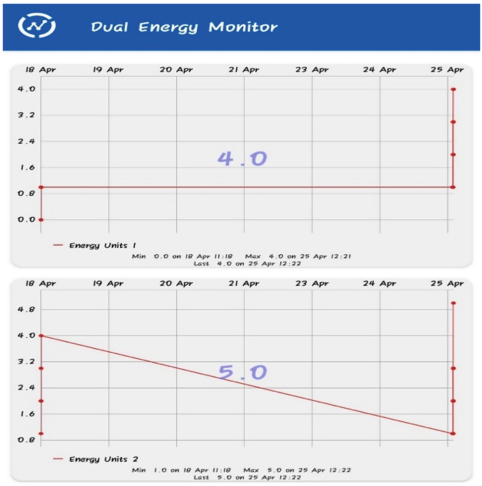

Fig. 6. Energy Consumption Graph

6 Future Enhancements

Enhanced Data Analytics: The current system collects data on energy consumption but there is scope for further analysis of the data to provide insights into energy consumption patterns, such as identifying which appliances consume the most energy and at what time of day. This could help users make more informed decisions about their energy consumption and identify areas for potential energy savings.

Artificial Intelligence: AI could be integrated into the system to provide predictive analysis of energy consumption patterns, enabling users to make more informed decisions about how they use their energy. For example, the system could predict when energy usage is likely to be high and suggest ways to reduce consumption or reschedule energy-intensive tasks.

Renewable Energy Integration: With the increasing adoption of renewable energy sources, such as solar panels, wind turbines and hydroelectric systems, IoT-based energy monitoring systems can be enhanced to measure the energy generated from these sources as well as the energy consumed. This would enable users to optimize their use of renewable energy and potentially sell excess energy back to the grid.

Smart Grid Integration: With the advent of smart grid technology, IoT-based energy monitoring systems can be integrated with the smart grid to enable more efficient energy consumption. For example, the system could receive signals from the grid indicating when energy prices are low, enabling users to schedule energy-intensive tasks accordingly.

Voice-Activated Controls: Integrating voice-activated controls into the system would provide a more convenient way for users to control their appliances. Users could simply issue voice commands to turn appliances on or off or adjust their settings.

Augmented Reality: By integrating augmented reality into the system, users could get a visual representation of their energy consumption in real-time. For example, they

could use their smartphone or tablet to view a 3D model of their home and see which appliances are consuming the most energy.

Blockchain Technology: Integrating blockchain technology into the system could provide a more secure and transparent way of managing energy transactions. For example, users could earn rewards for reducing their energy consumption during peak demand periods, and these rewards could be stored on a blockchain-based platform.

7 Advantages

Energy Savings: One of the primary advantages of an IoT-based energy monitoring system is the potential for energy savings. By monitoring and controlling the energy consumption of connected appliances, users can optimize their energy usage and reduce their overall energy bills.

Increased Awareness: IoT-based energy monitoring systems provide users with real-time information on their energy consumption, which can increase their awareness of how much energy they are using and where it is being used. This can help users make more informed decisions about their energy consumption and potentially reduce their energy usage.

Remote Control: IoT-based energy monitoring systems allow users to control their connected appliances remotely, which can be particularly useful for households with multiple occupants or for users who are away from home for extended periods.

Improved Efficiency: By optimizing energy consumption patterns, IoT-based energy monitoring systems can improve the overall efficiency of energy usage. This can lead to reduced energy waste and potentially lower greenhouse gas emissions.

Data Analytics: IoT-based energy monitoring systems provide users with detailed information on their energy consumption patterns. This information can be used to identify inefficiencies and areas for improvement, enabling users to make informed decisions about their energy consumption.

Integration with Smart Home Devices: IoT-based energy monitoring systems can be integrated with smart home devices such as thermostats, lighting, and security systems, providing users with a more seamless user experience.

Cost-Effective: IoT-based energy monitoring systems are generally cost-effective compared to traditional energy monitoring systems. Additionally, the potential for energy savings can help users recoup the initial investment in the system over time.

Environmental Benefits: By reducing energy waste and potentially lowering greenhouse gas emissions, IoT-based energy monitoring systems can provide environmental benefits and contribute to a more sustainable future.

8 Limitations

- While an IoT-based energy monitoring system has many benefits, it also has some limitations that should be considered. Here are some potential limitations:
- Cost: IoT-based energy monitoring systems can be expensive to install and maintain. This could limit their adoption among households and small businesses that cannot afford the upfront costs.

- Connectivity: The reliability of the system depends on the strength of the internet connection. Poor connectivity can affect the accuracy of the data collected and the ability to control appliances remotely.
- Compatibility: The system may not be compatible with all types of appliances. Older appliances may not be able to connect to the system, or may require additional hardware to do so.
- Security: IoT devices are vulnerable to cyber-attacks, and an energy monitoring system is no exception. Hackers could potentially gain access to the system and control appliances remotely or steal sensitive data.
- Data privacy: Collecting data on energy consumption raises concerns about data privacy. Users may not want their energy usage data to be shared with third-party companies or government agencies.
- Reliability: The accuracy of the system's data collection depends on the accuracy of the sensors used. If the sensors are not properly calibrated or are faulty, the data collected may not be accurate.
- Limited Control: While the system allows users to control their appliances remotely, it may not provide the same level of control as manual control. Users may not be able to adjust the settings of their appliances as precisely as they would if they were physically present.
- Overall, while an IoT-based energy monitoring system has many advantages, it is important to consider these potential limitations and address them appropriately.

9 Conclusion

In conclusion, the IoT-based energy monitoring appliance offers an efficient and effective solution to monitor and manage energy consumption in homes and businesses. By providing real-time energy consumption data and historical records of energy usage, the system enables users to make informed decisions about their energy usage and identify opportunities to save energy and reduce costs.

The ability to remotely turn off connected appliances to conserve energy also offers added convenience and control. The system provides accurate measurements of energy usage for each appliance, allowing users to understand the energy consumption of individual appliances and make informed decisions about their usage.

Moreover, the system is easily accessible through a user-friendly software application that provides a comprehensive overview of energy consumption, making it easy for users to understand their energy usage and identify areas for improvement. By storing historical records of energy usage, the system also allows users to track their energy consumption over time and identify patterns and trends.

Overall, the IoT-based energy monitoring appliance represents a significant step forward in energy management technology and has the potential to revolutionize the way we monitor and manage energy consumption in homes and businesses. The system provides a cost-effective and easy-to-use solution for energy management that has numerous benefits for both individuals and society as a whole, including reduced energy consumption, cost savings, and a more sustainable future.

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