IoT-BASED SMART ENERGY METER

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Abstract - An ESP32-based IoT energy meter with the Blynk IoT platform works by measuring a device's or system's energy consumption and transmitting that data to the Blynk cloud server for further analysis and visualization. The ESP32 module is a small, low-power, and powerful microcontroller with built-in Wi-Fi and Bluetooth capabilities. It is capable of measuring the electrical parameters of a system, such as voltage, current, and power, using sensors such as current transformers and voltage dividers. The measured data is then processed by the ESP32 module and transmitted to the Blynk IoT cloud platform using Wi-Fi or cellular data. Blynk is a cloud-based IoT platform that provides an easy-to-use interface for monitoring and controlling IoT devices. It allows users to create customized dashboards, graphs, and notifications based on real-time data from connected devices. Blynk also offers various widgets that can be used to display the data in different formats. In summary, an ESP32-based IoT energy meter with the Blynk IoT platform works by measuring the energy consumption of a device or system using sensors and transmitting that data to the Blynk cloud server for analysis and visualization. The Blynk platform provides an easy-to-use interface for monitoring and controlling the device and displaying the data in real time.

I.INTRODUCTION

One of the essential elements for maintaining life's essentials is electricity. To ensure proper use, it should be used very sparingly. However, there are numerous locations in our nation where there is an excess supply of electricity, whereas many others do not even have access to it. Because of the state of technology, you must travel to the meter reading room to record readings. As a result, tracking and monitoring your electricity usage is a laborious effort. We can make use of the Internet of Things to automate this. The Internet of Things automates distant data collection to save time and money.

Because we are still unable to accurately predict our precise needs and power theft is still an issue, our distribution practices are also partially to blame. On the other side, customers are also dissatisfied with power firms' services. They typically complain about statistical mistakes in the monthly bills. With this, we can keep an eye on the meter and determine whether or not a fault exists. A circular metal strip rotates in the previous meter, and we calculated the consumption based on that revolution. However, our meter operates on a pulse that is generated based on consumption, and we had previously connected an Android board that monitors the pulse and generates bills based on the pulse. We hope to use this project to transmit the monthly energy use from a remote point to a central office. By doing this, we can decrease the amount of time that must be spent visiting each residence one at a time to record the meter readings, which are now done manually. A smart energy meter is a piece of technology that accurately calculates how much electricity is used by a building, a company, or any other electrically powered item. A smart meter is a trustworthy source for the most accurate data on energy used, minimizing the possibility of error in the current billing system.

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Origin

The great invention of the nineteenth century was the method of invention: The method of innovation was the greatest invention of the nineteenth century. This adage, attributed to the English mathematician and philosopher Alfred North Whitehead (1891–1947), is particularly applicable to the evolution of the electrical meter, which was made better by a series of discoveries that built on earlier advances and encouraged additional research.

The first half of the 19th century brought brilliant discoveries in electromagnetism: The early part of the 19th century saw some outstanding electromagnetic discoveries. André-Marie Ampère (1775–1836), a Frenchman, discovered the electrodynamic interaction between currents in 1820. A German, Georg Simon Ohm (1787–1854) discovered the connection between voltage and current in a conductor in 1827. The rule of induction, which forms the foundation for the operation of generators, motors, and transformers, was discovered in 1831 by the British scientist Michael Faraday (1791–1867).

Motivation

One of our most basic demands is electricity, which is frequently used in today's society for home, commercial, and agricultural uses. Most of us are aware of the energy meter's function in the electrical grid. It is a crucial part of the distribution grid. The utility (the electricity distribution firm) utilizes energy meters to account for the kw-per-hour usage of electricity by consumers. The corporations that distribute energy are unable to keep up with shifting consumer demand using the current billing method. Regular customers encounter issues with late payments for bills that have already been paid as well as unreliable electricity delivery. To ensure proper invoicing, track peak demand, and identify threshold values, it is necessary to maintain track of all consumer electricity usage on a timely basis.

Problem Definition

• To comprehend this, we first identify the shortcomings of the current energy meter and the main issue with electricity metering.
• The largest issue with power distribution is the manual collection of meter reading data, which leaves room for corruption and human mistake in reading. Additionally, it wastes useful resources and labor.
• The electricity meters we now have are not tamper-proof. There are far too many instances of tampering.
• The current meter does not have Undervoltage or overvoltage protection.
• There is no overpowering alert system. The Utility is unable to collect fees for maximum demand cross as a result.
• The largest issue nowadays, which costs electrical boards a lot of money, is power theft.

Project Objective

The Main objectives of IoT based Energy Meter must have

- AMR (Automatic Meter Reading)
- Meter Tampering Detection
- Overpower cut-off
- Overvoltage Protection
- Overcurrent Protection
- Remote Disconnection and Reconnection
- Post-paid plans
- Detailed analysis of energy consumption
- Online energy analyzation
- Less error in taking a meter reading
- Online power management.

II. LITERATURE SURVEY

A. “IoT Based Smart Energy Metering System for Power Consumers” Md. Mohitul Haque, Zakir Hasan Choudhury, G. Sai Tejesh, and Fakir Mashuque Alamgir [12] [2019]:

In recent years, the number of smart devices has increased, making it possible to build smart cities. A smart grid that permits intelligent management of the electric grid is the core component of a smart city. The network must have smart meters that can communicate with the network in a duplex for this to happen. This business has led to the widespread usage of intelligent meters, which allow for the assessment of each household unit's consumption. The goal of this program is to develop a widely used chip-based IoT electrical meter that will record all meter data and wirelessly transfer the necessary meter data to the main server.

B. “Wireless IoT-based Metering System for Energy Efficient Smart Cites”- Maha Aboelmaged, Yasmeen Abdelghani, Mohamed A. Abd El Ghany :

We now have the opportunity to create energy-efficient smart cities, systems, and gadgets thanks to the recent emergence of the Internet of Things concept. This study suggests a design for an IoT-based energy-efficient wireless smart metering system in response to the pressing demand for energy conservation. As a completely integrated metering system at a cheap cost, it competes with the current meters. Along with a website and database for the electricity supply business, it provides users with an Android application that is simple to use. The proposed system design has a 97% accuracy rate and costs around 25% less than its competitors in the international market. The recommended design resulted in a 16% reduction in power consumption.

C. “Smart Energy Meter Surveillance Using IoT”- Anitha. K, Anitha. V [2019]:

In daily life, electricity plays a crucial role. With a 5.5% global share in 2016, India's electrical energy consumption ranked third after that of China and the United States. India uses energy at a rate closer to 0.7 KW per person. By 2035, India's portion of the world's energy demand will increase to 9%. A revolution in electronics and IT has been brought about by the Internet of Things (IoT), a new field. The main goal of this initiative is to raise knowledge about energy usage and the effective use of home appliances to reduce energy consumption. Our current electricity billing system has significant flaws because it requires manual labor. This system provides information on meter readings, power outages, and alert devices that use IoT to sound an alarm when energy use exceeds a set limit.

D. “IOT Based Smart Energy Meter for Efficient Energy Utilization in Smart Grid”- Bibek Kanti Barman, Shiv Nath Yadav, Shivam Kumar Sadhan Gope:

Efficiency in energy use is essential for the growth of the smart grid in the power system. So the smart grid's top priority is to properly monitor and control energy consumption. One of the main issues with the current energy meter system, which has numerous other issues as well, is that full duplex communication is not available. An Internet of Things (IoT)-based smart energy meter is suggested as a solution to this issue. The suggested smart energy meter uses ESP 8266 12E, a Wi-Fi module, to manage and compute energy use and uploads the results to the cloud, where the consumer or producer can examine the results. As a result, consumer energy analysis is made considerably simpler and more manageable.

E. “Arduino Based Smart Energy Meter using GSM”- Himanshu K. Patel, Tanish Mody, Anshul Goyal:

India has a significant problem with energy theft. To reduce the error that typically results in confusion and corruption related to energy use, this study offers a method that eliminates human interaction in meter readings and bill creation. The proposed system is developed using an Arduino® microcontroller equipped with a GSM shield module, an LDR sensor, and a relay. The proposed meter can be implemented with very minor changes to the current metering system. The suggested method involves attaching an LDR sensor to the flickering LED and using a GSM shield to transmit data to the microcontroller.

F. “IOT Based Energy Meter Reading System” - Cicero Raimundo Estibeiro:

Energy efficiency is crucial to the development of the smart grid in power systems. Consequently, a crucial step is to properly monitor and manage energy consumption. The smart grid is the top priority. There are many issues with the current energy metering system. The absence of full-duplex communication is a significant issue. We suggest a smart energy meter based on the Internet of Things (lot) to address this issue. The suggested smart energy meter uses the Wi-Fi module ESP 8266 12E to monitor and compute power consumption, then uploads the results to the cloud where the consumer or manufacturer can examine the results. This makes customer energy analysis considerably simpler and more in control. This system aids in the detection of energy theft. As a result, this smart meter facilitates wireless communication and home automation via IoT, which is a significant milestone in India's digital revolution.

G. “ARDUINO BASED WIRELESS POWER METER”- Christopher McNally:

The reduction of energy consumption in families is one way to address the current energy issues. The current utility system only offers feedback in the form of a bill and the number of kilowatt hours (kWh) used at the end of the month. There is no method for a homeowner to monitor their energy usage more frequently. A non-intrusive current meter for domestic power with a MATLAB interface, the wireless power meter is built on an Arduino platform. Transformers with split cores are used to monitor the current. The base station and MATLAB interface receive this data via an 802.11b connection via the wireless network in the home. The project seeks to present an accurate image of a home's current usage and to estimate power consumption using this information. By analyzing this recent data, the research also attempts to pinpoint which gadgets are turned on and off. The intention is for users to optimize and reduce their power usage by receiving such data.

H. "GSM Based Automatic Energy Meter Reading and Load Control"- Thota Akhila, Ch. Balaram Murthy, T. Ragini:

This essay examines the various automatic meter reading (AMR) system techniques. The AMR technology allows the energy provider to remotely access an existing energy meter. The old method of manually reading electricity meters, in which a meter reader makes periodic trips to each meter location and manually reads the meter value, is being replaced by the AMR system. This allows us to regularly check the meter readings without having to go to the consumer's location. The Global System for Mobile (GSM), General Pocket Radio System (GPRS), Broadband Carrier in Power Line, and Radio Frequency are some of the communication modules this AMR system uses. The reading of an energy meter is transmitted from the consumer site to the electricity board using one of the many techniques described in this document.

I. "Smart energy meter using Arduino and GSM"- Sneha Chaudhari, Purvang Rathod, Ashfaque Shaikh, Darshan Vora, Jignesha Ahir:

It demonstrates how clever flywheel shape design could improve Specific Energy performance and lessen operational loads placed on the shaft and bearings as a result of lower mass at high rotational speeds. So that the project's clear goal can be observed, we shall compare the theoretical values with the ANSYS numbers. Here, a different form of flywheel has been selected, such as rim type. It is compared to the actual shape, and the results are shown.

J. "GSM Based Automatic Wireless Energy Meter Reading System"- P. Harish, S:

This paper describes the creation of a GSM automatic power meter reading (GAPMRR) system. Every consumer unit in this system has a GSM digital power meter attached. The energy meter is wired to a GSM modem. Each modem will have its SIM. The utilized sim card is integrated into the energy meter and notifies the user through text messages when a bill is overdue. The hardware module for the user interface uses an LCD. The consumption of units and current usage are shown on the LCD. The system here has two modes of operation. The first mode is dependent on the passage of time, whereas the second mode depends on the consumption of electricity. Using GSM, information on the units is sent to the power board office every 30 days.

III.METHODOLOGY

Block Diagram

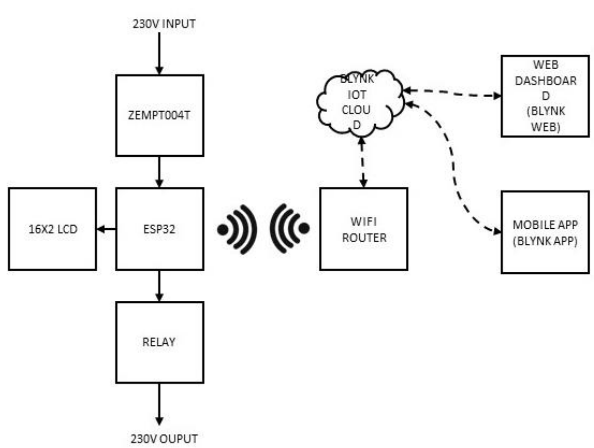

Fig. 1. Block Diagram

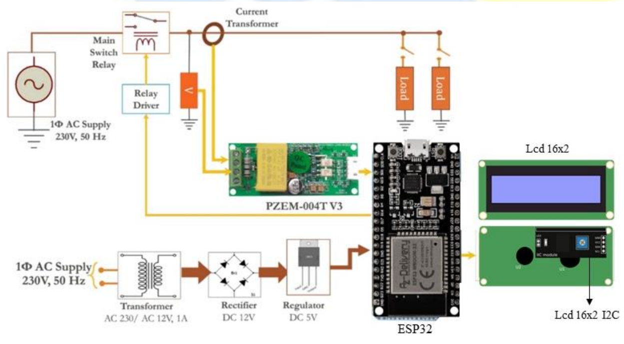

Fig. 2. Circuit Diagram

A powerful development board based on the ESP32 microcontroller is the ESP32 Devkit V1. It is the perfect platform for IoT applications because it has dual-core processors, Wi-Fi and Bluetooth connections, and a variety of connectors for sensors and peripherals.

The Internet of Things, or IoT, is the idea of using common things to collect and exchange data by connecting them to the Internet. Due to its wireless networking capabilities, low power consumption, and support for several protocols and interfaces, the ESP32 Devkit V1 is well-suited for IoT applications.

The ESP32 Devkit V1 has several important features, including:

- Dual-core processor with a clock frequency of up to 240 MHz
- Bluetooth and Wi-Fi connectivity at 2.4 GHz

- SRAM and SPI flash memory integrated
- Several interfaces for digital and analog input and output, including UART, I2C, SPI, ADC, and DAC
- Support for well-known IoT protocols such as CoAP and MQTT

These characteristics allow the ESP32 Devkit V1 to be utilized to create a variety of IoT applications, including smart home gadgets, environmental monitoring systems, and industrial automation solutions.

B. PZEM004T

The PZEM004T is an integrated module that integrates functionality for measuring voltage, current, power, energy, and frequency. It is frequently used to measure and monitor electrical properties in a variety of applications, such as power distribution units, smart plugs, IoT devices, and energy monitoring systems. Here is a thorough description of the PZEM004T sensor:

1. Voltage Measurement: The PZEM004T can gauge the AC voltage of the connected electrical system. It may be used in the majority of household and commercial applications because of its operating voltage range of 80 to 260 volts AC. Typically, the measurement accuracy is within 1%.

2. Current Measurement: The AC passing through the electrical circuit can be measured by this sensor. It can measure currents of up to 100A. Typically, the measurement accuracy is within 1%.

3. Power measurement: The PZEM004T multiplies the measured voltage and current values to get the instantaneous power usage. It offers watts (W)-based real-time power measuring. The accuracy of the power measurement is typically 2% or less.

4. Energy Measurement: The module can calculate the total energy usage in kilowatt-hours (kWh). It contains an energy accumulator inside that track how much power is used over time continually. The accuracy of the energy measurement typically hovers around 1%.

5. Frequency Measurement: The PZEM004T can measure the frequency of the AC power source in addition to voltage, current, power, and energy. The majority of common AC power systems are covered by their operating frequency range of 45 to 65 Hz.

The PZEM004T is a sensor module, not a stand-alone device, which is a crucial distinction to make. It has to link with an external microcontroller or system to read the measurements and process the data to the demands of the individual applications.

Please note that while the PZEM004T sensor module is covered in broad terms in this overview, there may be differences or unique features depending on the module's maker or version.

C. 16x2 LCD with I2C

A common style of alphanumeric display module combines a 16-character by a 2-line display with an I2C communication interface: the 16x2 LCD with I2C interface. The wiring and operation of the display are made simpler by this combination, making it simpler to incorporate into a variety of applications. Here is a thorough explanation of a 16x2 LCD using I2C:

1. Display Resolution: A 16x2 LCD has two rows of 16 characters apiece, with each row able to show up to 16 characters. Alphanumeric, graphical, and especially specified characters can all be displayed at each character place.

2. Backlight: The majority of 16x2 LCD panels with I2C have an integrated backlight that provides illumination for improved visibility under various lighting conditions. Other colors might be offered, however, the lighting is typically white or blue.

3. I2C Interface: The I2C interface makes it easier for the microcontroller and LCD to communicate. It transmits data and commands using the two-wire serial communication protocol (SDA and SCL). Multiple devices can be linked on the same bus thanks to the I2C interface, which lowers the number of pins needed on the microcontroller.

D. 5v Adapter

A device that produces a consistent and regulated 5-volt direct current (DC) output for powering electrical equipment is referred to as a 5-volt adapter, also known as a 5V power supply or 5V DC adapter. Here is a thorough explanation of the 5V adapter:

1. Function: A 5V adapter's primary function is to change the voltage coming from a wall socket or other power source from alternating current (AC) to low-voltage direct current (DC), which may then be used to power a variety of electronic devices.

2. Output of Voltage and Current: The controlled output voltage of a 5V adaptor is 5 volts DC. For the linked device to get consistent power, this voltage is normally fixed and stable. Depending on the model, the current output capacity (measured in amperes or milliamperes) varies and is created to satisfy the power requirements of the connected device.

3. Connector kinds: Different connector kinds, including USB Type-A, micro-USB, USB Type-C, barrel connectors, and other proprietary connectors, are available on 5V adapters at the output end. The exact device or application for which the adapter is intended determines the connector to be used.

4. Input Voltage Range: A 5V adapter's input voltage range is determined by its design and intended application. The majority of the time, 5V adapters are made to function with typical AC power sources that deliver voltages between 100V and 240V AC. To ensure compatibility with the local power supply, it's crucial to review the adapter's specs.

E. 5v Relay Module

An electromechanical component known as a 5V relay is frequently used in electronic circuits to manage higher voltage or current loads with a lower voltage signal. Here is a thorough explanation of a 5V relay:

1. Function: A 5V relay's main function is to control and isolate a low-voltage control circuit (usually 5V) from a higher-voltage or current circuit (like 120V or 240V AC).

2. Control Signal: A 5V control signal is applied to the relay coil to turn on the relay. A microcontroller, logic circuit, or other electronic parts may produce this signal. The contacts of the relay change state when the coil is energized, either opening or closing the load circuit.

3 Relay types: Relay types include single-pole single-throw (SPST), single-pole double-throw (SPDT), double-pole single-throw (DPST), and double-pole double-throw (DPDT) combinations, among others. The decision is based on the needs of the particular application.

4 Relay Driver: A relay driver circuit could be needed to supply enough current and voltage levels to energize the relay coil because the control circuit normally runs at a lower voltage (5V). Transistors, optocouplers, or specialized relay driver ICs may be used in this circuit.

It's important to keep in mind that a 5V relay's precise features and qualities can change according to the model, manufacturer, and application requirements. For correct information on the relay's specs, pin configuration, and recommended usage, it is imperative to reference the datasheet or documentation.

F. ESP32 DEV KIT VI

The ESP32 is a microcontroller device with several Bluetooth and Wi-Fi connectivity capabilities, which are the primary needs of IoT projects. The ESP32 serves as the project's primary brain, collecting, processing, and sending data to an IoT platform, where we can view and analyze the data.

G. PZEM004T

We have measured the voltage and current values using the PZEM004T sensor, which also measures power, energy, and frequency. These data are transmitted to the ESP32, which will process them by the provided codes. In this sensor, CT is utilized to measure the conductor's current flow.

H. 16X2 LCD WITH I2C

The flywheel is available to raise the RPM at the generation component with low input side RPM. To speed up the generator's rotation and make it last longer, the flywheel is equipped with a counterweight. By mounting the flywheel on the hub that is attached to the little sprocket, the flywheel can be turned. The chain joins the flywheel's bigger sprocket to its smaller counterpart.

I. 5V RELAY

The power source is controlled by a switch called a 5V relay. ESP32 provides the signal input for the relay in this case dependent on the requirements or circumstances.

J. 5V Power Adapter

Normally all the sensors, relay, and ESP32 need a 5V DC supply to work. So we are using a 5V DC adapter to convert 230V AC supply to 5V DC.

K. SOFTWARE IMPLEMENTATION

When using the Blynk IoT platform, an ESP32-based energy meter measures the energy usage of a system or device and sends that information to the Blynk cloud server for additional analysis and visualization.

A compact, high-performance microprocessor with Bluetooth and Wi-Fi capabilities is called the ESP32 module. Using PZEM004T sensors, voltage dividers, current transformers, and other components, it can measure a system's electrical parameters, including voltage, current, and power. The ESP32 module processes the measured data before transmitting it over Wi-Fi or cellular data to the Blynk IoT cloud platform.

A cloud-based IoT platform called Blynk offers a simple user interface for managing IoT devices. Users can design dashboards, graphs, and notifications that are based on real-time information from linked devices. Additionally, Blynk provides a variety of widgets that can be used to show the data in various formats.

In conclusion, an ESP32-based IoT energy meter with the Blynk IoT platform measures the energy usage of a system or device using sensors and sends that data to the Blynk cloud server for analysis and visualization. The Blynk platform offers a simple user interface for keeping an eye on and managing the device as well as showing the data in real time.

Here is a quick explanation of how it operates:

- The ESP32 microcontroller processes the energy data and sends it wirelessly to the Blynk cloud platform using Wi-Fi or cellular network connectivity.
- The ESP32 microcontroller is connected to an energy sensor, which is in charge of measuring the amount of energy consumed by a device or appliance.
- Users can track their energy use remotely thanks to the Blynk platform, which receives the energy data and presents it in real time on a customizable dashboard.
- To conserve energy and money, users of the Blynk platform can configure alerts and notifications depending on certain energy usage levels.
- Overall, the ESP32-based IoT energy meter with the Blynk platform offers consumers a straightforward and efficient approach to tracking their energy usage and making wise energy-use decisions.

L. ESP32 CODING

With the ZMPT004T voltage sensor, you might build an ESP32-based energy meter by writing code that detects the voltage and figures out how much power is used by a certain gadget or appliance.

We are using the Arduino IDE software to program the ESP32. This software is normally designed for programming Arduino microcontrollers, however by initializing the ESP32 Dev Kit V1 board and using the board management feature, we can program the ESP32 with ease.

The library files for all the sensors, LCDs with I2C, Wi-Fi, and BlynkIOT must first be downloaded.

Where it may be downloaded from any browser or the library manager, and then added to the libraries of the Arduino IDE.

The Wi-Fi connection is completed in the code, and the LCD is also switched on, after initializing all of the header files and the Wi-Fi ad project credentials in the setup portion.

We are developing a function that will read data from the sensors and process it.

Additionally, this function defines how all data is to be shown on the LCD screen and serial monitor. And for the data to appear on the dashboard and in the mobile app, the processed data must be sent to the Blynk cloud.

M. BLYNK CLOUD setup

The ESP32 microcontroller's Wi-Fi functionality is used to gather data from or send data to Blynk, an IoT-based cloud service.

We must establish a dashboard and initialize the device we are utilizing in the dashboard. To gather data from the ESP32, we must first construct data streams. These data streams retain the data collected from the ESP32 and allow us to view it on the dashboard by choosing the appropriate indicator or gauge.

In addition to data collection, relay control is required for both main control and relay control.

As a result, by choosing the switches icon and linking it to a digital pin, DataStream may control the esp32's digital pin directly, allowing us to control the signal input to the relay module.

IV.ADVANTAGES

1. Real-time monitoring: Smart energy meters enable consumers to keep an eye on their energy use as it happens. This can assist in locating energy wastage and enabling the adoption of corrective actions to lower energy usage.
2. Economical: By identifying energy wastage and recommending changes to reduce energy use, smart energy meters can help consumers save money on their energy bills.
3. Automation: To control energy use, smart energy meters can be connected to home automation systems. Users can, for instance, program their appliances to automatically turn off when not in use to save energy and lower their expenses.
4. Remote Access: Smart energy meters have a remote access feature that enables consumers to keep tabs on their energy usage and manage their appliances from any location in the world.

V.APPLICATIONS

Numerous uses for a smart Blynk IoT-based energy meter can be found in various contexts. Several potential uses include:

1. Residential energy monitoring: A smart energy meter can assist homeowners in tracking their energy usage and spotting appliances that use an excessive amount of energy. They may be able to make more educated judgments about how they consume energy and even reduce their utility costs with the aid of this knowledge.
2. Industrial energy monitoring: Smart energy meters can be used in manufacturing facilities, distribution centers, and other industrial settings to track energy usage and pinpoint areas for improvement. This can lower energy expenses for businesses and increase their overall energy efficiency.
3. Renewable energy systems: To track energy output and consumption, smart energy meters can be used in conjunction with renewable energy systems like solar panels and wind turbines. By maximizing their use of renewable energy and possibly reducing their reliance on the grid, homeowners and businesses can benefit from this knowledge.
4. Smart grid management: To enable real-time monitoring and management of energy use across the grid, smart energy meters can be incorporated into smart grid systems. This can assist utilities in distributing electricity more efficiently and lower the possibility of brownouts or blackouts.
5. Monitoring and controlling the charging of electric vehicles is possible with smart energy meters. By doing this, it is feasible to guarantee that cars are charged cheaply and effectively.
6. Cost savings: You might find ways to reduce your energy costs by keeping an eye on your energy usage. For instance, you can set the thermostat to save heating and cooling costs, turn off appliances when they're not in use, and swap out inefficient items for more energy-efficient ones.
7. Predictive maintenance: You can learn more about the condition of your appliances by using a smart energy meter. You can tell whether an appliance needs maintenance or replacement by keeping an eye on how much energy it consumes.

VI.CONCLUSION

The IoT-based smart energy meter used in this project has unit cost indicators, which is a system that enables users to track their energy usage and determine the price of electricity in real time. The power consumption of different appliances and gadgets in a home or building is measured by this system using an IoT device, the Blynk app, and energy sensors.

This system's primary output is the provision of real-time data on energy consumption and cost, which can aid users in making defensible choices regarding their energy usage. Users can reduce their energy use and lower their electricity costs by identifying places where they can cut back on their usage.

Additionally, this system's unit cost indications enable customers to estimate their electricity costs based on their energy consumption. Users are encouraged to adjust their energy consumption habits to save money by using this function, which enables them to understand how much they are spending on electricity.

Overall, a unit cost indicator-equipped IoT-based smart energy meter has a lot of potential to enhance energy management and encourage the use of sustainable energy, and its prospects appear bright.

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