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Smart Energy Meter: A Comprehensive Survey on Maintaining Power Consumption and Customer Requirement

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Abstract
Owing to the exponential growth of the human population and the heavy reliance on electrical energy, there has been a substantial surge in electricity consumption, leading to a shortage of electrical energy during periods of high demand. It is imperative to upgrade the electrical infrastructure to address the energy concerns. Internet of Things (IoT) technology can be used to manage energy usage and distribution in many situations. This article primarily addresses the topics of automated invoicing, power card functionality, theft detection, power optimization, and the provision of pertinent energy consumption data to consumers. The IOT-based smart energy meter system comprises three primary components: the controller, Wi-Fi, and the theft detection device. The theft detector sensor promptly identifies and responds to any theft or malfunction. The controller is essential for maintaining the functionality of all the components. Energy meters in this system are linked to the Internet through the Internet of Things (IoT) concept, hence removing the need for human involvement in electricity maintenance. The proposed project involves the development of an Internet of Things (IoT) meter reading system. This system would continuously monitor the meter reading and enable the service provider to cut the power source if the consumer fails to pay the monthly payment. Additionally, it eradicates the need for human involvement, provides accurate meter readings, and safeguards against billing errors.

Keywords: Maintaining Power Consumption, Comprehensive Survey, Customer Requirement

1. Introduction

Electricity consumption has increased dramatically in recent years. It meant that a significant increase in the energy supply was needed. As a result of economic and demographic growth, other variables will develop in the upcoming decade. A mismatch exists between supply and demand [1]. Given their circumstances, mainly from fossil fuels, they will exhaust themselves in the next twenty years. There are presently very accurate electronic energy monitoring systems on the market. Most residential applications observe the electricity consumption inside a home. Customers are regularly dissatisfied with their electricity costs due to their need for more information on the amount of power consumed by the gadget [2]. The web, or an example of the Internet of Things, is a relatively recent industry, and accessories found on the Internet of Things have ushered in an era of electronic and information technology revolution.

One of the biggest problems we currently need is energy usage, especially electricity use. It takes an efficient method to keep an eye on this energy usage. The Internet of Things (IoT) provides an answer to these problems [2- 3]. There are connections between software, equipment, and the cloud. Consequently, we present a model of energy consumption. A system for monitoring household appliances can be used to determine the family's energy usage [4]. A domestic appliance monitoring device may be utilised to track the family's energy usage, inform the user about how much electrical power they use, and help them make decisions. As Internet of Things (IoT) technologies have emerged [5], it is possible to enhance the interaction and observation of power and energy consumption by modifying an energy meter that is currently in place that uses a format for commercial communications. The Internet of Things can help with all this. In order to enable online monitoring, this research, therefore, offers a method for modifying the digital energy meters currently installed in buildings to allow for online monitoring by utilising IoT technology [6].

2. Literature Review

Kumar L developed a bit of the Internet of Things clever energy meter with an AT Mega 328p, a microcontroller current and voltage sensor, an ESP 8266 wireless chip, and a 900 GSM SIM card [7]. ESP 8266 transmits information related to the Thing Speak cloud-based infrastructure by the internet. Another option for revising information to the cloud is to use a 4G GSM module to send data as an SMS to the relevant contacts. The energy meter uses the Fast Fourier Transform to determine both the cost and quantity of energy used in one hour. Nevertheless, a low-cost microprocessor in smart meters is required due to the high cost of the AT Mega 328p. In order to measure and regulate the amount of energy used by electrical appliances in both industrial and residential settings, Yaghmaee M created an intelligent energy metering setup. The system comprises sensor nodes, aserver, anda gateway. The sensor node gathers data on temperature and humidity, gas leakage, power consumption, and power line characteristics. The Raspberry Pi 3-based Android HTTP gateway receives the data from the sensor node [8].

The gateway establishes an Internet connection to transmit data to the central server. A proposed smart meter uses a voltage transformer, CT sensor, and PIC microcontroller PIC16F877. The meter controls the energy flow and assesses power consumption about load demand [9]. The ability of this meter to determine the price of the grid and solar power usage for settings that utilise both is its most significant feature. A GSM module and the Node MCU with an integrated Wi-Fi chip, ESP 8266, were the tools Prathik M suggested using to design and construct a system for measuring energy [10]. This structure controls the appliances and supplies the electrical equipment's daily power consumption, saving energy. Customers can get information regarding their bills, payments, and planned outages from the system's electricity board section.

An Atmega328P-based system was created by Visalatchi S. The energy meter uses the system to detect and regulate power theft [11]. An algorithm connects and disconnects the meter if a fault is discovered. The meter is connected to the utility devices and disconnected using relay logic. The consumer can receive automated SMS messages to the power meter and servers for central authority thanks to the GSM module.

Anirudh Kumar suggests a unique LDR-based technique like tracking the power consumption of a self-contained meter reading apparatus. Since the utility company owns the energy meter, it is not feasible to alter or interfere with the same energy. Every AMR power meter has a specific operating frequency, for which the light-emitting diode will either flash or shine. The energy consumption noted on the data storage is related to this frequency. LED flashing is used in the calculation of the power consumption utilisation factor. The ESP 8266 module and HTTP will send the estimated energy data to the server [12].

The suggestion was made for a wireless energy meter with Bluetooth capability. With the most minor human involvement possible, the system uses an automatic polling mechanism and automatic meter reading. Using an Analogue Devices ADE7756 power meter and a CSR, the Bluetooth BlueEZ module, a low-priced, trustworthy Bluetooth power meter, is created. Long-distance communication is not possible with Bluetooth due to its limited communication range.

The principal objective of this study is to produce an independent ESP32 power consumption meter. The objectives that follow complement this purpose.

1. To determine the current Root Mean Square
2. To determine the voltage Root Mean Square
3. To determine how much energy and power a consumer load

3. Proposed Scheme

The Ethernet Serial Port 32 (ESP32) is a well-liked and adaptable microcontroller and system-on-chip (SoC) that is frequently utilized in embedded systems and Internet of Things (IoT) applications. Espressif Systems is the company behind its development. These are some of the ESP32's main characteristics.

1. **Dual-Core Processor:** The ESP32 has a dual-core Xtensa LX6 CPU, enhancing performance and facilitating effective multitasking.
2. **Wireless Connectivity:** A notable feature of the ESP32 is its integrated support for wireless. It makes it suitable for a wide range of IoT applications that require wireless communication.
3. **Minimal Power Usage:** Battery-powered applications can benefit from the ESP32's power-efficient architecture. It includes various modes that save power to extend battery life.
4. **Rich Peripheral Set:** The ESP32 provides a rich peripheral, such as an Asynchronous Receiver-Transmitter (UART), SPI, I2C, and GPIO pins. It allows for interfacing with various sensors, actuators, and other devices.
5. **Development Frameworks:** The ESP32 is well-supported by several development frameworks, such as the IoT Development Framework (Espressif IDF), the Arduino IDE and Platform IO. It makes it accessible to a broad community of developers.
   - a) **Programming Language:** It is possible to program the ESP32 in C and C++. Additionally, the Arduino framework allows developers to use a simplified programming environment and access a vast collection of libraries.
   - b) **Open-Source:** Espressif provides a comprehensive Software Development Kit (SDK) for the ESP32; much of the software and documentation related to the ESP32 is open-source. It fosters a collaborative development environment.
   - c) **Community Support:** The ESP32 has gained popularity in the maker and DIY communities, leading to a large and active community. This community support is beneficial for troubleshooting, sharing projects, and finding resources online.

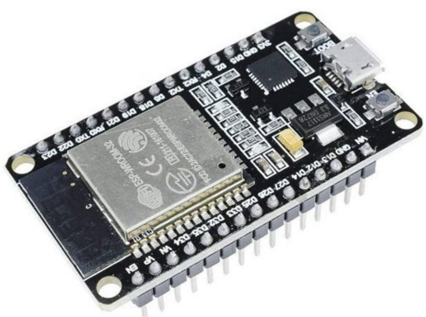


Fig 1: Microcontroller ESP32

3.1 ZMPT101B AC Voltage Sensor
The AC Voltage Sensor Module ZMPT101B (Single Phase) is ideal for do-it-self projects requiring precise AC voltage measurements utilizing voltage transformers. It is best option for measuring the AC voltage on an open- source platform such as Arduino, ESP8266, or Raspberry Pi. A few fundamental criteria, such as high galvanic isolation, wide range, high accuracy, and good consistency, are directly dealt with by engineers in many electrical projects.

Active phase AC output voltage transformer module onboard precision tiny voltage transformer. Suitable compensation, signal sampling, and onboard precision op-amp circuitry for accurate tasks. Modules are measurable up to 250 V AC voltage, and the analogue output corresponding to that voltage can be modified. It is high-performance, high-quality, and brand-new.

3.2 Specification

Table 1: Specification for ZMPT101B AC Voltage Sensor

Detail	ZMPT101B AC Voltage Sensor
Measurement within	~250V AC
Output Signal	0-5V
Operating Voltage	DC 5V-30V
Rated input current	~2mA
Dimensions	49.5 x 19.4 mm
Operating temperature	40 C to 70ºC

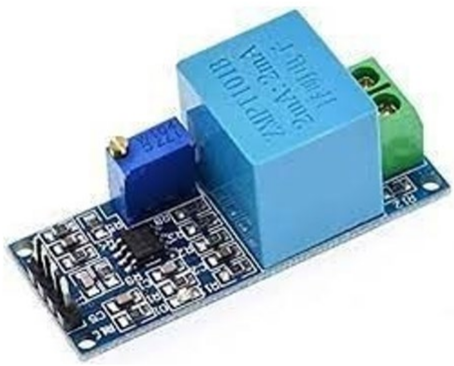


Fig 2: ZMPT101B AC Voltage Sensor

3.3 16X2 I2C LCD Display
A display is required to incorporate visual output into an Arduino project. The LCD 16x2 Parallel LCD Display is a wonderful option in order to demonstrate only need a tiny quantity of information to show.

This impressive LCD monitor has a yellow backlight. For an Arduino-based project, it is excellent. The interaction of this 16x2 Parallel LCD Display with Yellow Backlight with Arduino or Microcontroller is quite simple. With this LCD 16x2 Parallel LCD Display, it can move swiftly and affordably incorporate a 16x2 Black on RGB Liquid Crystal Display into any project. Black lettering against a yellow backdrop with a backlight is quite readable and contrasts well in this 16-character, 2-line display.

Simple text or numerical values, such as temperature or pressure, or even the number of cycles the Arduino executes, can be displayed on the display, as well as other data gathered from the sensors.

Fig 3: 16X2 I2C LCD Display

3.4 SCT-013 Current Transformer
It is the Non-interfering Sensor Clamp for AC Current 30A, SCT-013-030. The SCT-013-000 is a current transformer designed to gauge up to 100 amps of electrical power without being interfering.

It can determine how much current passes through a load up to 30 amps by measuring it with this non-interfering AC sensor that was secured to the supply line. Two possible uses are constructing an AC load's over-current prevention device or putting together an energy monitor. A current as high as 30A can be detected using this current clamp. It can be easily attached to the current source a person wants to measure, generating a very modest AC voltage proportionate to the current. A typical 3.5mm socket, similar to a headphone socket, terminates the wire on one end.

Construct an AC load's over-current prevention mechanism, or utilize it to create an energy meter and lower the electrical use. View a sample project by clicking the link below. The 3.5mm jack pinout can be found by consulting the datasheet.

Fig 4: SCT-013 Current Transformer

3.5 Specification

Table 2: specification for SCT-013 Current Transformer

Details	SCT-013
AC Input Ia	0A–30A
Signal Output	0-1 V DC
The absence of consistency	2-3%
Inbuilt opposition to sampling (RL)	62 Ω
Ratio of Turnabout	Around 1800:1
Level Grade of Resistance	B Grade
Operating Temp.	-25°C to +70°C
Power of Dielectric	~1000 V AC/5 mA per minute

3.6 Software Requirements: Arduino IDE
With Arduino's open-source software, everyone is able to create and test the code that comprises a code or schematic regarding the Arduino board. It makes writing program more accessible.

It may add designs to the boards of microcontrollers with this easy-to-use tool. It works with Mac OS X, Linux, and Windows. In this investigation, several factors were considered before developing the code for the ESP32. First, the IDE now includes the ESP32 package. Second, new libraries for Blynk and EmonLib have been added.

3.7 EmonLib Library

Electricity Energy Meter makes use of the Emonlib Library. A sequence of voltage and current readings is repeated Constantly Monitoring Electricity Energy Per 5 or 10 Seconds by EmonLib. EmonLib continuously measures the input channels for voltage and current in the background. It then computes the mean of each channel's value and notifies the drawing when measures are prepared for reading and processing.

3.8 Blynk Library

Blynk, the Internet of Things platform that is most commonly utilized, enables the creation of control apps, link any device to the cloud, and increase the number of products having deployed. The Blynk Library may connect the Blynk Cloud to over 400 hardware variants, such as the ESP8266, ESP32, and Arduino. With the Blynk app, consumers may operate whatever Internet of Things usage they want. It is compatible with iOS and Android mobile devices. It lets users design an exclusive graphical interface for Internet of Things applications. The Blynk application will show information from the prototype's Internet of Things electric energy meters.

3.9 Technical Description: Circuit Diagram

The connection between circuit schematic diagrams can be easily understood. Two components are linked to the ESP32's 5V supply: the SCT-013 Current Transformer and the ZMPT101B Voltage Sensor VCC. The GND pin of the ESP32 is linked between the two modules' GND pins, while its GPIO35 is linked towards the analogous the result pin on the ZMPT101B Voltage Sensor. Similar connections are made between the GPIO 34, the ESP32, and the SCT-013 Current Sensor's analogous output pin. TenK resistors, two 10K resistors, a 10uF capacitor, and one 100-ohm resistor comprise the circuit with voltage division and filters. The AC cables that require voltage and current measurements are connected to the voltage sensor's input AC terminal. Similar to the previous sensor clip, the current sensor clip has only one live or neutral wire inside, as seen in the figure.

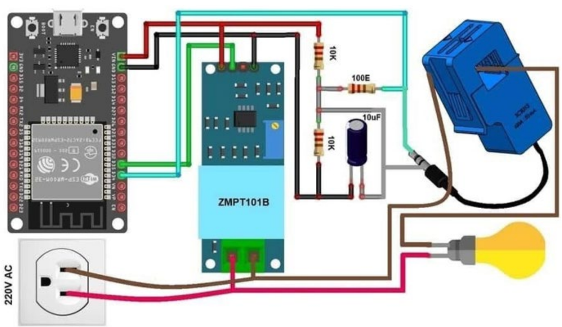
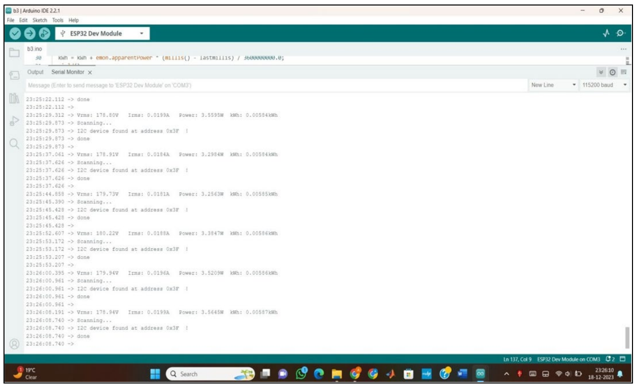


Fig 5: Circuit Diagram

4. Experimental Results

This section describes how the developed Works with an ESP32 electrical energy consumption meter. The figure displays the dashboard with its user interface. The sensor node's online dashboard served as an illustration. The dashboards were created with the Blynk app.



Gauges on the dashboard display the RMS voltage, current, and power used in addition to the energy used. The 16X2 LCD shows the temporal variations in the measured energy data. The energy detector prototype had been used to collect and send sensor data to the Blynk server.

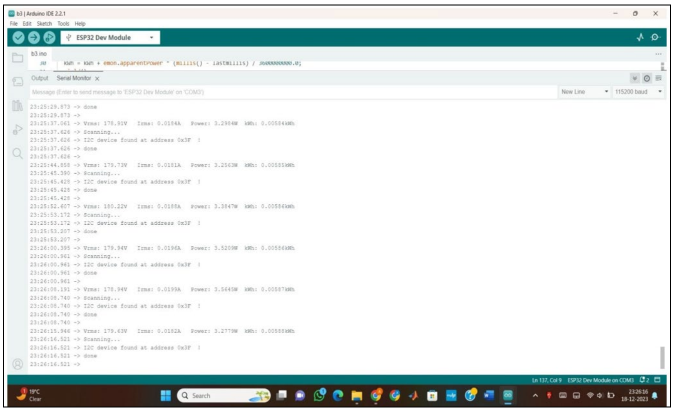


Fig 6: Serial Monitor Results

Conclusion

One of the biggest obstacles toward implementing the ESP32 electric power use meter is the automated context of today's innovative world, where numerous networks coexist with varying traits and degrees of energy economy. This study described the architecture for the energy monitoring. A monitoring system with power and energy consumption awareness. An automatic energy monitoring system is part of the suggested smart house. The prototype voltage sensor and current transformer were interfaced with the ESP32 Microcontroller to gather sensor data and run the system. Web clients were able to retrieve sensor data from the Blynk cloud. The trials' findings demonstrated that temperature, active power, voltage, and current- the amount of electricity used over time- could all be successfully monitored by the energy monitoring system that was built. Future studies could be expanded to learn more regarding the details of energy consumption and the automatic identification of in-use equipment using machine learning algorithms.

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