

Design and Implementation Smart Energy Metering System Integrated with Internet of Things using SCT-013 Current Sensor

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Abstract—The population's need for electricity is growing steadily these days, and it is used for a variety of things, including domestic chores, businesses, hospitals, and agriculture. Thus, handling it is getting harder and harder. A new type of electric energy meter called as a "smart meter" has begun to be developed in recent years by utilities. In comparison to a conventional energy meter, a smart meter uses digital technology to measure electrical energy use and give other information. This paper presents a smart energy meter to make energy monitoring simple for both the consumer and the supplier. The smart grid is thought to be incomplete without smart meters, which will increase interaction between consumers and service providers. Real-time, two-way communication will be made possible between consumers and providers thanks to smart meters. This solution takes the place of conventional meter reading techniques and permits the energy provider to remotely access an already-installed energy meter. They can also periodically check the meter readings without having to visit every home.

Index Terms— Smart grid, Energy meter, Wi-Fi, Internet of things(IoT).

I. INTRODUCTION

An improved energy meter called a "smart meter" uses a two-way communication system to measure a consumer's energy usage and give the utility additional information. Customers are better aware on how to use energy, which allows them to choose more wisely when doing so. Suppliers, on the other hand, wouldn't need to manually record the energy used because they would receive this information automatically. The energy meter displays the number of units utilised and transmits the data to the electrical board and the client, helping to reduce the need for staff. Wherever and at any time, the user can check their Power usage. The objective of this system is to keep track of how much electricity is used. The eventual reduction in overall Electricity usage will be advantageous to both the distributor and the consumer. An energy management system (EMS) for a household can assist homeowners in monitoring and controlling their energy usage, leading to optimized energy efficiency and reduced energy costs. One of the key components of an EMS is an energy monitoring system, which enables users to track their energy consumption in real-time and pinpoint which appliances or devices are using the most energy. By identifying energy consumption patterns, homeowners can make informed adjustments to their usage and reduce overall energy consumption. Incorporating an EMS in the home can lead to not only cost savings but also a reduced carbon footprint and a more sustainable lifestyle. The main objective of this paper is to develop an IoT-based smart energy meter is being designed and

implemented to make a tool that can precisely measure how much energy is spent by a building, home, or any other facility and transfer this data wirelessly to a centralized monitoring system. Real-time data on energy consumption should be available from the system, allowing for more effective monitoring and management of energy use.

II. LITERATURE SURVEY

In 1999, Kevin Ashton developed the concept of the Internet of Things (IoT). Internet of things (IoT) is an integrated platform of things or things that are interconnected to each other wirelessly or over wires and share information to create applications. The internet of things is divided into two main areas. The first area includes physical objects, such as equipment, vehicles, buildings, and other things. The second component consists of the electronics, software sensors, and network connectivity that are integrated into the first component. They permit the objects to gather and exchange data [1]. Computer connections were the first step in the evolution of the internet. Later, the World Wide Web was created as a result of many computers being linked together. Once mobile devices could connect to the internet, the mobile Internet technique was born. Social networks were the first way that people used the internet. Finally, the notion of attaching common objects to the internet was put forth, giving rise to the Internet of Things technology [2]. The main aim of their study is to investigate the possibility of employing an Internet of Things (IoT) strategy to track student attendance and presence in the school grounds in real-time in order to protect them [4]. India has an excess of power producing capability, but it lacks the necessary infrastructure to provide electricity to all those in need. The Indian government introduced a program named "Power for All" with the goal of building the infrastructure necessary to provide sufficient energy to all those in need throughout the nation by March 2019. By enhancing critical infrastructure, this plan would provide a constant and uninterrupted supply of electricity to all businesses, residences, and industrial facilities. The Indian government and the states share responsibility for allocating resources and fostering general economic expansion [3]. IoT connects internet access and mobile device remote control to smart home equipment that have a variety of sensors built in. The refrigerator, air conditioner, and lights can all have sensors, and other environmental sensors can be connected to devices used in the home. Based on modern IoT apps that use customers' alarm triggers, the overcurrent or circuit overloading can be recognised early [5]. A smart energy meter's design, construction, and deployment that makes use of embedded systems technology. To add a "Smart" function to a conventional household energy meter, an Arduino microcontroller with a Wi-Fi modem was utilised. The electrical supply authority can read the meter periodically without going door to door thanks to the IoT-based smart energy meter created in this study. This was accomplished with the aid of an Arduino device, which continuously captures and monitors the readings from the energy meter. The meter can communicate with the internet using a Wi-Fi modem, which makes the system a component of the Internet of Things. Both the customer and the service provider will be able to monitor and interpret the pattern of energy use as well as the associated amount using this smart energy meter. Voltage, current, energy, power, and power factor are all data that the meter can record and transmit. Both the Android mobile app and the webpage both display all of these parameters. The service provider can monitor the pattern of energy usage through such a thorough record of events, allowing for more accurate and effective load forecasting and control. On the other hand, the consumer will have greater transparency in the billing system [6]-[9]. The measurements from smart meters can be sent across communication lines, and they can also identify addresses and turn on and off internal modules. AMR needs a particular infrastructure to be able to have that functionality, which would make it bidirectional [10]. The consumer's illegal connections or other misdeeds that would lower or halt the meter reading or power supply cannot be discovered by the manual operator. An chance for fraud by a human meter reader may arise from human error. As a result, the billing system's issue may become inaccurate and ineffective [11].

III. HARDWARE IMPLEMENTATION

Energy meters plays a vital role in monitoring the power received and delivered and consumed and it is being connected with the IoT plays an important role so as to have a proper way to maintain the power quality and management. You must enter the meter reading room in order to capture readings due to the current state of technology. Tracking and keeping an eye on your electricity use is therefore a time-consuming task. We can use IoT to automate this. The smart energy meter has recently gained a lot of recognition among people everywhere world. Selecting both the current sensor and the voltage sensor is necessary in order to measure current and voltage and additional information on power consumption. The SCT-013 is currently the best current sensor on the market. The SCT-013 Non-invasive AC current Sensor Split Core Type Clamp Meter Sensor allows you to

measure AC current up to 100 amps without physical contact. The AC voltage sensor module is highly recommended for accurate AC voltage measurement with a voltage transformer. Using the current sensor SCT-013 and the voltage sensor, all the necessary elements of the electricity meter can be measured. These sensors are connected to the ESP32 WIFI module and the data is transferred to the Blynk application for monitoring. The Blynk app dashboard shows voltage, current and power.

A. Circuit Diagram & Hardware Setup

Block Diagram

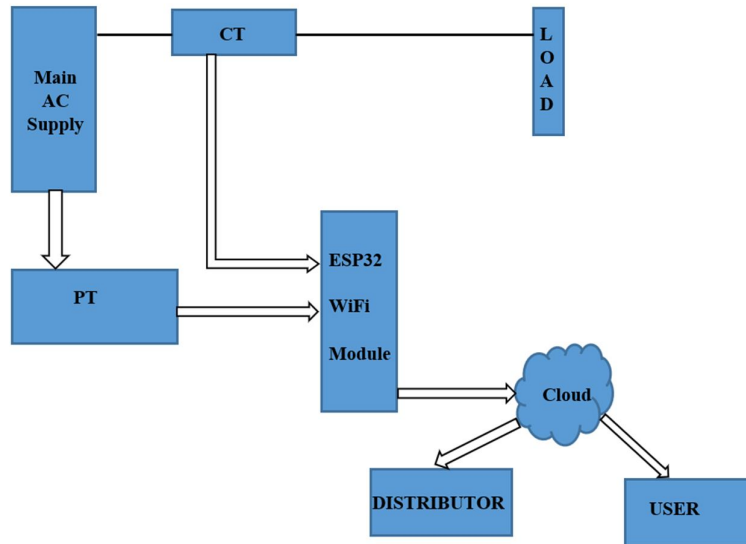


Fig. 1 Block Diagram

Figure 1 shows the Block Diagram of the IoT based smart Energy Meter.

The supply voltage is determined using a voltage sensor, while the current measurement from the meter is obtained through a CT sensor. By utilizing the ESP8266 WiFi module, users can receive real-time data, and the current usage can be sent to the cloud. Average Power is calculated by taking the average of the Instantaneous Power over a specific period, typically measured in terms of effective or RMS value. It consists of both real power and reactive power. In the case where the phase angle between the voltage and current is the same, it is assumed that the load is purely resistive and absorbing all power. If the load is reactive, it will reflect the average power back to the AC source.

The apparent power (S) of an AC system is determined by multiplying its voltage by the total current flowing into it. It is expressed in volt-amperes and may be figured out by multiplying the RMS voltage by the RMS current. Real power(P) is the ability of the circuit to perform several tasks simultaneously. The apparent power (S) of an AC system is determined by multiplying its voltage by the total current flowing into it.

This can only be calculated by monitoring the voltage and current at the same time, multiplying those numbers, and then averaging the results across time. The Power Factor is calculated by dividing perceived power by real power (PF). It refers to the electrical system's capability to convert electric current into an usable function, such as heat, rotation, or light, on the installation.

AC Current Sensor The split-core clamp meter sensor is currently the best sensor available for measuring AC current up to 100 amps without physical contact. To measure AC voltage, the ZMPT101B AC voltage sensor module is the best choice, especially when used with a voltage converter to get accurate results.

The combined current and voltage sensor can measure all the parameters required by the energy meter. These sensors connect to the WIFI module of the ESP32 and the data they collect is transferred to the Blynk application. In the Blynk app, users can see the voltage, current, power and total kWh consumed.

B. Abbreviations and Acronyms

SCT-013 Current Sensor –

Figure 2 shows SCT-013 current sensor which functions as a non-intrusive split core type clamp meter sensor and SCT-013 current sensors have the ability to measure AC current, making them a reliable option for gauging



Fig. 2 Current sensor

alternating current. These sensors, also known as current transformers (CTs), are particularly useful in determining the overall amount of electricity consumed by buildings. One of their notable features is that they can be easily clipped onto the neutral wire without requiring any high voltage operations.

ZMPT101B AC Single Phase Voltage Sensor –

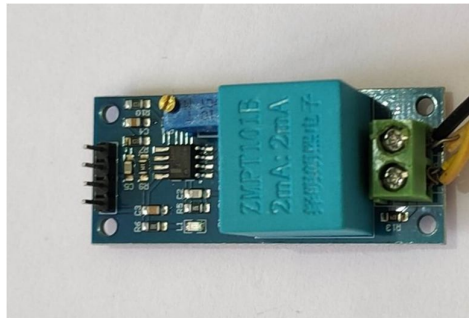


Fig. 3 Voltage sensor

Fig 3 shows ZMPT101B voltage transformer, the basis of the AC Single Phase voltage sensor module, which is used to measure the exact AC voltage with a voltage transformer. The best method for ESP32 or Arduino AC voltage measurements is this one. The Modules' analogue output can be altered, and they can detect voltages of up to 250V AC. The ADC output can be calibrated and modified using the module's multi-turn trim potentiometer.

Circuit Diagram

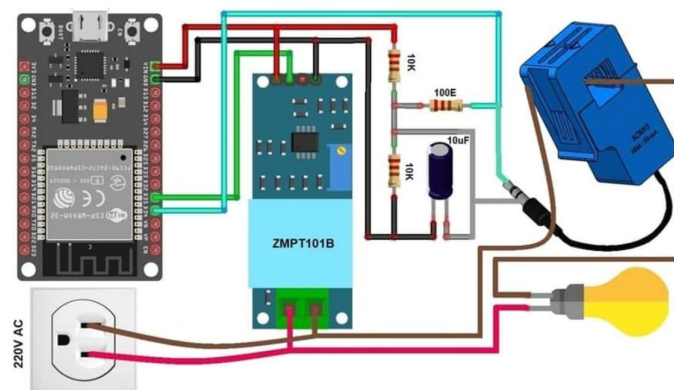


Fig. 4 Circuit diagram

Figure 4 shows circuit diagram of IoT based smart energy meter. The Voltage Sensor's input AC terminal is attached to the AC wires where, in addition to the circuit section, the current and voltage need to be monitored. The clip section of the current sensor circuit, which is like the circuit above in that it has lack connections, takes a single live or neutral wire. Using the 16x2 LCD is not required for this project.

C. Methodology of the smart meter

To program the ESP, one can use the Arduino IDE, which is commonly used for coding. In order to use the ESP32 board with the Arduino IDE, one must first download the ESP32 board package created by the ESP32 community via the board manager. Additionally, to establish a connection with the Arduino IoT cloud platform, one must also download the necessary libraries for ESP coding.

```
#include "EmonLib.h"
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>

char auth[] = "vH84t2yuob_rxFghaj3joiWoRTMX6neK";
char ssid[] = "Realmel";
char pass[] = "123456789";
```

Libraries and Authentication token and Wi-Fi connection for IoT. After finishing the configuration of the Arduino IoT cloud platform, the authentication token is provided. The authentication token, which may be used to interface with the Arduino IoT platform, accepts commands and updates the user's phone on the current state of their appliances. It makes use of the user's login name and auth ID.

```
#define vCalibration 83.3
#define currCalibration 0.50
```

The calibration value for the voltage and current sensors. The calibration value for the voltage sensor ZMPT101 is 83.3 and the calibration value for the current sensor is 0.50. calibration used to maintain the accuracy of the readings.

Step for Arduino IoT cloud

The Arduino IoT cloud platform is a key component of the entire article and requires a few setup procedures. First, we need to register for an account on the cloud-based Arduino IoT platform. Second, a new template that contains the device, network, and variable information needs to be made. Choose setup third party device, ESP32, and give the device a name to get started. To establish the connection between the ESP, the platform will offer an authentication ID. The following step is to give variables names. On the variable's permissions menu, select read and write. Even though the variables' names are different, they are created using the same process. The setup window will appear like this when the variables have been added.

Web dashboard

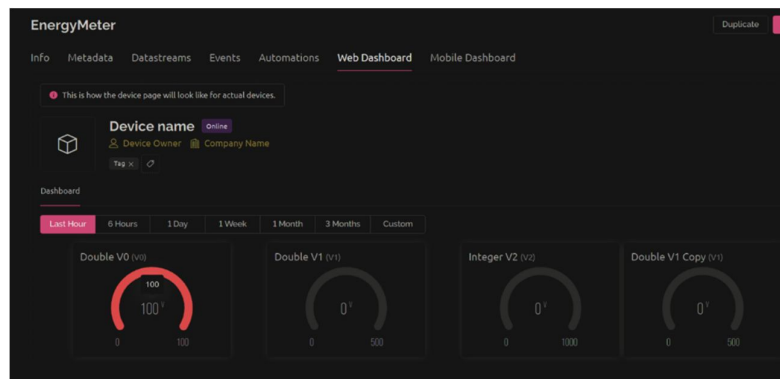


Fig. 5 Web dashboard

Figure 5 shows web dashboard setup. In the both the dashboard first meter indicates the voltage consumed by the load. Second meter indicates the current consumed by the load. Third meter indicates the power in watt. Fourth one is display used to show the power in kwh.

SCT-013 Current Sensor

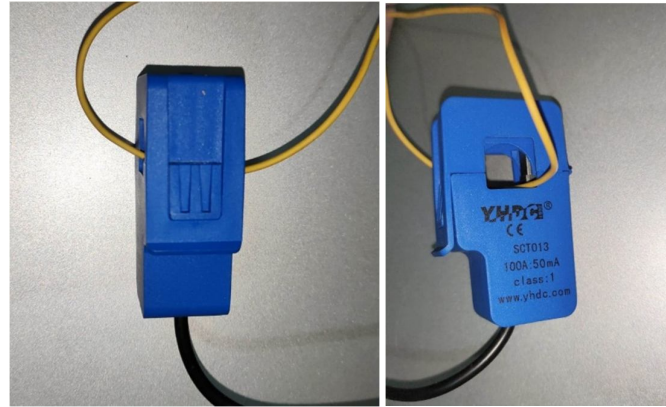


Fig. 6 Current sensor connection

Figure 6 shows the current sensor connection. It contains split-core CT comes with operable jaw. The jaw is opened in between that main load wire is placed and the jaw is opened as shown in the figure.

IV. RESULT AND DISCUSSION

13:22:55.300	-> Vrms: 12.35V	Irms: 0.0124A	Power: 0.1530W	kWh: 0.00918kWh
13:23:02.524	-> Vrms: 15.96V	Irms: 0.0769A	Power: 1.2274W	kWh: 0.00918kWh
13:23:09.839	-> Vrms: 10.87V	Irms: 0.0103A	Power: 0.1115W	kWh: 0.00918kWh
13:23:17.062	-> Vrms: 3.78V	Irms: 0.0091A	Power: 0.0342W	kWh: 0.00918kWh
13:23:24.285	-> Vrms: 5.20V	Irms: 0.0089A	Power: 0.0461W	kWh: 0.00918kWh
13:23:31.553	-> Vrms: 14.33V	Irms: 0.0082A	Power: 0.1169W	kWh: 0.00918kWh
13:23:38.826	-> Vrms: 3.38V	Irms: 0.0097A	Power: 0.0327W	kWh: 0.00918kWh
13:23:46.706	-> Vrms: 9.56V	Irms: 0.0080A	Power: 0.0767W	kWh: 0.00918kWh
13:23:53.975	-> Vrms: 1.34V	Irms: 0.0079A	Power: 0.0105W	kWh: 0.00918kWh
13:24:01.198	-> Vrms: 2.23V	Irms: 0.0065A	Power: 0.0144W	kWh: 0.00918kWh
13:24:08.701	-> Vrms: 15.32V	Irms: 0.0377A	Power: 0.5782W	kWh: 0.00918kWh
13:24:15.923	-> Vrms: 3.64V	Irms: 0.0201A	Power: 0.0732W	kWh: 0.00918kWh
13:24:23.238	-> Vrms: 3.59V	Irms: 0.0147A	Power: 0.0526W	kWh: 0.00918kWh
13:24:30.461	-> Vrms: 2.91V	Irms: 0.0111A	Power: 0.0324W	kWh: 0.00918kWh
13:24:37.734	-> Vrms: 15.66V	Irms: 0.0087A	Power: 0.1361W	kWh: 0.00918kWh
13:24:44.958	-> Vrms: 1.93V	Irms: 0.0126A	Power: 0.0243W	kWh: 0.00918kWh
13:24:52.365	-> Vrms: 137.90V	Irms: 0.0195A	Power: 2.6890W	kWh: 0.00918kWh

Fig. 7 Serial monitor values when load(light) is on

In a real-world setting, the smart energy meter was tested, and the outcomes were quite positive. The meter was able to precisely gauge energy usage and transmit the information in real time to the cloud. The user could decide on their energy usage when the data was shown to them in an understandable manner by the cloud-based application. Setting energy consumption targets and receiving alerts when energy usage exceeds a predetermined threshold were just a couple of the tools and capabilities the application offered for managing and monitoring energy usage. An IoT-based smart energy meter has a number of benefits over conventional energy meters. It first gives customers access to real-time data on their energy usage, enabling them to plan their energy usage accordingly. It can also spot locations where energy use can be cut back, resulting in cheaper energy costs and a smaller carbon footprint. Finally, by giving utility companies access to real-time data on energy consumption, it can assist them in managing their energy grids more effectively. Overall, the development of a smart energy meter based on the Internet of Things is a very promising option. for effectively and sustainably managing energy use.

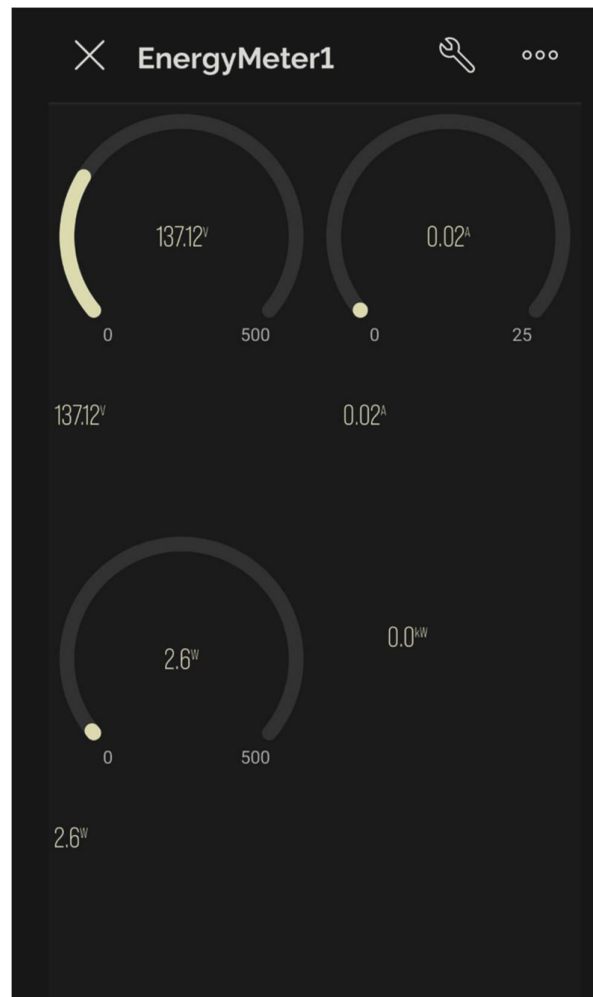


Fig. 8 Values obtained when the load(light) is on in mobile app(blynk app)

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