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# Review on Implementation and Design Optimization of Smart Energy Meter

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**Abstract:** Today, traditional meter reading systems are used to calculate power meter readings. Electricity is the driving force behind the development of every country. With the rapidly increasing number of residential, commercial, and industrial consumers of electricity around the world, utilities to measure utility consumption so they can create and charge accurate bills. It is now imperative to develop better, less intrusive, and environmentally friendly technology. The invention of the smart meter changed the process of billing systems from commercial energy usage previously done with digital meters. After identifying the advantages and limitations of existing technology, we explored key gaps and subsequently conducted a feasible study to fill in the open issues related to adapting research work to smart meters.

**Keywords:** Smart energy meter, WIFI module, GSM, Mobile Application, Current, Voltage, Billing

## INTRODUCTION

Human assistance is still required to read units from energy meters and record units from houses. The solution to all these problems is to timely track consumer loads to ensure accurate billing, track peak demand and identify thresholds. Since 2000, smart meter development has been rolled out in many countries. The smart meter is a key enabler of the smart grid and is expected to bring economic and environmental benefits to multiple stakeholders. Data analytics for smart meters is one of the key factors for the success of smart meters. This helps transmit, process, and interpret the data collection and benefits all parties involved. Unlike traditional analog meters, smart meter readings are in digital form and are automatically sent to suppliers through various communication means.

## 1. Design and Construction of GSM-Based Smart Energy Meter

The designed energy meter uses ADE7755 measurement chip, ATmega32 microcontroller and other discrete components. SMS communication with the meter is established using the GSM module SIM900. AT command can be sent from mobile phone to GSM module for communication. WIFI based communication can also be done using ESP-32 microcontroller or any other WIFI module like Zigbee wireless module, etc. They also used a 4x3 keypad to load the energy tokens and get the energy information from the meter. Energy data is displayed on liquid crystal display. Simulations of the electronic circuit design were performed using the Proteus software, an Atmel AVR development kit, and a monitor with a serial port via a 232 RS connector. Use of ADE7755 reduces number of components used which ultimately reduces cost. Use of token for recharge purpose, is another great feature for added security purpose. Using GSM wide range network can be accommodated.[1]

## 2. Smart Energy Meter based on Arduino and Internet of Things

In this system, voltage is measured with the ZMPT101B, current is measured with the ACS712, and the estimated power is calculated using the rms values of both the voltage and current signals. Arduino is used to read sensor values and send data to the server via Ethernet. The server receives the data, calculates the estimated performance, and displays it to the user. User can access data on mobile his devices. Easily available components help in reducing cost of the system. Also, a central server does the bill estimation so a basic microcontroller can also be used just to measure power and transmit to the server using GSM or WIFI module.[2]

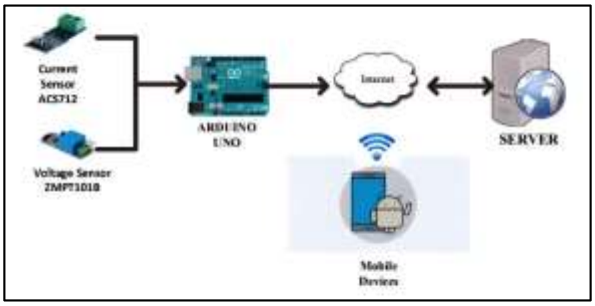


Fig.1. Implementation idea for Smart Energy Meter

### 3. Design of a smart energy meter

The system used Node MCU ESP-32 low-cost microcontroller as the main control unit. This project has two features - Energy meter with digital display and mobile app and controlled by IoT. For the energy meter, the microcontroller is connected to the voltage sensor (ZMPT101B) and current sensor (ACS712). Values are recorded, units are measured in corresponding values, and prices are calculated. Main power refers to relays to switch loads on and off. When the system removes the overcurrent from the nominal mark, the overload de-energizes the relay and turns off the load. The output obtained is displayed on a 16*2 LCD module and Blynk mobile application. Collected readings are sent via Wi-Fi to cloud storage (Blynk Cloud), where they are recorded and analysed graphically. The load is connected to the relay module and operated via mobile over Wi-Fi via his Blynk app which is IOT based. Readily available components make it easier to implement and the microcontroller has built-in WIFI and Bluetooth capability so no need to buy additional modules. Also load can be controlled remotely using Blynk App which can be used to switch on-off the main supply.[3]

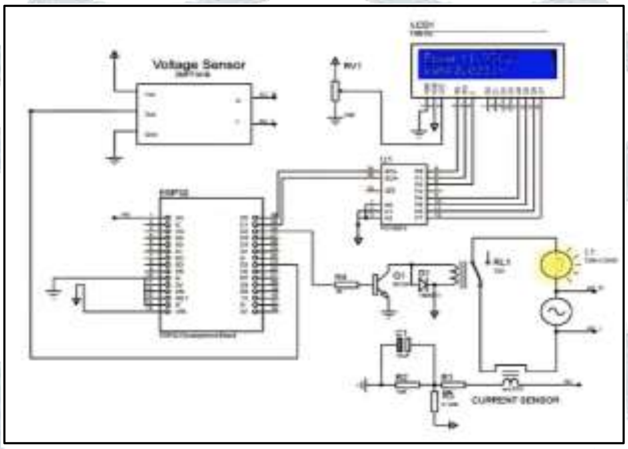


Fig.2. Design of a Smart Energy Meter using ESP32

### 4. GSM Based Smart Energy Meter System

The microcontroller, LCD and GSM units are connected to a power meter in each home. The heartbeat of the energy meter is fed into an optocoupler, and the output of the optocoupler is fed into the microcontroller. The output of the power meter is connected to the load through a relay. This is exactly where relays are used to connect or disconnect power to the load. While the server (power company) is sending requests to her GSM modem, the modem commands her microcontroller to perform the required actions. In response, the microcontroller sends the response to the modem and mod sends the fact to the server. This system is very easy to implement as it only required to connect to a kWh meter and transmit the data to the server. However, it has a drawback that it can only measure units consumed, no other variables like voltage, current, power factor, etc. [4]

### 5. Advanced smart energy meter for energy conservation

Advanced smart energy meters include a microcontroller for measuring electrical parameters such as voltage, current, frequency and power, a RTC timer for linking consumption data with time variables, and a GPS sensor to initialize the RTC timer and unit consumption cost information at each location, each location uses a GSM module to enable a GPRS connection to send and receive text messages. An LCD display is used to display the parameters of the meter to the consumer and a microcontroller is also used to facilitate this and transmit control. signal to auxiliary component. Also, smart apps are built using APIs provided by ThingSpeak for IoT purposes. This is the most advanced implementation of Smart Energy Meter with GPS location and RTC allowing to get regional billing based on different tariffs and slabs based on units consumed. Only drawback of this system is its price due to use of more components like RTC and GPS module.[5]

### 6. Milli wattmeter

To measure power consumption of a LED which uses current of few milliamps at 3-5V or a standard 4-20mA signal is very difficult due to noise or lack of capability of most common sensors. So, we need a power meter which can measure such parameters. This can be done using a sensor i.e., INA219 which is capable of measuring currents at a resolution of 0.1mA up to 26V. It can be easily interfaced with a microcontroller to get voltage, current and power and display on an OLED screen and transmit the data over WIFI to mobiles. It is a cost-effective solution and can measure up to 70W. [6]

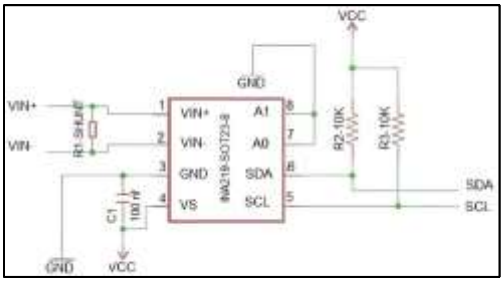


Fig.3. Design of Milli wattmeter using INA219

**7. Affordable Smart Meter**

This Smart Energy Meter (SEM) is affordable and suitable for Indian environment. The main theme of this system is to minimize cost of the system to make it accessible for wide scale implementation. The given SEM uses a digitalized billing system that estimates each household device's usage time and notifies the user of consumed units via a GSM module, and continuously assesses the system. It uses an ARM7 microprocessor and a Wi-Fi module that allows constant data updates and remote management of home equipment. The suggested SEM solves the overloading issue in real time and eliminates power leakage issues. It is evaluated against other SEMs that are already in use, and it is discovered to be superior in terms of accuracy, circuit complexity, and economy. The SEM offers an accuracy of up to 0.7-0.9% and is intended to be used for INR 3k to 3.5k.[7]

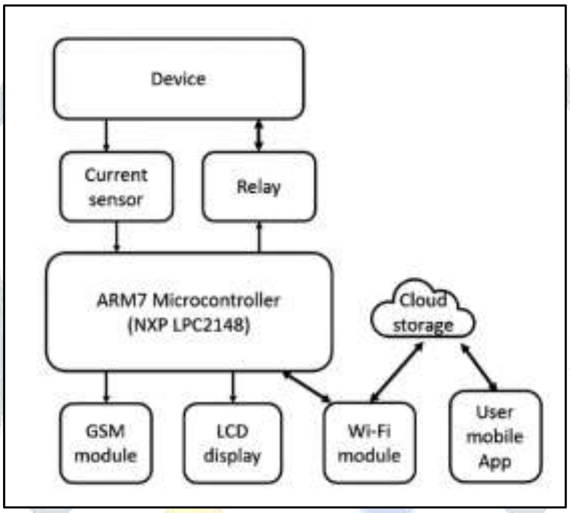


Fig.4. Block Diagram of Energy Meter using ARM7 microprocessor

**8. Smart Meter with Theft prevention**

In this construction of Smart Energy Meter (SEM). It uses wireless communication technology for automation of meter reading and its billing. The current manual meter-reading system is very time-consuming, inefficient, and has chance of error. The SEM given here combines an energy meter chip and a wireless protocol for communication. It displays the energy consumed and the respective amount on LCD screen and sends the data to a base station. Feedback from user will help to identify any unauthorized usage and control power theft. This is done using RFID card which allows only authorized personnel to check the meters. Zigbee is used for communication between the user and the substation, and the GSM network is used to send SMS alerts to authorities in case of theft. It can function as either a prepaid or post-paid meter. The SEM offers several benefits over traditional manual system which has improved efficiency, reduction in human error and easy identification of power theft. Also, addition of token-based recharge can further improve the security of the system.[8]

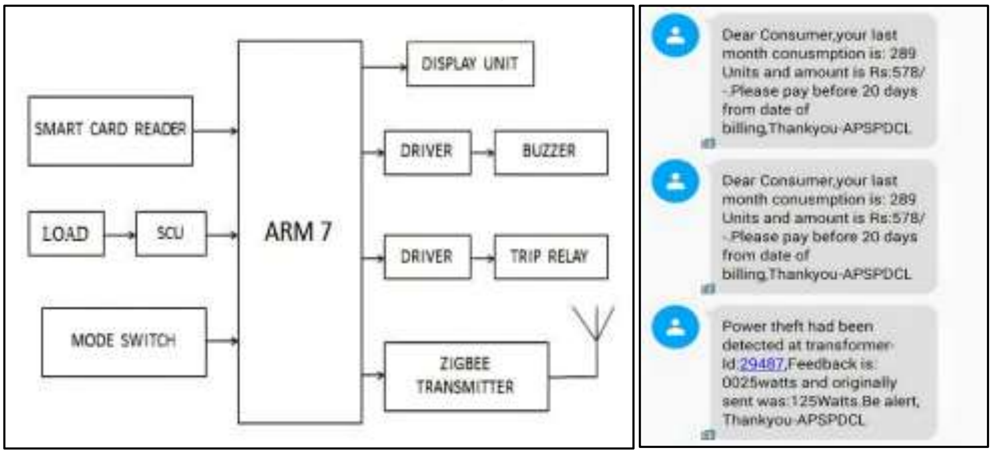


Fig.5. Block Diagram of Energy Meter using RFID with Billing System

### 9. Bidirectional Energy Meter for Grid Connected Solar System

A net meter is used to measure the net energy between the energy charged into the grid and the surplus energy from all renewable energy sources feeding the grid. The proposed system consists of a voltage and current measurement circuit, a power supply, an amplifier (op-amp IC 741), a regulator (LM 7809), and a processing unit. The voltage and current detection circuit provides the appropriate instantaneous voltage and current values as inputs to the Arduino. The Arduino uses the instantaneous values of voltage and current to calculate net energy. The net output energy is displayed by an LCD connected to the Arduino.[9]

### 10. Our Implementation

Our goal is to measure wattage from the range of few milliwatts all the way to 1kW. We are using a single ESP32 microcontroller and two separate circuits – First for measurement of AC power using ACS712 and ZMPT101B in the range of 30 – 1000W. Both the sensors provide an analog output based on the sensed parameters and send it to analog pins of the ESP32. The inbuilt ADC in ESP32 converts the analog values in digital. From the measured voltage and current values, we can calculate instantaneous power, energy, electricity units and cost of electricity used at Rs. 6.50 per unit. Secondly, we are measuring DC power using INA219 in the range of milliwatts to 70W. It has a selectable range to change the resolution of the parameters ranging from 400mA at 0.1mA resolution to 3.2A at 0.8mA resolution from 0 - 26V DC. It communicates with the ESP32 via I2C protocol. We have a common display for both the circuits. The display is a 0.96-inch 128X64 OLED display. It also communicates via I2C protocol.

To switch from AC to DC or vice versa, we are using a toggle switch which switches the code to be run to measure AC or DC. The data will be shared over WIFI to our mobiles on the Blynk app. Its benefits are that we can measure both AC and DC parameters using a single system and the components used are readily available with their libraries on the Arduino IDE.

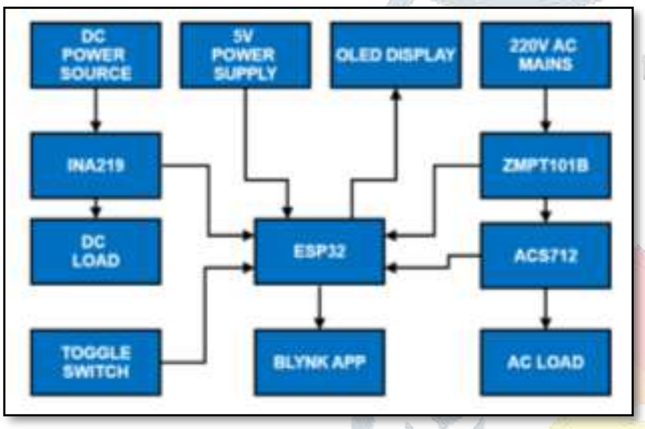


Fig.6. Block Diagram

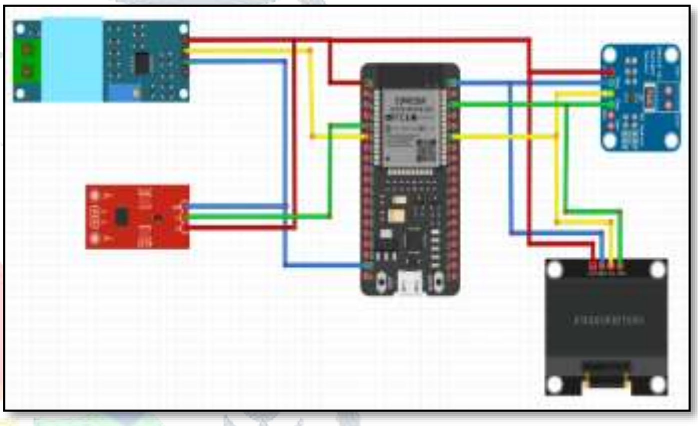

Fig.7. Circuit Diagram

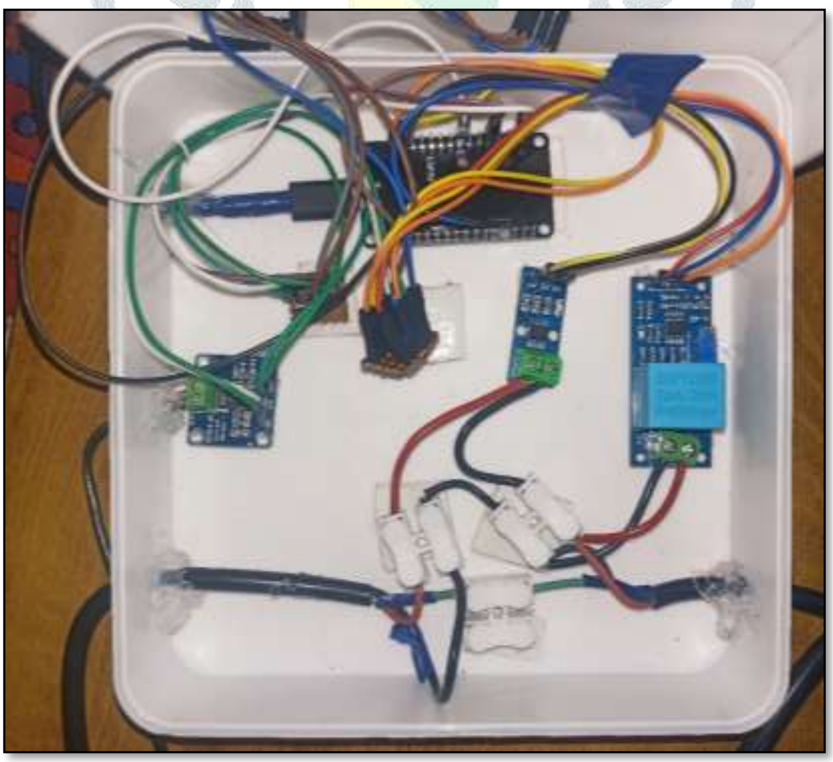

Fig.8. Implementation

## TESTING AND RESULTS

When switched to AC, the wattage readings of AC loads connected to the circuit were displayed. We used loads such as an 800W iron and a 55W table fan. The power consumed by them and the cost incurred and all other important data were displayed on the 128*64 OLED display and they were communicated to the BLYNK IoT software through ESP32. The measurement of other AC loads till 1kW can also be measured effectively using this energy meter.

The LED used was of 2V and it consumed 60mA of power and the cost of which was calculated as per unit charge by the BLYNK IoT software. The measurement of other DC loads with other sources can also be measured effectively.

Fig.9. AC Load Measurement

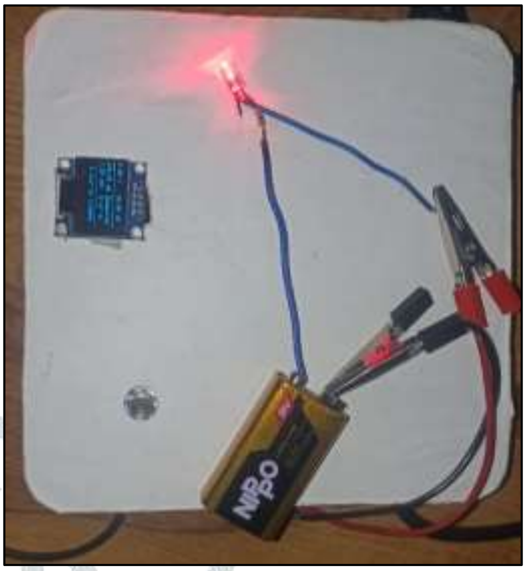

Fig.10. DC Load Measurement

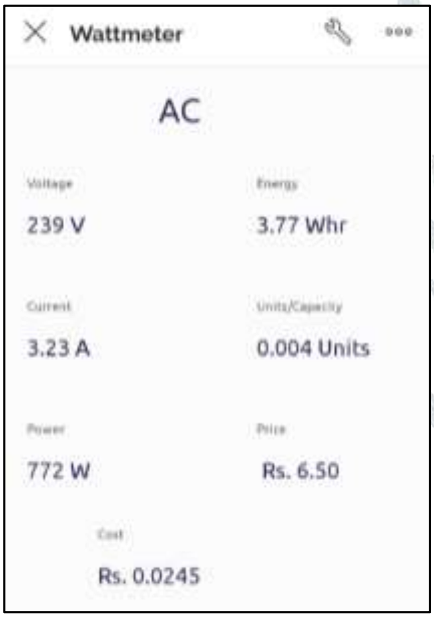


Fig.11. 800W Iron


Fig.12. 55W Table Fan


Fig.13. 120mW LED

## CONCLUSION

We have seen the design of a single-phase energy meter for in this review article based on various smart meter designs created thus far. The signal conditioning circuit, microcontroller, and relay that make up the energy meter sense data from the primary source and compute bills in real time. Additionally, the design incorporates a Wi-Fi module to enable online storage of the data for additional data analytics. This design enables users and utilities to manage load utilisation while also displaying peak hour usage and real-time billing to customers.

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