Fabrication of Low Cost Smart Energy Meter

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Abstract: Electricity is one of the fundamental necessities of human beings, which is commonly used for domestic, industrial, and agricultural purposes. Smart Energy Meter (SEM) is an electric device having an energy meter chip for measuring the electric energy consumed. This paper presents a low-cost smart energy meter for an automatic metering and billing system with the capacity to load the information into the website. The data from the current sensor and transformer are fed into microcontroller (ESP8266) where the energy consumed by the connected load is calculated. This is done by using voltage from step-down transformer and current from current sensor. The digital pin from the XOR gate is used for power factor calculation based on Zero Crossing Detection (ZCD) and finally overall power consumption is measured. And the inbuilt Wi-Fi module of microcontroller helps to transmit the data into the Blynk server. In this way the developed SEM is able to provide results in an accurate and efficient manner.

Keywords: Blynk Server, Zero Crossing Detection, Wifi Module

I. Introduction

An electric meter, or energy meter is a device that measures the amount of electric energy consumed by a building, tenant space, or electrically powered equipment. Electric utilities use electric meters installed at customer's premises to measure electric energy delivered to their customers for billing purposes. They are typically calibrated in billing units, the most common one being the kilowatt hour [kWh]. They usually read once in each billing period. When energy savings during certain periods are desired, some meters may measure demand, the maximum use of power in some intervals. "Time of day" metering allows electric rates to be changed during a day, to record usage during peak, high-cost periods, and off-peak, lower-cost periods. Also, in some areas, meters have relays for demand response load shedding during peak load periods. Most electric meters installed are analog meters, which display units intended to be read visually. Recently, meters have been developed for granular and cloud-connected energy tracking. This trend is helping achieve better operational performance in buildings.

First, by monitoring the energy use of buildings, equipment and tenant spaces in real time, operators can recognize immediately when there is an issue in the building. Secondly, when it comes to maximizing energy efficiency, energy audits are only a snapshot of efficiency; meters that track energy use in real time provide continuous visibility into a property. The first specimen of the AC kilowatt-hour meter produced on the basis of Hungarian Otto Blathy's patent and named after him was presented by the Ganz Works at the Frankfurt Fair in the autumn of 1889. In 1894 Oliver Shallenberger of the Westinghouse Electric Corporation applied the induction principle previously used only in AC ampere-hour meters to produce a watt-hour meter of the modern electro-mechanical form, using an induction disk whose rotational speed was made proportional to the power in the circuit [1]. At past, Electricity meter distributed by electricity authority is analog, which works by the eddy current effect. The current flowing through the meter runs through a pair of loops which induces eddy current, and this current rotates the aluminum coil whose speed is dependent on the amount of power being consumed (P.M, 1990) [2]. A paper published in IEEE presents a low-cost approach to real time energy management in a smart grid. It involves using smart meters that connect aggregator via CAN bus, a web server for remote control and smart meters. Moreover, it has MAC based security software to guard against outside assaults [3]. A low-cost smart energy meter based on the internet of Things with LoRa-Wifi for online energy measurement and billing was proposed. In this model the users may receive real-time supply voltage, current and power usage data on smartphones thanks to the system, which also enables energy firms to identify thefts and problems while offering clients dependable service [4]. Another similar smart energy meter (USEM) with load management, adaptable tariff plans and remote configuration was suggested in one study [5].

The low SEM presented here can make energy monitoring accessible to wider range of households and small business particularly in developing countries like Nepal where energy access and affordability are major challenges. These devices can provide economic benefits by reducing energy bills and promoting energy efficiency.

II. Methodology

A single-phase AC supply is used for driving the loads. The loads are connected in series with the source and the current sensor as, to measure the current flowing through the circuit. As shown in the block diagram the current sensor converts the current flowing through the circuit with sensitivity of some particular mv per amp i.e., current flowing through the circuit is converted into voltage (<=5V) then it is measured by the Arduino which calculated the voltage. The output of voltage sensor and current sensor is also connected to the zero-crossing detector which calculated the phase difference between voltage and current. The resultant phase difference is fed to the digital pin of the Arduino for the calculation of power factor. Finally, all the necessary calculations are done to calculate the amount of energy consumed and its consecutive cost and display it on output device (LCD).

An AC current sensor and a voltage sensor were selected based on our requirements. The AC current and voltage sensors were thoroughly calibrated to minimize the error. Here, the voltage was converted from 220 volts (V) to 12 volts (V), and a voltage divider was used and then fed to the analog pin. Similarly, the current ACS712 was selected and calibrated to get the current value. After that, compilation and calculation were coded onto the Arduino UNO to get the power consumed by the user. The power consumed is transferred to the time domain to determine the energy consumed. Then, with the help of a tariff, the electricity bill is calculated. These values are made visible to the user through an LCD screen. After the whole device was developed, the outputs were monitored.

The working mechanism are described in more details below:

A. ***Voltage Measurement***

The transformer converts 230-volt AC to 12-volt AC. Then, using a voltage divider, it is converted to 5 V. Further half-rectifiers are used to convert the AC to DC volts, and capacitors are used to filter the ripples. The Zener diode prevents the excess current from passing through the Arduino, and only voltages up to 5 can be fed to the Arduino.

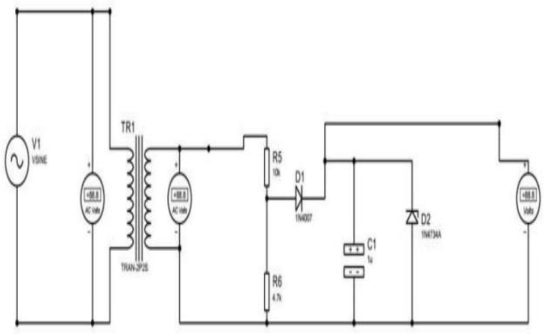

Fig. 1: Voltage Measurement Circuit

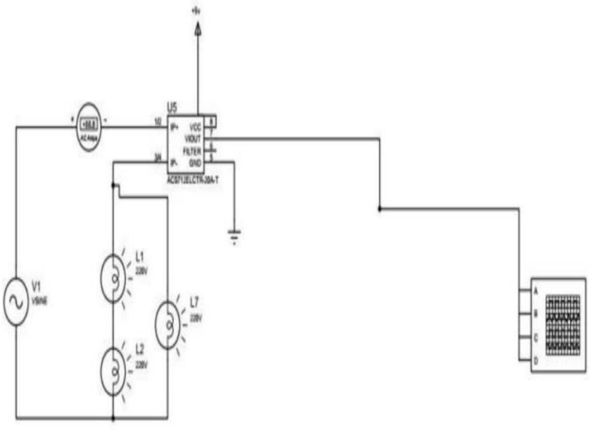

Fig. 2: Current Measurement Circuit

B. ***Current Measurement***

While measuring current with the current transformer (CT), we see some fluctuations in the output. For this reason, and to overcome it, we used a current sensor. It is connected in series with the load, and its output signal ranges around 2 volts. So, some programming is done to get the exact fluctuation in the current.

C. ***Power Factor Measurement***

The op-amp is used to create square waves for zero crossing. To protect the Arduino, opto-couplers are used to separate the AC and DC sides. Then an XOR gate is used to get the time difference between the voltage and current. With the help of the pulse input, we find the phase difference between them, which helps to calculate the power factor.

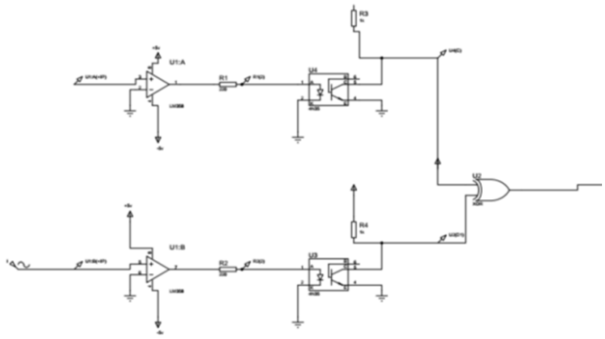

Fig. 3: Power Factor Measurement Circuit

D. ***Data Transfer***

We are interfacing NodeMCU, specifically, with the Blynk platform to communicate with the energy meter. First of all, we have created interfaces for our model using different widgets that are provided by the Blynk Web dashboard. The widgets are designed to display current, energy, power factor, and power from the NodeMCU esp8266. Now for the communication between the hardware (ESP8266) and web dashboard, a Blynk server is used, where we get Blynk clouds and run our private Blynk server locally. And for the incoming and outgoing commands between the hardware components and server, Blynk libraries are used. This will link our energy meter with the IoT cloud, and we will be able to display the meter parameters like current, power, power factor, and energy on the cloud users will be able to login into their particular web dash and be able to monitor their energy meter parameters.

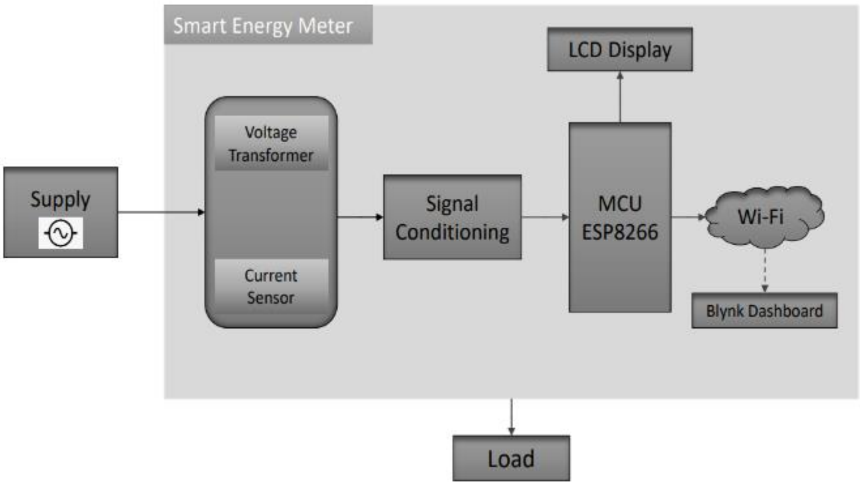

Fig. 4: Block Diagram of SEM

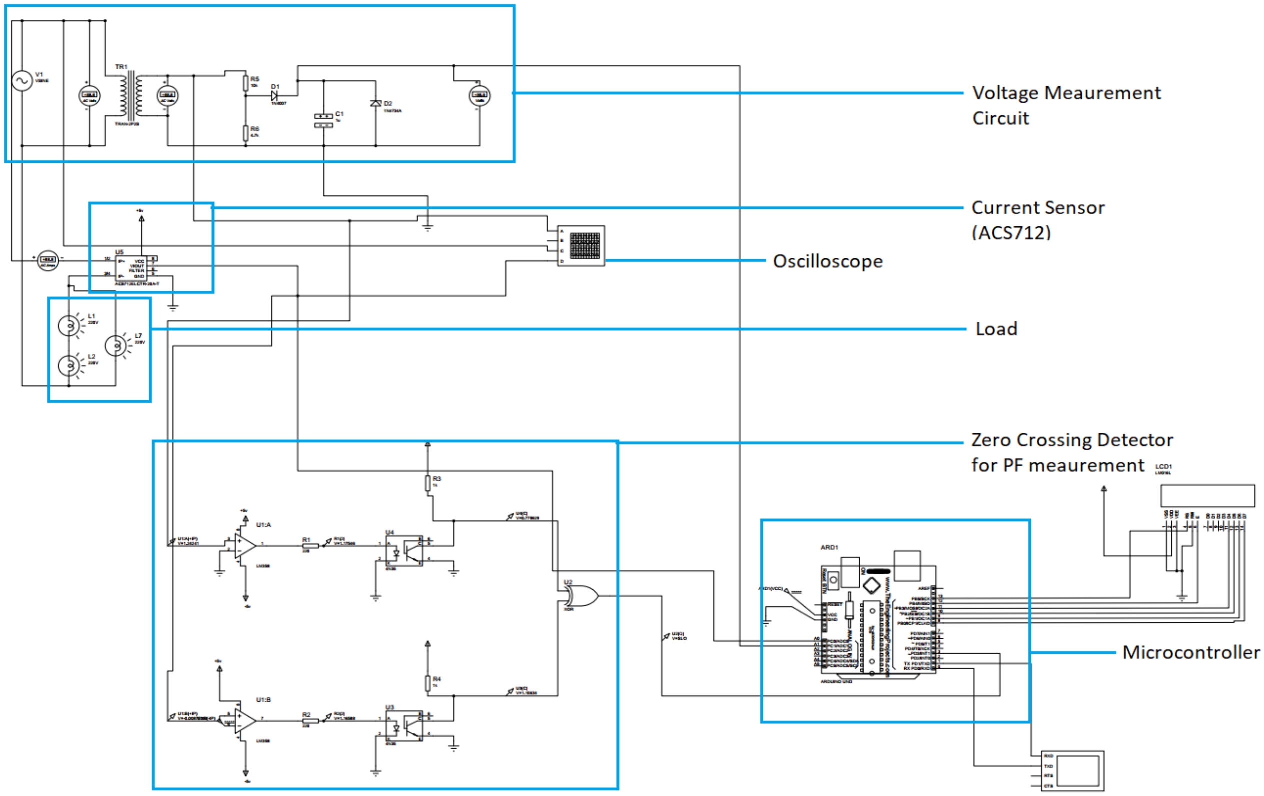

Fig. 5: Overall Circuit of SEM

III. Results and Discussion

All the simulations were done in Proteus software and a hardware setup was also made in the lab. The results obtained in Proteus are:

A. Resistive Load Condition

The current and voltage signal were found to be in same phase. Other results obtained could be seen in the figure below:

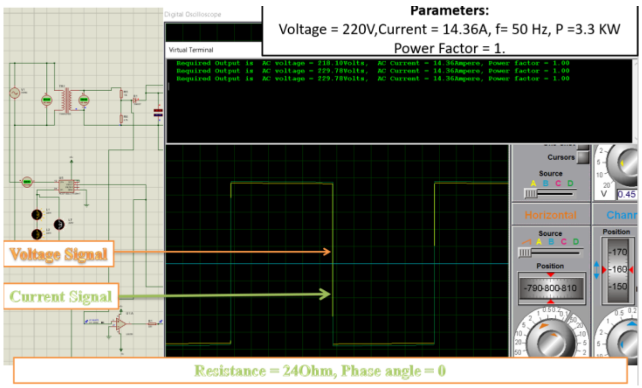

Fig. 6: Resistive Load Condition

B. *Inductive Load Condition*

The voltage signal was found to be leading the current signal. Other results obtained could be seen in the figure below:

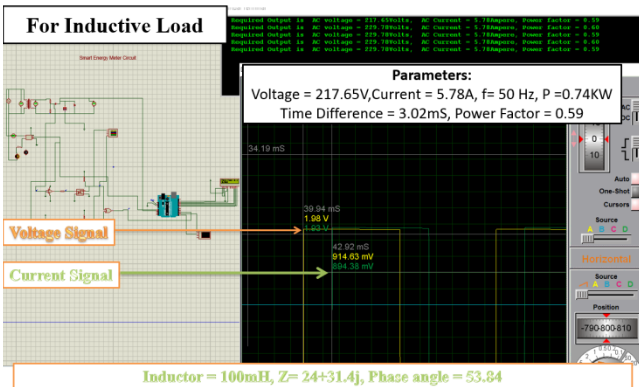

Fig. 7: Inductive Load Condition

C. *Webpage Display*

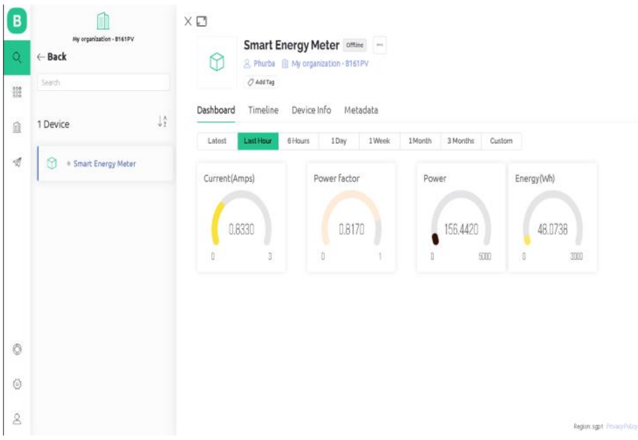

Fig. 8: Webpage Display

D. *Hardware Setup*

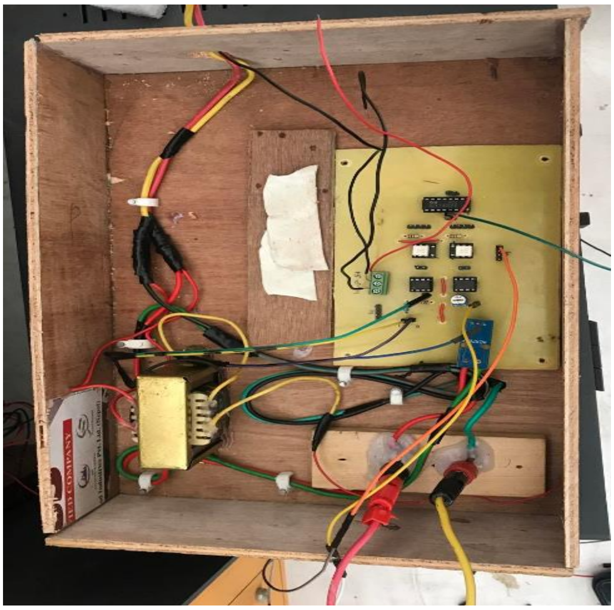

Fig. 8: . Hardware Display

IV. Conclusion and Future Works

This paper discusses an energy meter that was able to provide energy consumption with the help of a microprocessor where the voltage and current data were fed. Finally, the power factor was calculated using zero cross-detection. This data was then fed to Node MCU which performed necessary calculations and then sent to the Blynk website through the Wi-Fi module. This data can be observed from any place where there is an internet facility. In this way, the Energy Meter was designed to read the necessary parameters and display them over the internet.

It can be further extended to incorporate direct load control through a relay driver. Further fault could also be detected using this system with the help of current rating and prevent overflow or short circuit conditions. The testing of the accuracy and comparison with other similar technologies are part of our future plans which also includes commercialization.

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