

Design and Construction of a Load Monitoring Programmable Energy Meter for Effective Energy Audit

Joseph O. Olowoleni, Cladius O. A. Awosope, Anthony U. Adoghe, C. A. Okeke, and Francis E. Idachaba

Abstract—A load monitoring energy meter has been presented in this paper. The watt-meter monitors the electrical energy consumed by the consumer's load. The Arduino uno, current sensor, voltage sensing circuit, keypad and LCD are the major building blocks of this project. The electric load power is displayed in watts, and the cost of running a particular load for a given period of time can be determined by the user by inputting the duration of time (i.e. number of hours) the load is to run, using a keypad and the cost is dependent on the programmed tariff plan. Designing a programmable watt-meter involves the use of an Arduino Uno, LCD (Liquid Crystal Display), voltage sensing circuit, YHDC current sensor, and keypad.

Index Terms— Arduino uno, YHDC current- transformer, 20x4 LCD, Potential transformer

I. INTRODUCTION

ENERGY crisis is a fundamental issue which has become a source of concern in this present time. Interrupted and unreliable electrical power supply has become a menace in most third world countries. In this present day, some nations with limited natural resources for generating their electricity, use non-renewable energy sources such as gas, are faced with the dilemma of changing their electricity tariff rate, based on the cost of gas.

In some nations, the energy audit system is in a deplorable state, and in some areas, public utility consumers complain of the high electricity tariff rates, while in other areas, electricity bills are issued at the end of the month without the DISCO (Distribution company) carrying out a comprehensive energy audit.

According to ISO50002, "An energy audit is a systematic analysis of energy used and energy consumption within a defined energy scope." An energy audit is like an energy assessment.

Therefore, to carry out an effective energy audit, there is the need for a device capable of monitoring the load consumption and is not prone to the mistakes which are traceable to manual input. Hence, the need of a

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programmable energy meter.

II. METHODOLOGY

In implementing this project, the main controller used was the Atmega 328 micro-controller found in the arduino Uno. The arduino Uno was powered with 9V dc with its Vin port, while the Atmega 328 is supplied with 5V dc from the arduino.

The research uses a YHDC current sensor capable of measuring a maximum of 100amps. The current sensor is clamped on the positive mains cable; it measures the current being consumed by the load and then sends the analogue signal to the analog pin of Atmega 328 micro controller. A voltmeter circuit is also incorporated in the design, which measures the voltage reading from the mains supply and sends the analog signal to the analog pin of the micro controller. To calculate power, the micro controller samples the voltage and current readings thousands of times a second.

The voltage, current, power and energy readings are displayed on the LCD, with their respective S.I units.

Based on the tariff rate used in the code, a user can determine how much it will cost to run at a particular load rating for a specified time. The time duration is inputted by the user, using the keypad, and then the cost is displayed on the LCD (Liquid Crystal Display).

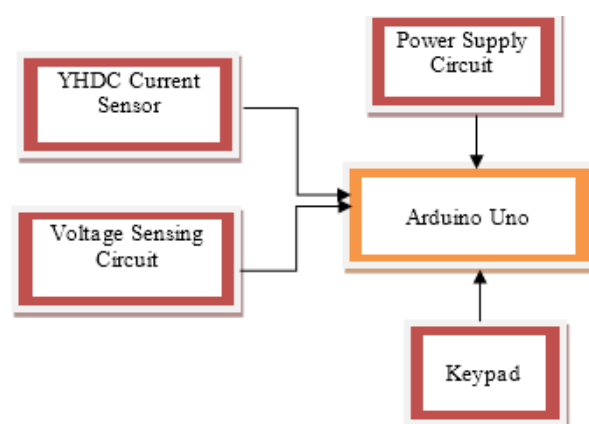


Figure 1. Block Diagram of the Programmable Energy Meter

III. DESIGN STAGES AND COMPONENTS

A. Voltmeter Circuit

The voltage across the mains supply terminals is stepped down to 12V ac, and then converted to dc by connecting the 12V ac to a bridge rectifier. The rectified voltage is then filtered using a 1000-uf capacitor. The output 12V dc is then connected to the positive and the negative terminals of a variable resistor. A 5-V zener diode is connected between the ground and the wiper, which is the output of the variable resistor. This is to ensure that the voltage across the ADC (Analogue to digital converter) pins of the microcontroller does not exceed 5V dc, since the maximum voltage rating of the Atmega 328 is 5V dc.

The output of the variable resistor has to be calibrated before connecting it to pin A4 of the arduino.

The voltmeter circuit is calibrated thus:

Max ac voltage reading: 250V ac = 5V dc

The voltage from the mains is measured using an external voltmeter. Then, the corresponding dc value of the measured ac voltage has to be calculated mathematically. i.e.

Measured ac value from mains = 230V ac

250V ac= 5V dc

230V ac= unknown dc voltage

Unknown dc voltage= (230*5)/250= 4.6V dc

The variable resistor output will be adjusted to the unknown dc voltage value, and series of processes such as: low-pass filtering, sample and hold, quantization and encoding, occur at the ADC port of the micro- controller to read the analog signal value.

B. YHDC Current Sensor



Figure 2. YHDC Current Sensor

It is a non-invasive current sensor, it doesn't have an internal resistance. Zener diodes limit the output voltage in the event of a disconnection from the burden resistor. It can develop sufficient voltage to drive a 5-V input, and in this work, the YHDC current sensor acts as a CT (current transformer). A current transformer usually consists of a primary side and a secondary side, and in a CT, the transformer has a ten-turn secondary and a one-turn primary. If 1amp flows in the primary coil, it will result in 0.1amp in the secondary coil. The arduino micro controller is capable of reading voltage signals, and since the output from the CT is a current signal, then there is the need to convert it to a voltage signal. Therefore, a burden resistor is needed.

Sizing the burden resistor:

-The maximum current range of the CT been used is

100A. Maximum RMS (root mean square value) = 100Amps.

- Primary peak current= RMS current $\times \sqrt{2}$

Primary peak current= 100A $\times \sqrt{2}$ = 141.4A

-The YHDC SCT-013-000 has 2,000 turns,

Secondary Peak Current = $\frac{\text{Primary peak current}}{\text{No of turns}}$
 $\frac{141.4A}{2000}$

Secondary peak current= 0.0707A

-For maximum measurement resolution, the voltage across the burden resistor should be half of the arduino AREF (Arduino reference voltage).

Ideal burden resistance = $\frac{\left(\frac{AREF}{2}\right)}{\text{Secondary Peak Current}}$
 AREF = 5volts.

Ideal burden resistor value = $\frac{(5/2)}{0.0707A}$
 Ideal burden resistor value = 35.4Ω

Since a 35.4-Ω resistor could not be found, a 33-Ω resistor, which is close enough to the calculated value, was used.

The two 10-kΩ resistors used for voltage divider are to reduce the 5V to 2.5V.

C. Power Supply

The AC voltage from the mains supply was stepped down to 12V AC by using a potential transformer. The 12V AC was converted to DC, using a full-wave rectification circuit. The rectification circuit consists of four rectification diodes (1N4007) connected in a bridge configuration. After rectification, the output DC voltage was filtered to remove ripples and get a pure DC voltage output. A 9-volt regulator (LM7809) was used to step down the output DC voltage of 13.5V to 9 volt which was used to power the Arduino.

D. Arduino Uno

It is a microcontroller board based on ATmega328P. It uses a 16-MHz crystal oscillator, and it has 6 analog input pins. 14digital output/input pins, (out of which 6 can be used as PWM outputs), one USB jack, an ICSP header, one power jack and a reset button.

The Arduino Uno can easily be used to program the ATmega328p microcontroller, using the Arduino IDE. The Arduino Uno was powered with 9V DC, using the power jack. The Arduino Uno has an internal voltage regulator which steps the 9V down to 5V DC for the ATmega328P to function properly.

IV. RESULTS

The circuit was connected as shown in the circuit diagram below. The watt-meter was tested with predefined loads such as an electric iron and it was able to measure the voltage, current, power and energy. The keypad was also tested. It displayed the cost based on the number of hours inputted.

The accuracy of the energy meter was tested by comparing the actual power rating to the measured power of some household device [1, 2]. There was a very minimal percentage error when the reading from the energy meter was compared with that of the actual wattage of the devices.

$$\frac{\text{Percentage Error}}{\text{Actual wattage} - \text{obtained wattage}} \times 100\%$$

The highest percentage error was 4%, and the variations in the measurement could be due to the difference in the voltage used in calculating the actual wattage and the measured wattage.

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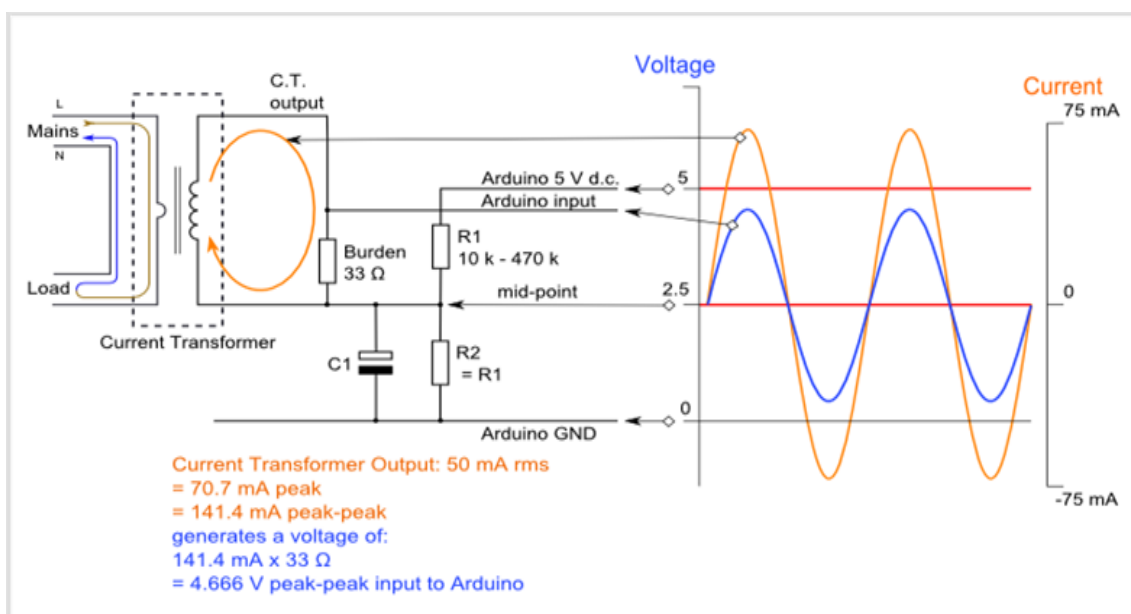


Figure 3. Current Transformer with Burden Resistor

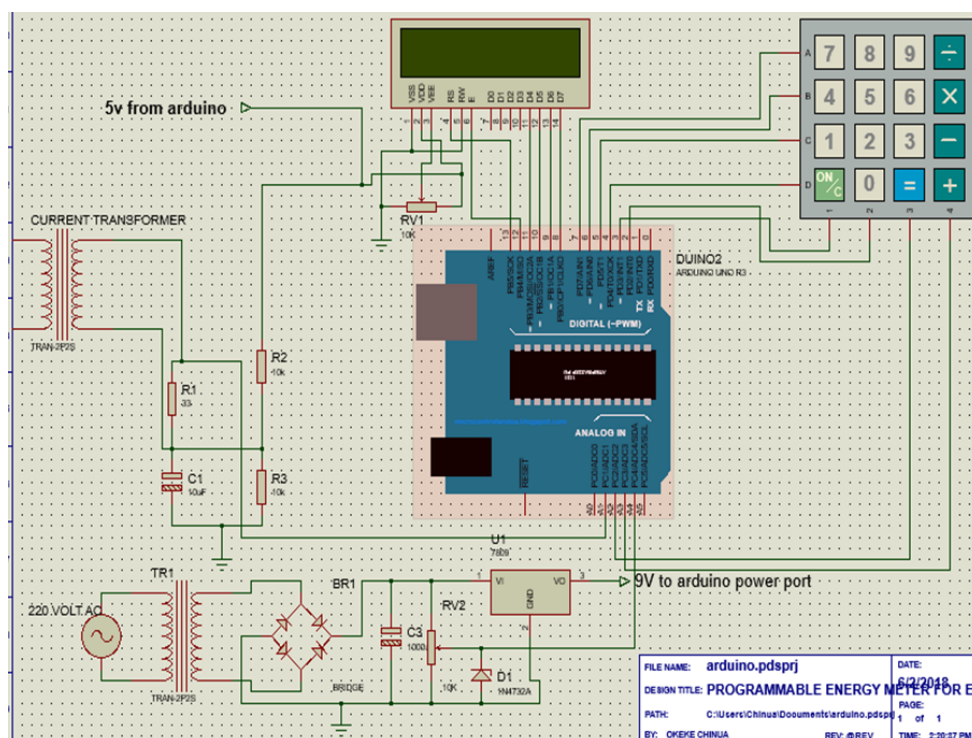


Figure 4. Open Energy Monitor

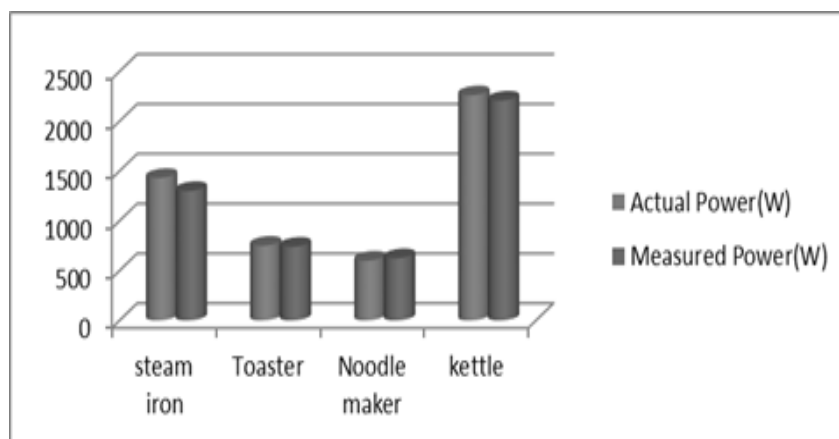


Figure 5. Results



Figure 6. Measuring the Power of a Noodles Maker

V. CONCLUSION

Implementing this load monitoring wattmeter with its added feature will provide the user with real time information of the energy consumption of the household. Thus, it leads to reduction of energy consumption and effective energy audit, thereby reducing energy cost and preventing electricity wastage.

Further work can be done on the project, such as including a password to access the keypad. By connecting the energy meter to the web using a WIFI (wireless fidelity) module, the user can know his or her energy consumption from anywhere. Making the meter energy smart, such that a user can input the maximum energy that will be consumed and once it reaches that level, an electronic switch switches off the power supply to the load. This kind of meter can be used in event centers, residential areas etc.

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