

Smart Meter Integrated With Iot

Puppala Rajendhar, J Belwin Edward

Abstract: With the existing metering system, the system becomes very difficult in real time. By integrating the domestic energy meter with IoT, the present difficulties are solved. This research provides an IoT-integrated smart meter design and implementation. This System has been designed to measure the parameters of the appliances such as voltage, current, power factor, frequency. It also measures power and energy parameters. The design comprises of a smart sensing unit for monitoring the parameters that also detects and controls the status of the home appliances. The measured parameters have been displayed in pc using Arduino and these parameters have been interfaced with Internet of Things (IoT) devices using Ethernet. The Ethernet shield has been used to transmit the measured data to the dedicated webpage with the help of ThingSpeak webserver, which has been developed by using HTML, CSS style and PHP. The development is cost-effective and user-friendly products easy to expand. The model built was tested and the results are very promising.

Index Terms: Home Energy Management Systems, Energy Monitoring, Internet of Things, Advanced Metering Infrastructure, Smart metering, Smart Sensing.

1 INTRODUCTION

Energy meter is a device used to measure any residence or industrial establishment's energy consumption. Under the traditional metering scheme, the electricity consumption was determined by the hiring company of the energy provider, the individual who visits that area and manually records the reading of the energy meter. The reading of this meter was used to measure the electricity bill. Persons can exploit meter reading through various corrupt practices such as current reversal or CT reversal tampers, partial earth failure state, bypass meter, magnetic interference, etc. Especially in the rainy season, this process becomes very difficult. If the bill has not been charged by any customer, the worker must go to their homes to disconnect the power supply. It's not an easy way to measure power consumption. Advanced metering infrastructure (AMI) smart meter technology offers two-way data communication and is able to report current and voltage measurements on a regular basis in addition to information on energy consumption. The benefits of a smart meter based on AMI include increased accuracy and reliability, as well as Power line connectivity and other technology such as Ethernet for a meter reading. Authors conducted their preliminary research in exploring HEMS' best modeling and hardware practices along with adoptable communication protocols and also concentrated on exploring how HEMS benefits from demand response and optimization techniques. Authors checked various smart grid modeling methods that can be used for smart HEMS [1]. Authors used ZigBee, NodeMCU, suitable sensors, and relays to prototype a substation online monitoring and control of electrical systems. The substation app is also developed using the MIT app developer [2]. Electrical parameters are measured in the article [3]. The voltage transformer used in this paper is the MYRRA developed step-down 127/4 voltage transformer for calculating the voltage. They used the new transformer ASM010 given by Talema in the current calculation.

For wireless transmission of electrical parameters, the output signals from the sensors are integrated and connected to the XBee unit. Such parameters are stored and evaluated in a database. The data collected will be displayed by (GUI) on the screen. The ZigBee was connected via the host computer's USB cable, which stores the data in a computer system server. There were three types of control techniques used to turn electrical appliances on / off, such as automatic control, manual control and remote control. The voltage and current transformers were used to detect the sinusoidal waveform from an electrical appliance to calculate the appropriate electrical parameters [4]. Used to transform the sinusoidal to a square wave, Zero Crossing Detector (ZCD). This output is provided to the 8051 microcontrollers external interrupt. All information that the microcontroller processes is sent through serial port communication through the XBee. The electrical parameters are transferred and displayed on the PC through this Xbee. Researchers developed power meters in the literature [5] through the use of voltage and current transformers and the Arduino computing system. A series of voltage and current transformers were set up for preliminary tests to determine the parameters (Vrms, Irms, Power Factor) equipped with a reference power meter AXE MMX-P1 to measure the voltage, current and actual power of a variable array of portable appliances. Authors in article [6] uses the microcontroller module Arduino Uno Rev3 together with the chip ATmega328. The hardware that uses the Arduino microcontroller board, serving as the central controller. It will be connected to a current transformer through the current and voltage sensor circuit to control the electrical parameters. The system converts these measured raw data into digital data input for data acquisition and logs them to a SD card for data retention using the SD / MMC shield module. During testing, numerous data were dumped with loads resulting in distinct results. And the cost of the materials invested on the device is very practical for conventional use of the prototype

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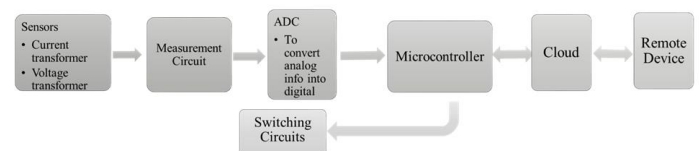


Figure 1 Block Diagram of the proposed smart meter integrated with IoT

[7] Focused on the design and development of an Internet-of-Things (IoT) automatic meter reading (AMR) system for smart cities deployment. A ZigBee wireless sensor network (WSN) supports this framework. The administrator for ZigBee serves as a ZigBee portal responsible for connecting to the Internet. Before transmitting to the cloud, the gateway transforms a data packet (received either from energy or a network router node) from the ZigBee to the TCP / IP protocol. The system was developed in several nearby buildings at Newcastle University, Australia. In this paper [8], they first used static methods to evaluate the Power Factor of varying load and compensate. A power factor such as zero crossing detectors, opto-couplers and EXOR gate has been tested using different techniques. Super diode was used here to check voltage and current. And microcontroller shall measure these parameters. On the basis of these measurements, all other information available to assess the potential to solve the problem is determined. On this basis, condensers are automatically taken online or offline by flipping the solid state relay to compensate for the lagging power factor and microcontroller shall measure these parameters. On the basis of these measurements, all other information available to assess the potential to solve the problem is determined. On this basis, condensers are automatically taken online or offline by flipping the solid state relay to compensate for the lagging power factor. This system allows the electricity board to read monthly energy meter readings without a human resource that can be introduced with the aid of the Arduino unit which continuously tracks and records the energy meter reading in its permanent (non-volatile) memory spot. This prototype records the reading continuously and the reading of the live meter can be shown on the consumer's web page on request.

2. BLOCK DIAGRAM AND BASIC CIRCUITRY FOR MEASURING THE PARAMETERS

2.1 Voltage Measurement

The step down potential transformer is used to convert the input supply of 230V to 6-0-6 V_{rms} AC signal with center tapped secondary winding. The output of the transformer given to the adder circuit to ensure the voltage varies from 0 to 5V. This output signal is then fed to an analog input channel of Arduino end Device which will show measured voltage in the PC by sampling the input voltage and find the rms value of the voltage signal. Below Figure 2 shows the circuit designed for the voltage measurement.

Where V_{rms} is given by,

$$V_{rms} = \frac{\sqrt{\sum_{i=1}^n V_i^2}}{n} \quad (1)$$

Where n is the Number of Samples.

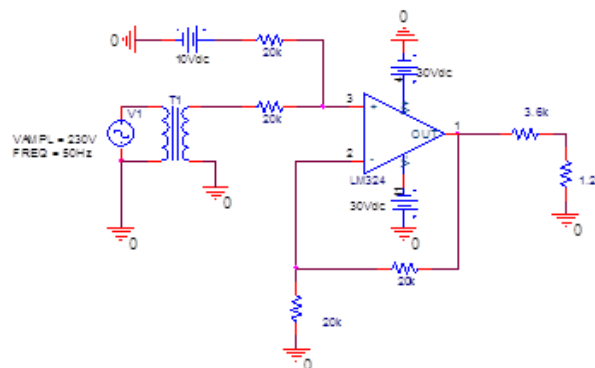


Figure 2 Voltage Measurement Circuit

2.2 Current Measurement

The wire that connected to the load is passing through the current transformer. The voltage is measured across burden the resistor of 50 ohm resistor of the current transformer. The measured voltage is in the range of milli volts. This output signal is given to the amplifier circuit which is made up of LM324. Again the signal fed to the adder circuit to ensure the voltage varies from 0 to 5V. The output signal is then fed to an analog input channel of Arduino Device which will show measured voltage in the PC by sampling the input voltage and find the rms value of the current signal. Figure 3 shows the current measurement circuit diagram.

Where I_{rms} is given by

$$I_{rms} = \frac{\sqrt{\sum_{i=1}^n I_i^2}}{n} \quad (2)$$

Where n is the Number of Samples.

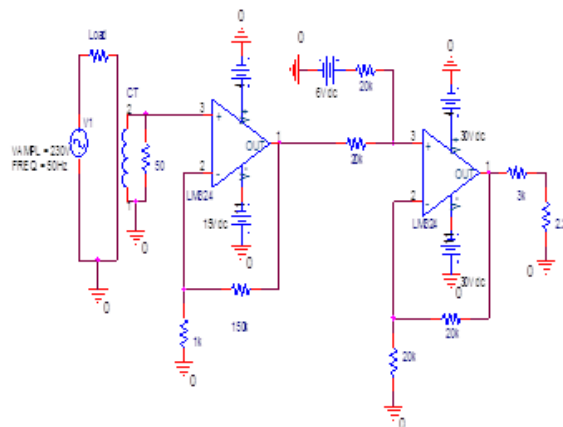


Figure 3 Current Measurement circuit

2.3 Frequency Measurement

In order to measure the frequency, the zero-crossing detector (ZCD) has been used which is made up of LM324. The output of the ZCD is fed to one of the digital inputs of the Arduino and Ton (= Toff) is calculated. The below Figure 4 shows the Frequency measuring circuit.

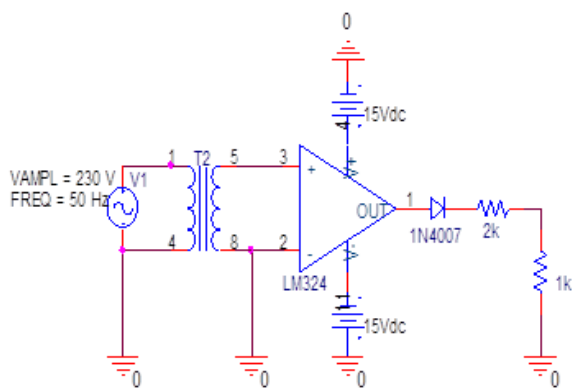


Figure 4 Frequency Measurement Circuit

$$\text{Frequency } F = \frac{1}{\frac{1}{T_{on}} + \frac{1}{T_{off}}} \quad (3)$$

2.4 Power Factor, Power and Energy Measurement

The PF is calculated based on the current and voltage instantaneous values determined from the load. Based on these quantities, the rms current, the rms voltage, P, S, and then the PF can be estimated. Where,

$$\text{Active power } P = \frac{1}{n} \sum_{i=1}^n V_i I_i \quad (4)$$

$$\text{Apparent Power } S = V_{rms} I_{rms} \quad (5)$$

$$\text{Power Factor } PF = \frac{P}{S} \quad (6)$$

$$\text{Energy } E = P * t \quad (7)$$

Where V_{rms} is the rms voltage, I_{rms} is the rms current and t is the total time

3 PROPOSED SMART METER INTEGRATED WITH IOT

Figure 1 shows the block diagram of the proposed work. A potential transformer used to reduce the voltage from single phase 230V ac to 6V ac and 50Hz waveform. Adder and Potential divider circuit used as the signal conditioning circuit in order to prevent the Arduino from over voltage and current. To measure the current, the main line is taken through the CT and connected to the Load. The project used ASM010 series CT to measure the current through line which converts the maximum of 10A current into 40mV waveform. Again, this low voltage cannot be read by Arduino. Hence, the signal is given to the LM324 amplifier circuit to amplify the magnitude of the signal. Again this signal is given to adder and Potential divider circuit for signal conditioning. After getting the conditioned signal of both voltage and current waveform, the signal given to Arduino which is having an in-built Analog to Digital converter (ADC) gives the digital signal. Then, the digital signal is processed by the microcontroller and V_{rms} , I_{rms} , Power factor, Power and Energy can be measured. The output of the voltage transformer is given to the Zero Crossing Detector (ZCD) which will give the rectangular waveform with the

frequency of input voltage waveform frequency. From the rectangular waveform, the negative portion can be eliminated using a simple diode, and the peak voltage is reduced using the voltage divider circuit. The final pulse will be given to Arduino digital pin to measure the pulse width. The frequency of the signal is calculated by inverting the total time of one cycle. Those details will be displayed on the PC using the serial monitor.

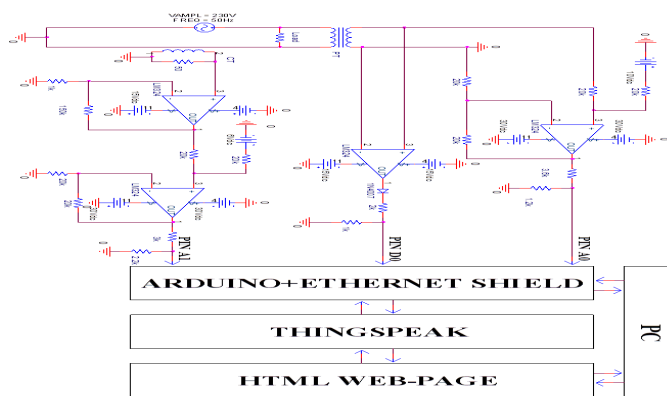


Figure 5 Overall Hardware Arrangement

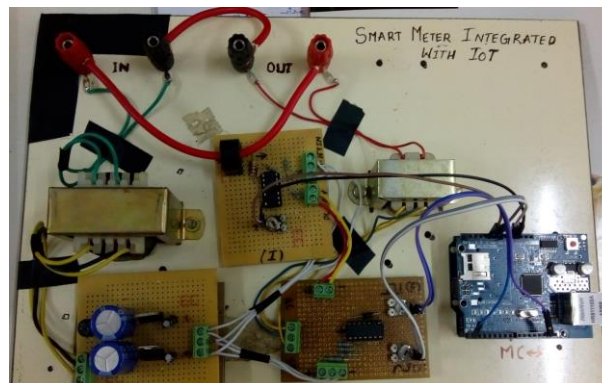


Figure 6 Prototype of Hardware Arrangement

The overall hardware arrangement is shown in Figure 5. The output of the circuit will be given to the Arduino as discussed above. (Note: Arduino can be used only for lower frequency applications. However, the frequency of the supply voltage in India is 50Hz which can be processed by arduino). The Arduino connected to the Ethernet shield and is connected to the PC through RJ45 cable. This setup will provide the internet to Arduino through the Serial Peripheral Interface bus (SPI). The calculated data of RMS voltage and current, Frequency, Power Factor, Active Power, Reactive Power and Energy are uploaded to the cloud (ThingSpeak Server) using the Ethernet shield. ThingSpeak server used to store and view the data on web-based server. A web page is created using the program languages like HTML, Java Script, PHP, and MySQL. The page will take the user to the login page to login with his unique username and password. After login user can view his measurement values, minimum and maximum values. The user can view the data from a specified date to a particular date as graphical representation using the view data button in the main page. The prototype of the proposed work is represented in figure 6. The website contains a login page,

Main page, Data logging page and details page. Languages like HTML, PHP, MySQL, CSS, and Java Script are used to create the webpage. The page reads the data from the thingspeak server using the read API key and Calculate the minimum and maximum value of the data which is passed and shown on the Main page. The login page is used to make sure that the right user accessed the data. From the data logging page, the user can view their data as a graphical representation. Considering all these in mind the page is designed. In the power supply unit, we have used DB107 instead of individual diodes which consume more space and power when compared to DB107. However, the cost of DB107 is a little high compared to diodes.

4 DEMONSTRATION OF PROTOTYPE RESULTS

RIGIOL DS1000E series Digital Oscilloscope used in this project for the Calibration of the signal to fetch the hardware results. Also, HAOYUE DT830D Digital Multimeter used for measurements. Each stage outputs are shown below.

4.1 Voltage Measurement

Figure 7 depicts the output of the Voltage transformer, input of 238V (RMS) output is 7.17V (RMS). This voltage waveform fed to the adder circuit to make sure that voltage swings only on the positive side since the negative signal cannot be given to Arduino or any other ADC circuit.

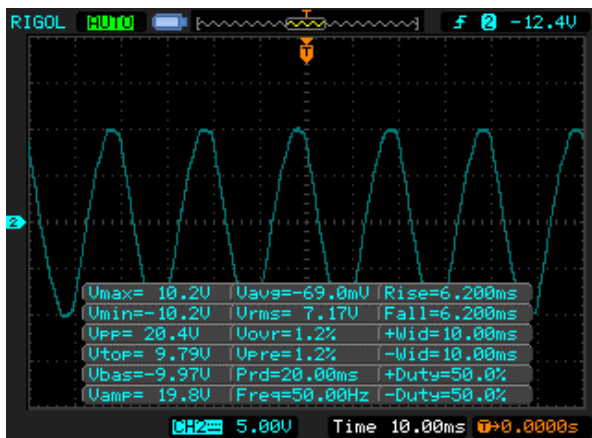


Figure 7 Output of Voltage Transformer

Figure 8 shows the output after the signal conditioning. There are two stages of signal conditioning. One is adder and another one is a voltage divider. The analog input to the Arduino should be a maximum of 5.5V. But the output of the adder will be 2 times more than the peak voltage if the input signal. Hence, it should be reduced to 5V in order to feed the signal to the Arduino analog pin. This signal is given to Arduino and will be processed (sampled) and VRMS calculated as per Equation 1

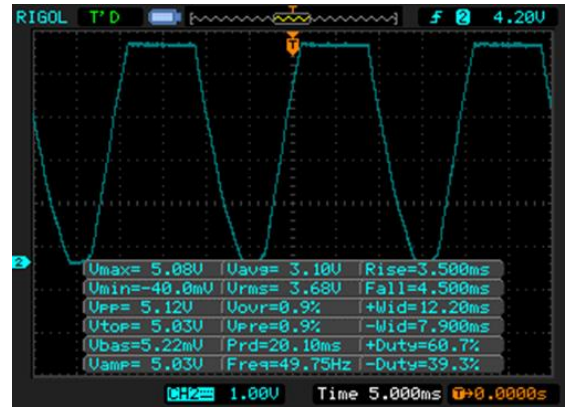


Figure 8 Output of Voltage waveform after signal conditioning

The output of the Arduino after calculation in terms of RMS voltage is 237.76V which is almost equal to the input RMS voltage of 238V (Measured by Digital Multimeter). The error percentage is 0.1.

4.2 Current Measurement

Figure 9 shows the Output of the Current Transformer. ASM-010 converts a maximum of 10A current into 40mV Peak Voltage across 50Ω connected parallel to the output leads of the Current Transformer. For the 1000W resistive load, the output voltage across the 50Ω resistor is 19mV peak voltage. This small variation in output cannot be read by the Arduino.

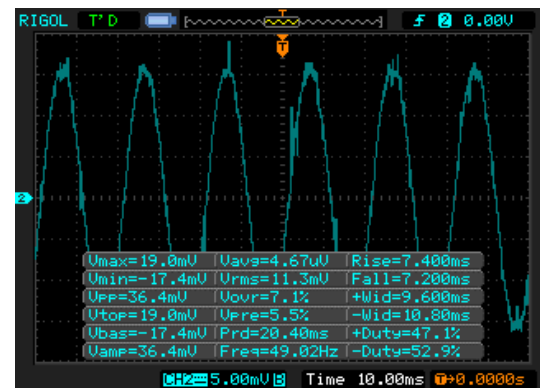


Figure 9 Output of Current Transformer

Hence, this waveform should be amplified with Non-Inverting amplifier with a gain of 151 according to Equation,

$$V_{out} = \left[1 + \frac{R_F}{R_2} \right] * V_{in} \text{ when } R_2 = 1k\Omega \text{ and } R_F = 150k\Omega$$

Figure 10 shows the output of the amplifier. For the input peak voltage of 19mV then the output is 2.40V (Peak) according to above Equation.

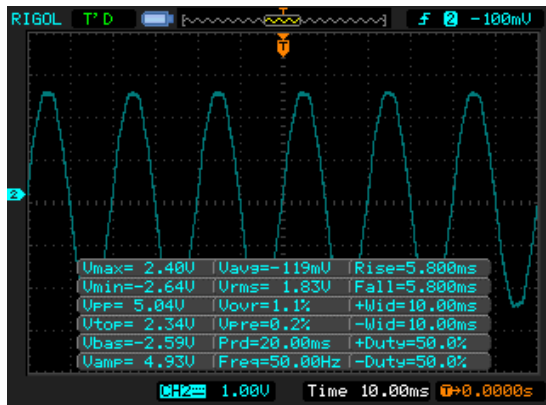


Figure 10 Output Current waveform of Amplifier

As mentioned under Voltage measurement section 4.1 Signal condition should be done in order to give the signal to an analog pin of Arduino. Figure 11 shows the output of the Adder Circuit. The voltage swing from -400mV to 8.80 V. This will be given to a voltage divider circuit to make sure that the voltage does not exceed more than 5V. For maximum case, the output from the CT is 40mV. Hence, the output from the Amplifier is almost 5.45V. When this is given to the adder circuit the maximum voltage is 11V.

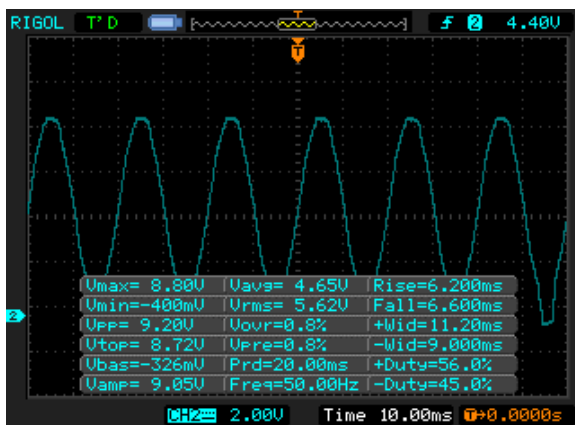


Figure 11 Output Current waveform after Adder

Hence, the divider circuit will have $R_1=2.2k\Omega$ and $R_2=3k\Omega$ according to Equation .

$$V_{out} = \frac{R_2}{R_1 + R_2} * V_{in}$$

This signal will be given to Arduino and RMS value of current Calculated as 4.17A.

4.3 Frequency Measurement

Figure 12 represents the output of the voltage transformer. The maximum voltage of 10.2V. This waveform is given to Zero Crossing Detector to convert the sine wave to a rectangular waveform. After that, a 1N4001 diode is used to

remove the negative portion of the rectangular waveform. After that Voltage divider used to reduce the maximum voltage of 13.2V to 5V two resistors with the ratio of 1.6 are used (i.e. $R_1 = 1k\Omega$ and $R_2 = 2k\Omega$).

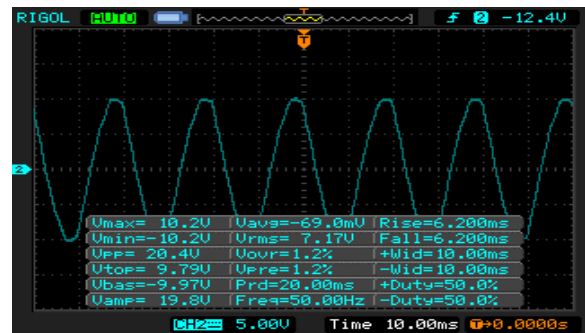


Figure 12 Input Voltage waveform to the Zero Crossing Detector

Figure 13 shows the final Arduino input of the pulse signal to find the frequency. The Arduino will calculate the T_{on} and which is equal to T_{off} both will be added and the frequency can be calculated using Equation 3. The final Calculated value of the Frequency is 50.05Hz for the input of the 50Hz waveform.

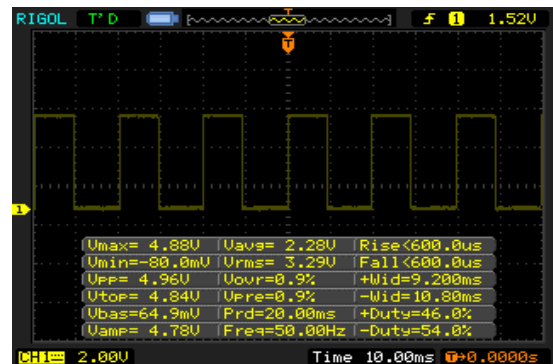


Figure 13 Output of Zero Crossing Detector after signal conditioning

4.4 Power Factor, Power and Energy Measurement

As discussed in section 2.4, Active power P can be calculated using the formula 4 and apparent power S can be calculated by multiplying the RMS Voltage and RMS Current as Equation 5. The difference between Apparent power and Active power will give Reactive power. The power factor can be calculated using Equation 6. For the above results the Active power calculated as (through Arduino) 980.55W and apparent power as 991.46VA. From this Power factor calculated as 0.989 and Reactive power as 10.91VAr. The below Table 4.1 shows the Parameters measured for the R Load and Table 4.2 shows for R-L Load

Table 4.1 Parameters Measured for R Load

V_{RMS}	I_{RMS}	F	P	S	Q	PF
237.76 V	4.17 A	50.05Hz	980.55 W	991.46VA	10.91VA	0.989

Table 4.2 Parameters Measured for R-L Load

V_{RMS}	I_{RMS}	F	P	S	Q	PF

236.21	2.78	49.98H	489.86	656.65V	166.79VA	0.74
V	A	z	W	A	r	5

to the data logging page and he/she can give the required details and submit, he/she will receive the details of the reading in terms of graphical representation as shown in the below Figure 4.9.

4.5 Results in PC

Below Figure 14 shows the output displayed in the PC through the Arduino IDE Serial monitor.

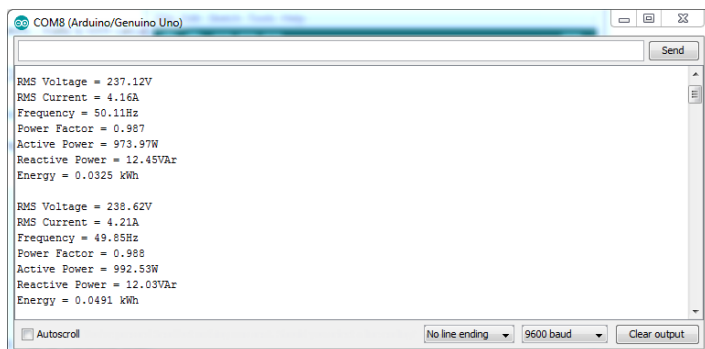


Figure 14 Output displayed in PC Serial Monitor

4.6 Webpage Results

Users can go to <https://mysmartmeter.000webhostapp.com/> to view the smart meter readings on the website. The user can login with his details. For this proto-type Username is "SELECT" and Password is "VIT". After login user will get the main page as shown in Figure 15. There he/she can see the current readings, minimum and maximum readings.

4.7 Data Logging Page

By clicking the Detailed view from the main page user can go

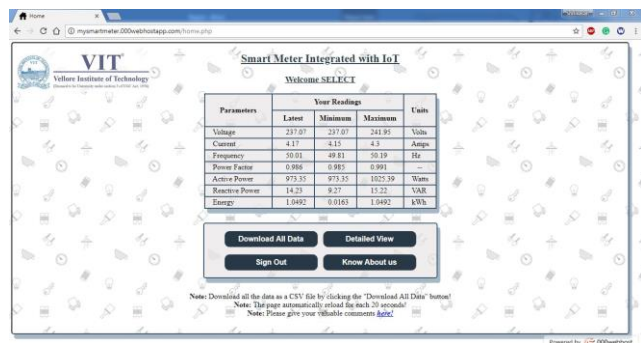


Figure 15 Main Page of the Website

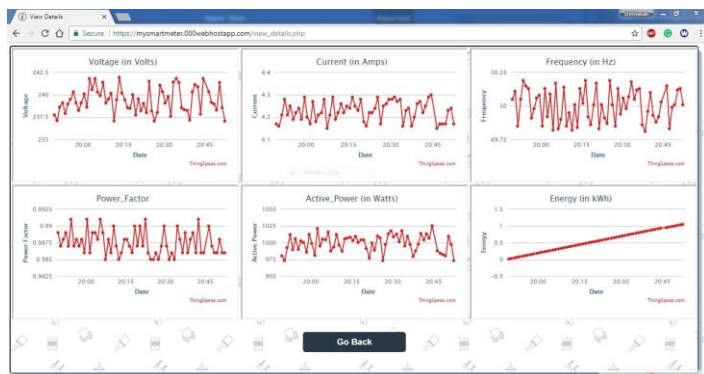


Figure 16 Data Logging Page

5 CONCLUSION

The proposed model is used to track the household's energy consumption. Such smart meters can be used to solve problems such as over-use of energy, large amounts of resources control of use and expense and resource wastage, bribery, etc. It therefore decreases energy consumption and raises awareness among everyone. The value of the working model is to reduce the requirements of resources in the assessment of energy readings and also to minimize the errors caused by them.

6 ACKNOWLEDGMENT

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