ISSN 2278-3091
Volume 10, No.2, March - April 2021
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse711022021.pdf
https://doi.org/10.30534/ijatcse/2021/711022021

IoT Based Digital Wattmeter

Pavan S K[1],Kiran V R[2], Prashant V.Joshi[3],Sudharshan K.M.[4]
[1]School of ECE,REVA UNIVERSITY,Bangalore,pavansk000@gmail.com
[2] School of ECE,REVA UNIVERSITY, Bangalore,
kiranvr96@gmail.com[3]School of ECE,REVA UNIVERSITY, Bangalore,
prashantvjoshi@reva.edu.in[4]SchoolofECE,REVAUNIVERSITY,
Bangaloresudharshankm@reva.edu.in

ABSTRACT

Intelligent power measurement strategy for cost optimization. This paper gives idea about Arduino based power measurement for residential homes, using multidisciplinary concepts in electronics. The system features real time demand side management using composite design methodology (CDM). It comprises the metering and cloud server cluster units. The work introduced current sensing and voltage sensing element circuit, Arduino nano (with ATmega328 chipset), and ESP8266 to achieve the system functionalities. The design description on editor run-time environment enabled direct debugging in the open source Integrated Development Environment (IDE). The approach is evaluated through selected case studies and usability experiments. With the latter, the suitability of the system provided an efficient means of monitoring power measurement with minimal errors. The results showed that when the device is switched-on with no load, an output of 0.00kW was read. By connecting load to it, an output of 4.3kW was then observed on the cloud thingspeek(real time). The output kept increasing even as the load is connected to different load as expected. Utilities can smartly provide value-added services using the system, thereby increasing the system reliability through cloud.

Key words : Arduino nano, ESP8266, LCD Display

I. INTRODUCTION

The traditional analog wattmeter is an electrodynamics instrument. The device consists of a pair of fixed coils, known as current coils, and a movable coil known as the potential coil. The current coils are connected in series with the circuit, while the potential coil is connected in parallel. Also, on analog wattmeters, the potential coil carries a needle that moves over a scale to indicate the measurement. A current flowing through the current coil generates an electromagnetic field around the coil. The strength of this field is proportional to the line current and in phase with it. The potential coil has, as a general rule, a high-value resistor connected in series with it to reduce the current that flows through it. The result of this arrangement is that on a DC circuit, the deflection of the needle is proportional to both the current (I) and the voltage (v) thus conforming to the equation P=VI.

For AC power, current and voltage may not be in phase, due to the delaying effects of circuit inductance or capacitance. On an AC circuit the deflection is proportional to the average instantaneous product of voltage and current, thus measuring active power,

$$P=VI \cos \varphi.$$

Here, $\cos \varphi$ represents the power factor which shows that the power transmitted may be less than the apparent power obtained by multiplying the readings of a voltmeter and ammeter in the same circuit. The two circuits of a wattmeter can be damaged by excessive current. The ammeter and voltmeter are both vulnerable to overheating—in case of an overload, their pointers will be driven off scale—but in the wattmeter, either or even both the current and potential circuits can overheat without the pointer approaching the end of the scale. This is because the position of the pointer depends on the power factor, voltage and current. Thus, a circuit with a low power factor will give a low reading on the wattmeter, even when both of its circuits are loaded to the maximum safety limit. Therefore, a wattmeter is rated not only in watts, but also in volts and amperes. A typical wattmeter in educational labs has two voltage coils (pressure coils) and a current coil. The two pressure coils can be connected in series or parallel to change the ranges of the wattmeter. The pressure coil can also be tapped to change the meter's range. If the pressure coil has range of 300 volts, the half of it can be used so that the range becomes 150 volts.

A modern digital wattmeter samples the voltage and current thousands of times a second. For each sample, the voltage is multiplied by the current at the same instant; the average over at least one cycle is the real power. The real power divided by the apparent volt-amperes (VA) is the power factor. A computer circuit uses the sampled values to calculate RMS voltage, RMS current, VA, power (watts), power factor, and kilowatt-hours. The readings may be displayed on the device, retained to provide a log and calculate averages, or transmitted to other equipment for further use. Wattmeters vary considerably in correctly calculating energy consumption, especially when real power is much lower than VA (highly reactive loads, e.g. electric motors). Simple meters may be calibrated to meet specified accuracy only for sinusoidal waveforms. Waveforms for switched-mode power supplies as used for much electronic equipment may be very far from sinusoidal, leading to unknown and possibly large errors at any power. This may not be specified in the meter's manual.

ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize and analyse live data streams in the cloud. ThingSpeak provides instant visualizations of data posted by your devices to ThingSpeak. With the ability to execute MATLAB code in ThingSpeak you can perform online analysis and processing of the data as it comes in. ThingSpeak is often used for prototyping and proof of concept IoT systems that require analytics.

II. LITERATURE SURVEY

Fransiska R.W. Septia E.M.P.[1]studies have been conducted in making wattmeter which is interfaced with a personal computer utilizing Arduino microprocessor and LabVIEW program. This study consists of conditioning analog signals, converting the analog signal into a digital signal (ADC), and digital data processing. This wattmeter displays voltage, electric current, power consumption, energy use, frequency of the power source, and the usage fees alculation. It can measure device that uses AC voltage above 46 VRMS or DC voltage which is multiplication of 0.66 Volt, and has power between 2 to 1200 W.

RAYMOND S. TURGEL,[2]Average electric power can be measured by a system that samples voltages and currents at predetermined intervals. The sampled signals are digitized and the result is computed by numerical integration. The response of the system agrees with that of a standard electrodynamic wattmeter within 0.02 percent from dc to 1 kHz, with the possible exception of zero power factor measurements. Measurements up to 5 kHz can be made with somewhat greater uncertainties.

DON E. GARRETT, FRANK G. COLE,[3] A direct reading wattmeter is described which will read either positive or negative peak or average power of complex voltage and current waveforms containing components in the frequency range from dc to 71 kc. The instrument will measure up to 50 watts, covered in three ranges with an accuracy of 3 per cent. The scale may be extended by suitable resistance changes. The voltage and current inputs are mutually dc isolated to allow measurement of the current at any point between the ground and the voltage source. Multiplication of the current and voltage is accomplished by modulating a 10-mc carrier with the current, and then modulating the resultant with the voltage in a cascade of two suppressed-carrier modulators. The instantaneous product is recovered in a phase sensitive demodulator, and then passed through an integrating network for average power, or through a peak detector for peak power. The wattmeter was designed with particular reference to the measurement of the plate dissipation in television horizontal output tubes. It was designed, nevertheless, to be a general-purpose instrument capable of accurately measuring power in any type of circuit where the voltage and current involved can be measured.

Mohamed H. Shwehdi,Chris Jacobsen[4] A Digital Telewattmeter System (DTS) has been designed, developed and its prototype real time clock board has been tested according to a sponsoring agency's (utilities, manufacturing company, etc.) specifications. The DTS is a device that measures electrical energy consumption and reports via telephone. At a remote location, a microprocessor controlled wattmeter will sense current, voltage and time and convert this into kilowatt hours. For customer convenience, this information is displayed continuously. Every month, the remote location is polled by a main computer and the actual current value of kilowatt hours is read for its use by the billing

department. This paper deals with the designing, assembling, and the operation of the DTS as an innovative design and its use as load management device. Test results and specifications of the DTS showed that its basic properties conform with other available similar products and has more features.

Soeharwinto, M. FadhlanAriska,[5] a design to produce a microcontroller based digital wattmeter that measures the magnitude of power consumption of various loads (electronic devices) connected through it. To measure the power consumption under a sine wave signal (AC supply), the root mean square (rms) of both voltage and current is multiplied. The design is implemented using the techniques of digital signal processing and transformation. By this approach, both voltage and current are sampled a number of times during a cycle, the rms of the signals, real power, apparent power and the power factor are computed on the discrete signals. Finally, the magnitude of the power consumption is computed by integrating the power usage over a period of time. Product of this effort is a MIDIWAT that can measure rms voltage and current and power consumption over a period of time up to 1 kVA of loads (± 2%) with an overload protection.

III. METHODOLOGY

For ease of understanding the arduino wattmeter circuit is split into two units. The upper part of the circuit is the measuring unit and the lower part of the circuit is the computation and display unit. For people who are new to this type of circuits followed the labels. Example +5V is label which means that all the pins to which label is connected to should be considered as they are connected together. Labels are normally used to make the circuit diagram look neat.The circuit is designed to fit into systems operating between 0-24V with a current range of 0-1A keeping in mind the specification of a Solar PV. But you can easily extend the range once you understand the working of the circuit. The underlying principle behind the circuit is to measure the voltage across the load and current through it to calculate the power consumes by it. All the measured values will be displayed in a 16*2 Alphanumeric LCD. Further below let’s split the circuit into small segments so that we can get a clear picture of how the circuit is indented to work.

Measuring Unit

The measuring unit consists of a potential divider to help us measure the voltage and a shut resistor with a Non-Inverting Op-amp is used to help us measure the current through the circuit. The potential divider part from the above circuit is shown below

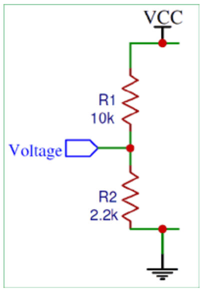


Figure 1: voltage divider circuit

Here the Input voltage is represent by Vcc, as told earlier we are designing the circuit for a voltage range from 0V to 24V. But a microcontroller like Arduino cannot measure such high values of voltage; it can only measure voltage from 0-5V. So we have to map (convert) the voltage range of 0-24V to 0-5V. This can be easily done by using a potential divider circuit as shown below. The resistor 10k and 2.2k together forms the potential divider circuit. The output voltage of a potential divider can be calculated using the below formulae. The same be used to decide the value of your resistors

$$Vout = (Vin \times R2) / (R1 + R2)$$

The mapped 0-5V can be obtained from the middle part which is labelled as Voltage. This mapped voltage can then be fed to the Arduino Analog pin later.Next we have to measure the current through the LOAD. As we know microcontrollers can read only analog voltage, so we need to somehow convert the value of current to voltage. It can be done by simply adding a resistor (shunt resistor) in the path which according to Ohm's law will drop a value of voltage across it that is proportional to the current flowing through it. The value of this voltage drop will be very less so we use an op-amp to amplify it. The circuit for the same is shown below

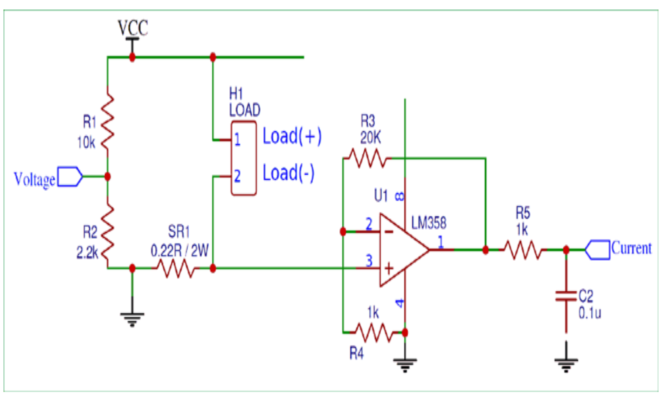


Figure 2: op-amp

Here the value of shunt resistor (SR1) is 0.22 Ohms. As said earlier we are designing the circuit for 0-1A so based on Ohms law we can calculate the voltage drop across this resistor which will be around 0.2V when a maximum of 1A current is passing through the load. This voltage is very small for a microcontroller to read, we use an Op-Amp in Non-Inverting Amplifier mode to increase the voltage from 0.2V to higher level for the Arduino to read.The Op-Amp in Non-Inverting mode is shown above. The amplifier is designed to have a gain of 21, so that 0.2*21 = 4.2V. The formulae to calculate the gain of the Op-amp is given below, you can also use this online gain calculator to get the value of your resistor if you are re-designing the circuit.

$$\textbf{Gain} = \textbf{Vout} / \textbf{Vin} = 1 + (\textbf{Rf} / \textbf{Rin})$$

Here in our case the value of Rf is 20k and the value of Rin is 1k which gives us a gian value of 21. The amplified voltage form the Op-amp is then given to a RC filter with resistor 1k and a capacitor 0.1uF to filter any noise that is coupled. Finally the voltage is then fed to the Arduino analogpin.The last part that is left in the measuring unit is the voltage regulator part. Since we will give a variable input voltage we need a regulated +5V volt for the Arduino and the Op-amp to operate. This regulated voltage will be provided by the 7805 Voltage regulator. A capacitor is added at the output to filter the noise.

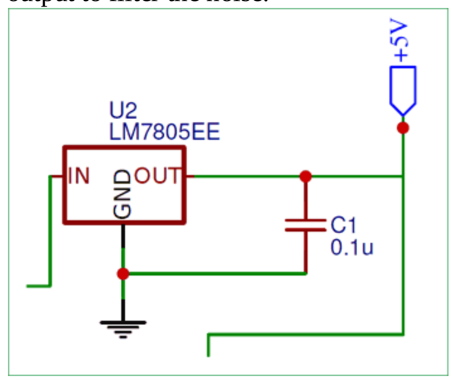


Figure 3: voltage regulator circuit

Computation and display unit

In the measuring unit we have designed the circuit to convert the Voltage and Current parameters into 0-5V which can be fed to the Arduino Analog pins. Now in this part of the circuit we will connect these voltage signals to Arduino and also interface a 16×2 alphanumeric display to the Arduino so that we can view the results. The circuit for the same is shown below

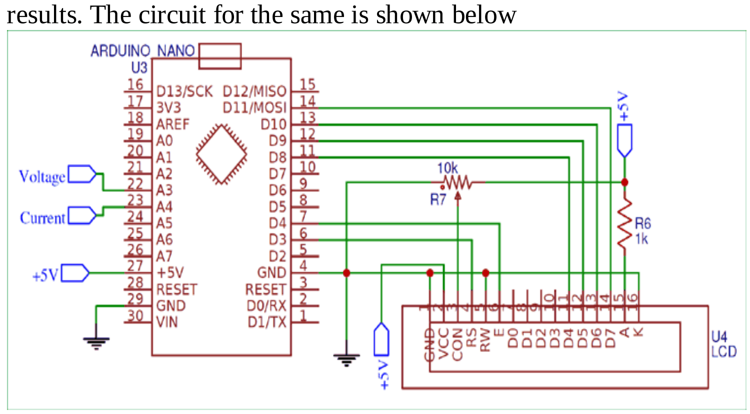


Figure 4:Computation and display unit

As you can see the Voltage pin is connected to Analog pin A3 and the current pin is connected to Analog pin A4. The LCD is powered from the +5V from the 7805 and is connected to the digital pins of Arduino to work in 4-bit mode. We have also used a potentiometer (10k) connected to Con pin to vary the contrast of the LCD.

IV. BLOCK DIAGRAM

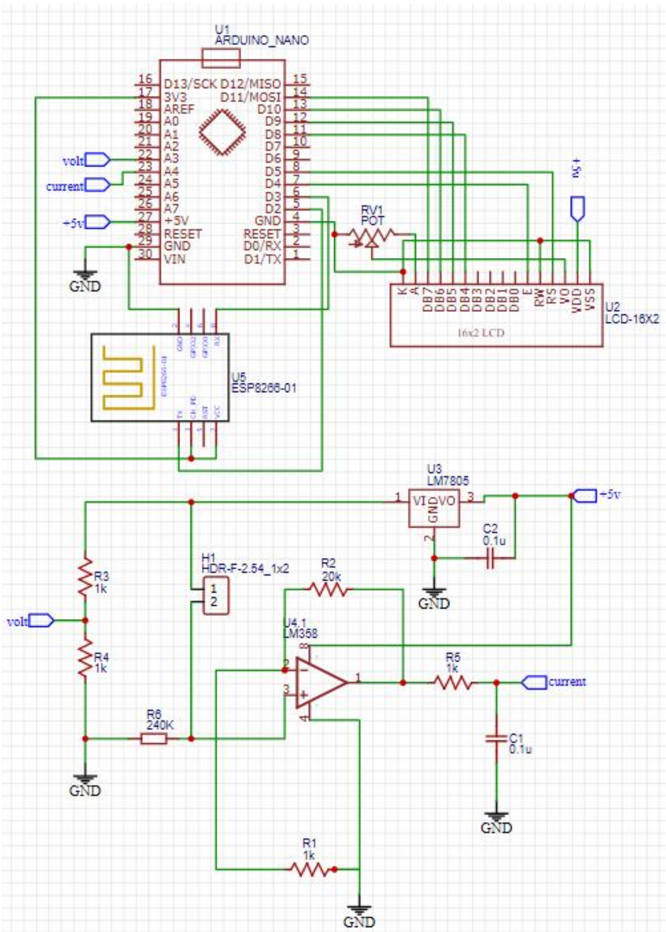


Figure 5:BLOCK DIAGRAM

V. RESULTS

Figure 6: Display page

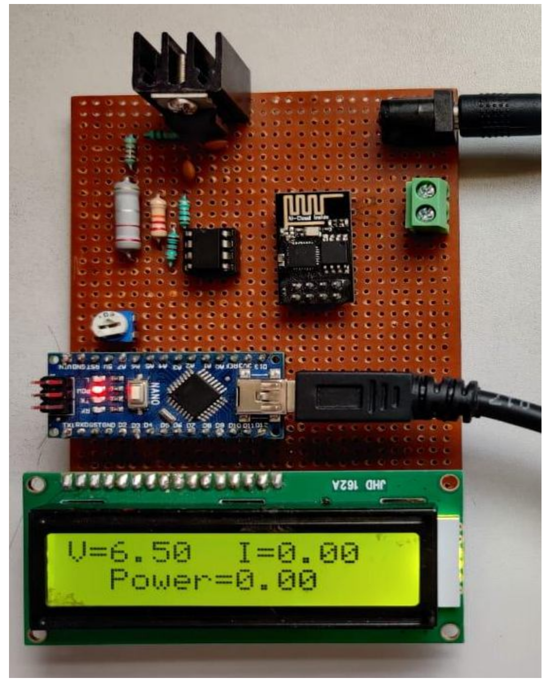


Figure7: Voltage, current, power values without load

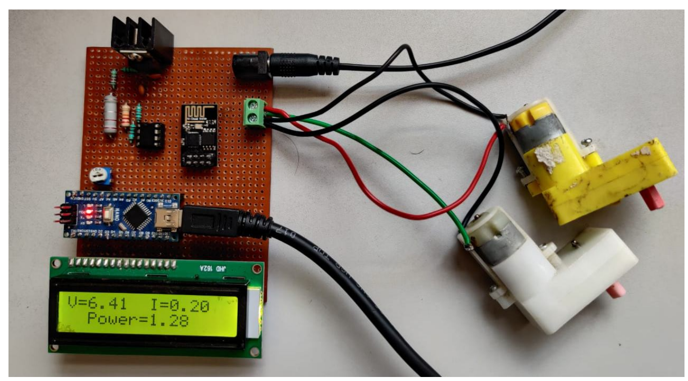


Figure 8: Voltage, current, power values with load

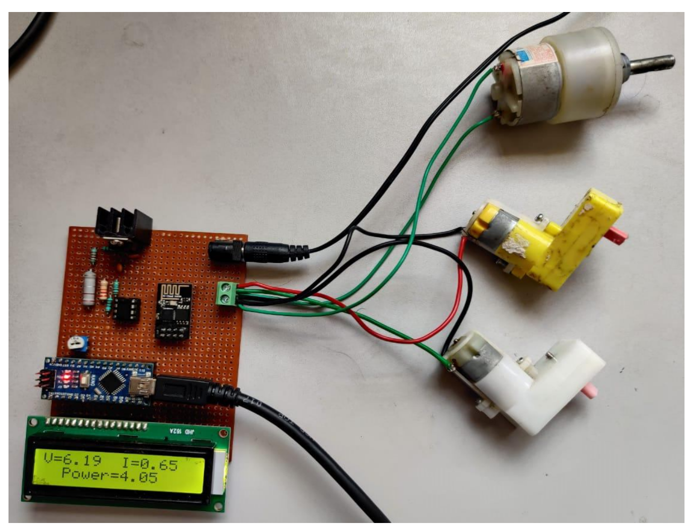


Figure 9: Voltage, current, power values with more load

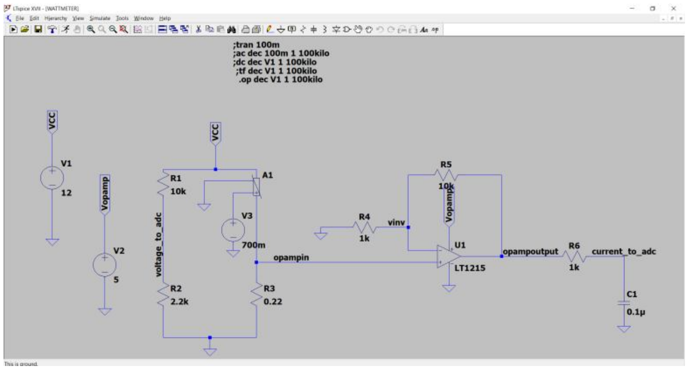
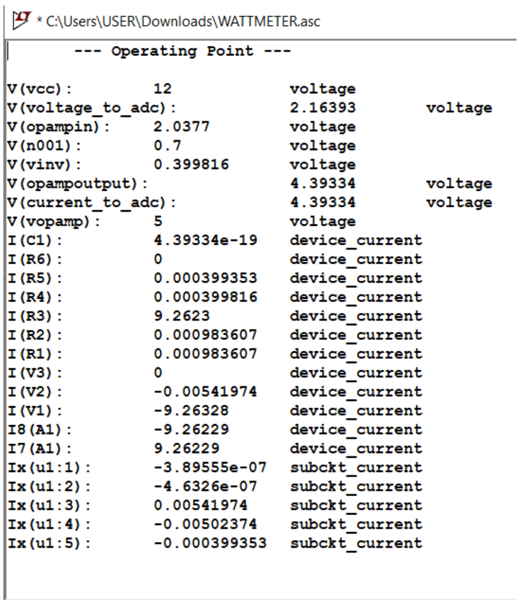


Figure 10: Circuit simulated in LT spice



* C:\Users\USER\Downloads\WATTMETER.asc

--- Operating Point ---

V(vcc):	12	voltage	
V(voltage_to_adc):		2.16393	voltage
V(opampin):	2.0377	voltage	
V(n001):	0.7	voltage	
V(vinv):	0.399816	voltage	
V(opampoutput):		4.39334	voltage
V(current_to_adc):		4.39334	voltage
V(vopamp):	5	voltage	
I(C1):	4.39334e-19	device_current	
I(R6):	0	device_current	
I(R5):	0.000399353	device_current	
I(R4):	0.000399816	device_current	
I(R3):	9.2623	device_current	
I(R2):	0.000983607	device_current	
I(R1):	0.000983607	device_current	
I(V3):	0	device_current	
I(V2):	-0.00541974	device_current	
I(V1):	-9.26328	device_current	
I8(A1):	-9.26229	device_current	
I7(A1):	9.26229	device_current	
Ix(u1:1):	-3.89555e-07	subckt_current	
Ix(u1:2):	-4.6326e-07	subckt_current	
Ix(u1:3):	0.00541974	subckt_current	
Ix(u1:4):	-0.00502374	subckt_current	
Ix(u1:5):	-0.000399353	subckt_current	

Figure 11: Output report in LT spice

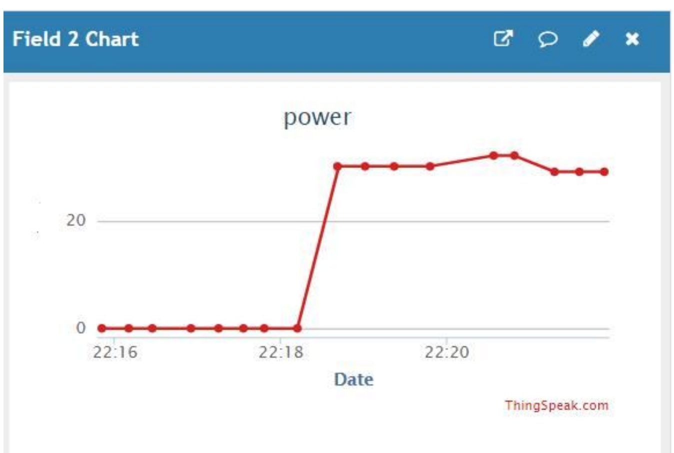


Figure 12: Output in ThingSpeak server

ACKNOWLEDGMENT

The authors are gratefully acknowledge the facilities and support provided by the director of the school of Electronics And Communication Engineering of REVA UNIVERSITY, We also extend thanks to all teaching and non-teaching staff who had helped directly or indirectly to make this project successful

REFERENCES

[1] Fransiska R.W. , Septia E.M.P. , Vessabhu W.K. , Frans W. , Abednego W. , Hendro("Electrical Power Measurement Using Arduino Uno Microcontroller and LabVIEW") INSPEC Accession Number: 14023180, DOI: 10.1109/ICICI-BME.2013.6698497, Date of Conference:06 January 2014

[2] RAYMOND S. TURGEL,("Digital Wattmeter Using a Sampling Method")INSPEC Accession Number:0018-9456, DOI: 10.1109/TIM.1974.4314307, Date of Conference:4, Dec. 2013

[3] DON E. GARRETT, FRANK G. COLE, ("A General-Purpose Electronic Wattmeter"), INSPEC Accession Number:0096-8390, DOI: 10.1109/JRPROC.1952.274018, Date of Conference:2, Feb. 2013

[4] Mohamed H. Shwehdi,Chris Jacobsen ("A MICROPROCESSOR-BASED DIGITAL WATTMETER SYSTEM DESIGN"),INSPEC Accession Number: 5490355,DOI: 10.1109/IECEC.1996.553382,Date of Conference: 11-16 Aug. 2000

[5] Soeharwinto, M. FadhlanAriska, BaihaqiSiregar, UlfiAndyani, FahmiFahmi,("Power Meter Monitoring for Home Appliances Based on Mobile Data Communication") INSPEC Accession Number: 17525105, DOI: 10.1109/ICON-SONICS.2017.8267832,Date of Conference: 8-10 Nov. 2017

[6] N.T. Makanjuola; O. Shoewu; L.A. Akinyemi; and A.A. Ajasa ("Design and Development of a Microcontroller Based Digital Wattmeter")Volume 16. Number 1. Date of Conference:May 2015