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IoT Enabled Power Monitoring Device

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ABSTRACT

In this paper, an IoT enabled power monitoring device is presented and discussed. The device enable user to determine the energy usage for each electrical appliance. The device hardware consists of NodeMCU DevKit v3.0, split core current transformer (CT), OLED display. C/C++ language is used programmed the device through Arduino IDE and ThingSpeak web server to record and display the power consumption and the usage cost. During measurement, the device has an average of 4.04 % of current (A) error percentage compare to the measured industrial clamp meter especially for high power electric appliances. The device is also capable for power consumption cost calculation whether hourly or daily.

Key words: Arduino, IoT, Power Monitoring, Power Consumption.

1. INTRODUCTION

It is important to know that electricity tariff will be affected when there is a change in the price of generation costs, which can be split into fuel cost such as piped gas, coal and liquefied natural gas as well as the cost of importing electricity [1]. It is user responsibility to keep their energy fees as low as possible and energy efficiency as high as possible to maximize the energy usage. Premises owner such as commercial premises with multiple stall or lot have some problem regarding energy usage fees that need to be pay by stall or lot renter. The premises owner does not have the equipment or device to charge the stall owner on the energy use by their respective stall or lot for type G socket outlet. A power monitoring device is required to determine energy usage for each different stall.

The important role of energy in powering and supporting global economic growth is undisputed, and global energy demand is estimated to increase by more than one-third over the period to 2035 (International Energy Agency, 2014). It is also worrying because according to statistic, energy sector contributes two-third of greenhouse gas emission. It is therefore important for us customer, to use energy efficiently. Not only has it helped to sustain this earth for future generation it also reduces your energy utilities bills.

Customer will know their energy usage when there is a need to pay the utilities bills. It is therefore important for user to know their energy usage hourly or daily in order for customer to use energy efficiently. This project prototype will monitor energy usage through current measurement at socket outlet. The term measure from Oxford Advanced Learner's Dictionary 8th Ed. year 2010 is define as to find the size, quantity, etc. of some-thing in standard units using standard measurement device [2].

The law of conservation of charge states that charge neither can be created nor destroyed only transferred [3]. A feature of electric charge or electricity is, it can be transferred and can be con-verted to another form of energy. Current sensing function for this project is used to measure "how much" current is flowing in a circuit, which may be used for power management to con-serve power [4]. Current measurement will be compared be-tween clamp meter and the proposed device. An industrial clamp meter is an electrical test tool that combines a basic digital multimeter with a current sensor. Device used Current Transformer (CT) as current sensor. The primary winding of a current transformer usually consists of a single turn, obtained by running the power system's primary conductor through the CT core [6].

Past research has been done by other researchers. IoT based energy meter has been presented in [7]. Arduino Uno is used as microcontroller unit (MCU) and optocoupler is used as ADC input for power usage. however, the proposed design involves a lot of components which the production cost. In [8], 0pen source IoT meter devices for smart and energy-efficient school buildings is discussed. Arduino Micro as MCU and CT sensor is use for current measurement. The prototype uses XBee radio software for wireless communication board. The development of Arduino based IoT metering system for on-demand energy monitoring has been presented in [9]. The prototype uses Arduino UNO as MCU, ACS 712 for current measurement and SIM 800L GSM Module for data communication. Similar concept of transmission has been discussed in [10]. The IoT based smart energy meter uses Arduino Uno as MCU and GSM SIM900 &

ESP8266 for communication. However, GSM communication limits the amount of data send at one time. IoT based smart power metering using Raspberry Pi as MCU and Arduino Uno as ADC processor is presented in [11]. The usage of Raspberry PI as MCU increases the production cost of the device. Similar research has been done for power monitoring purposes in [12-13].

In this paper, IoT enabled power monitoring device is presented and discussed. The device uses NodeMCU DevKit v3.0 with on-board WiFi module as MCU and split core current transformer (CT) as the current sensor. The data from the device is trans-mitted using WiFi communication and send to ThingSpeak Web Server to record and display the energy usage and cost of the electrical appliance. The device is designed to have less component used for production cost reduction.

2. DESIGN METHODOLOGY

Complex system tends to cost more. Therefore, it is important to use only the essential component only. Figure 1 shows the system block diagram of the IoT enable energy monitoring de-vice. NodeMCU was selected because of the microcontroller unit has an onboard WiFi module. NodeMCU DevKit v3.0 was selected for this project. Current transformer (CT) sensor (Split core CT ECS1030-L59) was selected as indirect current sensing unit. Microcontroller use the data from the CT sensor to calculate the power consumption and cost in Ringgit Malaysia (RM). This information from microcontroller will be displayed on the OLED display unit. The data also later on, sent to ThingSpeak web host service for record and display purposes. This data is stored in cloud storage provided by web host. This data also can be accessed by user through web host link.

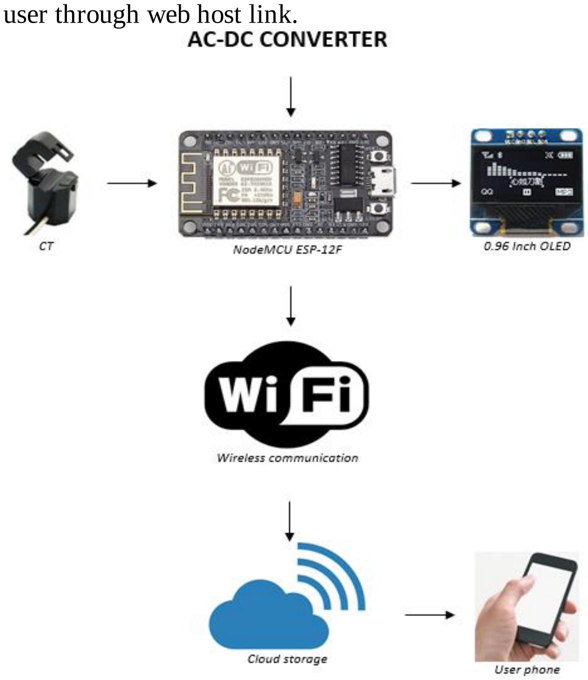

Figure 1: System block diagram

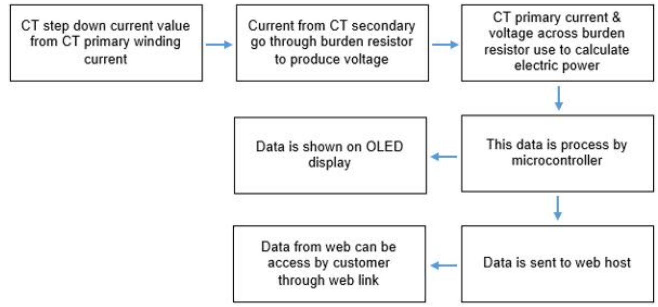

Figure 2: Data transmission block diagram

Data transmission block diagram is shown in Figure 2. CT step down current value from primary where current pass through wire that the CT sensor clamped. CT sensor generates voltage across a burden resistor proportional to the current passing through the wire that are clamping the CT. Using this current and voltage value, electric power can be calculated. Since our voltage is alternate current (AC), it has negative values and DC offset is added so that the alternation would only happen above zero or positive value. The data is processed by the MCU and it will be displayed on the OLED and send to the cloud server for recording and displaying at the website.

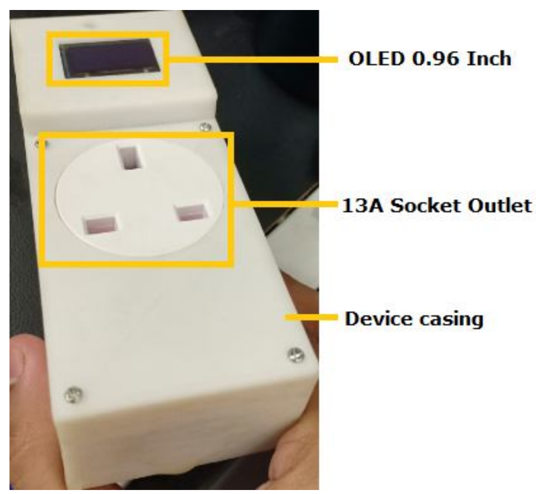

Figure 3: Prototype top view

Project prototype was developed based on the hardware specification. Project hardware was first developed on breadboard be-fore it was construct using strip board later on. Figure 3 and 4 show the front and side view of the prototype. Data are dis-played on the OLED display while the same data also sent to the cloud storage via Wi-Fi. Customer could access this data through their phone whenever desired. 13A socket outlet is provided so that the electrical appliances can be connected to the device. From the side view, a 13A UK plug pin is used for connection to the home electrical grid. Socket Type G plug used is available in UK, Ireland, Malta, Malaysia & Singapore. The circuit was completed first before designing the casing for this device. Designer need to take into consideration the form factor of this device because of certain limitation of space. For better illustration, Figure 5 shows the prototype device in operation. The OLED display shows the rms current, power usage and cost.

Figure 4: Prototype side view

Figure 5: Device prototype in operation

3. RESULT AND DISCUSSION

Prototype underwent data reading test. The test comprises of current (I_{rms}) reading between industrial clamp meter (Kyoritsu clamp meter KEW2117R) and device (prototype) for five different electrical appliances. The electrical appliances are laptop adaptor, charger with phone + USB fan, electric kettle, electric rice cooker and electric clothes iron.

Those electrical load can be divided further into two category that is low power electrical appliances and high-power electrical appliances. Low power electrical appliances are laptop adapter and charger with phone + USB fan. High power electrical appliances are electric kettle, electric rice cooker and electric clothes iron. Table 1 shows the comparison between clamp meter and prototype reading of the electrical load.

Table 1: Comparison between clamp meter and prototype current (A) reading

No.	Electrical Load	Clamp Meter I_{rms} (A)	Device Irms (A)	Margin Error (A)	Error (%)
1	Laptop Adaptor	0.27	0.37	0.10	37.037
2	Charger with phone + USB Fan	0.13	0.21	0.08	61.538
3	Electric Kettle	6.89	6.47	0.42	6.096
4	Electric Rice Cooker	2.40	2.34	0.06	2.500
5	Electrical Clothes Iron	7.36	7.10	0.26	3.533

Based on value of the percentage of error, it is visible that the device has lower error percentage when measuring high power consumption appliances. The average error percentage for low power electrical appliance is 49.29 %. High power electrical appliances have average error percentage of 4.04 %.

This 4.04 % error percentage for high power electrical appliance is considered better than other previously developed product that achieved 6.15 % of Average Percentage Error [14]. Early result show that electrical appliances with heating element are having higher I_{rms} reading compare to other electrical appliances. True power is equal to multiplication of rms current with supply AC voltage and power factor as describe in Equation 1 [15]. Figure 6 shows an example of total power usage recorded in ThingSpeak for December 10th, 2018. In addition, comparison between power and cost for 8th and 10th December 2018 is shown in Table 2. The power consumption at 8th December is higher due to the increase of electrical load.

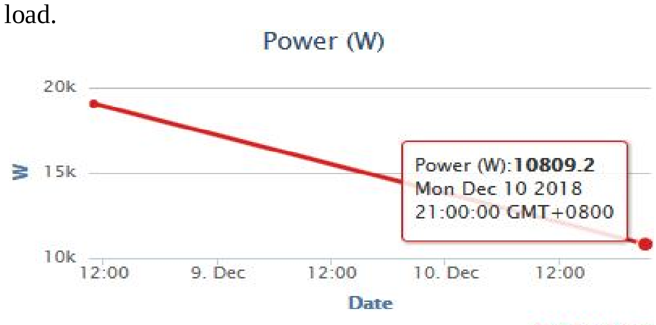

Figure 6: Total power usage recorded in ThingSpeak for December 10th, 2018

$$\text{True Power} = I_{rms} \times \text{Voltage} \times 0.85 \qquad (1)$$

Cost for each load is calculate by using Equation 2 [16]. The cost is display on user device OLED display unit. User can also view real time power usage and energy cost on their smart phone. Figure 7 shows an example of total cost recorded in ThingSpeak for December 10th, 2018. Meanwhile, Figure 8 shows the ThingSpeak Website viewed in smartphone.

$$\text{Cost} = (\text{True Power} \times \text{TNB Tariff}) / 1000 \qquad (2)$$

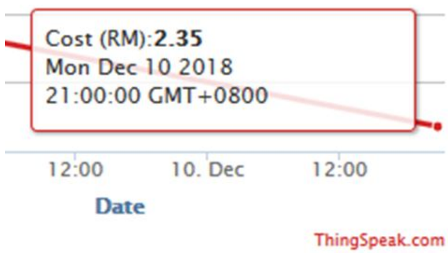

Figure 7: Total cost recorded in ThingSpeak for December 10th, 2018

Table 1: Comparison between power and cost for 8th and 10th December 2018

No.	Date	Power (W)	Cost (RM)	Electrical Load
1	08/12/2018	19056.15	4.14	Rice cooker, kettle, iron, laptop adaptor and charger
2	10/12/2018	10809.20	2.36	Kettle

Figure 8: ThingSpeak view on smartphone

4. CONCLUSION

This device will help solving premises owner problem to deter-mine energy usage for each different stall or business and it will not burden the stall renter in term of cost of ownership of the device. The coding was written in C/C++ programming language over Lua for convenience of editing and updating in the near future. The device was able to measure the rms current with 4.04 % of error percentage for high power electrical appliances as compared to clamp meter reading. The device was able to calculate the cost of running an electrical appliance for power management purpose whether hourly or daily. Improvement in term of hardware can be done by adding an external ADC such as AD1115 for more precision. AD1115 is a 5V, 16 bit ADC with the capability to offer higher reading resolution compare to NodeMCU DevKit v3.0 internal 1V. As a conclusion, a power monitoring device using CT indirect current measuring method that have 4.04 % error percentage was successfully developed with certain limitation factor.

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