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SMART METERING DEVICE FOR HVAC SYSTEM

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ABSTRACT

This paper presents the design, fabrication and testing of a smart metering device for Heating, Ventilation and Air-Conditioning (HVAC) systems. The device was fabricated by using Arduino UNO shields combined with GSM module (SIM900A) and current sensor or current transformer (CT). The device was used to measure the power consumption of the air-conditioner. It was observed that the device can read and calculate the current flow directly from current transformer (CT). From the CT, the value of power consumption could be measured and the Arduino programming would run the calculation of the parameters and display the values on the LCD. The device was tested on the computer linked Air Conditioning laboratory unit in thermofluids lab. It can be concluded that the device can help to improvise monitoring system on air-conditioning power consumption. The device can be a handful gadget for all users to estimate their power consumption independently.

Keywords: Heating, Ventilation and Air-Conditioning (HVAC); Smart Meter device; Arduino UNO shields; Current sensor; Power consumption
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1. INTRODUCTION

Air-conditioning is one of the heating, ventilating and air-conditioning (HVAC) system which is widely used in many applications [1]. Energy management of HVAC systems is a prior concern in building development as the power consumption of electricity has the highest percentage among other building services and home appliances [2]. Smart metering device system can be proposed to monitor and directly measure the power consumption of particular household application to reduce power loss. The smart meter is frequently heralded as the key

component assisting energy displays that could notify domestic occupants in their energy utilization [3]. Air-conditioning unit is one of the biggest consumers of power usage compared to other electrical application in a house. Moreover, due to the change in climate of Malaysia, users tend to install and use air-conditioner continuously regardless of their daily power consumptions.

Smart metering is an electrical device that measures the energy consumption in a certain period of time. The device is able to give feedback to users by giving the data in two-ways communication between the meter and the central system. Kadar et al. (2009) stated that an advanced metering infrastructure (AMI) enables the two-ways communications with the meter when compared with the traditional automatic meter reading (AMR) [4]. Nowadays, many developed countries have started implementing AMI technology. Srikandi et al. (2014) discussed that many companies from Europe and including Japan and Korea have invested millions of dollars to apply AMI smart meters in residential areas [5]. Before the invention of the smart metering devices, energy data were measured and recorded manually by workers for billing purposes. This traditional way of application was applied by mechanical rotating disc energy meter where it only records and shows the energy consumption in kWh.

Metering devices are widely used in monitoring and maintenance works in laboratory, buildings, and households for data collection and analysis [6]. It may have various types of features with different purposes. Some can be used to measure the quality of air, the speed of vehicles, power consumption, fluid flow in pipeline and etc. Nowadays, many household appliances are widely used as it has become a requirement in daily life. Sudhakaran et al. (2009) stated that many countries use the electrical power as power supply to develop their economies. If power consumption is not managed properly, it can cause massive amount of losses [7]. The power produced, usage and savings can be affected by the user's manner of living and the economic growth. Most people are unaware that power of electrical appliances can still be consumed for its standby state, either the switches are in 'on' or 'off' state [8]. Household appliances such as televisions (TVs), video recorders, telephones, computer, and printers contribute to some standby losses with typical loss per appliance ranging from less than 1W to as much as 25W.

In the past, the power usage readings are usually taken manually by moving from one consumer location to another. It requires large numbers of labor operators and long working hours to finish the task in a day. Sometimes, the task can be delayed due to unpredictable weather condition [9]. The printed billing also has a tendency of getting lost due to the environmental conditions. Therefore, the innovations of automated billing system were introduced to consumer. In matter of time, the development of technology has brought the billing systems for better improvement [10]. The implementation of GSM technology has been applied to help consumer receive message about their power consumption.

GSM development also made the meter reading system wireless. Its national wide coverage infrastructure can be used to request and retrieve the power consumption alert messages on individual houses and flats. Moreover, GSM billing system needs to be made prepaid to reduce the power that could be wasted freely. An Arduino microcontroller is an open-source hardware developed by a group of engineers that shared the same goal in developing a line of easy-to-use microcontroller hardware and softwares [11]. The Arduino board are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to expansion boards such as shields and sensor and other circuits.

Commonly most experiments in laboratory or workshop require an accurate and precise control of multiple input and output signals. These signals are often transmitted and recorded via computer or external hardware. However, the hardware are usually very expensive and it is necessary to add an additional software to control hardware's behavior. One of the

advantages of Arduino is the capability to upload a program on the board's memory and run it without interfacing with external hardware, thus allowing it to work independently with complete precision and accuracy [12].

Maintenance management in electrical power is a concerned in power saving purposes. Good management in maintenance could help in saving money. Maintenance process would easy be conducted if there is a way to detect any abnormalities on the electrical appliances. Moreover, with the application of smart meters, it would facilitate the maintenance procedures by skipping unnecessary procedure without affecting power consumptions. Moreover, the maintenance works can be difficult to be conducted due to the worker's limitation in detecting any abnormality in the system. Most of metering device were installed permanently into the system such as BTU meter and it is difficult for maintenance job as the main power source needs to be shut-off first prior to the work. Thus, the device might be damaged and decreases its sensitivity due to the installation procedures and could affect the whole system. Therefore, the objective of this paper, was therefore, to design, fabricate and test a user friendly metering device to measure the power consumption of HVAC's components.

2. METHODS AND MATERIALS

2.1. Overview of flowchart

Figure 1 shows steps involved in the design, fabrication and testing of the metering device.

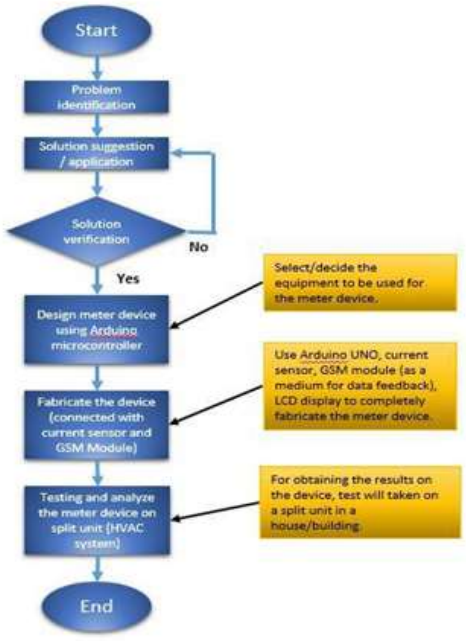

Figure 1 Steps in designing and fabricating the meter device

2.2. Designing the metering device

Arduino has become the most reliable open-source hardware. Microcontroller's programming software is also necessary to transfer the data in the memory of the device. The software is an open-source making it easy to write code and upload it to the board. The main components are shown in Figure 2.

Figure 2 Main components for smart meter device:a) Arduino UNO shield – main board for device fabrication, (b) Current sensor, or known as Current Transformer (CT) – used to detect the current load of any electrical appliances, (c) GSM Module (SIM900A) – for messaging alert/data feedback to be linked with smartphone, (d) LCD display (16x2) – display meter reading measured by the device

2.3. Fabricating the meter device on Arduino Board

There are several ways to fabricate the device. When dealing with current and voltage, there is possibility of overload current and voltage or short circuit during fabricating work. Therefore, some precaution needs to be taken as safety measure. Proper and suitable components shall be used to prevent this occurrence from happening. Some applicable components were selected with appropriate specification that was suitable for the fabrication of the meter device. Since the device is to be tested on an air-conditioning unit with supply of 1hp up to 2hp of power, rather than HVAC unit in big buildings, therefore its capability to measure the power consumption can be reliable and applicable.

An LCD was used to display the entire letter, numbers or any data and reading taken from the sensor. With the aid of the programming, all the parameters appear through the LCD. Programming code is the important steps in fabricating the device in order to get better and accurate results. Figure 3 shows the connection of Arduino UNO (main board) with LCD display. For trial attempt, breadboard was used to test the functionality of the components.

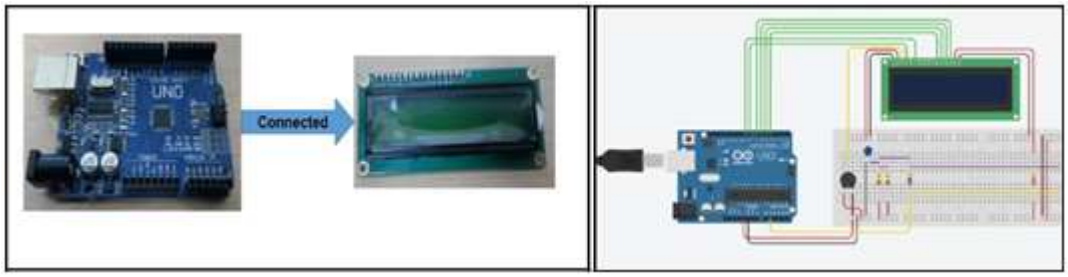

Figure 3 Circuit diagram of LCD display connected to main board.

The other component that plays an important role for this device is the GSM module (SIM900A). It is a shield that can transmit or transfer the data to other medium or devices such as smartphone. Nowadays, all things can be remotely controlled by using smartphone applications. In order to fulfil that requirement of application, same method was applied by using GSM module shield. The shield sends an alert message to the smartphone that notifies users on the power consumption of air-conditioned unit. Figure 4 shows the GSM module fabrication on Arduino UNO shield.

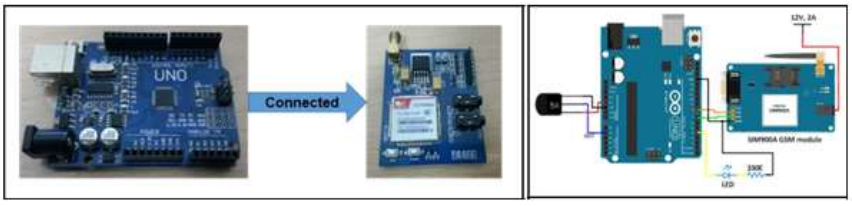

Figure 4 GSM module connected to main board.

2.4. Electrical Formulation for power consumption

In order to obtain the power consumption, current transformer (CT) will be used to measure the current load of the air-conditioner and then convert it into kilowatt-hour (kWh) value. A metering device is a tool that provides energy by a source to a load in a unit time. According to Wasana Boonsong et. al, (2014), considering an alternating voltage v(t) with amplitude V_o applied to a load and current i(t) circulating through the load with an amplitude I_o and power factor of cos φ [13], the power equation for this calculation is defined as:

$$P = VI \cos \varphi / 1000 \times \text{runtime} \quad (1)$$

P = power consumed (kWh)

cos φ = power factor, where (0.85 < *cos* φ < 0.90)

I = phase current (A)

V = Root-Mean-Square (RMS) voltage (V)

From the power values, cost estimations were then calculated as follows

$$\text{Total Cost} = P \times \text{Cost per unit} \quad (2)$$

Where:

P = Power consumed (kWh)

Cost/unit = cost rates from TNB's latest tariff (in RM)

3. RESULTS AND DISCUSSION

Serial monitoring and GSM monitoring, LCD programmings codes were written to perform monitoring processed. Once the power consumption was obtained, a signal will be sent to GSM module. It then delivers a message to the mobile phone which notifying users on the power consumption. The device was left on an electrical appliance (laptop) for about an hour to monitor the power consumption. It took the current load reading for every 10 minutes and then calculates the power consumption after an hour. The cycle was repeated until it reached an hour of the runtime. Figure 5 shows the fabricated main components on Arduino board. The power consumption that appeared on the LCD is depicted in Figure 6.

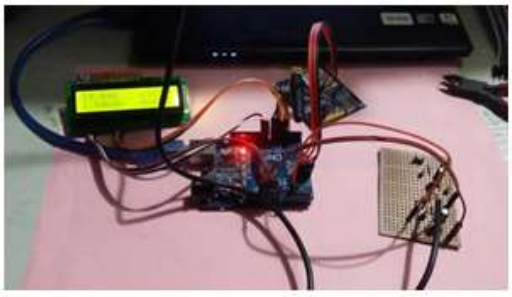

Figure 5 Fabricated main components on Arduino board

Figure 6 power consumption behavior from the tested unit

Based on the LCD display, it shows 0.05kWh (left figure) of power consumed from the applied unit. After a 10 minutes interval, the value rose up to 0.07kWh (right figure) with the same current reading. Assumed that there is increment of 0.02kW of power since the laptop starts running. The heat produced by the laptop processor is cooled down by a fan. The fan would consume more power if the temperature is high to balance it with the core temperature. The power may keep increasing if more application were running in the laptop. Same procedures can be applied to air-conditioned unit (or split unit) by adjusting the temperature between the lowest and highest temperature available which usually set from 16-30°C. Thus, it is proved that the device functioned well. After obtaining the power consumption, the estimation cost can be calculated based on latest TNB's domestic tariff. The device is monitoring the consumption for one hour. Therefore, the cost can be estimated immediately by multiplying the tariff value with the power consumption obtained. There are some categories of power consumption value listed in the tariff with different charge rate on it. Figure 7 shows smart meter reading on power consumption and billing cost.

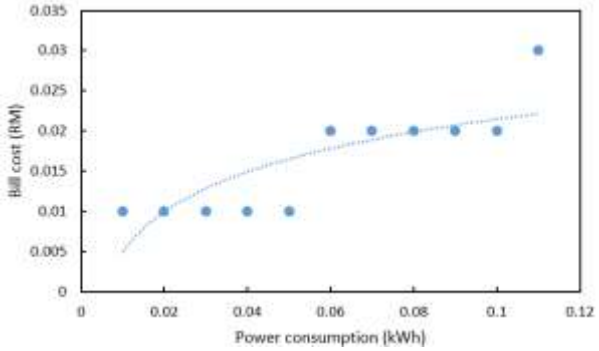

Figure 7 Smart meter reading on power consumption and billing cost.

4. CONCLUSION

HVAC systems are important to provide comfort condition. It can operate for long-term usage to fulfil people's requirements. However, without a systematic monitoring and maintenance, the systems cannot provide a better performance. This paper presents the design, fabrication and testing of a smart metering device for Heating, Ventilation and Air-Conditioning (HVAC) systems. The device was fabricated by using Arduino UNO shields combined with GSM module (SIM900A) and current sensor or current transformer (CT). It was observed that the designed device measured the required parameters with less percentage of errors. Therefore, by the existing of the smart meter device, monitoring and maintenance work can easily be conducted not only for maintenance personnel usage, but also applicable for normal users at home. This device can be a handful gadget for all users to estimate their power consumption independently.

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