Analysis of the Effectiveness of the Utilization of Power Monitoring Devices in Reducing Electric Energy Consumption

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Abstract. Huge amount of energy consumptions in electrical households appliances are greatly influenced by the behaviors of people who live there. Unawareness in the use of the electrical appliances made a surge in electrical bills each month. To make savings, a technology to monitor the electrical energy consumptions is needed. This research focuses on analyzing the use of energy consumption control devices combined with wireless fidelity (WiFi) and mobile phones technology. These devices combine monitoring, reporting and control functions. Any electrical appliances that uses electrical energy from Electricity Company will be connected to this system for monitoring energy consumption. It is recorded and subsequently reported to the user for savings measurement. After the installment of these devices, the test results showed that the savings measurements have decrease the daily energy consumption by 15.88%. While the weekly consumption shows a decrease of 6.43%. Within three months of observation from there was a decrease in energy consumption by 33.77%.

1. Introduction

The amount of home electrical energy consumption, especially used for household appliance were tightly affected or strongly depend on who were stay in that home. Ignorance or careless in use and operate electrical appliances will lead to an unpredicted raise of monthly electrical bill. It’s normal for such ignorant and careless to be punished by a huge electrical bill at the end of the month, just a waste. But, to compel people to watch and monitor continuously their electrical energy usage is inhuman. Although there is a KWH (Kilowatt hour) meter, still it is not a good idea to record electrical energy usage manually. So it’s right way to use an appropriate technology to handle such routine and annoying task in monitoring electric energy consumption minute by minute. It will help consumer to monitor and record their home electric energy usage in a real time, so they can decide are there are waste of electricity and take a proper action to overcome and made an efficiency program.

Research on the development of energy monitoring systems using wifi technology and Internet of Thing (IoT) was carried out by Habaebi et al. In this research, a study of communication device technology used in the Home Energy Monitoring System (HEMS) application is conducted to monitor energy consumption in deep sleep mode. The results of the study showed an increase of 0.3W in each cycle and an average power dissipation of less than 0.1W/s [1]. Hiremath et al conducted a system development to see energy from household appliances. By knowing the energy consumption of household appliances activities, actions can be taken to carry out energy conservation. Their energy monitoring devices development was use an Arduino and ESP8266 technology. Energy measurements are carried out by measuring current with assumption that the voltage is 230Vrms, which is a lack of the studies conducted by Hiremath et al [2].
Raja et al develop an energy monitoring system by combining household appliances monitoring and operation, video and processing systems using Raspberry Pi. By monitoring the on/off operation of the equipment, it is used to trigger a video recording of equipment activity whether it is turned on by the homeowner or by an unwanted person. Web applications was used to make monitoring actions. The development show results in increasing sense of security by remote monitoring mechanism [3].

While the development of applications for measurement of smart energy and payment systems, that use Arduino technology and GSM SMS (Short Message Service) communication devices, was carried out by Padmajothi et al [4]. The results of this development indicate the effectiveness of reporting and reducing energy costs, but indirectly will cause communication costs that are not examined in this study. The development of control and automation technology is currently so advanced, supported by integration with wireless technology (wireless) makes it easier to manage electricity at home automatically. Sun and his team conducted research related to the development of environmental monitoring systems in one room using wireless sensor networks [5]. In this research zigbee communication module and O2 and CO2 gas sensor network are used to monitor the condition of the room environment.

This study conducts an analysis to see how much reduction in power consumption can be achieved, by using an automatic control devices that are combined with wireless fidelity (WiFi) technology and mobile phones to perform control functions of energy consumption at home. The application name is Home Energy Consumption Control (HECC). HECC combines monitoring, reporting and control functions. Every device that uses electrical energy from State Electricity Company (SEC) are connected to the HECC system to monitor its energy use, recorded and subsequently reported to the control device for optimization action.

2. Methodology

2.1. Kwh Meter Device Development
KWH meter is an electrical energy consumption instrument which is conducted by measuring voltage and current simultaneously. Another method is to calculate the number of pulses that are proportional to the amount of energy consumption used [6]. In accordance with technological developments, especially data and wireless processing technology (ICT), KWH meters also have significant development. At the beginning, the main function of the KWH meter was only to measure and record of electricity usage. KWH meter develops into an automatic measuring instrument that can send the measurement results to the electricity company or to the user/customer. Initially the function of the KWH is:

- Customers Power limiter (according to installation contracts)
- Record consumers power usage. That’s why its get a name "kWh Meter" or "Electric Meter" (kWh: kilowatt hour)
- As a main circuit breaker or MCB (Mother Circuit Board), its switch off if customer power usage reach their limit or there is a short circuit incident, it may also be needed for home electrical installation.

Currently there are 2 types of KWH meters, analog and digital. Analog models are still very commonly used in housing, while digital models mostly used for prepaid customers of SEC (known as pulse systems) [7]. There are also smart card model, where the KWH value to be purchase is stored on the card and inserted into KWH Meter.

2.2. Energy Consumption Calculation (kWh) by Electricity Measurement
Measurement of energy consumption is calculated based on the amount of electrical power used in each unit of time. Measurement of electrical power is carried out based on the measurement of voltage, current and cos Θ with the equation is as follows [8]:

\[ P = V \cdot I \cdot \cos \Theta \] (1)
where:
• $P$: Power (Watt)
• $V$: Voltage (Volt)
• $I$: Current (Amper)
• $\cos \Theta$: Phase angle

The higher the Watt value the higher the electrical power consumes. Consumption of electrical energy is measured by watts of hours (watt hour = WH). Generally measurement of electrical energy consumption by SEC is stated in kWh (kiloWatt Hour). The equation is:

$$E = P.t$$  \hspace{1cm} (2)

where:
• $E$: Energy consumption (kWh)
• $P$: Power (Watt)
• $t$: time (hour)

2.3. KWh Measurement System Online
Online kwh measurements are made by adding communication devices at kwh meters. From several studies that have been carried out, there are some communication method ranging from using the electricity network (power line carrier), low power radio communication (Zigbee) up to using GSM communication infrastructure [9]. Current developments in online kwh studies are carried out using IoT (Internet of Things) technology. IoT is the concept of data communication by utilizing internet networks. In kwh meter applications using IoT, a wifi network technology make used of mobile device [10],[11],[12]. Aside from being a kwh monitoring device, IoT technology is also used in home automation and home security applications [13,14].

2.4. Testing Method
Research activities are carried out by installing energy monitoring devices to monitor home electrical load. Based on the choice of appropriate and optimal devices, energy monitoring devices from Xiaomi is choosed based on price and availability. Electric power consumption monitor diagram as shown in Figure 1.

![Electric Power Consumption Monitor Diagram](image-url)
There are two power meter (smart power strip) installed to measure the electrical power consumed by all devices at home. The smart power strip device is installed in a group of devices that dynamically change their use, namely refrigerators that intermittently use power according to the setting temperature. Also other load such as computers, laptops, lights and other equipment that are used at certain times. Installing a Power Strip in a group of dynamic energy consuming devices is shown in Figure 2.a.

Furthermore, the power consumption will be recorded dynamically. The installation of the power strip on the main circuit board (MCB) is shown in Figure 2.b. By installing on the smart power strip on the MCB it is possible to measure, record and record the overall level of electrical energy consumption. Furthermore, software installations from the power strip controller or smart plug are carried out to mobile devices. Software downloaded from the play store and installed immediately. The installation results will display the interface as shown in Figure 2.c.

3. Result and Discussion
The equipments installed are tested with procedures according to specifications so that optimal configuration can be obtained. Further measurements of electrical energy consumption and recording are carried out. The following are the results of the data obtained during the experiment, in several measurement ranges.

Figure 3. shows the measurement of the power consumed by home devices recorded every hour. It appears that energy consumption is very dynamic, but it can be marked that every day after 12:00 a high consumption occurs sustainably. Thus it can be analyzed to provide a solution for the efficiency action that need to be taken. Data recording in Figure 4. shows that electricity consumption generally increases at the end of the week. This is because at the end of the week all family members gather and do activities that tend to require electrical energy such as cooking an oven, opening more refrigerators, using washing machines, more water pumps, and leisure activities such as watching TV, turning on the sound system, using computers more intensively and more. This research is relatively short, so that a monthly data record can only be obtained for three months.
Data and information obtained from testing and measurement are recorded in the log data series, so that energy consumption history is obtained for further analysis to obtain the most efficient energy consumption pattern. From the daily of hourly data, can be seen that energy consumption generally increases after 12 up to 23 o'clock. This is because the activity starts at this hour increases due to more intensive household appliances usage.

By recognizing the energy consumption pattern, it can be done rescheduling the use of certain devices that can be turned on earlier than 12 o'clock or after 23 o'clock. Tools such as water pumps and irons for example can be used on the proposed clock. This scheduling can be done automatically by programming the device on the smart plug or done manually through the command from mobile device by its software.

In first 4 days testing, there was a decrease in daily energy consumption by 15.88%. Data recording for each day of the week also shows that at the end of each week there is always an increase in the consumption of electrical energy, as discussed above. Weekly energy consumption decreased by 6.43%.

Figure 3. Energy Measurement Data every hour Logs
Figure 4. Record of Electric Energy Consumption Every Week

Figure 5. Records of Monthly Electric Energy Consumption Data.
Trend of monthly data recording has not been fully analyzed because it only has 3 months of data. However, it can be seen that the HECC system can work normally and is able to record monthly data. Figure 5. Monthly energy consumption within 3 months of testing when viewed there was a decrease of 33.77%.

4. Conclusion
Based on the results of the tests and measurements, the following conclusions can be drawn:

- In general it can be concluded that the purpose of the study is to be able to see the effect of HECC installation, on the amount of electrical energy consumption, already achieved. Where the system is able to optimize the consumption of electrical energy in households with HECC which utilizes control technology and Wifi wireless communication can be realized. The system is able to work by monitoring, measuring, reporting, recording and taking control actions have been proven and possible to install.
- The reliability of the system is also very dependent on the selection of the right component/devices. It is proven that the selected device is able to work according to the planned specifications and relatively provide constant reliability during the study. The system is able to work without experiencing significant interference, so that it can continuously record data and respond to each control command.
- During the 3 months of testing, can be seen there was a reduction in energy consumption to reach 33.77%. Based on other study in power monitoring that can save electricity consumption by up to 30% [15], this current study shows that the results achieved are little bit better in saving electricity consumption.

If the duration of the research can be done longer, or continued, it is possible to be able to see the reliability of the system for an annual period. At the same time also has the opportunity to know the economic value of the savings or conservation of energy obtained.

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