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Monitoring System and Auditing on Internet of Things (IoT) Based Electricity Using Arduino Mega 2560

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Abstract: - One form of energy that is most often and most widely used by people in carrying out their daily activities is electrical energy. The most common use of electrical energy is in industry or office buildings. To reduce the use electrical energy on a large scale, it is necessary to conduct an electrical energy audit. This research was conducted to produce an electrical energy control system design that is equipped with an automatic energy control system. The system built is called the Electrical Energy Monitoring and Audit System. The Electrical Energy Monitoring and Audit System is grouped into two groups, namely information systems and automatic control system that can provide output in the form of Energy Consumption Intensity value. The design of an automatic control system made using the Arduino Mega 2560 which is equipped with Internet of Things (IOT), which can provide information in the form of data, perform data processing, and provide data output from the system mentioned above. The results of monitoring the use of electrical energy that was measured for two months at the Kedonganan Village Credit Institution (LPD) office with a building area of 755 m2 were 4232.73 kWh in August and 3782.09 kWh in September. The IKE values obtained are 5.6 kWh / m2 and 5.0 kWh / m2. and based on the IKE table the use of electrical energy at the Kedonganan an Institution for Village Credit of Bali (commonly known as LPD) was categorized as very efficient category.

Keywords: Electric Energy, Energy Audit, Arduino Mega 2560, Thing Speak, Sensor.

1. BACKGROUND

Electrical energy is one of the energies that is widely used in almost all sides of life. One of the most common users of electrical energy we encounter is in office buildings. An office building is a room or building that functions as a place to perform a business activity. The more activities in an office building, the more it has an impact on the large use of electrical energy in the office building. The use of electrical energy can have a negative impact if used excessively plus there is no awareness of the use of electrical energy. This can result in many losses both from the consumer side because they must pay more costs for using electrical energy, while from the State Electricity Company of Indonesia or known as "PLN" side as a provider of electrical energy can also experience losses in the form of wasted fuel in the process of generating electrical energy.

To avoid waste in the use of electrical energy, an electrical energy audit was conducted. Electrical energy audit is a method that can be used to determine the level of electrical energy consumption of a building, where the results will later be compared with existing standards to find a savings solution in the event of electrical energy consumption that exceeds the limit in the building.

Currently, to calculate electrical energy in a building can be done using a kWh meter installed

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in a building and to see the energy that has been used, it is necessary to have a direct visit in the field. With the development of technology in the field of electronics, the process of monitoring and auditing electrical energy can be done using a microcontroller and integrated with the Internet of Things (IoT) system. The Internet of Things (IoT) is a concept that aims to expand the benefits of continuously connected internet connectivity. With the existence of the Internet of Things (IoT), this makes it easier for people to monitor and analyze data using our internet devices.

2. THEORETICAL FOUNDATIONS

A. Monitoring

Monitoring is the process of collecting and analyzing information based on systematically and continuously established indicators about an activity or program so that corrective actions can be taken for the subsequent improvement of that program or activity[1]. Monitoring can be interpreted as observing and influencing the main activities and results of work[2].

B. Energy

Energy is a matter that is abstract which is difficult to prove but can be perceived. Energy is the capability for doing work. While natural energy is something that can be used for various interests and needs of human life to live a more prosperous life, natural energy can exist anywhere such as in the soil, water, soil surface, air, etc[3].

C. Power

Electrical power is the magnitude of the rate of conduction of electrical energy that occurs in an electrical circuit. In international units of electric power is W (Watt) which expresses the amount of effort made by the voltage source to conduct electric current per unit of time J/s (Joules/sec). The following is the formula used to calculate electrical power[4].

P = W / t

Information:

P = Power (W)

W = Work (J)

T = Time(s)

D. Energy Audit

Energy audit is a periodic inspection activity to determine whether there are deviations in an energy use activity. Energy audits also can be used in tracing where and how much energy are being used, identifying energy leaks or inefficiencies, determining corrective steps, and assessing the level of feasibility[5].

E. Energy Use Intensity (EUI)

EUI is a comparison between total energy consumption to units of building area in a certain period (kWh/m2 per month or kWh/m2 per year)[6]. EUI is calculated using the following formula:

$$EU = \frac{value\ of\ Electrical\ Energy\ Usage(kWh)}{Building\ Area\ (m^2)}$$

The results of the energy audit process will be used to measure the energy efficiency potential of building as shown in table 2.1

Table 2.1 EUI Reference Values of Air-Conditioned Office Buildings

Criterion	EUI (kWh/m²/month)
Very extravagant	23,75 - 37,5
Extravagant	19,2 - 23,75
A bit extravagant	14,58 - 19,2
Quite efficient	12,08 - 14,58
Efficient	7,93 - 12,08
Highly efficient	4,17 - 7,93

F. Arduino Mega 2560

Arduino Mega 2560 is a development of the previous Arduino Mega board. At first Arduino Mega used the Atmega1280 chip which 22 was later changed to the Atmega2560 chip, because of the name change, it is now better known as Arduino Mega 2560. Until now the Arduino Mega 2560 has arrived at the 3rd revision (R3). There are also other differences apart from the ATmega chip used, namely that it no longer uses the FTDI chip as a USB to Serial Conveter function but uses the ATmega16u2 chip in the 3rd revision (R3), while in revisions 1 and 2 it uses the ATmega8u2 chip as a USB to Serial Converter function.

G. Voltage Transformer

A transformer is an electrical equipment that can move electrical power between two or more electrical circuits through electromagnetic induction. This transformer works based on the principle of electromagnetic induction and can only work at alternating voltages, namely AC.

H. YHDC Current Sensor SCT013

The YHDC SCT013 current sensor is a current sensor that can be used in measuring AC current, where the working principle of this sensor uses the induction of electricity flowing on the primary side of the sensor and changes it on the secondary side of this sensor so that the microcontroller can read the current value to be measured. In its installation, this sensor is quite easy because it is installed only on one of the conducting cables that will be measured.

I. Liquid Crystal Display

Liquid Crystal Display is one of the electronic components that functions as a display of data, either characters, letters or graphics. In the market, LCD displays are already available in the form of modules, namely LCD displays and their supporting circuits including ROMs and others. LCD has data pins, power supply control, and display contrast adjuster.

J. IC DS3231

The RTC DS3231 module is a type of module which functions as an RTC (Real Time Clock) or digital timing and the addition of a temperature measuring feature that is packaged into 1 module. The interface to access this module is using I2C or two wire (SDA and SCL). So that when accessed using a microntroler pin, only 2 pins and 2 pin power are needed.

K. ESO8266 Module

ESP8266 is a WiFi module that functions as an additional microcontroller such as Arduino to connect directly with WiFi and create a TCP / IP connection. This versatile WiFi module is already SoC (System on Chip), so we can do programming directly to the ESP8266 without

the need for an additional microcontroller. Another advantage, the ESP8266 can perform the role of adhoc access point and client at the same time.

L. Arduino IDE

Is software that is often used to promote a microcontroller. Arduino IDE uses the base C programming language and is equipped with several supporting librariesso that it is easier for humans to use.

M. Internet Of Things

The Internet of Things (IoT) is defined as an invention that is able to solve existing problems through the combination of technology and social impact, while when viewed from technical standardization, IoT can be described as a global infrastructure that is able to meet the information needs of the community, enabling sophisticated services with interconnection both physically and virtually based on the development of information and communication technology[7].

N. ThingSpeak

ThingSpeak is an open-source Internet of Things (IoT) application and API platform for storing and retrieving data from things using the HTTP protocol over the internet or through a local area network. ThingSpeak allows the creation of sensor logging apps, location tracking apps, and social networking things with status updates.

3. METHODOLOGY

A. System Overview

In general, the electrical energy monitoring and audit system is carried out with several stages including: a) hardware design; b) software design; c) installation/installation process.

B. Hardware Design

There are several stages carried out in hardware design including the design of the circuit box and the design of an electronic circuit consisting of the Arduino Mega 2560 circuit, USB to serial, LCD drivers, voltage and current sensors, switches, RTC, and voltage regulators as shown below.

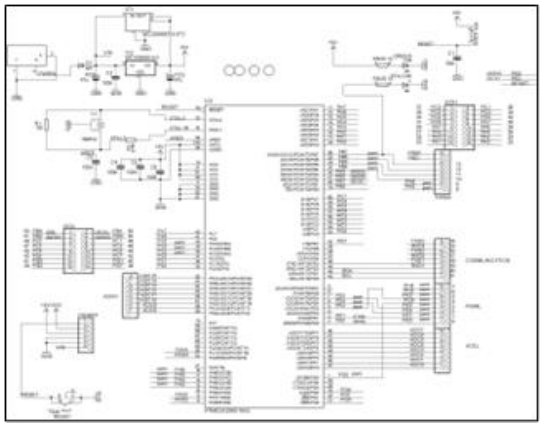

Figure 1: Microcontroller Circuit Arduino Mega 2560

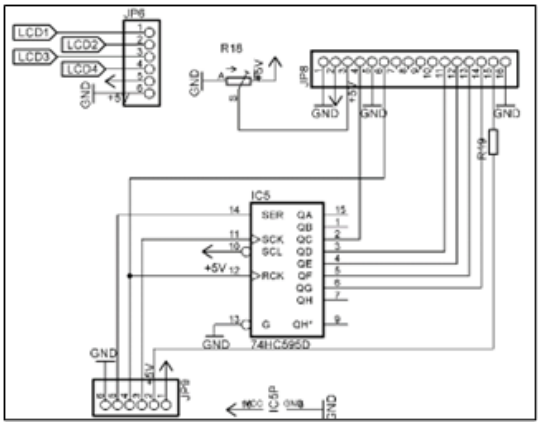

Figure 2: LCD Driver Circuit

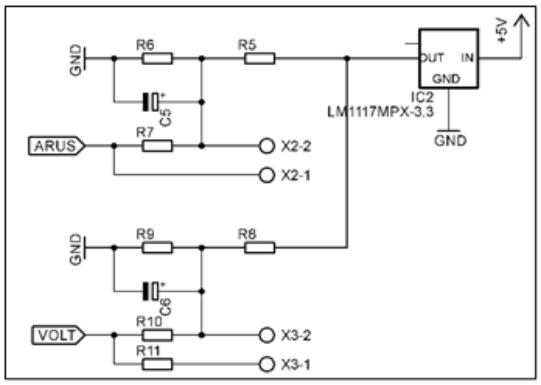

Figure 3: Voltage and Current Sensor Circuit

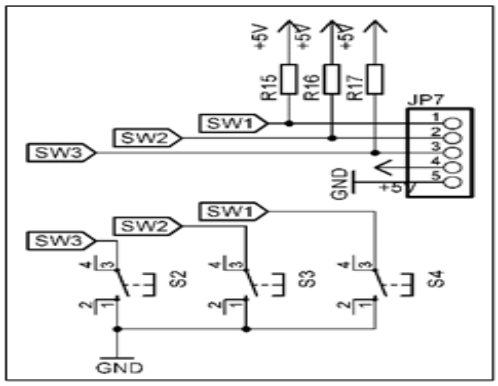

Figure 4: Switch Circuit

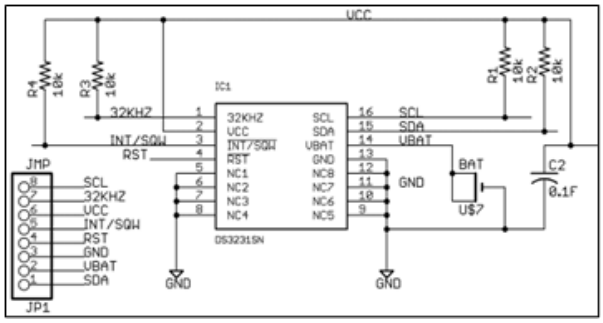

Figure 5: RTC circuit

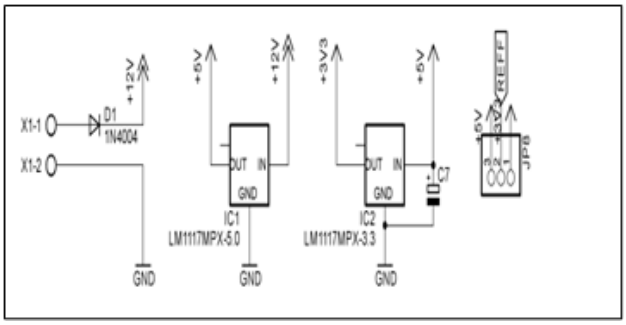

Figure 6: Voltage Regulator Circuit

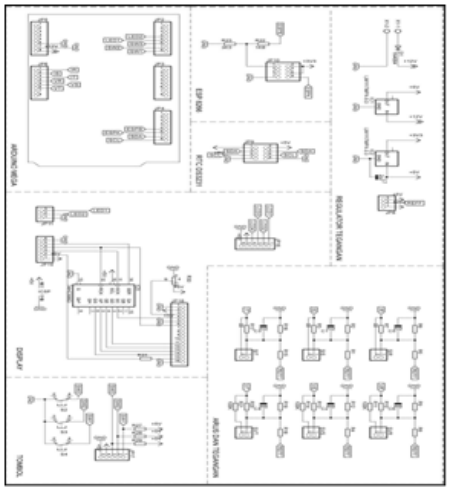

Figure 7: Overall Circuit

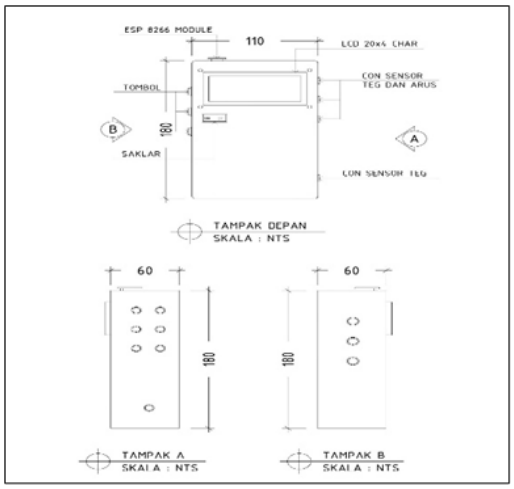

Figure 8: Series Box Design

C. Software Design

Designing software using Arduino IDE with C programming language according to the following flowchart:

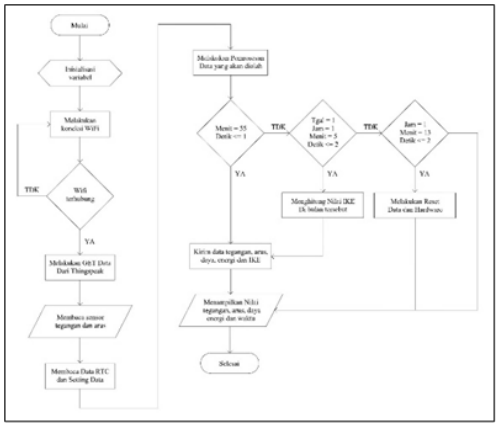

Figure 9: Flowchart Programming

D. Installation/Installation Process

The installation process or installation process is carried out by placing voltage and current sensors on the main MCB (miniature circuit breaker) line which aims to obtain the values of voltage, current and power as well as overall energy use as shown below.

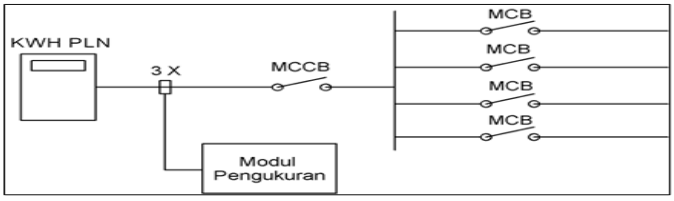

Figure 10: Installation Process

4. RESULT AND DISCUSSION

4.1 Design Results

The results of the design of an Internet of Things (IoT) based electrical energy monitoring and audit system using Arduino Mega 2560 are shown in the following figure.

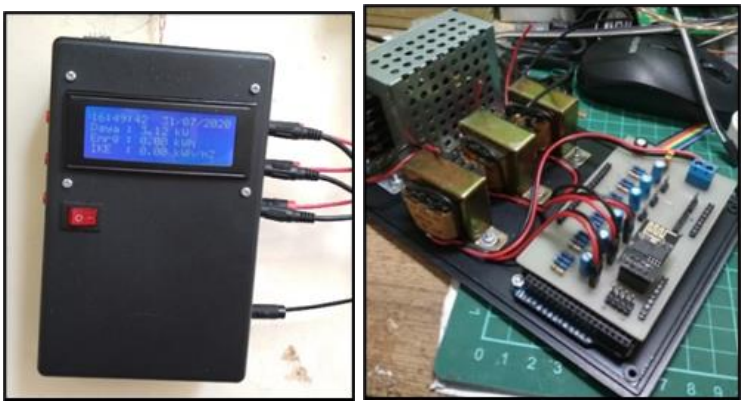

Figure 11: Design Results front view
Source: Personal Documentation

4.2 Circuit Testing

To be able to know that the system can work properly, it is necessary to have a test which includes; a) testing of the Arduino Mega 2560 microcontroller circuit; b) testing of LCD driver circuits; c) testing of voltage sensor circuits; d) testing of current sensor circuits; e) Testing of switch circuits; f) RTC testing; g) testing of the voltage regulator circuit and h) testing of the circuit as a whole as shown in the following figure:

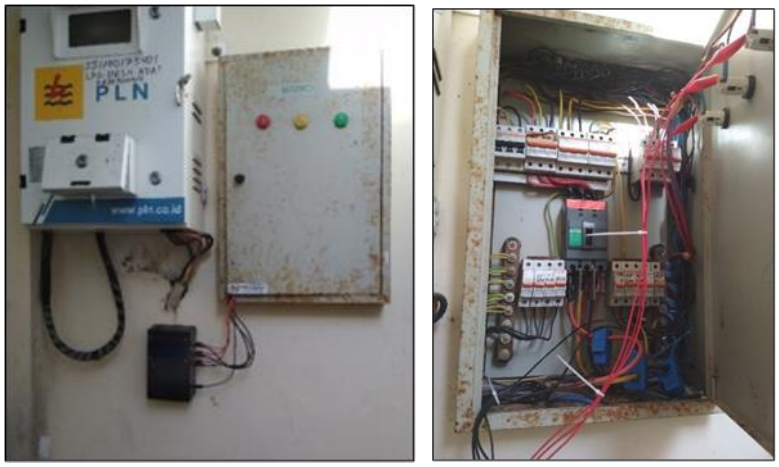

Figure 12: Installation of the device on the building panel
Source: Personal Documentation

4.3 Measurement Results Data

The measurement data obtained from this system is the output of the system, both voltage measurement, current measurement, electrical power measurement, energy use data, total energy use and energy use intensity data (EUI) which was carried out for two months from July 30, 2020 and ended on October 3, 2020 as shown in the following figure.

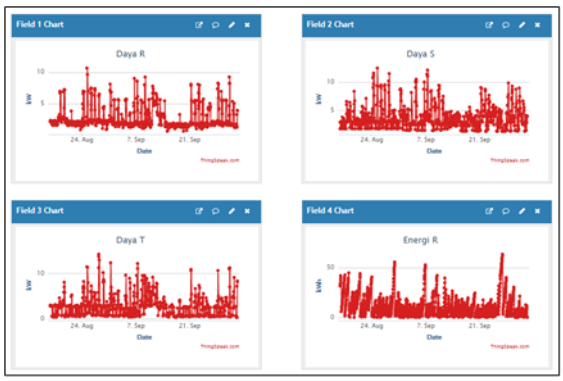

Figure 13: ThingSpeak Data View

4.4 Data Analysis

The performance of the electrical energy monitoring and audit system using the Internet-based Arduino Mega 2560 of Things will provide an overview of the use of electrical energy and further decide to take other alternative actions. The results obtained from the performance of this system are that the total consumption of electrical energy in two months was 4232.73 kWh in August and 3782.09 kwh in September, the type of building used as a pilot project is an office building with a total building area of 755 m2, so that the calculation of the Energy Use Intensity (EUI) value was done using following formula:

$$EUI = \frac{Energy\ Use/month}{Building\ Area}$$

$$\text{EUI Agustus} = \frac{\text{Energy Use/month}}{\text{Building Area}}$$

$$\text{EUI Agustus} = \frac{4232.73}{755}$$

$$\text{EUI Agustus} = 5.6\ \text{kWh}/\text{m}^2$$

$$\text{EUI September} = \frac{Energy\ Use/month}{Building\ Area}$$

$$\text{EUI September} = \frac{3782.09}{755}$$

$$\text{EUI September} = 5.0\ \text{kWh}/\text{m}^2$$

The results of the analysis showed that the EUI value for August was 5.6 kWh / m2 and in September was 5.0 kWh / m2, based on the table on energy use for office buildings the value that the value was included in the criteria for very efficient energy use.

Table 2: EUI Reference Value of Air-Conditioned Office Buildings

Criterion	EUI (kWh/m²/month)
Very extravagant	23,75 - 37,5
Extravagant	19,2 - 23,75
A bit extravagant	14,58 - 19,2
Quite efficient	12,08 - 14,58
Efficient	7,93 - 12,08
Highly efficient	4,17 - 7,93

After knowing the level of electrical energy use in the building, it is necessary to make savings in the use of electrical energy. This EUI calculation is automatically carried out by the monitoring system created and the data from the EUI value will be sent to ThingSpeak in real time as shown in the following figure:

Figure 14: Energy Audit Results Graph

5. CONCLUSION

In this study, an electrical energy monitoring and audit system has been created in office buildings using Arduino Mega 2560 based on the Internet of Things (IoT) and can perform well in terms of measuring voltage, current, power, energy and conducting energy audits in office buildings. The system can also transmit voltage, current, power and energy data in real time and can be accessed online via ThingSpeak. The results of monitoring the use of electrical energy for two months obtained the EUI value in August of 5.6 kwh / m2 and the EUI in September of 5.0 kwh / m2. And the value can be categorized as very efficient in the use of electrical energy.

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