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Report of Energy Audit in Building F1, F3, F4, and G6 of Universitas Muhammadiyah Yogyakarta

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Abstract - *Energy audits on buildings are carried out to determine the load profile of electrical energy usage and to avoid wasting electricity. This energy waste can cause the use of electricity in buildings that are not efficient. An electrical energy audit is carried out to produce actual data that is in accordance with existing building conditions. This study conducted on buildings F1, F3, F4, and G6 in Universitas Muhammadiyah Yogyakarta to determine the value of the intensity of energy consumption used, whether it is following the Indonesian National Standards Agency. Measurement of electrical energy consumption using a tool that is the Power Factor Analyzer. The results of the calculation of the value of the intensity of electrical energy consumption showed that the buildings of F1, F3, F4, and G6 at the Universitas Muhammadiyah Yogyakarta obtained an average energy intensity value of 10.18 kWh/month. In this case, building standards are known to be between 7.92 - 12.08, which means that the building standards are categorized as efficient because they are under established standards. Furthermore, the use of electrical energy consumption used in buildings F1, F3, F4, and G6 in Universitas Muhammadiyah Yogyakarta in a month that is equal to 190,952.769 kWh/month.*

Keywords*: Energy Audit, Building Installation, Efficiency, Electrical Energy Consumption*

I. Introduction

In this modern era, the development of technology and science is developing very rapidly, especially in increasingly advanced electronic equipment [1]. Thus the use of electronic equipment is also beneficial and practical for daily activities. If the use of electronic equipment more and more, it will cause electrical energy consumption will also increase. Increased consumption of electrical energy will cause electrical energy is not proportional to the amount of electricity supply from the center of electrical energy service providers. The use of excess electricity will result in a lack of financial availability [2]. To find out the extent of the use of electrical energy that is less effective, it is necessary to do an energy audit [3].

Energy audits on buildings are conducted to determine the profile of electrical energy usage loads and opportunities for saving electricity. So that the use of electrical energy in buildings can be more efficient and save costs [4]. An electrical energy audit is carried out to produce actual data that is following the existing building conditions, operational costs for electrical energy needs, and applied electrical energy management [5].

The increasing use of electrical energy has led to energy efficiency efforts being very important. The increase is also due to the limitations of primary energy sources and the high investment costs of new and renewable energy. Inefficient use of energy not only results in increased energy consumption costs but also increases in carbon dioxide emissions,

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which is also a component of greenhouse gases. Based on the Bali Action Plan on the 13th Conferences of Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC), the Government of Indonesia is committed to reducing greenhouse gas emissions by 26% on its own and reaching 41% if it receives international assistance in the year 2020 [6]. One of the steps taken is to use energy efficiently. Regulation of the Minister of Energy and Mineral Resources number 13 of 2012 states that in order to increase savings in electricity usage, it is necessary to use electricity efficiently and rationally, without reducing safety, comfort, and productivity [7]. Meanwhile, Minister of Energy and Mineral Resources Regulation No. 14 of 2012 outline states that energy management is an integrated activity to control energy consumption in order to achieve effective and efficient energy utilization [8]. One of the activities that are part of energy management is energy auditing.

An energy audit is a process of evaluating energy use and identifying energy-saving opportunities as well as recommendations for increasing efficiency in energy users and users of energy sources in the context of energy conservation. Green building can be defined as a structure and process of using environmentally responsible and saving resources, along with the life cycle of a building, starting from the choice of place, building design, construction, operation, maintenance, renovation, until the demolition of the building.

The objectives of this study are:

a. Knowing the value of Energy Consumption Intensity based on observations of the use of electrical energy in detail with a variety of equipment that consumes electrical energy and time of use.

b. Know the system that works well or not based on actual conditions in the field.

c. Look for opportunities for energy savings and cost savings based on actual conditions in the field.

II. Literature Study

II.1 Electrical Energy Audit

Understanding energy audits is the first step in energy conservation activities. Energy audits identify how much energy is consumed and how much energy is consumed by an existing facility, building facilities, and building facilities. Energy audits are assessments of the use and cost of energy consumed in a facility. The results of this energy audit assessment can be used as input in building a series of recommendations to reduce the use of electricity costs by implementing various changes both in terms of equipment and operations.

Energy Consumption Intensity (ECI) Electricity is a term used to express the amount of energy in a building and buildings that have been determined in various countries such as (ASEAN and APEC), expressed in units of kWh per year (SNI 03-6196-2000) with formula as follows:

$$ECI = \frac{Value\ of\ Electric\ Energy\ Usage\ in\ kWh}{Building\ Area\ in\ m^2} \tag{1}$$

The ECI value in the energy audit process is used as a reference value to determine potential energy efficiency that might be applied to a building. The ECI reference values for air-conditioned buildings are shown in Table 1.

TABLE I
THE ECI REFERENCE VALUES FOR AIR-CONDITIONED BUILDINGS

Criterion	ECI (kWh/m^2/month)
Very wasteful	23.75 – 37.5
Wasteful	19.2 – 23.75
Wasteful enough	14.58 – 19.2
Efficient enough	12.08 – 14.58
Efficient	7.93 – 12.08
Vary efficient	4.17 – 7.93

Energy conservation is a way to utilize energy effectively and efficiently without reducing user requirements and user comfort. Energy conservation aims to minimize energy consumption by reducing unnecessary waste of energy use. Reducing waste energy consumption based on applicable standards so as not to reduce consumer comfort and needs. To find out which systems can be saved, we must first conduct an energy audit.

In carrying out energy conservation, there are three important parts that must be considered, namely observation on the energy source; the intended energy source is the energy supply used in the building or building such as electrical energy sourced from PLN or the use of generator sets (Genset) in the building. The second is the conversion and distribution of energy sources; the intention is to choose the technology used such as electrical equipment, the use of lights or the use of electricity for air conditioning systems as well as the optimization and efficiency of the use of these energy sources. The last is energy consumption; energy consumption is focused on the behavior of users of energy sources and the use of energy sources according to needs or not. Figure 1 shows the illustration of audit of energy in a building.

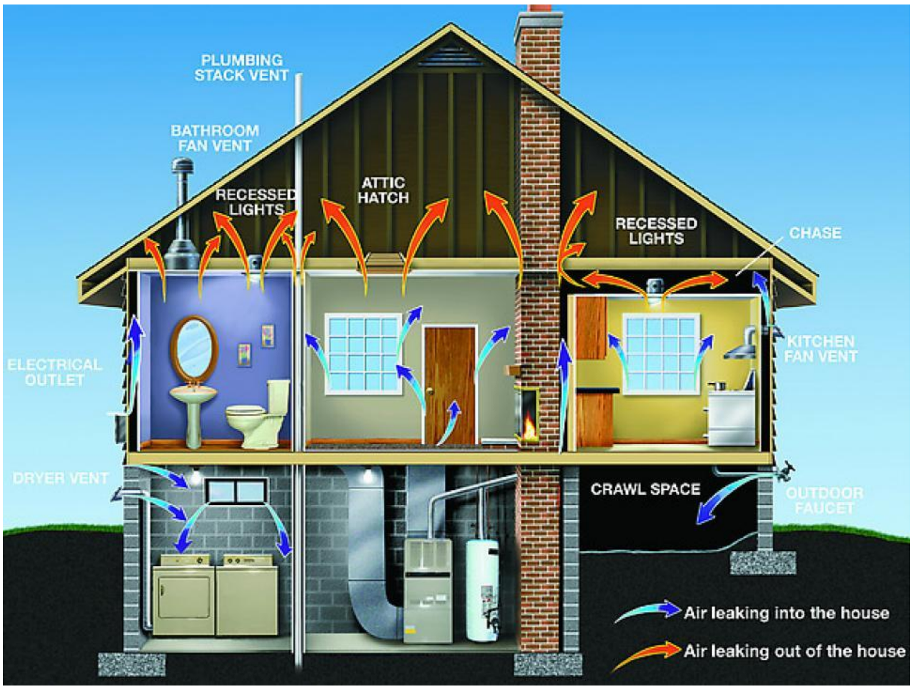

Fig. 1. The audit of energy in a building

II.3 Energy Conservation

The definition of electrical energy is energy derived from the movement of atoms towards a conductor that will produce an electric charge, the electricity that flows or propagates in a conductor possesses a unit of electric current in amperes (A). In addition to the current, electricity also has a voltage in volts (V) and electric power in watts (W). The use of electrical energy at this time in units of electrical energy is the watt (W). In its calculation, the electric power is obtained by multiplying the voltage with the current. The use of electrical energy, in addition to using the power unit (W) also depends on the length of use in units of hours (H). In order to simplify the process of calculating the use of electrical energy usually uses units of kWh.

Energy conservation in a building aims to make the building systematic, planned, and integrated in order to conserve energy resources efficiently without sacrificing the demands of human comfort to reduce the performance of the equipment. Energy conservation itself can help save money financially and can help in preserving the environment without reducing the quality of the user itself and increasing the increase in energy requirements every time.

There are three types of energy audit techniques, as follows:

1. A brief energy audit is an activity of collecting historical data, building documentation data available buildings and observation, or go directly to the field.
2. An initial energy audit is an activity in collecting building energy data with available data that does not require measurement and calculates energy consumption intensity.
3. A detailed energy audit is a data collection activity historical, building documentation data, direct observation or measurements to the field, and complete measurements.

Energy Consumption Intensity (ECI) is a term commonly used in understanding the level of energy usage in buildings in the form of factories, office buildings, markets, schools, hotels, hospitals, and others. Electricity Consumption Intensity is a term that states the amount of electricity used in buildings per square meter per month or per year. This ECI value is significant to be used as a benchmark in calculating potential energy savings that might be applied in every room or the entire area of the building or building. The electrical energy audit study was conducted in building F, which is used by the Faculty of Engineering, Universitas Muhammadiyah Yogyakarta, as shown in Figure 2.

Fig. 2. The building F of Universitas Muhammadiyah Yogyakarta

II.3 Power Quality

The quality of electricity is about the problem of changes in the form of voltage, current or frequency that can cause failure or misoperation of equipment, both PLN's and consumers' equipment. The quality of electricity requires more aspects that need to be reviewed; this quality involves several electrical parameters as follows:

1. Electric current, i.e., the amount of electric charge caused by the movement of electrons flowing through a point in an electric circuit every time unit. Electric current can be measured in units of coulombs/second or amperes.

2. Electric power, which is the rate of conductivity in electrical energy or an electrical circuit. In the International Unit (IS), electric power is a unit of wattage that states the amount of electricity that flows per unit of time (Joules/sec). Electric power can flow in the electric field, and the magnetic field is in the same place.

3. Electric voltage, i.e., the voltage or Electric Force (emf), the potential difference between two points in an electrical circuit. Electrical voltage or voltage has a unit called a Volt (V). This quantity is also used to measure the potential energy in an electric field that causes the flow of electricity in a conductor. Voltage can be said to be ideal if it has pure sine frequency waves that do not experience distortion, under normal conditions the voltage has a tolerance value allowed by the PLN of -10% to +5% if in an emergency condition according to IEEE 519-1992 standard in his book has a tolerance value of -13% up to +6%.

At the mains voltage can be expressed as extra-low, low, high, or extra-high depending on the significant potential difference. Electrical voltage can cause objects with negative electricity to be drawn from a low-voltage place to a higher-voltage place. Therefore, the direction of a conventional electric current in a conductor flows from high voltage to low voltage.

4. Frequency, i.e., the number of Alternating Current (AC) alternating current cycles per second. In Indonesia, the standard electricity frequency is 50 Hz because each country has different voltage frequencies. One of the parameters of the quality of a power source that is considered reasonable is that it has a constant frequency value if the frequency value can change, then it is the same as voltage.

5. Load Imbalance. Imbalance of load dramatically affects the distribution system, especially on the distribution transformer because it causes losses. Losses occur due to neutral currents that occur because large currents flow in neutral conductors as a result of load imbalances in each phase on the transformer secondary side (R, S, T).

6. Harmonics, i.e., disturbances in the voltage waveform or current waveform so that the waveform is not a pure sinusoid. Distortion caused by non-linear load, which is the source of the formation of high-frequency waves (multiples of fundamental frequencies, for example, 100 Hz, 150 Hz, 200 Hz, 300 Hz and so on). Harmonics of voltage or current are measured from the magnitude of each harmonic component to the basic component expressed in the percentage. In order to obtain a parameter that can be used to assess harmonics is called THD (Total Harmonic Distortion). Harmonics can also be caused by the symptoms of the formation of waves with different frequencies and are multiplications of integers with their fundamental frequencies.

Harmonic voltage or current measured by the magnitude of each component of a harmonic to its basic component expressed in terms of the percentage. The parameters used to assess defects in the harmonic are used total harmonic disability or Total Harmonic Distortion (THD). The nominal system voltage is 20 kV and below, including 220 volts low voltage, maximum THD of 5%, and for systems 66 kV and above THD maximum 3%. THDF (Transformer Harmonic Derating Factor) is a value or multiplier factor used to calculate the amount of new capacity (kVA) of the transformer. THDF (Transformer Harmonic Derating Factor) is a transformer that is affected by the presence of THD (Total Harmonic Distortion) in a transformer due to the use of non-linear loads on the load side. The amount of THD (Total Harmonic Distortion) is determined by measurement.

THDF (Transformer Harmonic Derating Factor) derating factor in transformers due to harmonics. In an ideal state (pure sinusoidal wave), there is no harmonic interference in the THDF (Transformer Harmonic Derating Factor) value system = 1, so that there is no decrease in the capacity of the transformer.

III. Methodology

This research was conducted in F1, F3, F4, and G6 at Muhammadiyah University, Yogyakarta. The procedure of this research was carried out through the following steps.

1. Preliminary Study

In the initial study carried out by conducting a direct survey with visual observations and brief data collection from sources such as security guards, students, staff, lecturers, academic staff, and building users, especially F1, F3, F4, and G6 at Universitas Muhammadiyah Yogyakarta.

2. Literature Study

A literature study is carried out by looking for information about the theory, methods, and concepts relevant to a problem. This information can be used as a reference or benchmark in solving a problem that occurs. This literature study is carried out by digging up information and references in the form of textbooks and information from the internet and from lecturers who provide the information needed.

3. Data Collection

Building energy data collection with available historical data, the data that need to be carried out in a building energy audit are as follows:

a. Data collection of installed loads and building areas on each floor.
b. Data collection is carried out by direct observation and measurement on each panel.
c. Measurements made for the sample observations on energy use in one day during lecture hours begin until after lecture hours.
d. Measurements made on the amount of energy consumption used in each device are then calculated and classified according to their level of efficiency according to the standard value of the intensity of energy consumption.

4. Data Processing

Data processing is performed on the calculation of data on energy usage, power expended, calculating the intensity of energy consumption, and analyzing graphs.

Fig. 3. Location of this research at Universitas Muhammadiyah Yogyakarta

IV. Results and Discussion

IV.1 Calculation of Electric Energy Consumption

The value of energy consumption used during one-month usage can be calculated as follows. Energy consumption in one-day usage is 6365092.3 Wh or equal to 6365.0923 kWh. Usage time is in one month or 30 days. Therefore, the value of energy consumption for one month is 6365.0923 kWh x 30 days, which is 190952.769 kWh/month.

From the above calculation, the value of energy consumption can be known, namely the use of electricity in usage for one month, which is equal to 190952,769 kWh / month.

Furthermore, the calculation of the use of electrical energy consumption in buildings F1, F3, F4, and G6 in Universitas Muhammadiyah Yogyakarta in one month is 190952,769 kWh/month. The building has a total area of 18740.16 m2. Based on the calculation of the value of the intensity of electrical energy consumption in buildings F1, F3, F4, and G6 at Universitas Muhammadiyah Yogyakarta obtained the average value of intensity energy consumption of 10.18 kWh/m^2/month. So, in this case, it can be seen that the building standards are between 7.92 - 12.08

kWh/m²/month, which means that these buildings are categorized as efficient according to the standards of the Ministry of National Education of the Republic of Indonesia, 2004, as can be seen in Table 1.

IV.2 Performance of Power Quality

Based on the results of the measurement of load data that have been made, the results have been obtained, as shown in the graph in Figure 4. In the power graph, it can be concluded that the use of electrical energy is greater during lecture hours, i.e., at 6.50 am to 8.50 pm. Furthermore, when there are no lectures or holidays, there is very little use of electrical energy. These results can occur because of the influence of the use of air conditioners, lighting systems, and electrical equipment that support the lecture activities.

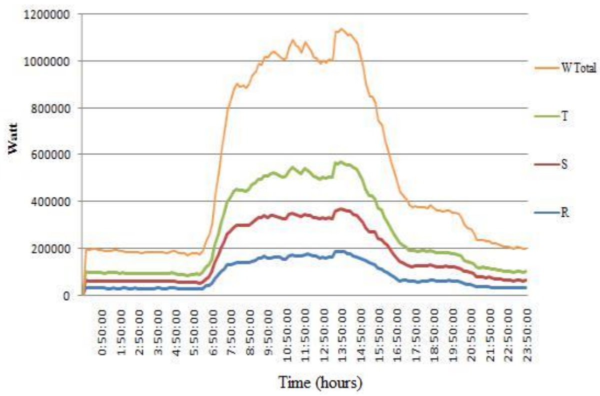

Fig. 4. Load data of the F1, F3, F4, and G6 buildings at the Universitas Muhammadiyah Yogyakarta

On the electrical load profile of buildings F1, F3, F4, and G6 in Universitas Muhammadiyah Yogyakarta that has been measured using an Electronical Power Analyzer on each panel in the main building. This measurement is carried out in order to get more actual electrical data results. The results of these measurements obtain apparent power data (kVA), real power (kW), power factor, voltage, current, inter-phase current, frequency, load, voltage harmonics, and voltage imbalance. In every building, several panels connect, namely for lighting, equipment, elevators, and air conditioners. The actual electricity is where the quality of electricity and its operation that serves the electrical loads in buildings.

Based on the results of the measurement of power factor data of the F1, F3, F4, and G6 buildings at the Universitas Muhammadiyah Yogyakarta that have been made, the results have been obtained, as shown in the graph in Figure 5.

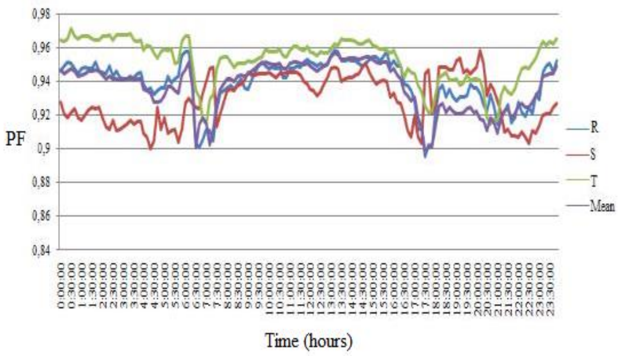

Fig. 5. Power factor data of the F1, F3, F4, and G6 buildings at the Universitas Muhammadiyah Yogyakarta

In the power factor graph in Figure 5, it can be concluded that the cos phi value indicates the electrical system in the building in good condition because it is following the standard value set by PLN, which is above 0.85. The power factor to be achieved must be above 0.85 so that the quality of power becomes better and avoids the additional costs of the electricity bill caused by the power loss. Good power quality will improve voltage drop, power factor, power losses, power capacity, and electrical energy efficiency. Good power quality if the power factor value is above 0.85 or close to 1.

For PLN customers, especially industrial customers, excess use of kVARh at an average power factor of less than 0.85 will incur an excess cost of kVARh or an electricity bill fine. Recording electricity bills is not based on the amount of real power consumption (kWh), but also based on the amount of reactive power (kVARh) that occurs on the burden of electricity consumption. The higher the reactive power that occurs, the greater the cost of the kVARh penalty to be paid by industrial customers to PLN.

The use of kVARh power by industrial customers cannot be avoided because electrical machinery and equipment used, such as electric motors, require reactive power to operate. Due to these reactive requirements, industrial customers must always pay attention to their reactive power usage so that they do not exceed the limits set by PLN.

The results of observations regarding voltage balance can be concluded that the results of the measurement data and calculation of the value of the voltage balance are less than 3%. In this situation, the value is categorized as useful according to the ANSI C84.1-1995 standard. The standardization of the balance must not exceed 3%.

The results of observations regarding the balance of the electric current can be concluded that the results of the measurement data and calculation of the current balance value are 1%, which means that the value is less than 3%. In this situation, the value is categorized as useful according to the ANSI C84.1-1995 standard. This result shows the same value as the measurement of the load voltage balance value.

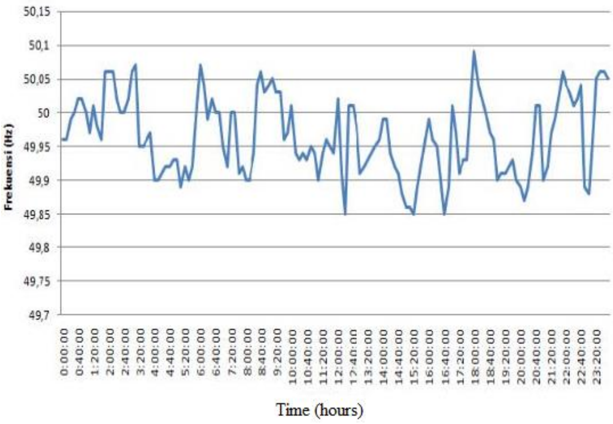

Fig. 6. Frequency data of the F1, F3, F4, and G6 buildings at the Universitas Muhammadiyah Yogyakarta

The value of the electric current balance is an essential thing that must be known when making measurements on the quality of the electrical system. If the current balance value above the standard value can cause the Harmonic Derating Factor Transformer (THD-Current) to be higher or higher, the emergence of neutral currents and insulation will make it hot and cause the distribution transformer performance can not work optimally. The standard of ANSI C84.1-1995 applies that the value of the unbalanced distribution system flow must not exceed 20%.

Based on the results of the measurement of frequency data of the F1, F3, F4, and G6 buildings at the Universitas Muhammadiyah Yogyakarta that have been made, the results have been obtained, as shown in the graph in Figure 6.

On the frequency graph, as shown in Figure 6, it can be concluded that after making observations and measurements of the frequency of electricity in the electricity distribution network in the building is classified as useful according to the standards following Regulation of the Minister of Energy and Mineral Resources No. 37 of 2008, namely 49.85 to 50.10 Hz.

V. Conclusion

From the results of the energy audit that has been carried out in the F1, F3, F4, and G6 buildings at the Universitas Muhammadiyah Yogyakarta, it can be concluded as follows:

1. The use of electrical energy consumption used in buildings F1, F3, F4, and G6 in September 2017 in the amount of 190952,769 kWh/month.
2. Frequency values, current balance, voltage balance, power factor, and power in buildings F1, F3, F4, and G6 in Universitas Muhammadiyah Yogyakarta have met the standard.
3. Average Energy Consumption Intensity Value (ECI) in buildings F1, F3, F4, and G6 in the Universitas Muhammadiyah Yogyakarta in the efficient category that is the average value of energy consumption intensity is 10.18 kWh/m^2/month. Where the average ECI standard value that has been set is 7.92 - 12.08 kWh/m^2/month.

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