

An electric energy reduction model for campus using the method of controlling energy consumptions

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Abstract

In this paper, an electric energy reduction model for campus using the method of controlling energy consumptions is proposed. The study used the building of Engineering Faculty of Universitas Andalas, Indonesia, as the object of research. In these models, the amount of electric energy consumption for a month is estimated as needed. Estimation of electric energy requirement is mapped from faculty activities, activities schedule, standards for power quality, standard lighting, room temperature standards, load technology and human behavior in the building. The parameters used in the calculation are obtained from direct observation in the field. Furthermore, the real-time monitoring of electrical energy system is designed with the installation of power logic on the substation faculty buildings and transmitted energy data through the campus web. The measurements of power and electrical energy consumption for one week using Fluke Power Analyzer 435 series II is needed for the design base of energy monitoring system. In this study, the difference between the results of real-time monitoring and the estimation of energy consumption in the object of study during October 2018 was 9,151,664 kWh (21.86%). This is a form of waste of electrical energy because of the use of electric energy in the room and time that is not appropriate. The initial solution to the waste indicated above is the management approach. However, this designed model is able to integrate all possible paths to reduce electric energy consumption, such as: improving power quality, increasing efficient technology in the load, and reduction of energy waste.

Keywords: Electric energy consumption control, energy saving, wasted energy, energy conservation

1. Introduction

The university campus is one type of electric load with medium power capacity that supplied from a utility grid. Because it includes a medium load, the campus usually gets power supply directly from the medium voltage (primary) of distribution network. In the provision of electric energy, university campuses can be analogous as a miniature city, which can have all load sectors (public, social, commercial, household and industrial) [1]. A complete campus usually consists of academic administration buildings, lecture buildings, student dormitories & lecturer housings, research centres & laboratories, hospitals & clinics, sports facilities, places of worship, library & exhibition buildings, and shops and canteens. Academic administration building; such as: rectorate office, dean office, and department offices; used for campus community administration services can be grouped as a public load sector. Student dormitories and lecturer housing can be analogous to household load sector. Research centres & laboratories have electrical equipment that is almost similar to industry load sector. Shops, canteens and guesthouses can be analogous to commercial load sector. Houses of worship and hospitals can be grouped into social load sector. In addition, the grouping of loads is based on the functions of the

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university building above that intended for grouping building loads based on the same characteristics, not grouping building loads based on the same tariff.

A number of experts have conducted studies on the reduction of electricity consumption at the University. Oyede et. al. in [1] proposed a simple concept to reduce energy consumption in student dormitories and lecturers' rooms at Covenant University, Nigeria. In this study, authors have replaced traditional fluorescent lights (FLTs) and incandescent bulbs with compact fluorescent lamps (CFLs) and replaced conventional resistance electric regulators with fans with electronic regulator fans. With this simple concept, it can be done the reduction of electricity consumption in 1 year by 16%. In line with the previous study, Beza Negash Getu et. al. in [2] has conducted an electrical energy audit at the American University of Ras Al Khaimah, UAE, and recommended the reduction of electric energy consumption through the replacement of existing lamps with Light Emitting Diode (LED), as well as the use of Air Conditioner (AC) with efficient technology. Hussain A. Attia et. al. in [3] has proposed an authorized timer to reduce electricity consumption in classrooms. This timer is used to control the working time of the LED lights and air conditioners (AC) in the lecture room according to the lecture schedule, so that it can avoid using energy in a useless manner. Dhivvy J P et. al. in [4] has designed Wireless Sensor Network (WSN) to reduce the use of electric energy in classrooms and laboratories by integrating of a number of sensors with wireless networks.

In this study, the Infrared (IR) sensor is used to detect the presence of people in the room. Ching-Lung Lin et. al. in [5] has utilized campus network to reduce its electricity energy consumption. In this study, campus networks are used hybrid to control the use of air conditioners in classrooms, so that It can do energy savings of 10%. Tzung-Cheng Tsai Lin et. al. from Industrial Technology Research Institute in [6] has implemented a Web-based Energy Management and Control System (Web-EMCS) for energy conservation in campus buildings. With the use of Web-EMCS, it has been able to manage the needs of electrical energy for a number of loads, so that within 4 months it can reduce electricity consumption by 450,400 kWh. Some other literature [7,8] has been also discussed the use of smart sensor to control electric energy consumptions. Osaka University since 2010 has made efforts to achieve sustainable campus through energy-saving strategies at campus facilities [9,10].

In this paper, an energy electric energy reduction model for campus buildings using a method of controlling electricity consumption is proposed. In this study, the electricity consumed is estimated according to its ideal needs. Then, this estimated electrical energy requirements compared with the results of real-time monitoring, if there is a large enough difference means there is a waste of electricity. Forms of waste that might occur, including energy losses due to low power quality, energy losses due to inefficiency of electrical equipment, waste energy because electricity is used at times and spaces that are not needed. In this proposed model a combination of several electrical energy saving methods has been carried out by previous researchers and the use of campus web so as to become a more comprehensive method of reducing electric energy.

2. Supply Structure and Usage Characteristics of Electric Energy on Buildings Campus

In order to obtain an effective model of electric energy consumption, an analysis of the structure of electricity supply and electric energy usage characteristics is needed.

2.1. Supply structure of electric energy

For this study, the structure of the supply of electric energy in the buildings in the Engineering Faculty, Universitas Andalas was used as the object of the case. As shown in Figure 1, the buildings in Engineering Faculty are supplied by the utility grid through a transformer 630 kVA, 20 kV / 380 Volt, which is one of 12 transformers available at Universitas Andalas. The provision of electric energy starts from the substation that gets supply from the utility grid. Substation distributes electric energy to 4 load groups, namely: load groups in mechanical engineering buildings, electrical engineering, administration faculty, and civil engineering group. In addition, the provision of electric energy in the civil engineering

building group also distribute electrical energy to industrial engineering & engineering environment buildings, as shown in Fig. 1.

2.2. Characteristics of electric energy usage

The characteristics of electric energy usage are influenced by several factors, including load grouping, load function, load usage schedule, and electrical equipment characteristics. In this study, the electricity load is grouped into 5 groups, namely: lighting, air conditioners (AC), computer equipment, laboratory equipment, and other equipment. Distribution of electrical energy consumption for one week based on the grouping of types of electricity load for Engineering Faculty, Universitas Andalas is shown by Figure 2a. As shown by this figure, the largest load group is space cooling (32%), followed by lighting group (25%), laboratory equipment (24%), while computer equipment as the smallest load group (8%). Figure 2b. shows the distribution of electrical energy consumption based on grouping of user buildings. As shown by this picture, the mechanical engineering building is the largest electrical energy consumption user in Engineering Faculty, with a composition of 27%. Then the next users of electric energy consumption are followed by the Civil Engineering building (26%), the Electrical Engineering building (17%), and the faculty administration building and Industry Engineering as the smallest user of electric energy (9%).

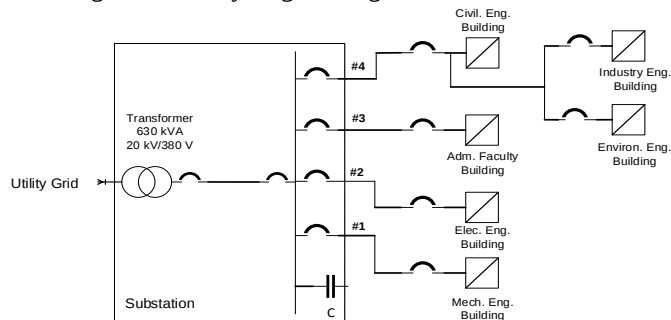


Fig. 1. The structure of the supply of electric energy in the object study

The function of electrical equipment in campus activities affects the electrical power capacity or electrical energy that must be provided. Some electricity loads operated according to their roles must meet applicable standards. For example, the use of a lamp loads that functions for lighting systems from the lecture room, it is necessary to load the lamp with sufficient power capacity to produce lighting intensity of 300 lux [11]. The schedule of electric loads usage is needed to determine when electric power is needed and how long it takes. The use of electrical energy outside the schedule will trigger waste. In addition, every load or electrical equipment has different characteristics in consuming electrical energy. Each lamp requires constant electrical power during its use, while for space cooling with conventional technology absorbs electrical power constantly as long as the room temperature is greater than the temperature set and does not absorb electrical power when the room temperature is lower than the temperature set.

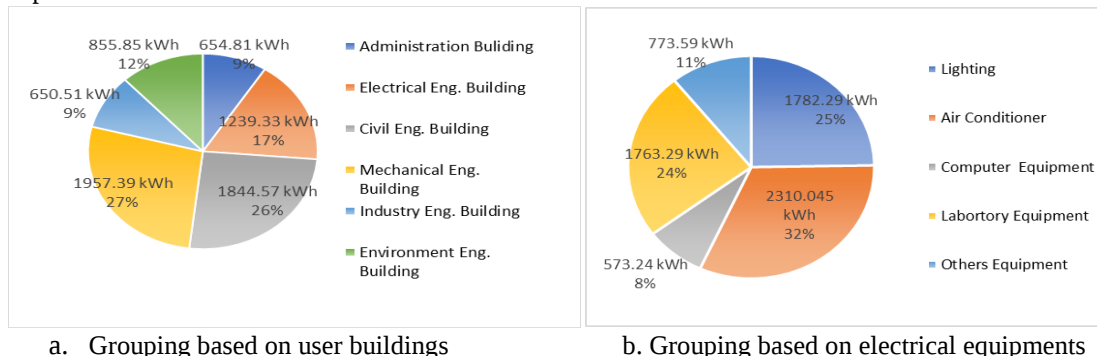


Fig. 2. Grouping the use of electric energy

Fig. 3 shows the electrical power usage characteristics for every day during 1 week in the Engineering Faculty, Andalas University. As shown by this figure, the trend of the characteristics of electric power usage for Monday to Friday is almost the same due to working days. Meanwhile, the trend of electric power usage characteristics for Saturday to Sunday is almost the same due to holidays. Here, Saturday and Sunday are week-end. Academic activities that require electrical power fluctuate from 8.00 to 18.00. The duration of peak load occurs between 11.00 – 15.00, with a capacity of 135-140 kW. Between 18.00 to 7.00, there is no activity on campus, but the use of electricity is still relatively large between 40-45 kW. Figure 4 shows the electrical energy consumption characteristics for the object study. As shown in this figure, the total electrical energy consumed for one week reaches 10,710.22 kWh, with the largest consumption occurring on Tuesday and the smallest consumption occurs on Sundays.

3. Sources of Electrical Energy Losses

Electrical energy supplied from the utility grid, then transmitted & distributed, and utilized by the loads to carry out its functions will shrink when converted into other forms of energy. In general, things that can cause the depletion of electrical energy are grouped into 3 things, namely: low power quality, inefficient technology, energy used at times and places that are not suitable. Energy loss due to the low quality of electrical power can occur in transformers and distribution lines. Meanwhile, energy losses due to inefficient technology in buildings & equipment, and energy waste due to electricity used at times and places that are not suitable to occur on the side of the load.

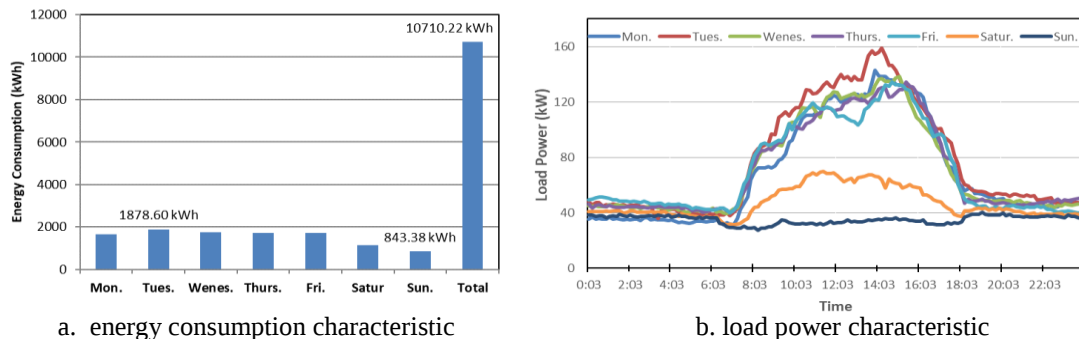


Fig. 3. The load power & energy consumption characteristics for the object study

3.1. Increased power losses due to low quality of electric power

During distribution of electrical power from the utility grid to the loads, there is power losses on the distribution line and transformer. Power loss is a natural process, but if the power is poor quality, it causes an increase in power loss. There are several conditions of deterioration in power quality that can increase power loss, including harmonic distortion, low power factor, and unbalance system. The decrease in power quality level due to harmonic current distortion is generally triggered by the presence of loads from electronic equipment, such as Personal Computer, photocopy machine, LED & CFL lights, UPS etc. These equipments will generate harmonic currents that cause an increase in rms current flowing in the transformers and distribution lines. An increase in rms current will cause an increase in power losses from the power transmitted from the utility grid to the loads. The amount of harmonic distortion in the load current is stated in Total Harmonic Distortion Current (THD_I). Figure 4a shows the results of the measurement of the average THD_I value of the current supplied by the utility grid to the load. As shown in this picture, the THD_I value tends to increase during working hours. This happens because during working hours, many electrical appliances are operated that generate harmonic currents, such as PC, photocopying machines, and CFL lights.

The low power factor of the system is caused by inductive loads, which are generally in the form of electrical equipment driven by induction motors, such as space cooling equipment, water pumps, etc. The

existence of these inductive loads will result in an increase in the inductive current flowing in the phase lines and transformer. This will result in an increase in the total rms current, and further increase the power losses in the distribution lines and transformer. The measurement result of the average power factor on the transformer output side is shown in Figure 4b. As shown in this figure, the fluctuation of the factor power value to the change in load is not too large. This is understandable because the capacitor bank has been installed on the output transformer side as a reactive power controller, as shown in Figure 1.

The unbalance of the electric power system generally occurs due to the uneven load distributions in each phase. This unbalance will generate current flowing in the neutral line. This will result in causing power losses on neutral line. Figure 4c shows the measurement results the current flowing in the neutral line for the object study. As shown in this figure, the largest neutral currents occur on Monday during working hours. This shows that the greatest unbalance of loads occurred at that time. The unbalance of the electric power system generally occurs due to the uneven load distributions in each phase. This unbalance will generate current flowing in the neutral conductor. This will result in generating power losses on neutral conductor. Fig. 4c shows the measurement results the current flowing in the neutral conductor for the object study. As shown in this figure, the largest neutral currents occur on Monday during working hours. This shows that the greatest unbalance of loads occurred at that time.

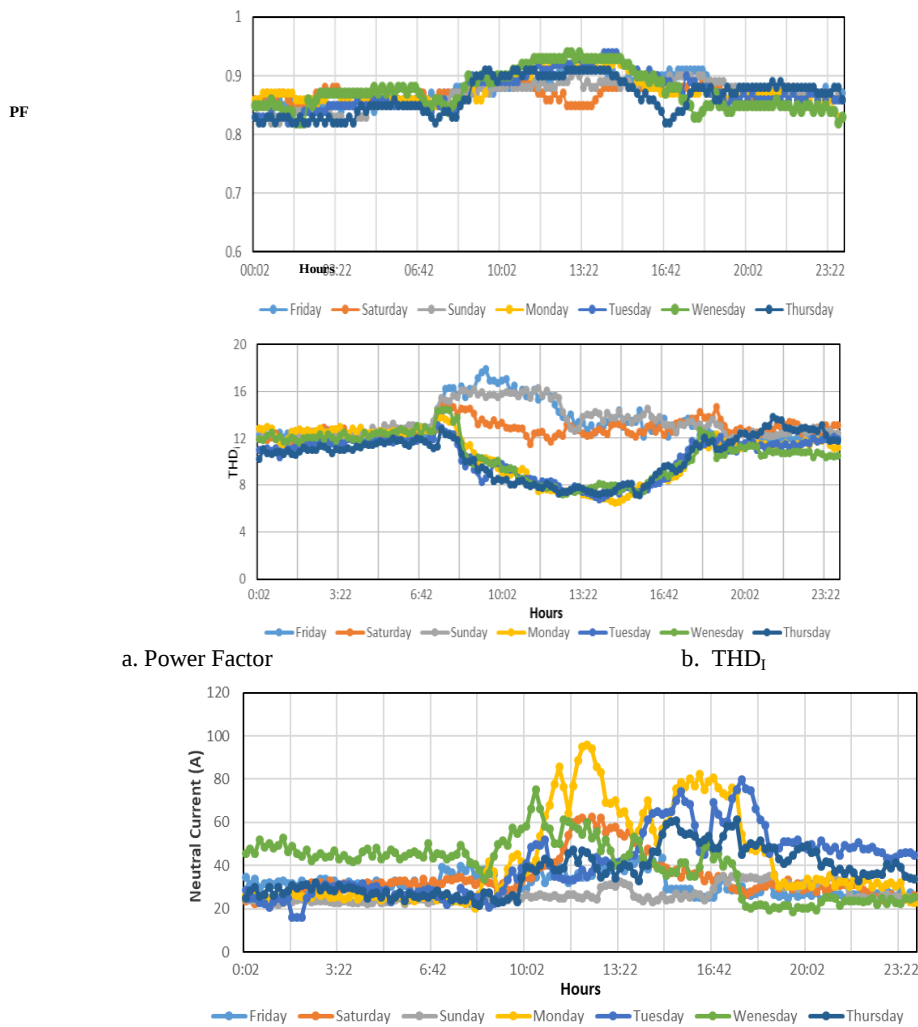


Fig. 4. The results of the measurement of the power quality variables

3.2 The extravagance of electric energy due to the use of loads with inefficient technology

The use of electrical loads with inefficient technology can be a source of wasteful use of energy. Replacing inefficient loads with similar loads with more efficient technology can reduce waste in electricity consumption, but replacement of these equipment will require relatively high costs. Therefore, in the application of this method, a feasibility study is needed.

In this stage, there are 2 groups of loads with the largest composition, which are a source of waste, namely: lighting system with a composition of 19% and space cooling with a composition of 49%. At present, there are 3 types of lighting technology that can be used, namely: Light (TL) Tube, Compact Fluorescent Lamps (CFL), CFL, and Light-Emitting Diode (LED). These three types of lights have increased efficiency and lifetime technology, ranging from TL, CFL, and LED. In table 1 is showed Efficiency & Life Time for different Phillip lamp technology [12].

Table 1. Efficiency & lifetime for different lamp technology [12]

TL-D Standard		CFL		LED	
Efficiency (Lumen/Watt)	Life Time (hours)	Efficiency (Lumen/Watt)	Life Time (hours)	Efficiency (Lumen/Watt)	Life Time (hours)
55 - 65	10000	60-70	10000	100-150	15000-30000

The composition of the use of the three types of lights in the Engineering Faculty, Universitas Andalas, can be shown in table 2. As shown by this table, the TL-D lamp type is the most widely used type of lamp, as many as 924 TLD lamps are used with a total power reaching 25.830 Watt. While the type of LED lights is still very little used, only as many as 102 lights are installed with a total power capacity of 1566 Watts. Therefore, there is still considerable opportunity to reduce waste of electricity as a result of the use of inefficient lamp loads.

The development of efficient technology in air conditioner (AC) is focused on the method of operating compressor motors during the controlling of room temperature [13]. On AC with non-inverter technology (conventional), the operation of the compressor motor is carried out with on-off method to get the room temperature at the value of the temperature setting. Meanwhile, in AC with inverter technology (efficient technology), the operation of the compressor motor is carried out with variable speed method to get the room temperature at the value of AC setting. With the use of air conditioners with inverter technology, it is estimated that it can save electricity energy consumed by AC loads reaching 30% [13].

Table 2. The composition of the application of light types for various groups of buildings

Buildings	TL-D Standard		CFL		LED	
	point	Watt	point	Watt	point	Watt
Electrical Eng.	244	4770	110	2871	35	277
Mechanical Eng.	171	4554	44	2503	1	7
Civil Eng.	271	8856	27	718	6	42
Industry Eng.	157	4806	11	474	4	36
Environment Eng.	28	972	42	1450	5	35
Administration Faculty	53	1872	34	812	51	1169
Total	924	25830	268	8828	102	1.566

4. The Electrical Energy Reduction Using Electrical Energy Consumption Control

4.1. Design of electrical energy consumption control model for campus

As discussed in the previous section, controlling the consumption of electrical energy is intended to control the amount of electrical energy consumption as needed. Electrical energy needs in a building can be estimated by taking into account the following variables: in-building activities, activity schedules, power quality standard, lighting standard, room temperature standard, load technology and human

behavior in the building. The influence of human behavior on the need for electrical energy is difficult to predict, but other variables are more easily estimated its effect to the electrical energy needs. The influence of human behavior is predicted through statistical approach. While the influence of other variables on electrical energy needs is estimated based on field observation and measurement data.

4.2. Electrical energy consumption estimation

Figure 5 shows the design of the electric energy consumption control model that proposed for campus. In the design of this model, the initial activities begin by estimating the total consumption of electrical energy in an ideal manner. The total consumption of electrical energy consists of energy consumed by the electrical load and energy losses that occur when transmitting / distributing electrical energy to the load. The amount of electrical energy required by the load is influenced by a number of factors, including campus activities, activity schedules, standard load requirements, and user behavior. In addition, the technology of electric energy conversion in the electrical load always evolves towards more efficient technology. Energy loss during transmission and distribution of electrical power from the utility grid to the load is affected by the power quality standard that is used.

The total energy consumed by the load during the time interval Δt can be estimated from field observation data and calculated through the following equation:

$$E_{\Delta t} = \sum_{i=1}^n P_i k_i t_i \quad (1)$$

where,

$E_{\Delta t}$ is the total energy consumed by the load during the time interval Δt (kWh),

P_i is the maximum load i^{th} power, which can be known from the specifications of the installed equipment (kW),

t_i is the time of use of the i^{th} equipment (hour).

k_i is the utilization factor of i^{th} equipment, which is determined by the characteristics of the use of the equipment.

Here, the value of k is one for lighting load. Here, the value of k is one for lighting loads, while the value of k varied 0.45-0.50 for conventional air-conditioning loads. The results of the estimation of electrical energy consumption for buildings of the Faculty of Engineering, University during the month of October 2018 were obtained at 32,713.80 kWh.

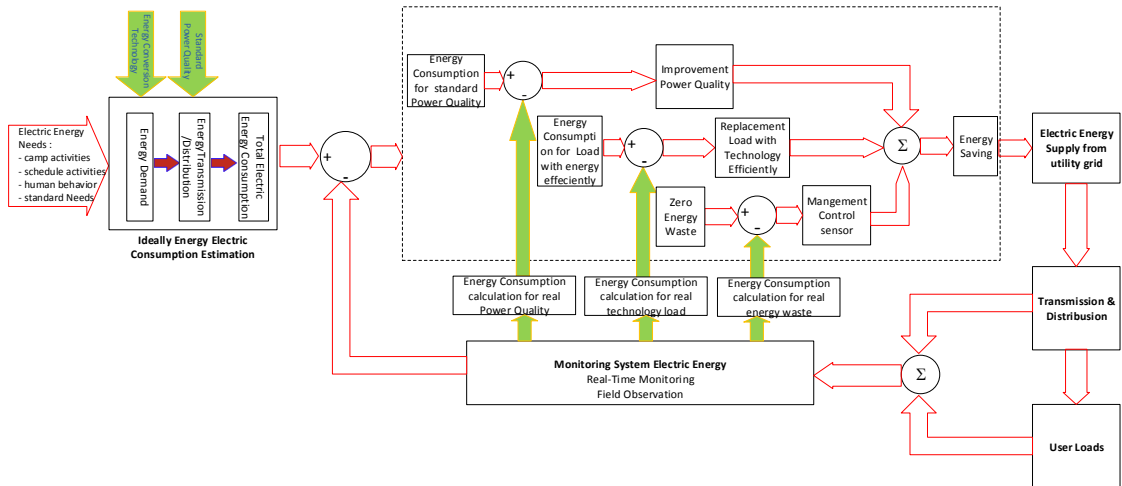


Fig. 5. The design of the electric energy consumption control model that proposed for campus

4.3 Monitoring energy system

In this model, the electrical energy monitoring system is built by real-time monitoring energy system and ideal energy estimation. Real-time monitoring energy system realized by 5560 Power Logic, which is installed in the building distribution panel. These monitoring results can be accessed on-line via the campus website. Variables that can be monitored in real-time include electrical energy consumption, all electrical variables, and all power quality variables. One of the results of real-time monitoring of energy consumption is shown by figure 6. The results of real-time monitoring of the electric energy consumption is a feedback from the control system of electricity consumption. As shown by figure 6, the results of real-time monitoring of electrical energy consumed by the buildings of the Faculty of Engineering, Universitas Andalas during one month (October 2018) reached 41,865.464 kWh.

Energy		
Parameter	Accumulated Value	Date/Time Last Reset
Energy		
Energy Delivered (kWh)	41,865.464	2018-10-11 06:11:17
Energy Received (kWh)	0.000	2018-10-11 06:11:17
Energy Delivered (kVARh)	25,170.109	2018-10-11 06:11:17
Energy Received (kVARh)	0.000	2018-10-11 06:11:17
Energy Delivered (kVAh)	49,029.804	2018-10-11 06:11:17
Energy Received (kVAh)	0.000	2018-10-11 06:11:17

Fig. 6. The results of real-time monitoring of energy consumption and electrical variables

The estimation of electrical energy consumed by the engineering faculty campus, Universitas Andalas, is 32,713.80 kWh, while the real-time monitoring results of its electrical energy consumption are 41,865,464 kWh. It shows that the differences between real-time and estimated results is at 9,151,664 kWh. It can be predicted as a form of energy waste. This waste of electric energy has occurred mainly due to the use of electrical energy in room and at time that unsuitable. In this case, the reduction of electrical energy consumption is prioritized on the management approach, especially energy waste that occurs at night. It is supported by analysis of load characteristics, as shown in figure 3. Meanwhile, reducing electrical energy consumption through smart sensors and controls are required a feasibility study because its relatively large costs are needed.

5. Conclusion

A model of conservation energy in campus using electrical energy consumption control method has been successfully designed and analyzed. The model is designed based on the concept of providing electrical energy that is tailored to the needs. In this method, the difference between the estimation of electrical energy consumption and the results of real-time monitoring energy system is the potential for reducing the electrical energy consumption that monitored. From the results of real-time monitoring and estimation of energy consumption during October 2018 on the study object, there has been indicated a potential reduction in electrical energy consumption of 9,151.664 kWh (21.86%). The designed model is able to integrate all possible paths to reduce electrical energy consumption, such as: improving power quality, increasing efficient technology in the load, and reduction of energy waste. Energy reduction can be done in a flexible and gradual manner, either based on the reduction path or at the level of reduction.

Conflict of Interest

The authors declare that there is no conflict of interest in the work submitted in this article.

Author Contributions

The first and the fifth author contributed in analyzing the data and building the writing structure. The second author had the role in observing and collecting the data. The third author had contributed in designing an energy monitoring system. Finally, the fourth author provided the equipment in obtaining the electrical data on buildings.

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