The influence of alternative sources on the efficiency of smart grid systems on campus buildings

D Maizana*, S Muthia Putri and Z Bahri
Department of Teknik Elektro, Universitas Medan Area, Jl. Kolam No 1, Medan 20223, Indonesia

*Email: maizanadina@gmail.com

Abstract. This paper tells about a smart grid system. The system uses electrical energy sources through the National Electricity Company, PV Solar Systems and Batteries as a backup. For the load, the rector building, lecture building, hostel and mosque are used. The method of calculating efficiency values uses conventional methods. In the analysis of the efficiency of the use of electrical energy found the highest efficiency value when there is excess energy from the National Electricity Company and as an additional load used batteries to store the excess energy. Demonstrate that the efficiency of electrical energy in smart grid is not only influenced by dynamic loads but also by the additio

1. Introduction

The resource of renewable energy comes from nature such as sunlight, wind, water, geothermal, and garbage. This is then processed by humans who can be used as a source of electrical energy. The use of fuel oil and coal to drive generator turbine in generating electrical energy is increasingly limited. The State Electricity Company (PLN) is a company that supplies electrical energy to consumers and has set electricity rates for customers to maintain the continuity of electricity use by this State-Owned Enterprises (BUMN). Customers who need a large electricity capacity can build new and renewable sources of electrical energy as an addition to existing sources of electricity sourced from PLN. In synchronizing the work of distributing electricity from different sources, it is necessary to build a smart grid to provide satisfactory results and the system can work smoothly. And Government has been produce policies and regulations in the use of renewable energy sources for customers.

The transition from conventional networks to the smart grid system is a popular electrical energy management system in millennial times. Where other investigators have been conducted research on the use of the smart grid system [1, 2].

In the management of electrical energy in the smart grid system, there is a process of excess and lack of electrical energy caused by the use of dynamic loads .[3] This means that the system must function properly to handle any changes due to dynamic loads. In addition, there is the effect of adding other sources of electrical energy such as the use of wind energy [4, 5], solar PV [4, 7, 8], microhydro [8], and
hybrids [9]. Which can overcome the shortcomings of the provision of electrical energy and batteries can be used to anticipate the excess of electrical energy.

Due to the advantages and disadvantages of the use of electrical energy, it will affect the efficiency of the use of electrical energy in the system [2, 10].

The problem is how dynamic loads and the addition of electrical resources can affect the efficiency of smart grid systems. And this will be analyzed later. The purpose of this investigation is to analyze the efficiency of energy use in smart grid systems.

2. Method
This investigation was carried out on campus 1 of the University of Medan Area where the fixed electricity resources used were taken from the State electricity company (PLN) and solar cell systems in addition. Loads are chosen from several buildings such as the rector building, the lecture building, the mosque and the hostel. While for excess electrical energy, batteries are used as storage and at any time can also be used as an alternative source. The design of an energy system in the form of a system circuit is shown in Figure 1.

![Figure 1. Power system design for smart grid system](image)

Sources from PLN provide power like $P_{s1}$, from PV Solar System like $P_{s2}$ and storage batteries depend on excess energy from PLN and stored to batteries like $P_o$. Each load is marked by $P_{L1}$ for the rector building, $P_{L2}$ for lecture building, $P_{L3}$ for mosque and $P_{L4}$ for hostel.

So that basic equations can be formed as follows:

$$P_{s1} = P_{L1} + P_{L2} + P_{L3} + P_{L4}$$  \hspace{1cm} (1)

Where the source of the PLN will flow to all loads based on installing power and fixed size. In this case there is a possibility that the power used by the load will exceed the installed power capacity. For that reason, the power from PV solar systems will provide additional power, the amount of which can be limited at any time based on weather conditions in charge energy to the battery or directly to the system.

As a conductor, large cables are used based on current flow capability. So that power loss will occur and can be considered through the following equation:

From PLN to AC grid, the power supplied is equal to
From the PV solar system to the AC grid, power if needed is equal to, 
\[ P_{s1} + \Delta P_{s1} \].

From the storage battery to the AC grid, sending power when needed will produce an equation, 
\[ P_{o} + \Delta P_{o} \].

For each load to AC grid, the power sent is, 
\[ P_{L1} + \Delta P_{L1}; \ P_{L2} + \Delta P_{L2}; \ P_{L3} + \Delta P_{L3}; \ P_{L4} + \Delta P_{L4} \].

And if the flowing power from the PLN is sufficient for all loads then equation (1) becomes:
\[ P_{s1} - \Delta P_{s1} = P_{L1} + \Delta P_{L1} + P_{L2} + \Delta P_{L2} + P_{L3} + \Delta P_{L3} + P_{L4} + \Delta P_{L4} \] (2)

Or, 
\[ P_{s1} = (P_{L1} + P_{L2} + P_{L3} + P_{L4}) + (\Delta P_{s1} + \Delta P_{L1} + \Delta P_{L2} + \Delta P_{L3} + \Delta P_{L4}) \] (3)

If there is an overload and the PLN source is not enough to provide the entire load power as additional power obtained through the Solar PV system then the equation (3) becomes:
\[ P_{s1} + P_{s2} = (P_{L1} + P_{L2} + P_{L3} + P_{L4}) + (\Delta P_{s1} + \Delta P_{s2} + \Delta P_{L1} + \Delta P_{L2} + \Delta P_{L3} + \Delta P_{L4}) \] (4)

If the load is reduced then the resources of the National Electric Company will be excessive, so in this system the excess power from the PLN will be saved to the battery or so that the equation (3) becomes
\[ P_{s1} = (P_{L1} + P_{L2} + P_{L3} + P_{L4} + P_{o}) + (\Delta P_{s1} + \Delta P_{L1} + \Delta P_{L2} + \Delta P_{L3} + \Delta P_{L4} + \Delta P_{o}) \] (5)

If PLN and PV solar systems are not sufficient to meet the power requirements as an alternative energy storage batteries can provide supporting power so that the equation (4) becomes:
\[ P_{s1} + P_{s2} + P_{o} = (P_{L1} + P_{L2} + P_{L3} + P_{L4}) + (\Delta P_{s1} + \Delta P_{s2} + \Delta P_{o} + \Delta P_{L1} + \Delta P_{L2} + \Delta P_{L3} + \Delta P_{L4}) \] (6)

It will produce 6 power equations from the smart grid systems Figure 1. To determine the efficiency of the system, the following equation is used:
\[ \eta = \frac{P_{out}}{P_{in}} \times 100\% \] (7)

where
\[ P_{in} = P_{out} + \Delta P \]
\[ \eta = \text{efficiency} \]
\[ P_{in} = \text{input power} \]
\[ P_{out} = \text{output power} \]
\[ \Delta P = \text{power loss} \]

If it is assumed:
\[ P_{L1} + P_{L2} + P_{L3} + P_{L4} = a \]
\[ \Delta P_{L1} + \Delta P_{L2} + \Delta P_{L3} + \Delta P_{L4} = \Delta a \]

Then equations 3, 4, 5 and 6 become:
\[ P_{s1} = a + (P_{s1} + \Delta a); \]
\[ P_{s1} + P_{s2} = a + (\Delta P_{s1} + \Delta P_{s2} + \Delta a); \]
\[ P_{s1} = (a + P_{o}) + (\Delta P_{s1} + \Delta P_{o} + \Delta a); \]
\[ P_{s1} + P_{s2} + P_{o} = a + (\Delta P_{s1} + \Delta P_{s2} + \Delta P_{o} + \Delta a); \] (8)

Then produced several efficiency equations from equation 8 based on the conditions given above as follows:
\[
\eta_1 = \frac{a}{a + \Delta P_{S_1} + \Delta a}
\]
\[
\eta_2 = \frac{a}{a + \Delta P_{S_1} + \Delta P_{S_2} + \Delta a}
\]
\[
\eta_3 = \frac{a + P_o}{a + P_o + \Delta P_{S_1} + \Delta P_o + \Delta a}
\]
\[
\eta_4 = \frac{a}{a + \Delta P_{S_1} + \Delta P_{S_2} + \Delta P_o + \Delta a}
\]

A value is dynamic including losses resulting from the channel to the load and made varied. From the above equation, some curves are generated and explained in the results section and discussion.

3. Results and Discussions

Based on the use of electric power, it shows the power usage as shown in Figure 1. Data collection for 2 weeks and losses are considered 0.01 times with the power used. In Figure 2 the power consumption varies due to dynamic loads. The highest use of such power is on Tuesday the first week and Thursday the second week. Which is the source is not only from PLN but also from PV solar systems and storage batteries.

Figure 2. Total power supply vs days.

Figure 3. Total load vs days.

Figure 3 shows the variation in the use of electric power by the load, the lowest power usage occurs on Sundays because there are no activities on campus. Power is only channeled to the dormitory and a small portion of the mosque and the remaining power is supplied to the battery. But on the Tuesday of
the first week and Thursday of the second week there was an excessive use of power due to the addition of campus activities outside the usual schedule.

Comparison of the overall power usage by the load on PLN electricity resources Figure 4. shows that on Tuesday 1 week and Thursday the second week shows the difference in power between the PLN supply and the load so that to overcome power shortages the power is taken from the PV solar system. If the available power is not enough, then the electrical power is taken from the energy storage battery so that the power will not apply. For a moment on Saturdays and Sundays excess electricity will be saved back to the storage battery.

![Figure 4. Comparison the total power supply and total load in normal condition](image)

![Figure 5. The efficiency comparison](image)

Due to fluctuations in the use of electric power it will cause variations in efficiency in the system see Figure 5. The highest value of efficiency applies to the state of the state electricity is not enough to supply energy to the load due to overload, so that PV solar systems and batteries as an option for additional energy. For the low efficiency value occurs where the supply from the PLN exceeds the load and the excess is stored in the battery.
From the efficiency curve generated, the average value is taken and shown in Table 1. The highest average value of efficiency is obtained in the third condition of 98.582% where the system experiences excess energy on Saturdays and Sundays and the excess energy is stored on the battery. In these circumstances the battery as a load and power losses that need to be taken into account are load power losses, power losses from the source of PLN and power losses from the storage battery conduit. So that the output of the system is quite large with the battery. For other efficiency values, the battery is also included as input power. And output is limited to normal load.

| Table 1. The average of efficiency |
|-----------------------------------|
| The efficiency average Value (%) |
| η₁     | 97.565   |
| η₂     | 97.563   |
| η₃     | 98.582   |
| η₄     | 97.515   |

4. Conclusions
The efficiency of the use of electrical energy in smart grid systems is influenced by dynamic loads and also the addition of electrical energy sources outside of the fixed electrical energy sources.

The highest efficiency occurs when the load is low and the excess energy is stored in the battery and the battery is considered a load.

The addition of the network may be done to anticipate the excess and lack of electrical energy from one network.

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