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Analysis of the feasibility of adding a grid-connected hybrid photovoltaic system to reduce electrical load

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ABSTRACT

The power generation system with hybrid system grid connected (HSGC) technology is an energy-saving technology that is able to compensate for electricity loads in an energy-efficient manner in today's technological advances. Electrical transient analyzer power (ETAP) simulation software is implemented so that the modeling will have an impact on the development of hybrid systems. Testing the reliability of the system is simulated at the load of school buildings, laboratories, mosques, and kindergarten schools. parameters obtained by evaluating the ratio of the voltage drop before and after the addition of photovoltaic. The value of the voltage drops decreases with the integration of hybrid photovoltaic. The school building panels experienced a voltage drop of 0.15%, reduced after the addition of photovoltaics and wind turbines. Then on the Laboratory panel, a voltage drops of 0.05% was obtained, on the mosque panel the voltage drop reached 0.11%, and on the kindergarten building panel the voltage drop reached 0.09% after the addition of photovoltaic hybrid. From this comparison it can be said that PV and wind turbines can affect the voltage drop and reduce the consumption of electricity loads from the grid caused by adding power from the hybrid photovoltaic hybrid to each load.

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1. INTRODUCTION

People's need for electricity keeps growing, but conventional energy production has dropped significantly around the world. This means that the expected electricity needs are not the same as the current electricity needs of the community. This is certainly a concern of the government to accelerate the development of renewable energy technology to anticipate energy crises in the future so that independence and energy security are maintained [1]. At the moment, the most important thing is to get power from traditional sources, especially during the day and night. The most dominant energy needs are met during the day, which is working time for the community, especially those who work in the industrial world and also schools. One of the strategies taken to reduce the condition of energy demand, especially when peak loads occur, is to carry out a hybrid system which uses two renewable energy sources (solar energy sources and wind energy) [2]–[4]. For the use of renewable energy from the sun itself, of course, there is a huge opportunity in Indonesia, and it also does not have a negative impact on the surrounding environment in its use [5], [6]. The efficient use of energy from the sun cannot be separated from the geographical position of the Indonesian region, which is located at the equator and where the most efficient solar radiation reaches 12 hours a [7]. Energy conservation can be done with several techniques, namely using new and renewable energy and using energy management with a smart grid system. One form of utilization of new and renewable energy resources is the use of a grid-connected hybrid system, or hybrid system grid connected HSGC [8], [9]. When implemented, the HSGC system is sourced from more than two different generators in order to obtain optimal power output based on needs [10]–[12]. Installation of PV installation systems and wind turbines or HSGC systems is strongly influenced by the source of sunlight obtained and also the average wind speed at the location such as when the intensity of sunlight decreases and the wind speed to rotate the wind turbine decreases then the power output The amount of electricity generated will also be significantly reduced [13]–[15].

Several investigators have previously used the electrical transient analyzer power electrical transient analyzer power (ETAP) tool to do simulations, such as estimating fault currents to build a system protection circuit [16]. The most recent system modeling is intended to construct an efficient hybrid photovoltaic (PV) reliability system, and testing is performed by simulating the ETAP program by creating a complete and accurate electric power system modeling by integrating power circuit data that will later be implemented directly [17]–[19]. Hybrid system installation in buildings has already been studied, such as developing hybrid photovoltaic-electrical energy storage systems for building electricity generation and supply [20], [21]. The installation of a hybrid PV system in school buildings is carried out using data from this study. Because all activities of the educational process of daily activities cannot be separated from the use of electrical energy sources, especially during academic activities, practicum, bureaucratic administration, worship, events, and other activities, consumers will no longer be burdened by increasingly expensive electricity tariffs. The power requirements and costs for electrical energy in schools are relatively significant due to the quantity of buildings and loads. Then, at peak loads, renewable energy sources can lower grid network demand to meet the school's electrical energy needs [22]. It is a school initiative to assist renewable energy development activities, albeit on a modest scale. A smart electricity network, also known as a smart grid, will be introduced in the future to manage bigger amounts of renewable energy so that electrical energy may be used as efficiently as possible [23]. Of course, in order to ensure network reliability, the grid to be developed must be stable during the application process. The inclusion of an on-grid photovoltaic system will help to lower the daily electricity load; however, due to the absence of wind speed in the North Sumatra region, the wind turbine will be less efficient in converting wind energy for hybrid PV installations in the school environment. Based on the findings of this study, real-world implementation and software simulations of adding electricity generated by solar and wind turbines are required to serve as a standard for future large-scale development of hybrid PV usage. The purpose of this paper is to do a feasibility analysis of adding grid-connected hybrid photovoltaic systems to reduce electrical loads. The benefits of hybrid PV installation will later become the basis for PV development on a small scale or scale, especially with an impact on 4 main dimensions, namely finance, energy, environment and society [24], [25].

2. METHOD

The analytical method in this study uses an electric power tariff system to determine the use of electric power in the form of kWh. By considering the continuity of the availability of power to the load. The ETAP simulation is based on the optimization value and stability of the HSGC power plant design system. The research approach tends to produce efficient energy management. Determining the ideal operating conditions for the power system will offer input data for error calculations and stability assessments. The Newton Raphson approach is used to complete the power flow design [26], [27]. The method has the advantage of solving power flow problems by solving a set of nonlinear equations to calculate the magnitude of the voltage and the phase angle of the voltage at each bus [28], [29]. The data needed at the school (MTs Parmiyatu) include: i) data on the coordinates of the school's location, ii) data on potential solar and wind energy in the school environment, iii) data on the load (kW) of the school's electricity network system, iv) and data school distribution transformer specifications, and v) photovoltaic and wind turbine specification data. The single line diagram model scenario is useful for modeling the integration of photovoltaic (load flow analysis) photovoltaics and wind turbines in the power grid system. Two single line diagram models will be created, one without photovoltaic and one with photovoltaic for wind turbines. The results of the (load flow analysis) LFA simulation are the amount of power supplied to the load by the Distribution Transformer before and after the addition of photovoltaics to the school's electricity network (MTs Parmiyatu). Figure 1 shows the flow chart of a grid-connected hybrid power plant.

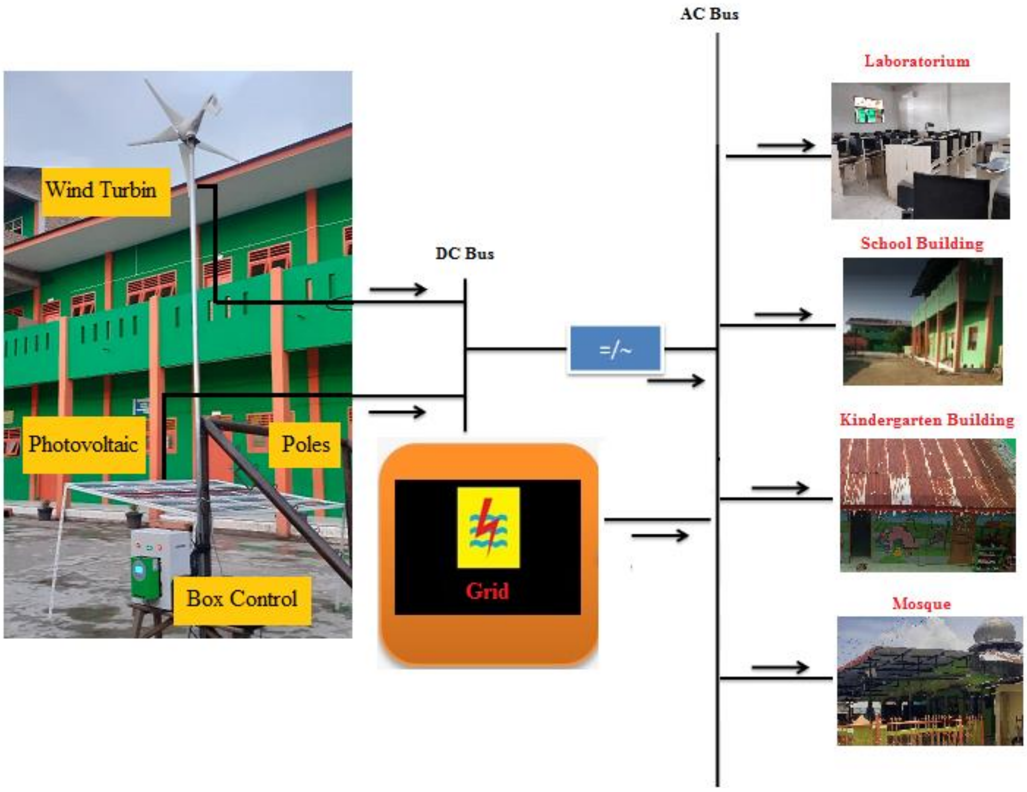


Figure 1. Grid connected hybrid power plant flow diagram

3. RESULTS AND DISCUSSION

The scenario design of the single line diagram model with ETAP Software is useful for viewing the (load flow analysis) LFA simulation of photovoltaic integration in the school electricity network system (MTs Parmiyatu). The (load flow analysis) LFA simulation results obtained are in the form of the amount of power distributed to the load by the Distribution Transformer before and after the addition of photovoltaic to the school electricity network (MTs Parmiyatu). For solar energy potential in schools (MTs Parmiyatu) it can be accessed through Meteorology Climatology and Geophysics Council data for the North Sumatra region. By inputting the average solar energy potential of 4.8 kWh/m^2. In obtaining the value of the power capacity of the photovoltaic, what is used in the calculation is the number of working hours of the sun to produce maximum power from the Photovoltaic. Therefore, the average data on solar energy potential is divided by the standard test condition, which is 1000 W/m^2.

$$Total\ Hours\ of\ Solar\ Performance = \frac{4800\ Wh/m2}{1000\ Wm2} \quad (1)$$

Total hours of solar performance = 4.8 h.

3.1. Data processing

Processing of calculations and data analysis of the comparison of the amount of power supplied to the load by distribution transformers, as well as simulation of power flow before and after the addition of photovoltaic and wind turbines. There are 2 single line diagram models that will be designed, namely without photovoltaic and addition with photovoltaic. Utilization of ETAP software for simulation, design, monitoring, control, optimization, and automated power systems ETAP will make it possible to conceptualize the collector system, determine wind penetration, and conduct network interconnection studies.

3.2. Simulation stage

ETAP software includes comprehensive renewable energy models combined with full spectrum power system analysis calculations for accurate simulation, predictive analysis, equipment sizing, and wind and solar field verification. Photovoltaic array analysis software solution to model, analyze, and study the impact of solar power generation on the power grid. Wind turbine generator analysis is carried out by modeling, analyzing and studying the impact of onshore and offshore wind turbine generators on the electric power network. Calculation of 4 case studies and analysis in terms of power settings connected to the grid network. The following is a case calculation on the addition and initial study of the addition of a hybrid photovoltaic that is connected to the grid network. PV power regulation consists of photovoltaic power regulation in school buildings, photovoltaic power settings in laboratories, photovoltaic power settings in mosques and photovoltaic power settings in kindergarten buildings. The calculation results will be simulated in the ETAP software. To support software performance in optimal PV installation in conducting simulations, PV specifications are needed as shown in Table 1.

Table 1. PV selection specifications used in the ETAP software

Characteristics	Specification
Peak Power / Pmax	250 W
Power Tolerance Range	+3%
Open Circuit Voltage / Voc	37.6 V
Rated Voltage / Vmp(V)	30.50 V
Short Circuit Current / Isc	8.67 A
Rated Current / Imp	8.21 A

3.2.1. Photovoltaic power management in school building

From the School Building load data including the offices of all employees and the principal's room, the power that must be generated from photovoltaic is 9.7 kW. To design a photovoltaic panel that will be used, it is necessary to pay attention to the voltage rating on the electricity network. It is known that the voltage on the electricity network is 0.4 kV, then the voltage on the photovoltaic panel must also be ± 0.4 kV. To get the voltage on the photovoltaic panel in accordance with the voltage rating on the electricity network, it can be done by installing the photovoltaic panel in series which is determined through as (2).

$$PV_{Series} = \frac{Voltage\ On\ Grid}{Voltage\ On\ PV}$$
$$PVseries = \frac{400\ V}{30.5\ V}$$
$$PV_{Series} = 13.11 \quad (2)$$

So, for a voltage of 0.4 kV it takes 13.11 photovoltaic panels or rounded up to 14 panels that are installed in series. The power generated from the 14 photovoltaic panels is obtained from the (3).

$$PV = P_{photovoltaic} \times PV_{series}$$
$$PV = 250\ W \times 14 \text{ Panels}$$
$$P = 3.5 \text{ kW} \quad (3)$$

To generate a power of 3.5 kW, the photovoltaic panels are installed in parallel which is determined by the (4).

$$PV_{Parallel} = \frac{P_{out}}{P_{series}}$$
$$PV_{Parallel} = \frac{9.7\ kW}{3.5\ kW}$$
$$PV_{Parallel} = 2.7 \text{ kW} \quad (4)$$

So, for a power of 9.7 kW, 3 units of photovoltaic panels are installed in parallel so that the solar panel reliability system in supplying the load becomes more efficient.

3.2.2. Photovoltaic power management in the laboratory

From the laboratory load data (computer load) it is found that the power that must be generated from the photovoltaic is 3.25 kW and to design the photovoltaic panel to be used it is necessary to pay attention to the voltage rating on the electricity network. The installation of photovoltaic panels in series is determined through the (5).

$$PV_{Series} = \frac{Voltage\ On\ Grid}{Voltage\ On\ PV}$$
$$PV\ series = \frac{400\ V}{30.5\ V}$$
$$PV_{Series} = 13.11 \quad (5)$$

So, for a voltage of 0.4 kV it takes 13.11 photovoltaic panels or rounded up to 14 panels that are installed in series. The power generated from the 14 Photovoltaic panels is obtained from the (6).

$$PV = P_{photovoltaic} \times PV_{series}$$
$$PV = 250\ W \times 14 \text{ Panels}$$
$$P = 3.5 \text{ kW} \tag{6}$$

To generate a power of 3.5 kW, the Photovoltaic panels are installed in parallel which is determined by the (7).

$$PV_{Parallel} = \frac{P_{out}}{P_{series}}$$
$$PV_{Parallel} = \frac{3.25\ kW}{3.50\ kW}$$
$$PV_{Parallel} = 0.92 \approx 1 \tag{7}$$

So, for a power of 3.25 kW, 1 unit of Photovoltaic panels is installed in parallel so that the solar panel reliability system in supplying the load becomes more efficient.

3.2.3. Photovoltaic power settings in mosque

From the mosque load data (AC load, lamps and other electronics) it is found that the power that must be generated from photovoltaic is 6.50 kW and to design the photovoltaic panels that will be used it is necessary to pay attention to the voltage rating on the electricity network. The installation of photovoltaic panels in series is determined through the (8).

$$PV_{Series} = \frac{Voltage\ On\ Grid}{Voltage\ On\ PV}$$
$$PV\ series = \frac{400\ V}{30.5\ V}$$
$$PV_{Series} = 13.11 \tag{8}$$

So, for a voltage of 0.4 kV it takes 13.11 photovoltaic panels or rounded up to 14 panels that are installed in series. The power generated from the 14 photovoltaic panels is obtained from the (9).

$$PV = P_{photovoltaic} \times PV_{series}$$
$$PV = 250\ W \times 14$$
$$P = 3.5 \text{ kW} \tag{9}$$

To generate a power of 6.50 kW, the photovoltaic panels are installed in parallel which is determined by the (10).

$$PV_{Parallel} = \frac{P_{out}}{P_{series}}$$
$$PV_{Parallel} = \frac{6.50\ kW}{3.5\ kW}$$
$$PV_{Parallel} = 1.8 \approx 2 \tag{10}$$

So, for a power of 6.50 kW, 2 units of photovoltaic panels are installed in parallel so that the solar panel reliability system in supplying the load becomes more efficient.

3.2.4. Photovoltaic power management in kindergarten building

From the load data of Kindergarten Building, it is found that the power that must be generated from photovoltaic is 3.25 kW and to design the Photovoltaic panels that will be used, it is necessary to pay attention to the voltage rating on the electricity network. The installation of photovoltaic panels in series is determined through the (11).

$$PV_{Series} = \frac{Voltage\ On\ Grid}{Voltage\ On\ PV}$$
$$PV\ series = \frac{400\ V}{30.5\ V}$$
$$PV_{Series} = 13.11 \tag{11}$$

So, for a voltage of 0.4 kV it takes 13.11 photovoltaic panels or rounded up to 14 panels that are installed in series. The power generated from the 14 photovoltaic panels is obtained from the (12).

$$PV = P_{photovoltaic} \times PV_{series}$$
$$PV = 250\ W \times 14$$
$$P = 3.5\ \text{kW} \quad (12)$$

To generate a power of 3.5 kW, the Photovoltaic panels are installed in parallel which is determined by the (13).

$$PV_{Parallel} = \frac{P_{out}}{P_{series}}$$
$$PV_{Parallel} = \frac{3.25\ kW}{3.5\ kW}$$
$$PV_{Parallel} = 0.92 \approx 1 \quad (13)$$

So, for a power of 3.06 kW Photovoltaic panels are installed in parallel as much as 1 unit so that the solar panel reliability system in supplying the load becomes more efficient.

3.3. Single line diagram hybrid PV modeling in 4 cases

The single line diagram modeling with ETAP software was carried out in 2 scenarios, namely the single line diagram model without the addition of a photovoltaic wind turbine and the single line diagram model with the addition of photovoltaic to the school electricity network (MTs Parmiyatu). Then the addition of PV and wind turbines is simulated in 4 different building cases as shown in Table 2. The simulation was carried out with 2 single line diagram modeling, namely before and after the addition of photovoltaic with the load being distributed from the distribution transformer. Electrical energy consumption in each panel is simulated in ETAP software.

Table 2. The performance of frequency 4 case modeling for data validation

		Case			
		Frequency	Percent	Valid percent	Cumulative percent
Valid	Kindergarten building	1	25.0	25.0	25.0
	Laboratory	1	25.0	25.0	50.0
	Mosque	1	25.0	25.0	75.0
	School building	1	25.0	25.0	100.0
	Total	4	100.0	100.0	

3.4. Single line diagram model without adding photovoltaic and wind turbine

The first single line diagram modeling scenario is without the addition of photovoltaic and wind turbines to the school electricity network system (MTs Parmiyatu), as shown in Figure 2. In Figure 2 it can be seen that the school network system (MTs Parmiyatu) consists of a 20/0.4 kV distribution transformer which has 4 load panels, namely the school building, laboratory, mosque, and kindergarten building. The simulation results using ETAP 12.6.0 software using load flow analysis obtained the value of the voltage drop. Data on the voltage drop of the MTs Parmiyatu environmental electricity network before the addition of photovoltaic and wind turbines can be seen in the Table 3.

Table 3. Data voltage drop before adding photovoltaic and wind turbine

No	Panel trans formator	Drop voltage (%)
1.	School building	0.2
2.	Laboratory	0.1
3.	Mosque	0.3
4.	Kindergarten building	0.1

3.5. Single line diagram model with addition of photovoltaic

Single line diagram modeling for scenario two without the addition of photovoltaic wind turbines in the school electricity network system (MTs Parmiyatu), as shown in Figure 3. In Figure 3 it can be seen that the addition of photovoltaic is carried out on each load panel, namely the school building, laboratory, mosque and kindergarten building. The simulation results using ETAP 12.6.0 software using load flow analysis obtained the voltage drop value. Data on the drop voltage of the school electricity network system (MTs Parmiyatu), after the addition of photovoltaic can be seen in Table 4.

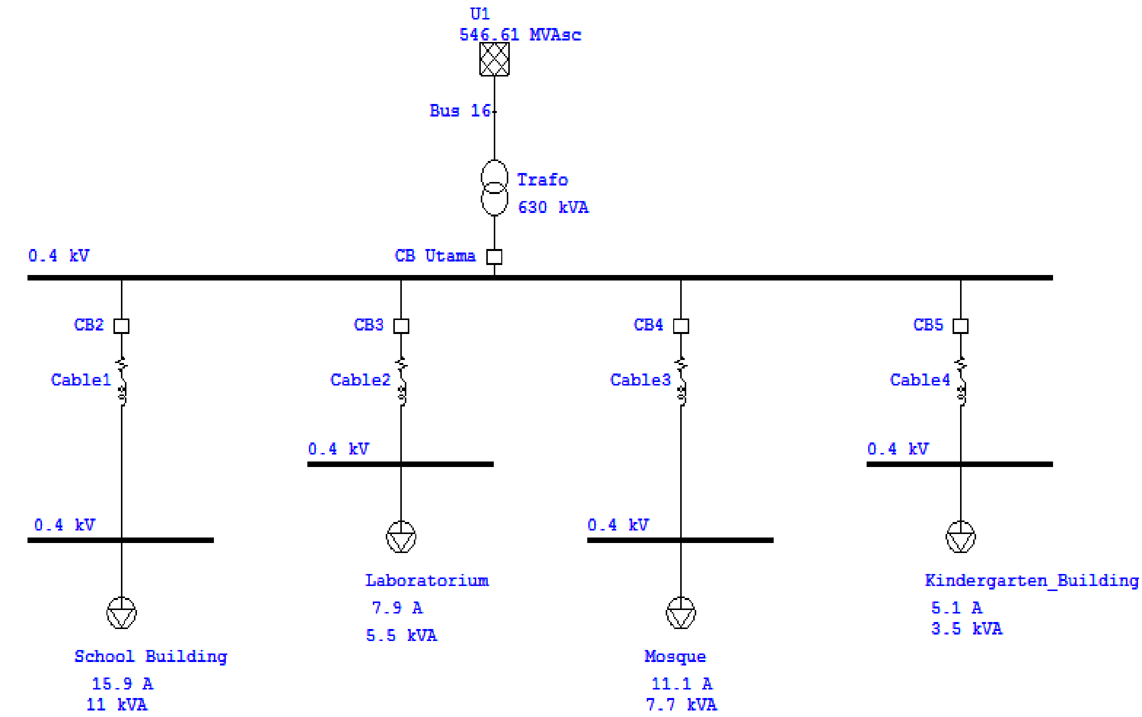


Figure 2. Single line diagram model without adding photovoltaic and wind turbine

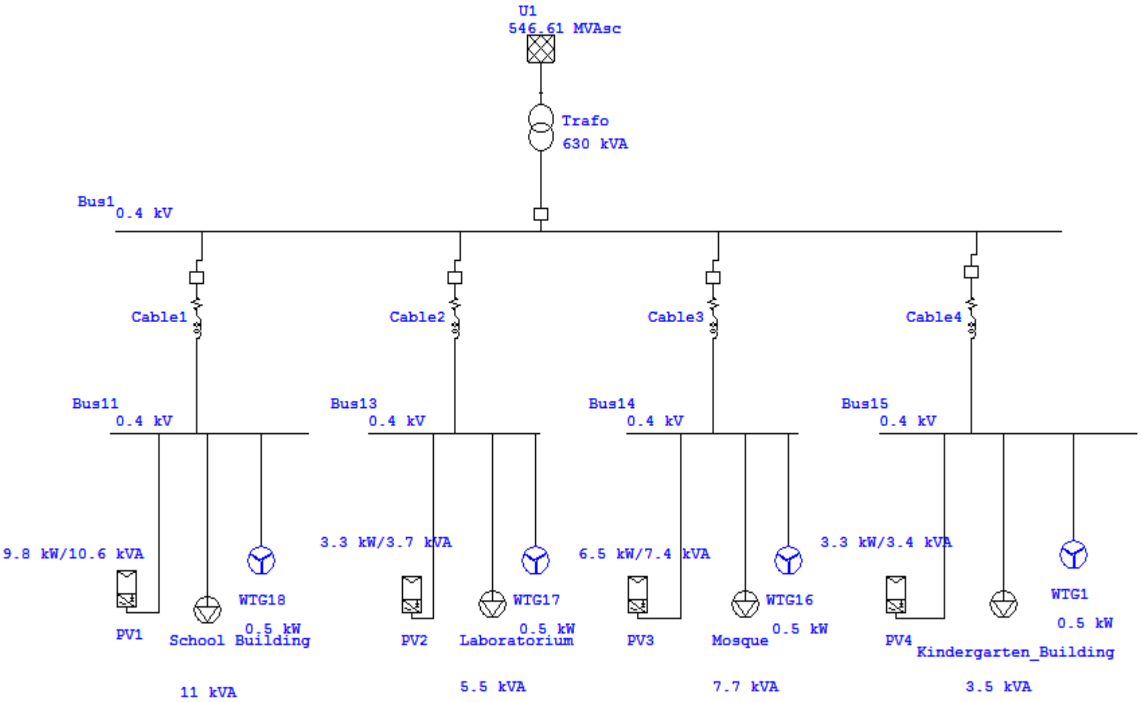


Figure 3. Single line diagram model with addition of photovoltaic and wind turbine

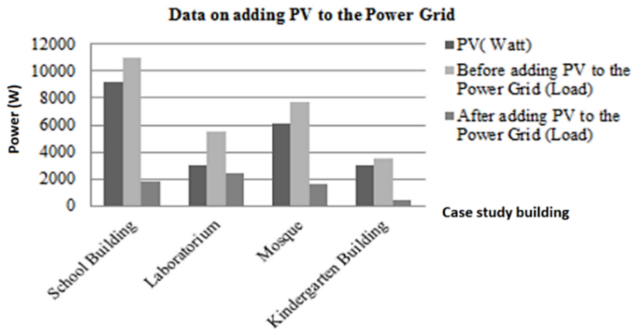
In Table 4 it can be analyzed that there are 4 load units served by the distribution transformer, including the burden of the school building, laboratory, mosque and kindergarten building. Comparison of voltage drop before and after the addition of photovoltaic. The value of the voltage drops decreases with the integration of photovoltaic and for the wind turbine there is no energy supply because the output produced is very small. In the school building panel, which has a voltage drop of 0.15%, it is reduced after the addition of photovoltaic and wind turbines, where the value is also for the laboratory, mosque, and kindergarten building panels. From this comparison, it can be said that photovoltaic and wind turbines can affect the voltage drop in the power grid system, this is due to the addition of power from the photovoltaic wind turbine to each load which results in reduced power borne from the power grid system.

Table 4. Data drop voltage after adding photovoltaic and wind turbine

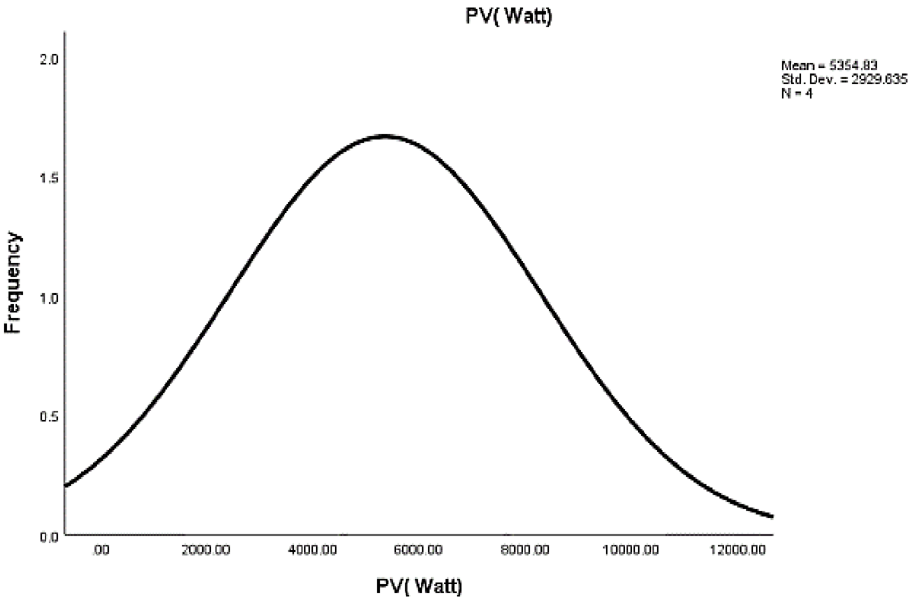
No	Panel trans formator	Drop voltage (%)
1.	School building	0.15
2.	Laboratory	0.10
3.	Mosque	0.11
4.	Kindergarten building	0.09

3.6. Data analysis with photovoltaic addition

In the data analysis carried out specifically by looking at the comparison of the addition of photovoltaic, this is because in real field testing the wind turbine cannot work properly. Several factors that affect the wind turbine, one of which is the wind speed that moves only reaches a value of 1.7 m/s. To see the simulation results data from the addition of photovoltaic in Figure 4.



(a)

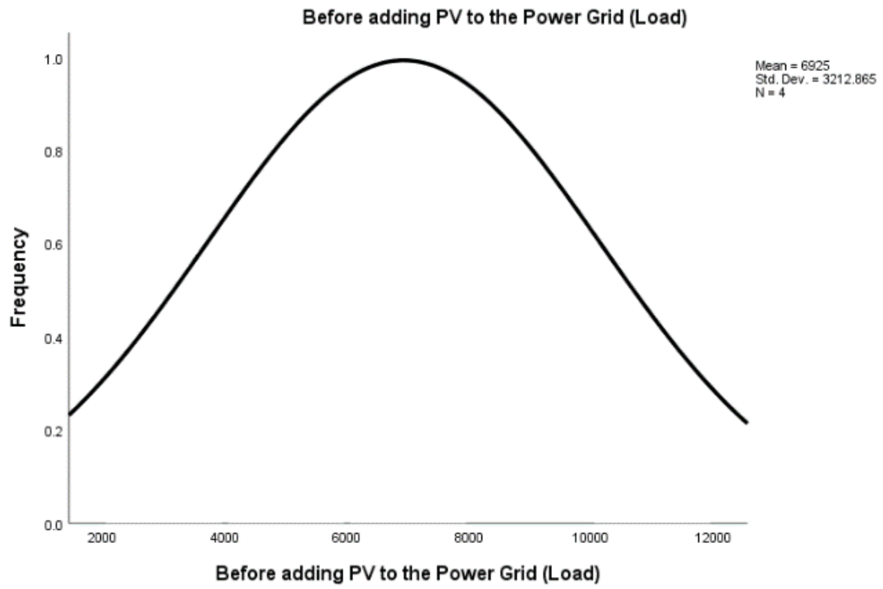


(b)

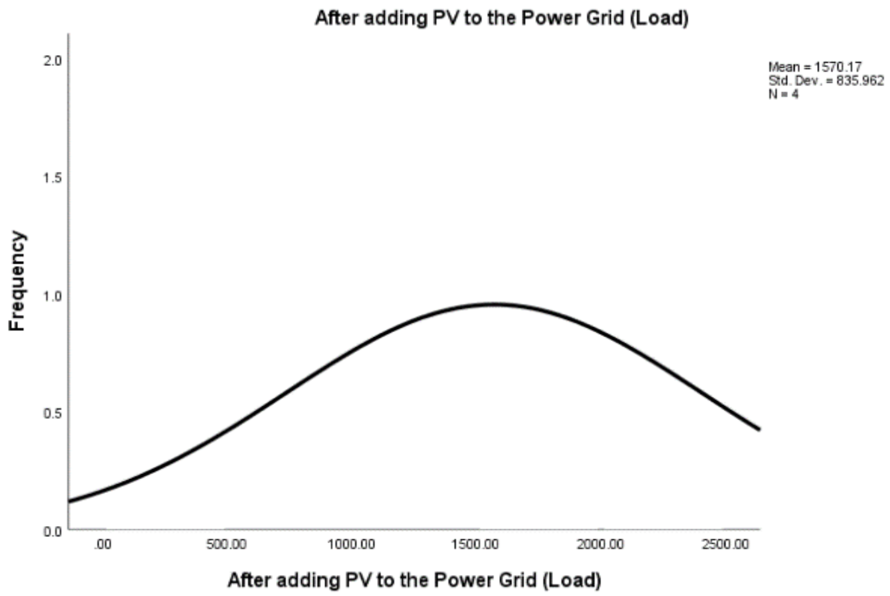
Figure 4. Graphical simulation model of the PV addition power relationship at load: (a) data on the addition of connected PV to the grid and (b) graphic of electrical energy supply (kWh) from the integrated grid on PV

From Figure 4(a) it can be seen that there are differences in the supply of electrical energy from grid in each school panel. The addition of energy from Photovoltaic reduces the supply of electrical energy from PLN at each school panel. Then Figure 4(b) is a simulation of PV power output data that has been integrated on the grid based on the data results from Figure 4(a). The simulation was carried out with 2 single line diagram modeling, namely before and after the addition of photovoltaic with the load being distributed from the distribution transformer. To see the comparison of electrical load reduction on the graph before and after the addition of PV in Figure 5.

The simulation that occurs in Figure 5 results in 2 scenarios, it can be seen that there are graphs before and after adding PV to the load-connected grid network. Figure 5(a) is the simulation result when the hybrid PV is added to the main grid source, then Figure 5(b) is simulated when the hybrid PV is added to the grid source with the result that the frequency decreases in the electric load.



(a)



(b)

Figure 5. Graphs before and after adding PV to a load-connected grid network: (a) the simulation results when building with the main source of the grid and (b) simulation when the grid source is added hybrid PV

4. CONCLUSION

After running the simulation before and after the addition of the on-grid PV system to the electricity grid system, it is possible to draw the conclusion that the results of the comparison of the power supply from the grid before and after the addition of PV when the conditions are integrated with each other include the burden of school buildings, laboratories, mosques, and kindergartens. in reducing the use of the load is quite efficient. This conclusion can be reached after determining that the simulation was run before and after the addition of the on-grid PV system to Before and after the installation of the HSGC system, the voltage drop may be mitigated to some degree by including on-grid photovoltaic technology. As a result of the installation of photovoltaic cells and wind turbines, the voltage drop across the panel of the School Building has been reduced by 0.15%. On the laboratory panel, which now has a voltage drop that is 0.05% lower than it was before the installation of solar and wind turbines, mosques, and other renewable energy sources, both the mosque's panel, which had a voltage drop of 0.11%, and the kindergarten building's panel, which had a voltage dip of 0.09%, had their voltage drops reduce after the addition of solar and wind turbines, respectively. It is possible to draw the conclusion from this comparison that on-grid photovoltaic coordination can have an effect on voltage drop in the electric power grid system, whereas for the wind turbine itself, this coordination does not have a significant impact because the wind speed in the North Sumatra region is very inconsistent.

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