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Improvement the Capacity of Electrical Energy in Residential Using PV With On-Grid System

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Abstract. As one of the renewable energy sources, sunlight or solar energy is considered appropriate to be one of the alternative sources of electrical energy that can be used. In this study, an on-grid system simulation model was carried out using PV. The goal is to find out the characteristics of the energy obtained using the control logic algorithm. In this simulation model design, previously calculations were carried out to determine pv capacity, because it will be adjusted to the power capacity used in residential houses. In this discussion, it is in accordance with the electricity needs of residential houses of 1,500 Watts or hourly energy conumsion of 1.5 KWh. This electrical load will be on at 07.00 to 17.00, meaning that this electric load will consume electric power for 10 hours. Then the total energy consumed per day is 1.5 KWh. In this simulation, 2 100 Wp (Watt peak) solar panels with an output voltage of 12 V DC are used. In a day, it can more or less produce electricity of 200 Wp x 10 hours of heating = 2,000 Wh.

1 Introduction

Electrical energy is a very important energy for human life, the current need for energy as a driver of life is increasing. This is driven by a surge in the number of human populations, especially in developing countries, while the availability of existing power supplies is also unable to meet these increasing needs, therefore a renewable energy source is needed [1]. Renewable energy in general can be defined as energy obtained from natural sources that exist around humans and we can obtain it for free. As one of the renewable energy sources, sunlight or solar energy is considered appropriate to be one of the alternative sources of electrical energy that can be used. Solar energy is a clean, renewable energy, and is available for a long time. This solar energy source is also the most commonly utilized renewable energy today and this solar energy can be converted into electrical energy [2]. The use of sunlight using solar panels as a power plant began to be developed to reduce the use of fossil fuels. Solar panels have advantages such as being environmentally friendly because they do not have waste that causes pollution, are cheap to maintain, and are easy to apply [3].

Solar panels are semiconductor components that can convert solar energy into electrical energy. However, because the different levels of solar energy irradiation on a daily basis cause the output power of the solar panels to vary and not be optimal, therefore a model that

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resembles the characteristics of actual solar cells is needed, so we can conduct a simple experiment from some data to find out how to get the maximum possible performance and maintain it [4]. From the last decade there has been an increase in demand for electricity, this will lead to a depletion of fossil fuels resulting in an increase in costs. To solve this problem, micro-grids (MG) are introduced and supported by renewable distributed generating systems (DG), such as, micro turbines, fuel cells, solar photovoltaics (PV) and wind generation due to limited fossil fuels [5]. From the above sources, solar energy provides tremendous benefits including environmental friendliness, surplus availability and low installation costs due to advanced technology and mass production [6]. Distributed generating systems (DG) are increasingly recognized as an alternative source to conventional central power supplies. The main component of the on-grid PV system is the GTI which functions to regulate the voltage and current received from the solar panels and ensures that the power supply is in line with the grid power. On the AC side, the sinusoidal output is synchronized to the grid frequency (50Hz) [7]. A study conducting a cost analysis and the benefits of adopting solar energy technology showed that PV systems are more cost-effective in the long run compared to PLN's electricity supply. Although the initial investment is relatively high in the PV system, it is a reliable investment in the long term [8]. Renewable energy sources such as wind or PV cannot provide a sustainable energy supply for loads due to weather changes [9]. Electrical energy systems using photovoltaics have an increasing role in on-grid systems, this is due to the decline in the world's conventional energy sources. A stand-alone photovoltaic energy system is a complete set of interconnected components for converting direct solar radiation into electricity and generally consists of PV plants, batteries, DC converters, inverters, and system loads [10]. A photovoltaic system also called a solar power system or PV system, is a power system designed to supply solar power that can be used through photovoltaics [11]. Photovoltaic (PV) systems connected to the network operating in changing weather conditions have been modeled and this model has been developed mainly for residential use [12]. Photovoltaic power systems can be used to provide an alternative source of electric power to homes to meet their daily energy needs through the direct conversion of solar radiation into electricity [13]. For on-grid solar energy systems, homes use electricity from local grids and PV arrays to meet consumers' own power demands and reduce electricity bills. The PV panel is connected with inverters and networks that directly convert DC power into AC power (220 V, 50 Hz) [14]. In on-grid systems, available solar energy may exceed the demand during high sunlight intensity. This study was conducted to explore the possibility of using PV systems in housing [15]. On-grid systems without storage cannot supply power on nighttime or rainy days when there is insufficient sunlight. Again, power output from certain renewable energy sources, such as wind and solar, can be intermittent [16]. Solar energy will be converted into AC using an inverter and DC energy obtained from the sun will be stored in batteries to provide DC supply to DC equipment [17]. The electrical energy produced and stored completely in the battery is sufficient to meet the demand for total loads throughout the year, which means a suitable solution to solve the power grid outage [18].

In this study, an on-grid system using PV is proposed to supply electrical energy to residential areas. This system is used to help meet the electricity needs of the utility grid. With this system, excess electrical energy can be channeled to the utility grid. Inverter settings use logic control method.

2 PV Modeling

Solar cell simulation models have been formulated [19] to predict and calculate potential output of PV cells. The solar cell can be simulated with the circuit shown in Figure 1. The correlation between the cell current I and the cell voltage V is shown in equation as follows

$$I = I_{pv} - I_0 \left\{ e^{\left(\frac{V+R_s I}{nV_t}\right)} - 1 \right\} - I_{sh} \qquad (1)$$

In ideal conditions Rsh has a very large value so that the current flowing in the resistance is small, while Rs has a very small value to avoid a drop in the output voltage. The current flowing in the resistance Rsh can be expressed mathematically by the following equation

$$I_{sh} = \frac{V + R_s I}{R_{sh}} \qquad (2)$$

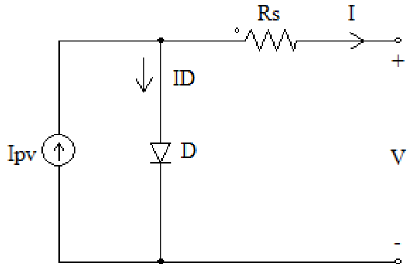

Fig. 1. PV equivalent circuit.

3 On-Grid System

A PV system connected to a grid that uses solar energy sources can generate electricity wherever it is connected to a utility grid. When sunlight hits the solar panel, the panel converts the energy of the sun into electricity that can power the load. Whether power is drawn from the PV system or whether the mains load power remains the same. The DC power of the PV system is reduced / boosted by the DC-DC boost / back converter respectively. The DC power generated by the DC-DC converter is converted to AC by the inverter. This AC current is the standard current used for most loads. Current flows from the inverter to the electrical control panel, which distributes the current to all loads. An optional tracking meter can track the total power consumption of all loads, the total performance of the solar system, and more. These tracking systems often include live display systems or online monitors that can track the amount of power the system is using and its performance at a particular point in time. If the output of the solar system exceeds the consumer during the day, the surplus power will be fed back to the grid. In this case, the electricity meter will rotate in the opposite direction. The fact that a solar array consumes more power than it produces overnight means that the extra energy needed to carry out the load is drawn from the grid as usual. Using batteries as energy storage in these grid-connected systems is not a fallback option as the grid provides the required load in the event of a PV power failure. A typical grid tide PV system is shown in Figure 5 [20].

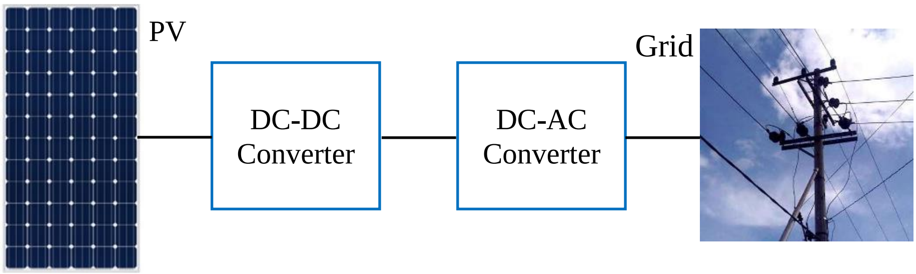

Fig. 2. On-grid system.

4 On-Grid System Design

This system does not require a battery storage system, the components used in the on-grid system are PV, DC-DC converters, and inverters. The inverter used is an inverter whose output voltage can be synchronized with the utility grid AC voltage. The on-grid system can work when there is a source from the utility grid, in this case the frequency and phase angle of the utility grid source become the reference.

4.1 Load Capacity Calculation

In the design of this model, previously calculations were carried out to determine the PV capacity, because it will be adjusted to the power capacity used in residential houses. In this discussion, it is in accordance with the electricity needs of residential houses of 1,500 Watts or hourly energy conumsion of 1.5 KWh. This electrical load will be on at 07.00 to 17.00, meaning that this electric load will consume electric power for 10 hours. Then the total energy consumed per day is:

- ✓ Total energy = 1.5 KW x 10 = 1.5 KW/day.
- ✓ So the overall total energy required is 1.5 KWh.

For electrical energy storage systems used 12 Volt batteries with a capacity of 100 Ah each. For battery needs, the calculation is carried out as follows:

- ✓ The electric current per day is 1,500 / (12 x 10) = 12.5 Amperes
- ✓ Number of batteries = 1,500 Watts/day : (12 x 50 Ah) = 3 batteries
- ✓ Battery supplied power = 1800 watts

The need for batteries with consideration can serve the needs of every day without sunlight , then, if we use a battery that is 50 Ah 12 V, then we need 3 batteries (50 x 12 x 3 = 1, 800 watts).

4.2 Capacity Calculation

From the calculation of energy consumption above of 1.5 Kwh or 1,500 Wh, then we can choose the size of the solar panel we need. In this design we use a 100 Wp (Watt peak) solar panel, that is, this panel will produce a maximum of 100 Watts at a voltage of 12 V DC per hour, so that if this solar panel is installed a day (07.00-17.00 = 10 hours) assuming it is not cloudy or the intensity of sunlight is constant then this solar panel can produce electricity 100 Wp x 10 hours = 1000 Wh or as much as 1 KWh. Power output of a 100 Wp solar panel is produced at a temperature condition of 25 ^{o}C, pressure 1.5 atm, with a light intensity of 1000 W/m^2. Actually the average 100 Wp solar panel will only produce an average electrical energy of about 300 Wh – 400 Wh in one day. This is due to the factor of unequal sunlight intensity throughout the day. In the design using 100 Wp solar panels, the following calculations are used: 1,500 / 100 x 10) = 2 solar panels. So the electricity generated is 2 units x 100 Wp = 200 Watts per hour of heating at the peak of heating. In a day, it can more or less produce electricity of 200 Wp x 10 hours of heating = 2,000 Wh.

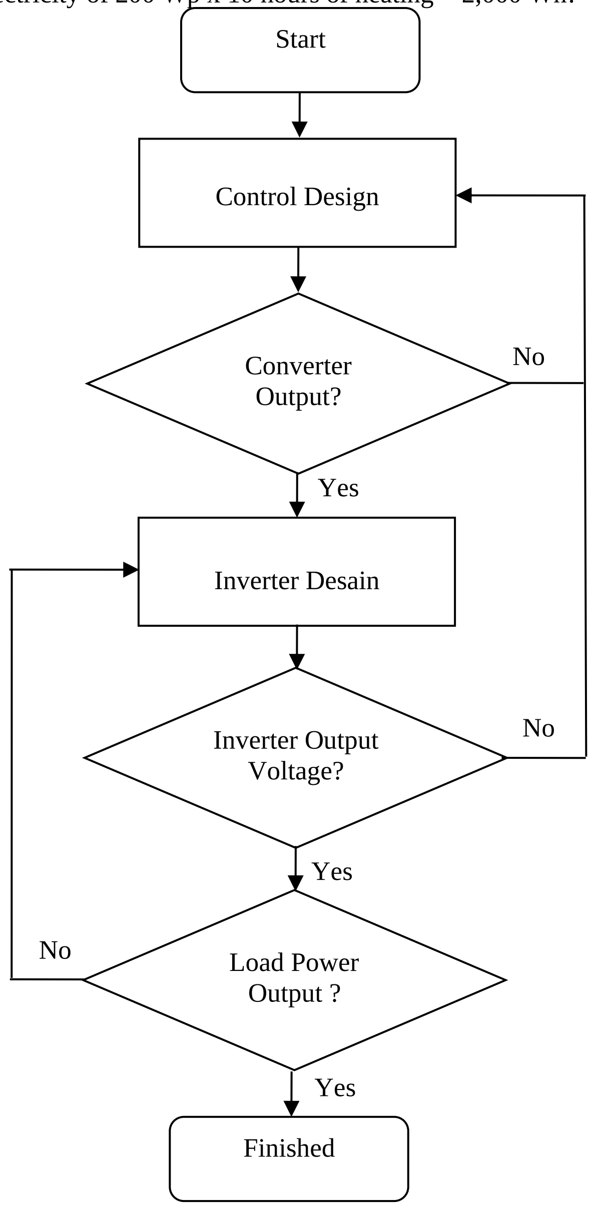

Fig. 3. Research algorithm.

4.3 Simulation Model Design

In making a simulation design using Matlab, the number and value of components are entered according to the results of manual calculations. For PV in this simulation using type TSM-230PD05.10. The amount of PV used two solar panels are connected in series. Meanwhile, in testing the intensity and temperature of the sun for PV, it is carried out with changes in the *irradiance* of solar energy and temperature as follows:

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- ✓ *Irradiance* 1000 W/m^2, temperature 20 ^oC
- ✓ *Irradiance* 1000 W/m2, temperature 35 ^oC
- ✓ *Irradiance* 500 W/^{m2}, temperature 20 ^oC
- ✓ *Irradiance* 500 W/^{m2}, temperature 35 ^oC

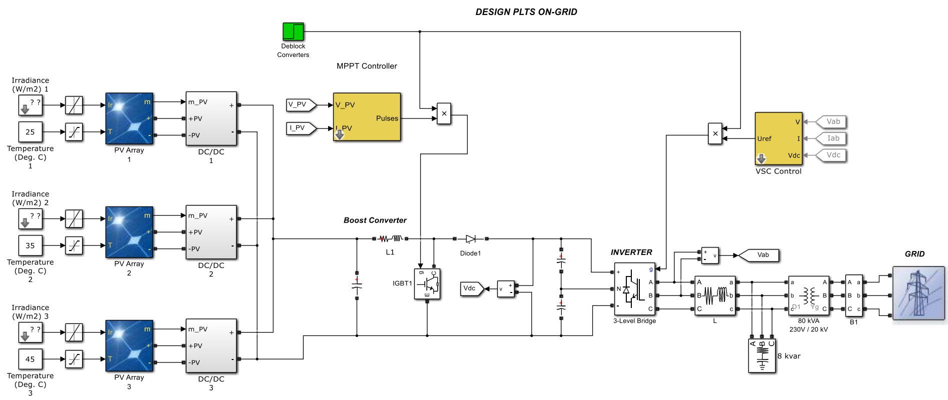

Fig. 4. On-Grid System Model.

5 Results and Discussion

The number of strings and the number of solar panels used in accordance with the planning, the intensity of solar radiation used is 1000 W /m2 with different temperatures for each string. In the simulation model multiple DC converters are used.

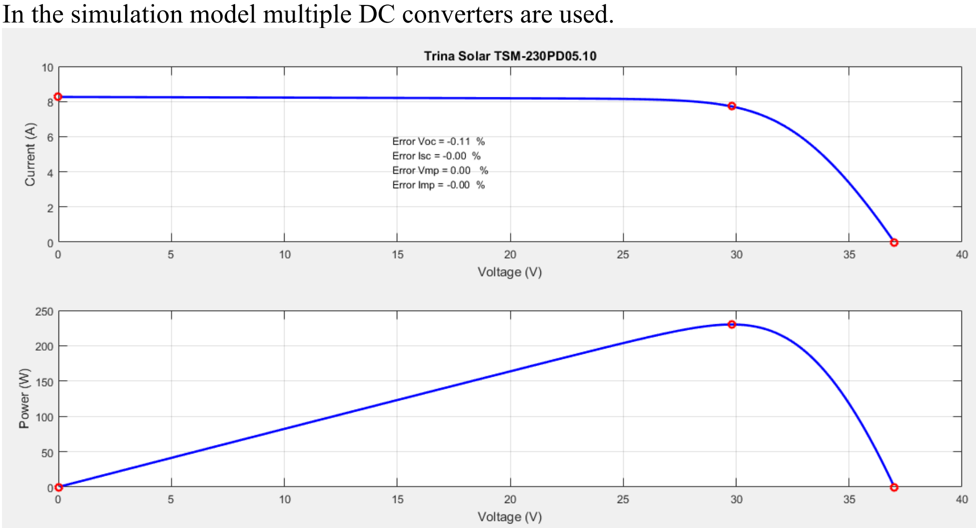

Fig. 5. PV characteristics.

Figure 5 shows the PV characteristics used in the on-grid system design.The measurement of the PV output power in the on-grid system was carried out at the same temperature and radiation intensity, namely at 1000 w/m2 and 30 C. In addition, the results of the measurement of the PV output power were compared with the use of different controls on the DC-DC converter. Figure 6 shows the PV output power when the DC-DC converter uses the PI control. The resulting PV output power is 1250 Watt. The output power reaches the reference value in 0.17 seconds. Figure 7 shows the PV output power when using a

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conventional control, which is 1100 watts. It takes 0.18 seconds to reach the reference value. The output power produced is lower when compared to using a PI control. In addition, the time required to reach the reference value is also 0.01 seconds longer.

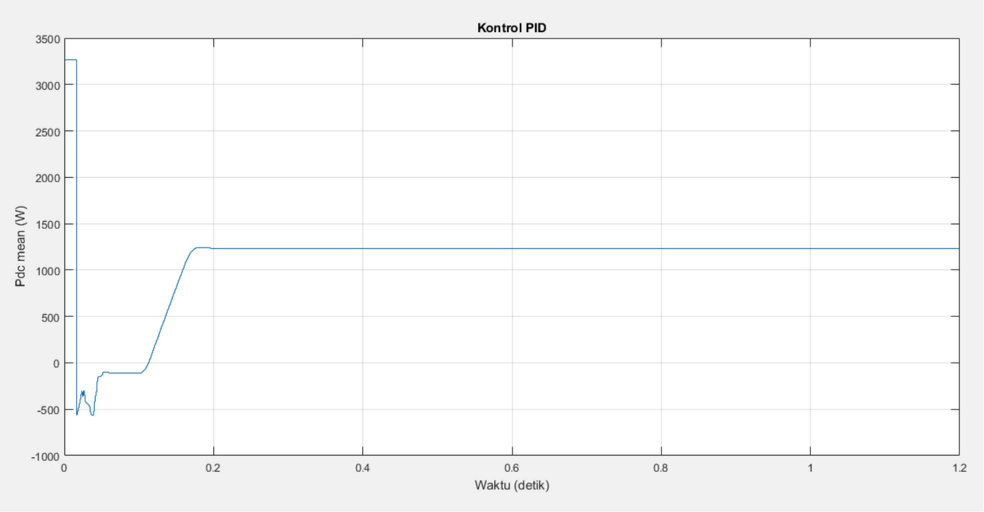

Fig. 6. PV output power with PI control.

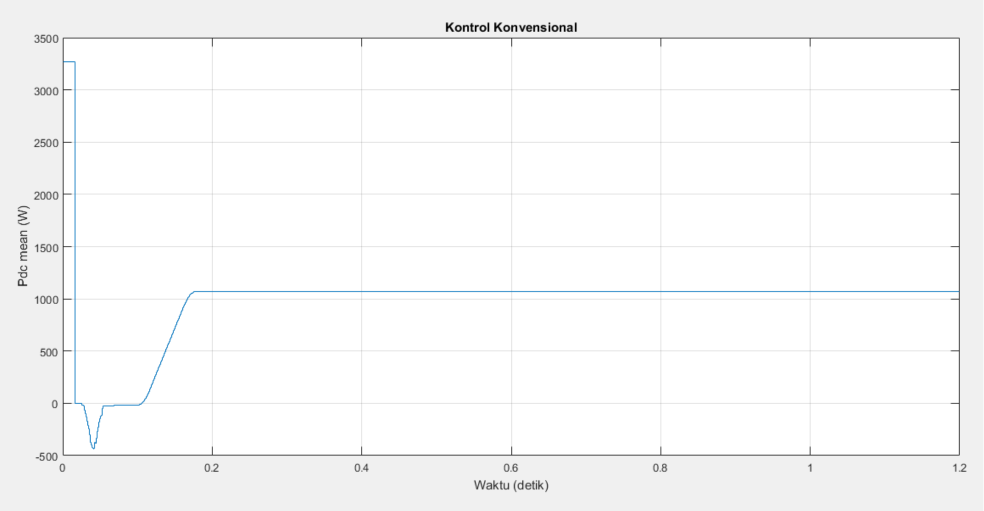

Fig. 7. PV output power with conventional control.

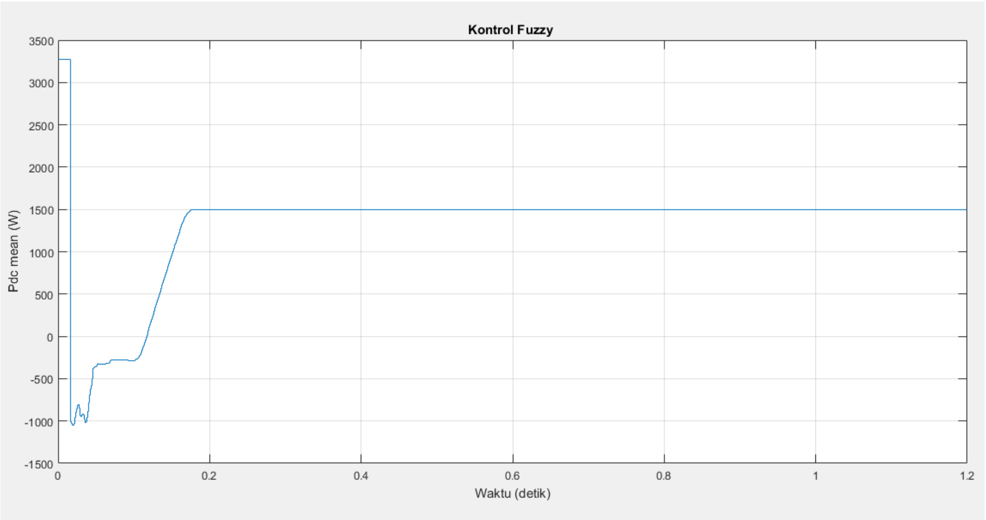

Fig. 8. PV output power with logic control.

Figure 8 shows the PV output power using control logic. The resulting output power is 1500 watts. The time required to reach the reference value is 0.165 seconds. Of the three control methods used in the DC-DC converter, control logic is able to adjust the DC-DC converter to produce maximum output power.

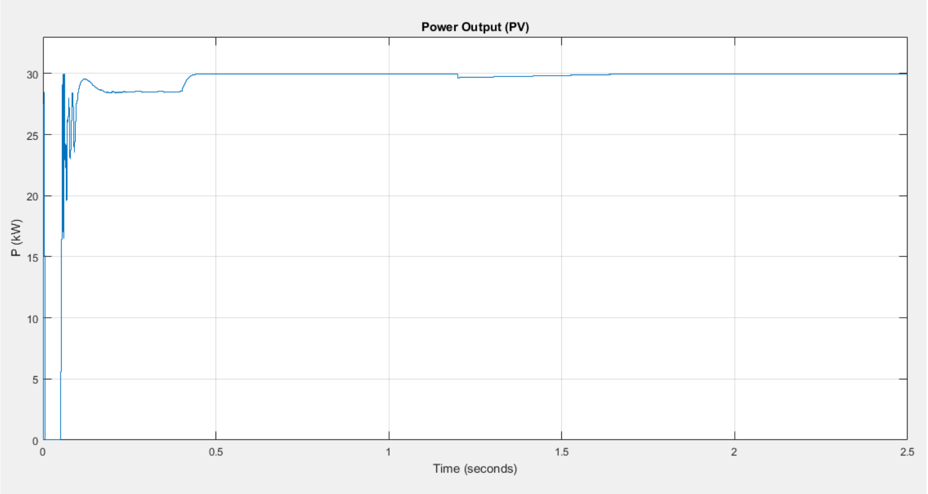

Fig. 9. PV output power (1000 W / m2, 25 C).

Figure 9 – 11 shows the PV output power in several residential houses connected to the DC bus. Measurements are made by looking at changes in the intensity of solar radiation and ambient temperature. Figure 9 shows the results of the PV power output test with 1000 W/m2 irradiation and a temperature of 25 C which produces a maximum power output of 30 KW. While Figure 10 shows if the irradiance is reduced by 700 W/m2 it will affect the amount of PV output power, which is 27.5 Kw.

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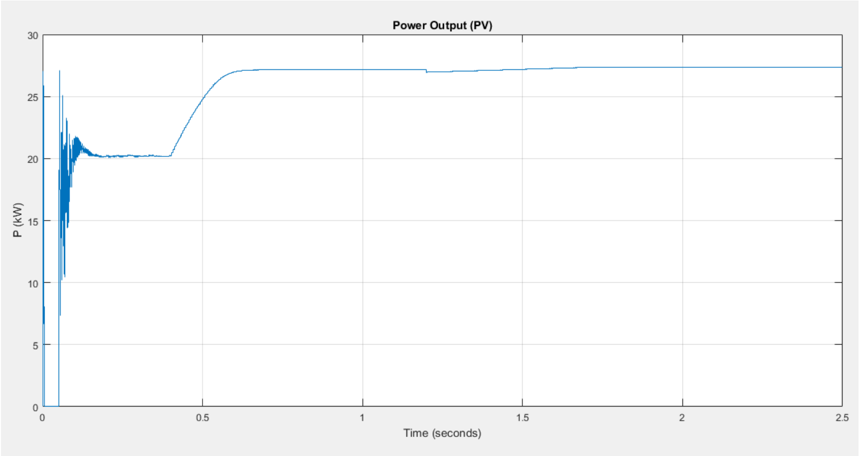

Fig. 10. PV output power (700 W / m2, 25 C).

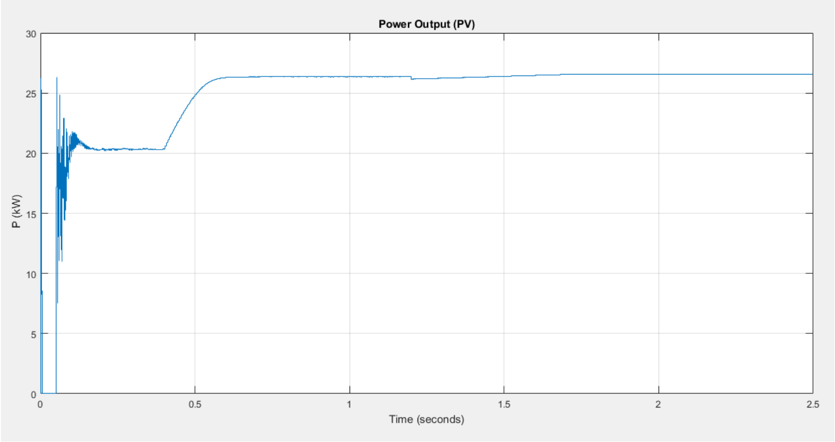

Fig. 11. PV output power (700 W / m2, 35 C).

Figure 11 shows, if the temperature rises to 35°C it does not cause too much change in the PV output power, which is 27.6 Kw. The DC voltage generated by the DC-DC converter is the input voltage of the inverter

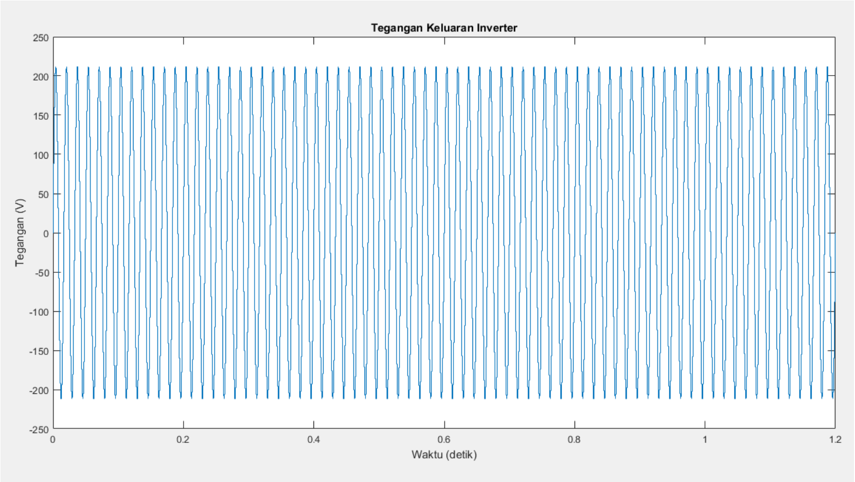

Fig. 12. Inverter output voltage.

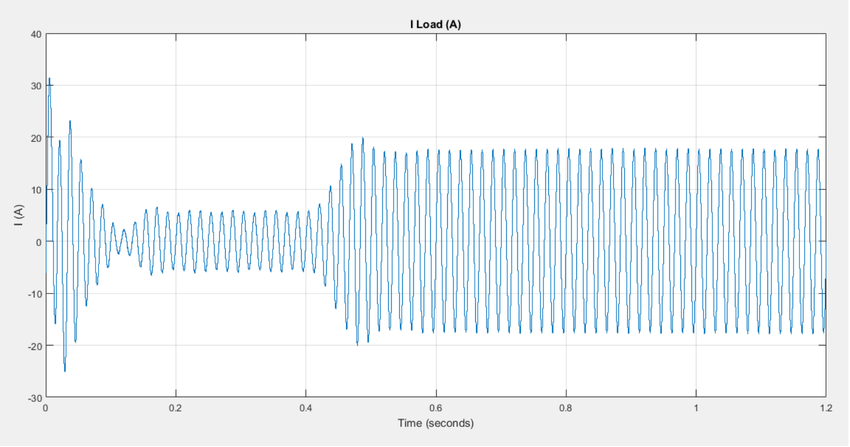

Fig. 13. Load current connected to the grid.

Figure 12 shows the output voltage generated by the inverter of 220 V AC. The resulting voltage is in sync with the utility grid voltage. While Figure 13 shows the load current, changes in load current occur from 0.18 seconds to 0.42 seconds.

6 Conclusions

In this research design, 1,500 watts of residential electrical power is used or an hourly energy consumption of 1.5 KWh, and this electrical load will turn on at 07.00 to 17.00. Therefore, for the electrical energy storage system used 3 12 Volt batteries with a capacity of 100 Ah each, and the power provided by the battery = 1800 watts. Because the power capacity used is 1,500 watts, this design uses 2 solar panels of 100 Wp (Watt peak) with an output voltage of 12 V DC. The output of 100 Wp solar panels is produced at a temperature of 25 C, a pressure of 1.5 atm, with a light intensity of 1000 W/m2 is 2 units x 100 Wp = 200 Watts per one hour of heating at the peak of heating. In a day, approximately 200 Wp x 10 hours of electricity can be generated. Heating = 2,000 Wh. In the design of the simulation model, it can be seen that the use of fuzzy logic controller control in the boost converter is able to produce higher output power when compared to other control methods. In addition, the output voltage overshoot is also lower. To determine the performance of the on-grid system, it can be developed using the PID-fuzzy algorithm, and implemented based on the simulation results using an FPGA or microcontroller. To overcome the limitations of solar energy when solar energy begins to fall after noon, it is recommended to use batteries as a backup energy source. Therefore, it is recommended that in residential homes, the use of PV can be used in two ways (standalone and grid connected) interchangeably.

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