Efficiency of 9KWp Sun Tracking Photovoltaic in Palembang, Indonesia

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Abstract. Solar energy is one of the renewable energy potentials as an alternative energy substitute for fossil fuels in Indonesia. Indonesia that is located on the equator is very profitable because it always gets sunlight throughout the year. Indonesia has an average of the solar energy potential of 4.8 KWh / m² equivalent to 112,000 GWp. Light or sunlight can be converted into electricity using solar cell technology (Photovoltaic). Electrical energy generated from the solar panels will be maximized if the solar cell is always perpendicular to the direction of the focus of the sun. Sun tracker is a system that can automatically control the solar cell to remain focused on the direction of the sun. This paper is a case study to determine the efficiency of solar panels that use the sun tracking system with monocrystalline silicon type with 9 KWp capacity. The solar panel system is located in Plaju Palembang (South Sumatra, Indonesia) where the average daily radiation levels are 4.96 kWh /m². To determine the efficiency of the solar panel, then Data collection was performed for two months, namely in December 2017 and January 2018.

1. Introduction
Utilization of solar energy as an alternative energy source to overcome the energy crisis, especially petroleum, which occurred since the 1970s has received considerable attention from many countries in the world. In addition to its unlimited amount, the utilization does not cause pollution that can harm the environment. Light or sunlight can be converted into electricity using solar or photovoltaic cell technology. Business opportunities in the field of solar energy power plants are so great. Indonesia has the potential of solar energy amounted to 4.8 KWh / m² equivalent of 112,000 GWp ten times the potency of Germany and Europe [1-3].

The main components of solar power plant systems (PLTS) using photovoltaic technology is a solar cell. Currently, there are many solar cell manufacturing technology. The latest commercially used conventional solar cells use crystalline silicon wafer technology which the production process is quite complex and expensive. In general, the conventional solar cell manufacturing process begins with the purification of the silica to produce solar grade silica (ingot), followed by the cutting of silica into silica wafer [4-6]. Furthermore, silica wafers are processed into solar cells, and solar cells arranged to form a solar module. The final stage is to integrate solar modules with BOS (Balance of System) into solar systems. BOS is supporting components used in solar systems such as inverters, batteries, control systems, and others [7-10].

Solar energy is the potential energy for alternative energy in Indonesia. However, the efficiency of the produced by solar panels is relatively low. Electrical energy generated from the solar panels will be greatest if the solar cell is always perpendicular to the focus direction of the sun. Therefore, we need
a system that can automatically control the solar cell in order to remain focused on the direction of the sun, namely solar tracker. Solar tracker is a system to maximize power production of Solar Power Plant (SPP) by directing the SPP to the direction of the sun. The use of solar tracker improves production efficiency solar power electricity between 20-50 percent depending on the location and type of tracker used [11,12].

Solar power plants are power plants that convert solar energy into electrical energy. Solar cell panels capturing sunlight and convert it into electrical current which is then stored in batteries so that it can meet daily energy needs. The electricity generation can be done in two ways, namely:
1. Directly using photovoltaics. Photovoltaic transform light energy directly into electricity using the photoelectric effect.
2. Indirectly through the convergence of solar energy. PLTS with this centralized system means that power plants are carried out centrally and supply power to consumers through distribution networks. The system is suitable and economical in areas with high population density.

Currently, the development of SPP in Indonesia has a strong enough base from the policy aspect. However, at the implementation stage, the existing potential has not been used optimally. Technologically, Technologically the photovoltaic (PV) industry in Indonesia is only able to do at the downstream stage, which is producing solar modules and integrate them into SPP, while solar cells are still imported. Though solar cells are the main component, but the most expensive in SPP systems. Prices that are still high are an important issue in the development of the solar cell industry. Various solar cell manufacturing technology continuously researched and developed in the framework of efforts to reduce the price of solar cell production in order to compete with other energy sources. Considering that the electrification ratio in Indonesia has only reached 55-60% and almost all areas that have not been electrified are rural areas that are far from the power plant, so PLTS that can be built in almost all locations are very suitable alternatives to develop. From 2005 to 2025, the government has planned to provide 1 million Solar Home System with a capacity of 50 Wp for low-income and hybrid 346.5 MWp solar power to remote areas. Until 2025 the government plans there will be approximately 0.87 GW of solar power capacity installed [13].

1.1. Type of Solar Power Plant (SPP) System Connection
Electrical Generating Solar Power Plant (SPP) is installed with 3 kinds of installation, namely:
1. Off Grid Systems (Stand Alone System), this power plant systems rely on solar energy as the only source of primary energy to produce electrical energy.
2. On Grid System, a series of power plant systems will keep related to the electricity network originating from PLN by optimizing the use of energy from solar panels to produce electricity as much as possible.
3. Hybrid systems, power plant systems utilizing solar energy as the main source to be combined with a generator or other renewable energy sources as a backup energy source.

The main characteristic that generally made the difference between the three systems is the use of batteries as electric energy storage media. In the Off Grid system, the battery becomes an imperative (mandatory) part of solar power as the major energy source. While in the On Grid system, the battery is not mandatory because solar power is not the main source of electrical energy. Likewise, with the Hybrid system, batteries must be adjusted to the conditions of use and the choice of primary energy [14].

2. Materials and Methods
Materials or equipment that are used in this study is the SPP with a design capacity of 9 Kwp equipped with a sun tracker installed in PT Pertamina (Persero) RU III Plaju. The equipment used, namely:
Sky Energy Monocrystalline Solar Module 250 Wp
With the following technical data:
- Rated Maximum Power-Pmax : 250 W
- Maximum Power Voltage-Vmp : 30.9 V
- Maximum Power Current-Imp : 8.12 A
- Open-Circuit Voltage Voc : 37.8 V
- Short-Circuit Current Isc : 8.74 A
Efficiency: 16.07%
Module: 60 Cells
Rated Maximum Power-$P_{\text{max}}$: 4,167 W
Maximum Power Voltage-$V_{\text{mp}}$: 0.515 V
Maximum Power Current-$I_{\text{mp}}$: 8.119 A
Inverter Conext RL 3000E
With the following technical data
MPPT voltage range, full power: 160 - 500 V
Operating voltage range: 90 - 550 V
Starting voltage: 100 V
Max. input voltage, open circuit: 550 V
Number of MPPT: 2
Max. input current per MPPT: 10 A
Custom – GTI Solar Module Single Axis Tracking System
Monitoring System – Schneider Ethernet Box

2.1. Structural design of on-grid solar power plants

![Figure 1. Design of on-grid solar power plants](image-url)
2.2. Functional design of on-grid solar power plants

![Diagram of On Grid Power Plants]

**Figure 2.** Single Line Diagram of On Grid Power Plants
3. Result and Discussion
The discussion of performance comparison is carried out with two data, including the difference in solar panel production at every hour and the difference in the efficiency of solar panels every day. Production observations of electric power generated by solar panels were done in October, November, December 2017 and January 2018. The data is taken from the electrical power produced each day.

![Figure 3. Daily power data graph of solar power plants 9 kWP](image)

From the graph of daily production and high efficiency solar panel shows that the highest average power production occurred in October 2017 and the lowest average power production occurred in December 2017. The low average production during December 2017 due to frequent rains and cloudy in the intensity of solar radiation received by solar panels is less than in October 2017, November 2017 and January 2018.

Daily power production of solar panels are always varied each day, this condition is influenced by weather conditions and ambient temperature.

The average production of solar panel power is 9 KWP each month are as follows:
- Month October 2017 : 30.6 KWp
- Month November 2017 : 26.5 KWp
- Month December 2017 : 22.1 KWp
- Month January 2018 : 26.8 KWp

The efficiency (η) with a maximum in the solar panel Monocrystalline Silicon solar cell type installed in PT.Pertamina (Persero), Refinery Unit III with average solar radiation in Palembang of 4.96 kWh / m², is happened on:
- October 14, 2017, the efficiency (η) = 14.1%, with a power output: 40.9 KWh.

The average efficiency of solar power panels 9 KWP each month are as follows: 10.5% in October 2017; 9.1% in November 2017; 7.6% in December 2017; and 9.2% in January 2018

4. Conclusions
Based on the data analysis and graphs made in this evaluation, it was concluded that:
1. SPP maximum power of 40.9 KWh is still not good ie + 50% of design capacity (design capacity of 9 KWP) with the operational assumptions SPP is 9 hours daily.
2. The efficiency (η) with a maximum in the solar panel Monocrystalline Silicon solar cell type installed in PT. Pertamina (Persero) Refinery Unit III with average solar radiation in Palembang of 4.96 kWh / m² is on October 14, 2017, the efficiency (η) = 14.1%, the average efficiency of solar power panels 9 KWP each month are as follows:
- Month October 2017 : 10.5%
- Month November 2017 : 9.1%
- Month December 2017 : 7.6%
- Month January 2018 : 9.2%

The efficiency of solar panels with the sun tracker is still below the design efficiency is 16.07%.

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