# Performance and Energy Saving Analysis of Grid Connected Photovoltaic in West Sumatera

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#### Article Info ABSTRACT The paper presents performance and energy saving analysis of 1.25 kWp grid Article history: connected photovoltaic system under difference weather condition in West Received Apr 19, 2016 Sumatera. The measured data were performed during weather data that often Revised Nov 23, 2016 occur in West Sumatra i.e. sunny, overcast, raining and cloudy. Accepted Dec 6, 2016 The synchronizing process successfully done even bad weather conditions when sunlight was low automatically. Photovoltaic in average start producing power from 7:00 AM to 6:00 PM for normal or clear sky, however Keyword: under overcast, raining and cloudy weather, the PV power decreased and disconnected earlier before sunset. During intermittent raining, overcast and Energy saving cloud covered the PV power output show an irregular profile. The PV energy Grid connected PV saving performed for three residential connection cases: 1300 VA, 900 VA Performance analysis with subsidized and 900 VA without subsidized. The solar PV installation have more benefits and energy saving for 1300 VA, 900 VA without subsidized with payback period around 8.5 years. However, the 900 VA with subsidized take longer 20.8 years, but still in PV lifespan 25 years. In the future, household subsidies may be reduced or eliminated, the solar energy will be viable alternative of energy resources when it can produce electricity at a cost equivalent to utility grid PLN rate. Copyright © 2016 Institute of Advanced Engineering and Science. All rights reserved. Corresponding Author:

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# 1. INTRODUCTION

The Installation of renewable resource based distributed generation have been increased in many countries with their policy of renewable energy and consideration of carbon emissions. Among renewable energy sources, solar energy is the most alternative has been developed and reliable [1]. Reduction of electricity subsidies and the implementation of incentive made installations solar power generation have increased over the houses and buildings [2] [3] [4]. Electrical energy resources in Indonesia are still dominated by fossil fuel, especially from coal and oil. Considering the reduction in availability of fossil fuel resource and increasing awareness for environmental protection, causing researchers continues to seek alternatives of new and renewable energy by utilizing the local resources.

Indonesia is an equatorial country and consists of more than 17,508 islands of which 6,000 are inhabited and 1,000 are permanently settled. Indonesia's solar irradiation stands at 4.8 kWh per m2 per day, however only 71.02MWp of solar PV has been installed, according to ESDM figures [5]. West Sumatera is one of province lies at the equator line which has high solar irradiation will always be exposed to the sun for 10-12 hours a day and almost all parts of West Sumatera to get a relatively uniform radiation intensity. The climatic condition of West Sumatera is specified as tropic climate which is arid and damp whereas the upland areas are dominated by moderate temperature. Therefore, the research in synchronizing process and electrical energy capture of PV system in West Sumatera need to analyzed.

Off grid solar PV particularly presents many opportunities. The dispersed, mountainous and seismically active geography of the West Sumatera archipelago have made off grid systems as a right solution. However, the integration of solar PV units into an existing distribution network can improve the voltage profile and reduce total system losses [6]. The grid connected PV have been installed in many countries abroad such as in Ireland [7], and United Arab Emirates [3]. These two types of PV installation will be viable energy resource alternative in Indonesia, but it performance and benefits need to be analyzed.

The performance of solar panels is dependent upon sunlight it receives [8]. In general, the sun will rise from the east toward the west in seconds, minutes and hours. As well as the sun wills light change in position from south toward the north in monthly [9]. Therefore, synchronizing and solar power produced not same, but depend on time and its location. This paper will report the PV performance during synchronize at the morning and out of synchronize at the evening time as well as energy produce and saving.

This paper is organized as follows. In section 2, describes the grid connected PV test system including performance of synchronizing process and energy saving analysis methods. The implementation results and discussion are presented in section 3. Finally, section 4 concludes the paper.

# 2. RESEARCH METHOD

In this research, a photovoltaic system is installed for 1.25 kWp with on grid inverter 2 kW. The PV system is part of a research solar energy located on the 4rd floor of Electrical Engineering Building, Universitas Andalas, West Sumatera, Indonesia. The solar panel was used IPV250P which maximum power in STC 250 Watt, 31.2 Volt polycrystalline silicon type. One unit Inverter on grid ICA Solar 2kW with MPPT SNV-GT-2001SM type used to convert the DC power to AC power as well as synchronized device. The overall setup of the 1250 Wp Photovoltaic system, consist of circuit breaker, grid-tied inverter and busbar as shown in Figure 1. The monitoring system of photovoltaic recorded the data of voltage, current and power for further analysis i.e. Synronization and energy saving.



Figure 1. Grid connected 1.25 kWp Photovoltaic system

# 2.1. Syncronization Process

The grid connected photovoltaic done after synchronizing the output phase, frequency and voltage with the utility grid.On-grid PV inverter, converts DC to AC electricity, which is synchronous to power grid. The magnitude of the sinusoidal voltage produced by the PV inverter must be higher than the magnitude of the sinusoidal voltage of the utility grid PLN. The phase of output voltage the PV inverter must be the same as the phase of the electrical system (Grid). Third, the frequency of the sinusoidal voltage produced by the PV inverter must be equal to the frequency of the sinusoidal voltage produced by the grid.

#### 2.2. Energy Saving Analysis

The costs have been spent for 1.25 Wp PV systemwas IDR 30.000.000. These cost have covered five units of 250 Wp solar panels and one unit 2kW grid-tied inverter. This cost used as inisial inverstation in PV installation energy saving analysis. Saving analysis performed for the following three cases:

- Case 1: 1300 VA household's customers.
- Case 2: 900 VA household's customers without subsidized
- Case 3: 900 VA household with subsidized.

The 900 VA household's customers have twos cenarios i.e. with subsidized and without subsidized. The power produced and payback period will be used as consideration parameters for feasibility grid connected PV installation in West Sumatera area.

The energy generated by PV system can be calculated from average power multiplied by time. The total energy over a certain time period will be calculated as equation (1).

$$\mathbf{E} = \int_{0}^{t} p(t) dt \tag{1}$$

Where: p(t) = instantaneous power (kW)

E = Daily energy generated (kWh)

t = time(s)

The electrical energy produces by PV system per year can be calculated using:

$$E_{years} = E * 365 \text{ days/year}$$
(2)

Energy saving can be obtained using equation (3):

Energy saving = 
$$E_{vears}$$
\* Electrical tariff (3)

The Indonesian government has already stopped providing electricity subsidy to residential customers who have subscribed electricity capacity of 1,300 volt ampere (VA) and 2,200 VA since earlier 2015. Therefore, the energy cost followed the tariff adjustment mechanism. Residential electrical tariff can be obtained from utility grid PLN website [10]. For July 2016 the 1300 VA tariff was IDR 1.412.66 per kWh. While for 900 VA connection, still have subsidized tariff of IDR 586.2 per kWh, but the Indonesian government have a plan to terminated subsidies for electricity subscriber swith connections of 450 VA and 900 VA. Without subsidized 900 VA tariff IDR 1,340 per kWh. Based on these utility tariff, energy saving for grid connected PV system can be analyzed.

# 3. RESULTS AND ANALYSIS

The monitoring system of photovoltaic recorded the data of voltage, current and power during synchronizing process between photovoltaic and utility grid PLN, at evening time and at morning time. Solar panels in average start producing power from 7:00 AM to 6:00 PM. The peak power time is from 10:00 AM to 3:00 PM with some fluctuations depending upon the weather conditions. The measurements were performed using this weather data that of ten occur in West Sumatera i.e. sunny, cloudy, over cast and raining.

#### 3.1. Performance Analysis

The PV system power generation under difference weather condition have been recorded in West Sumatera as shown in Figure 1. Solar panels in average start producing power from 7:00 AM to 6:00. The peak power time is from 10:00 AM to 3:00 PM with some fluctuations depending upon the weather conditions. During intermitten training, overcast and cloud covered the PV power output show an irregular profile.





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The PV current injection recorded data under difference weather condition show in Figure 2. The enlargement of this current curve are show in Figure 3 and Figure 4, which present the synchronization performances of grid connected photovoltaic under different weather condition. The Photovoltaic connected to grid at 7:14 AM and out of grid at 5:54 PM for normal or clear sky condition. The synchronizing process successfully done even bad weather conditions when sunlight was low automatically an shown in Figure 3. However, under overcast, raining and cloudy weather, the PV power decreased and disconnected earlier before sunset as shown in Figure 4. The 10-12 V voltage drop is there in on load condition after synchronized during sunlight rise at early morning time. The 3-4V voltage rise is there in offload condition when sunlight drops down in afternoon time. Figure 3 and Figure 4 shows that the synchronized time occurat 7:14 AM, even around 7:08 AM grid-tied inverter synchronize have been work.



Figure 2. PV Current injection under difference weather condition



Figure 3. Synchronized performance at morning time

The PV power and enegy produced in four difference weather condition are show in Table1. The result show that in sunny day with clear sky produced more power and energy than cloud covered sky. Therefore, the PV power and energy produced are highly dependent on weather condition. The power and energy produced will be used as consideration parameters for feasibility grid connected PV installation in West Sumatera.

Table 1.1 V Fower and Energy produced for four weather condition			condition
Cases	Average Power (Wp)	Energy (kWh)/day	Energy (kWh)/year
1st Case: Clear Sky	559.07	6.709	2,448.73
2 <sup>nd</sup> Case: Overcast	302.15	3.623	1,323.42
3rd Case: Raining	127.53	1.530	558.58
4th Case: Cloudy	451.36	5.416	1,976.96

Table 1. PV Power and Enegy produced for four weather condition



Figure 4. Out of synchronized performance at evening time

# 3.2. Energy Saving Analysis

Solar panels start producing power in average from 7:00 AM to 6:00 PM as shown in Figure 3 and 4. There are 12 hours that PV work and produces electric power per day. For recoded data on clear sky, the average power supplied to the grid was 559.07 Wp. By using equation (1), energy produced by PV system to be 6,709Wh per day. After one year operated the energy produced will be 2,448.73 kWh. Energy saving analysis performed using clear sky weather for the following three cases:

- 1. 1300 VA household's customers.
- 2. 900 VA household's customers without subsidized
- 3. 900 VA householdw ith subsidized.

The Indonesian government has already stopped providing electricity subsidy to subscribers who have electricity capacity of 1,300 VA and 2,200 VA since earlier 2015. Therefore, the energy cost followed the tariff adjustment mechanism. For July 2016 the 1300 VA tariff was IDR. 1.412.66 per kWh. While for 900 VA connection, still have subsidized tariff of IDR 586.2 per kWh, but the Indonesian government had a plan to terminated subsidies for electricity subscribers with connections of 4 50 VA and 900 VA. Without subsidized 900VA tariff IDR 1,340 per kWh.

The average electrical energy produced by PV system for one year is 2,474.7 kWh equal to energy saving IDR 3,459,218.12 3for 1300 VA, IDR 3,330,268.18 for 900 VA without subsidized and IDR 1,432,505.06 for 900 VA with subsidized. These saving then reduced from first investment cost for PV system installation year by year. The cumulative result of energy saving vs times hows as Figure 5.



Figure 5. Commulative energy saving

The Figure 5 shows the solar PV installation have more benefits and energy saving for 1300VA and 900 VA without subsidized with payback period around 8.5 years. However, the 900 VA with subsidized take longer 20.8 years, but still in PV life span 25 years. In the future, household subsidies maybe reduced or

eliminated, the solar energy will be viable alternative of energy resources when it can produce electricity at a cost equivalent to utility grid PLN rate.

# 4. CONCLUSION

The performance and energy saving analysis of grid connected Photovoltaic in West Sumatera have been presented in this paper. The synchronizing process successfully done even bad weather conditions when sunlight was low automatically. The PV power and energy produced are highly dependent on weather condition. There are 12 hours that PV work and produces electric power per day. For recoded data on clear sky, the average power supplied to the grid was 559.07 Wp or energy produced by PV system 6,709Wh per day. After one year operated the energy produced will be 2,448.73 kWh. However, in cloud covered skypower and energy produce are decreased. The solar PV installation have more benefits and energy saving for 1300VA, 900VA without subsidized with payback period around 8.5 years. However, the 900VA with subsidized take longer 20.8 years, but still in PV lifespan 25 years. In the future, household subsidies may be reduced or eliminated, the solar energy will be viable alternative of energy resources when it can produce electricity at a cost equivalent to utility grid PLN rate.

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#### REFERENCES

- [1] V.V Tyagi, N.A.A Rahim, N.A Rahim, and J.A.L. Selvaraj, "Progress in solar PV technology: Research and achievement.," *Renew. Sustain. Energy Rev.*, vol. 20, pp. 443–461, 2013.
- [2] S. Hagerman, P. Jaramillo, and M Granger Morgan, "Is rooftop solar PV at socket parity without subsidier?," *Energy Policy*, vol. 89, p. 8494, 2016.
- [3] Steven Griffit and R. Mills, "Potential of Rooftop Solar Photovoltaics in the Energy System Evaluation of United Arab Emirates," *Energy Strateg. Rev.*, vol. 9, pp. 1–7, 2016.
- [4] H. Shahinzadeh, M.M. Najaf Abadi, M. Hajahmadi, and A. Paknejad, "Design and economic study for use the photovoltaic systems for electricity supply in Isfahan Museum Park," *Int. J. Power Electron. Drive Syst.*, vol. 3, no. 1, pp. 83–94, 2013.
- [5] Ministry\_ESDM, "Rencana Strategis (Renstra) Direktorat Jenderal EBTKE Tahun 2015 2019," 2015.
- [6] Syafii and K.M. Nor, "Unbalanced Active Distribution Analysis with Renewable Distributed Energy Resources," *Telkomnika*, vol. 13, no. 1, 2015.
- [7] L.M. Ayompe, A. Duffy, S.J. Mc Cormack, and M. Conlon, "Measured performance of a 1.72 kW rooftop grid connected photovoltaic system in Ireland," *Energy Convers. Manag.*, vol. 52, no. 2, pp. 816–825, 2011.
- [8] A. Hiendro, R. Kurnianto, M. Rajagukguk, and Y. M. Simanjuntak, "Techno-economic analysis of photovoltaic / wind hybrid system for onshore / remote area in Indonesia TURBINE AC LOAD BATTERY GENERATOR," *Energy*, vol. 59, pp. 652–657, 2013.
- [9] Syafii, R. Nazir, and M. Hadi, "Improve Dual Axis Solar Tracker Algorithm based on Sunrise and Sunset Posistion," *J. Electr. Syst.*, vol. 11, no. 4, 2015.
- [10] PLN, "Tariff Adjustment bulan Juli 2016," 2016. [Online]. Available: http://www.pln.co.id/wp-content/uploads/2016/07/07\_TA.png.

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