Effect of Weather Dynamics to Energy Yield of Dual Axis Sun Tracker-Based Solar PV generation

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Abstract - Generally, solar PV Panel is constructed at fix tilted angle at different locations, such as: street light poles, rooftops, residential buildings, and canopy. The energy production from solar PV generation system is vary and influenced by site (location) and weather parameters. Solar PV generation analyzed in this research is Dual Axis Sun Tracker (DAST) Solar PV Generation. Dual axis sun tracker is a system controller to ensure solar PV panel following the sun path. Furthermore, energy production from DAST-based solar PV generation were measured and collected using energy meter as well as by using automatic weather station for the weather parameters. From these measrument data, it can be correlated the influence of weather parameters to the energy production from DAST PV generation system. The correlation between weather parameters and energy production are analyzed by statistical analysis using SPSS software and multiple linear regression models. From the results and analysis, it can be shown the amount of energy production from DAST-based solar PV Generation are influenced by weather parameters, namely: temperature, humidity, ultraviolet radiation, and solar radiation with significant level up to 98.2%.

Keywords - Dual Axis Sun Tracker, Energy, Photovoltaic, Weather

I. INTRODUCTION

Based on the regulation of the Ministry of Energy- Natural and Mineral Resources-Indonesia, to achieve an energy security, particularly in an electricity sector, the renewable energy sources must be utilized in the country [1]. The use of renewable energy source such as solar photovoltaic (PV) generation system will give some advantages, such as low operational and maintenance costs (OM Cost), clean energy (zero emission) as well as having a huge solar energy potential in the country [1],[2]. Energy production from solar PV generation system is greatly influenced by number of parameters, such as: solar panel technology type, solar radiation soure, and weather conditions. The weather parameters such as air humidity, outdoor temperature also influences the performance of solar PV Generation [3].

On the deployment of solar PV generation system, two mounting mechanisms are widely implemented, namely: fixed angle solar panel and sun tracker based solar PV generation. Furthermore, the advantage of sun tracker-based PV generation is the capability to track the location of solar soure, to have solar radiation coming to the solar panel with perpendicular angle. The effectiveness of the use of sun tracker shows capability to increase energy gain up to 22%-60% [3], [4].

The focus of this research is to analyse the correlation between the energy production from Dual Axis Sun Tracker-based solar PV generation system and weather parameters. Several field measurement and data collection were taken by using solar energy meter and Automatic Weather Station at the laboratory of Electrical Energy Conversion lab. Their correlation was then analyzed using graphical analysis methods and statistical analysis with the tools like SPSS and Excel.

The rest of this paper is organized as follows. In Section II, solar energy related theory is presented. Also presented in Section II, the process of data measurement and collection. A methodoly is presented in Section III to describe the processes that have been carried out. In the section IV, it shows the analysis of correlation between energy production of dual axis sun tracker-based solar PV generation and weather parameters dynamic. Finally, a conclusion is drawn in Section V.

II. OVERVIW OF SOLAR ENERGY

A. Solar Radiation

Solar radiation, often called the solar resource or just sunlight, is a general term for the electromagnetic radiation emitted by the sun. Solar radiation can be converted into another forms of energy, such as thermal and electricity, using a variety of technologies [5].

The energy radiated by the sun is around 7% ultraviolet light, 47% visible light and 46% infrared light. Its energy content at the distance of the earth from the sun is around 1.4 kW/m2. Not all this energy reaches the surface of the earth. Much of the shorter wavelength ultraviolet radiation is absorbed in the atmosphere. Water vapour and carbon dioxide absorb longer wavelength energy while dust particles scatter more radiation, dispersing some of it back into space. Clouds also reflect light back into space.

B. DAST-Based Solar PV generation system Dual

DAST-based solar PV generation is generation system that has vertical and horizontal axis to track the light source (sun) position to make incoming sun radition perpendicular with the solar panel surface, perpendicularly as show in Figure 1[3]. The position of solar panels which are always perpendicular to the incoming solar radiation can help to yield energy production up to 60% energy gain compared to PV generation at fix tilted angle. Furthermore, the dynamics of yielded energy from DAST-based solar pv generation are also strongly influenced by the surrounding weather conditions [9]. DAST-base solar pv generation used in this research is shown ini in Figure 1.

Figure 1. DAST-based solar PV generation

C. Automatic Weather Station

Automatic Weather Station (AWS) is an automatic weather station with the ability to monitor outdoor and indoor weather conditions. Weather parameters that can be measured include temperature, humidity, UV radiation, and solar radiation. The weather monitoring results are connected to the website in real time. AWS is installed at The Electrical Energy Conversion Laboratory in Department of Electrical Engineering, The University of Riau. The AWS used in this study is shown in Figure 2.

Figure 2. Automatic Weather Station at The Electrcal Energy Conversion Laboratory, Electrical Engineering Department, University of Riau

III. METHODOLGY OF REASEARCH

The experimental and data collection was conducted in December 2020 for 5 days measurement. Data collection on the influence of weather using AWS to energy production of DAST-based Solar PV generation was carried out for 5 days. The research location is located at the Electrical Engineering Laboratory, Faculty of Engineering, University of Riau where the its latitude ang longitude coordinate [6]. Geographically, it is located at north latitude 0.4822" N and east longitude 101.37659" E as shown in Figure 3.

Gambar 3. Research Location

Based on Figure 3. The red dot indicates the location of the research for collecting weather data and energy production of DAST-based PV Generation. In general, the location has an average value of relatively high temperature, moderate humidity, high UV radiation and solar radiation [7].

A. Descriptive and Inferential Statistic

In descriptive statistics, the aim method is to summarize and graphically represent data of a sample or a whole population. While in inferential statistics, not only for collecting numerical data as a sample from a population but this method also analyzes it and based on this analysis, draws conclusions with estimated uncertainties about the population [8]. A conclusion from sample data that is applied to the population has the probability of error and truth (confidence) expressed in the form of a percentage. This probability of error and truthis called the significance level [8].

The inferential statistic in this research aims to analyze the influence of weather parameters such as: temperature, humidity, UV radiation and solar radiation on the energy production of DAST-based solar PV generation by using using multiple linear regression analysis. The variable observed is the energy production of the solar PV generation system which is called the dependent variable Y_1.

The aformention weather parameters are called independent variables, namely: X_1,X_2,X_3, X_4 [9]. Before carrying out an inferential statistic analysis between variable X and variable Y, it is necessary to carry out several tests on each of these data. The tests were carried by using multiple linear regression analysis that aims to look at the relationship between 2 (more) independent variables (X) and the dependent variable (Y).

The multiple linear regression analysis consists of a determinant coefficient test, a simultaneous test (F), a partial test (T), and a regression equation model [10]. The target of coefficient of the determinant is to understand how big the percentage of influence of the independent variable (X) on the dependent variable (Y). Furthermore, F test aims to look at whether the independent variable (X) simultaneously affects the dependent variable (Y). While T test to know whether the independent variable (X) individually affects the dependent variable (Y) [11].

The regression equation model is the final stage of the regression statistical analysis method. The purpose of the regression model is to understand the constant value, the effect value of the independent variable (X) on the dependent variable (Y), and the form of the regression equation from the relationship between the independent variable (X) and the dependent variable (Y) [12].

Furthermore, the regression used in this research is a multiple linear regression that chosen based on the results of the classical assumption test. The test showed that the relationship between the independent variable (X) and the dependent variable (Y) formed a linear relationship [13]. The general form of the multiple linear regression equation can be seen in equation (1).

$$Y = \alpha + b1X1 + b2X2 + b3X3 + b4X4 + e \quad (1)$$

Dimana :

Y = Variabel Terikat

α = Koefisien Konstanta

X1 = Variabel Bebas 1

X2 = Variabel Bebas 2

X3 = Variabel Bebas 3

X4 = Variabel Bebas 4

e = error atau tingkat kesalahan

b1, b2, b3 = Koefisien Regresi masing masing variabel bebas.

IV. RESULT AND ANALYSIS

A. Multiple linear regression analysis

1. Coefficient determinant

To understand the influence of the independent variables (weather paramters) on the dependent variable (energy production) can be seen from R square in Table 1 column R Square. Table 1 is a summary table where temperature, humidity, UV, and solar radiation as independent variable. It shows the percentage of influence of the independent variables on the energy production (dependent variable) with R square 0.982. This value means that the aformention weather parameters ccsn affect the energy production of DAST-based solar PV generation.

Table 1. Model Summary (Independent Variabel- Weather) Dependent Variabel (Energy Production)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.991a	.982	.982	1.842533

Predictors: (Constant), Solar Radiation, Temperature, Ultraviolet, Outdoor Humidity

2. F Test

Furthermore, to understand the influence of predictor/independent variable (weather) to the dependent variable (energy production), it was carried out through F test. The results of F test can be seen in table 2.

Table 2. Coefficient ANOVA (Energy Production)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regresi	71083.71	4	17770	5234.55	.00b
	Residual	1313.837	387	3.395		
	Total	72397.546	391			

Dependent Variable: Energy Production

B. Predictors: (Constant), Solar Radiation, Temperatur, Ultraviolet, Outdoor Humidity

Based on table 2, It can be seen the significance values is 0.00 (< 0.05) were obtained. this means the independent variables namely Temperature, Outdoor Humidity, Ultraviolet and Solar Radiation have an influence on the dependent variable (energy production). Furthermore, to look at the influence of the independent variable (X) on the dependent variable (Y) by using descriptive analysis, it can be seen from Figure 4 and Figure 5, respectively.

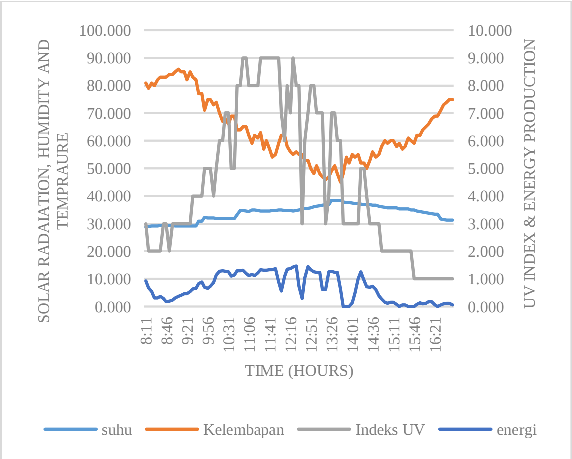

Figure 4. Temperature, Humidity, UV Index and Enegry Production (Day 1)

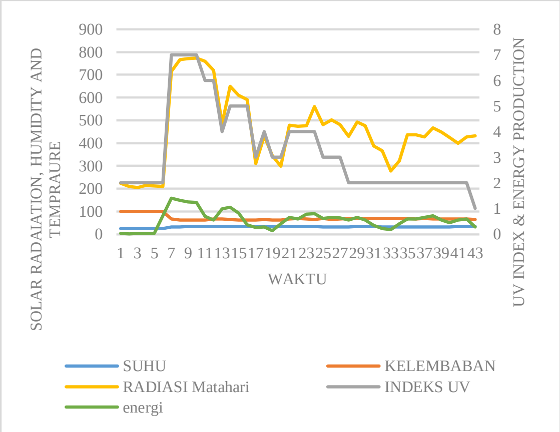

Figure 5. Temperature, Humidity, UV Index and Enegry Production (Day 4)

Based on Figure 4 and Figure 5, the influence of variable X, namely temperature, humidity, solar radiation, and UV index on variable Y (energy production) on the first day of measurement. The relationship between the UV index is directly proportional to the energy production. Meanwhile, temperature and humidity have a relationship that tends to be negative to energy production. The line graph of solar radiation variables has a similar pattern and is adjacent to the line graph of the UV index variable. Therefore, it can be assumed that the influence of the solar radiation value has a similar influence of the UV index value on energy production.

In accordance with research conducted by [14] it is stated that high humidity values in the morning and low during the day have no effect on the energy production of a solar PV generation system, this is due to the fluctuating of different humidity values in each region. Then the high temperature during the day affects the output of the solar PV generation system [15]. The value of solar radiation is directly proportional and greatly affects the energy production of the solar PV generation system.

Table 3. Coefficients Dependent Variable (Energy Production)

Model	Coefficients	Standardized Coefficients	T	Sig	
	β^	Std. Error	Beta		
1	(Constant)	5.941	4.829		1.230
	Temperature	-.118	.100	-.024	-1.18
	Humidity	-.023	.024	-.020	-.949
	Ultra Violet	.176	.065	.026	2.715
	Solar Radiasi	.080	.001	.973	84.31

Dependent Variable: Energy Production

Table 3 shows variable coefficients for independent variable (temperature, humidity, UV light and solar radiation). The standard values of the coefficients in the table 3 determine the magnitude of the influence of the independent variable on the energy production. It can be determined the interpretation of the equation model using multiple linear regression. values β^ is used to describe a multiple linear regression equation. The coefficients of temperature (X1) is -0.118, variable humidity (X2) is -0.023, variable UV light (X3) is 0.176, for variable solar radiation (X4) is 0.08. Based on these values, the linear regression equation can be written as equation (2). Based on the equation (2) above, the value of the regression coefficient for the temperature is 0.118 (negative sign). This means at every 1°C increase in temperature will decrease the energy production of the solar PV generation system by 0.118Wh. meanwhile, with 1°C temperature decrease, it will increase the energy production 0.118Wh:

$$Y = 5.94 - 0.118X_1 - 0.023\,X_2 + 0.176\,X_3 + 0.08\,X_4$$

V. CONCLUSION

The energy production of a DAST-based solar PV generation system is influenced by a few numbers of weather parameters, such as: temperature, humidity, ultraviolet radiation, and solar radiation with significant level up to 98.2%. Temperature is inversely proportional to the energy production of the DAST-based solar PV generation system while humidity has a very small effect on the energy production of the DAST-based solar PV generation system. On the other hand, ultraviolet radiation is directly proportional to the energy production of the DAST-based solar PV generation system. It also worth noting that solar radiation greatly influences the energy production from DAST-based solar PV generation system with directly proportional relation.

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