Predicting Solar Irradiance Using Regression Model (Case Study: ITERA Solar Power Plant)

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Abstract. Simple regression model can be used to predict the solar irradiance which cover a certain area in certain interval of time. With combining some variables like relative humidity, temperature and wind speed, a model which describe local solar irradiance can be developed. This paper elaborates the details of recently developed simple regression model, built with python based open-source cloud computing platform. This model dedicated to predict solar irradiance in certain relatively small area. For current study, it was in ITERA Solar Power Plant, Southern Lampung, Indonesia. Generally, this model can be applied in any places with vary conditions as long as all the required parameters are met, even though can only predict the local solar irradiance in a relative small spot. According to the computational issue, a simple linear regression model can be used to estimate the solar radiation in Lampung Selatan, Indonesia. The correlation between solar radiation and the average air temperature can be approached linearly. The coefficient value may be vary, but our computational progress resulting at 0.72768 for without outliers.

Keywords: Solar spectral irradiance; Regression model; Open access software

1. Introduction

As one of the unlimited currently being the most promising for clean renewable energy sources, solar powered energy demand has been increasing throughout the years. However, this energy source still considered as underutilized, compared with the immense usage of the non-renewable fossil fuels. Looking at the potential in solar power as the next energy source and the fact that it does not produce hazardous waste nor greenhouse gasses entice researchers to focus on increasing the efficiency of using this environment friendly, clean energy source [1].

As for being widely used, the most common technologies which able to generate solar power are photovoltaic cells and solar thermal energy [2]. Therefore, prediction of available solar irradiance become essential, particularly for developing highly efficient solar energy systems. But the rapid changes on the atmospheric components such as the surface of clouds, pollution, water vapor, and other components may prevent direct solar radiation [3-5]. It may reduce the amount of accepted solar energy [Figure 1].

Data collected for this paper was gathered by in situ measurement with interval of 10 minutes per data sampling for 24 hours a day, in 365 days a year. Considered parameters are the sun radiation, air temperature, humidity, wind direction and speed. The specimen, considering is the average value from all cells in the plant, was taken from data bank in Sumatera Institute of Technology (ITERA) solar power plant station, Southern Lampung, Indonesia. It can be compared or even backed up with satellite data and indirect estimation for another case for need of later study.
To fit the climate condition in certain places, existing models could be altered by changing its regression coefficient [3-5]. Sadly, study about solar irradiance is remain limited, especially in Indonesia. So, with all of this limitation, the current aim is focused only to predict the monthly solar irradiance, since Indonesia has no seasonal weather and has consistent temperature and rain throughout the year.

1.1 Mechanism of Solar Radiation
As the result of fusion atoms inside the sun, solar radiation brings energy by radiation [6]. Some of this energy scattered or absorbed by air molecules, clouds and every particulate matter in the air. The direct radiation reaches the surface directly in line from the PV module is called beam radiation, while the scattered radiation called diffuse radiation. The total solar radiation captured on the PV module surface consist of three components which usually named global irradiance. If the sky were clear with direct sunlight in line from the module, the maximum amount of global irradiance is around 1000 W/m²[7].

![Diagram of Solar Radiation](image)

**Figure 1.** Solar radiation on the earth surface

Even so, the usual radiation available considerably lower due to the rotation on the earth and climate condition, also because of the atmospheric general composition. This is why data about solar radiation become the most important part to estimate the outcome of photovoltaic system [8] [9]. From previous study, it is known that solar radiation greater than 3 kWh/m² indicates the clear sky, which has the highest intensity and become the most preferable condition for PV application [10].

1.2 Regression Model
In statistic, regression analysis is widely used for investigating and modelling relationship between variables [10]. A simple model used in this paper is given by

$$y = \alpha + \beta x + \varepsilon$$ (1)

where $\alpha$ and $\beta$ are the intercept and the slope, both are unknown and has to be estimated by sample data. $\varepsilon$ is the random error which assumed to have zero mean and unknown variance $\sigma^2$.

2. Data and Methods

2.1 Southern lampung climate
As a tropical country, Indonesia blessed with plenty solar radiation all year round. However, enormous clouds cut off the substantial amount of solar irradiance every day. With approximation 6 hours of sunshine per day and having tropical monsoon as the climate, southern lampung temperature is relatively within the range of 21°C to 32°C.
Humidity is consistently high on the lowlands ranging 82% to 86% per annum. The average rainfall per year is 2,032 mm to 2,540 mm and the wettest months are from May to December [11].

2.2 Existing statistical irradiance model
Proposed by El-Metwally [12], a nonlinear equation can be used to estimate monthly solar irradiance from relative sunshine value. The equation includes temperature data and cloud cover fraction as input parameters. Later, a model associate with the mean clearness index with the relative sunshine hours was proposed by Badescu [13]. The equation proposed included point cloudiness as an input parameter and concluded that the model with relative sunshine hours had higher accuracy than the point cloudiness models.

On the other hand, a linear temperature-based model which used to estimate global irradiance was developed by Almorox et al. [14] The five coefficients for previous models were modified to match the local environment. Temperature-based models become subject to errors caused by cloud movement and wind speed. These models are compatible for longer time steps, where it could reduce the effect of errors. Meanwhile, Zhao et al [3] add the Air Pollution Index (API) as variable to generate linear, exponential, and logarithmic models. The effect of aerosol on solar radiation is significant in polluted areas.

2.3 Regression method
The current model use a simple linear regression method. It can be written as

\[ y = \hat{a} + \hat{\beta} x \]

The correlation coefficient \( r \), range from -1 to 1, evaluates the goodness of the data fit and the standard error measures. For a strong correlation between \( x \) and \( y \) and if the value is zero there is not any linear correlation between the two variables.

3. Result and Discussion
Our first goal is to find a simple relation between solar radiation and air temperature. To find any relationship between these variables, we make a scatter plot as shown in Figure 2. Some outlayer already deleted before we do the regression and the regression coefficient we have resulting at 0.72768.
After we sure about the correlation between sun radiation and air temperature, we trying to plot mean radiation per hours as shown in the Figure 3. The timelaps start at 7.00 a.m everyday, so from the chart we can see that the highest mean radiation happened at mid day, and the highest value might hit a bit higher than 350 W/m2.
After we have the value of the radiation per daylight hour, we tried to plot the air humidity by hours as shown in the chart Figure 4. There was a humidity drop at daylight hours, with the lowest value which hit around 60% happened on 12-1 pm, but the average humidity were constantly around 75%.

**Figure 4. Humidity by hours**

4. **Conclusion**

According to the computational issue, a simple linear regression model can be used to estimate the solar radiation in Lampung Selatan, Indonesia. The correlation between solar radiation and the average air temperature can be approached linearly. The coefficient value may be vary, but our computational progress resulting at 0.72768 for without outliers. Thus we’re looking for the humidity and the radiation by hours, and found out that the higher the radiation, less humid the air would become.

5. **Acknowledgements**

As the authors of this paper, we’d like thank to School of Energy System Engineering and Engineering Physics, Sumatera Institute of Technology (ITERA) and thank to HIBAH MANDIRI GRANTS ITERA with contract number B/411/IT9.C1/PT.01.03/2020. In this study there was no conflict interest with other research activities.

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