Optimization of tilt angle on-grid 300Wp PV plant model at Bukit Jimbaran Bali

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Abstract. Optimum tilt angle of the photovoltaic (PV) modules are needed for determining the optimum solar energy producing in some specific area. Currently, there is no data for the optimum tilt angle in the area of Bukit Jimbaran Bali. In this paper, the optimization of the tilt angle of the on-grid 300-Wp PV plant model is presented using the PV system software simulation with solar radiation data are from Metronome 7.2. The system specifications on this research use a standard type module system, ground base disposition mounting, monocrystalline cell technology, and free-standing ventilation property. Using azimuth from 0 to 180 degrees in each direction and tilt angle from 0 to 90 degree with 1-degree interval, the simulations found that for fixed solar panels in a year, the optimum tilt angle values are from 12 to 18 degree in the azimuth of 0-degree direction with the system output at 528 kWh/year. The tilt angle is changed every six months, and for April to September, the optimum tilt angle is 32 degree at the azimuth of 0 degrees, while in October to March is in 24 degrees at the azimuth of 180 degrees with the system output at 561 kWh/year.

1. Introduction

Solar photovoltaic (PV) system is one type of renewable energy power plant that is currently being developed. This is due to this energy is cleaner and sustainable. The performance of PV modules and systems is affected by the orientation and tilt angle, as these parameters determine the amount of solar radiation received by the surface of a PV module in a specific region [1]. The magnitude of the intensity of the sun received by solar panels is influenced by several factors such as the location of the panel installation, daily and annual apparent motion of the sun and weather conditions [2]. To maximize the intensity of sunlight received by solar panels, it is necessary to calculate the most optimal slope of solar panels to be able to receive the maximum solar radiation. There are two angles that influence the installation of solar panels, namely the slope angle of the solar panel to the horizontal plane called the slope or tilt angle and the angle measured by the southern direction called the azimuth [2]. The most effective way to get maximum light intensity is to use automatic solar tracking where the azimuth direction and tilt angle of the photovoltaic can be adjusted automatically following the movement of the sun. But due to financial factors and high maintenance of equipment, there are not many interested people in this way. So that users prefer photovoltaic panels that can be manually set for a certain period of time [3]. Determination of the optimal slope for a particular location is very interesting and important for maximum energy production. A number of methods have been used to determine slope angles in various locations throughout the world [4].

The magnitude of the PV slope to receive the highest amount of solar radiation in each month in the city of Semarang varies from 1º to 34º. The most appropriate tilt angle for installing fixed array type panels in Semarang City is 18º, where the panel is facing north. The optimum azimuth direction and tilt angle of the photovoltaic panels in the Ciparay area of Bandung Regency for fixed type photovoltaic panels is with a 10º tilt angle and azimuth direction facing north [3]. Handoyo [5] through his research in Surabaya stated that, from March to September the optimum slope angle of solar panels ranged from 0 to 40º to the north, while from October to February ranged from 0 to 30º to the south. To be able to utilize solar resources efficiently, a simulation is needed to determine the size and parameters that influence the system. The amount of energy produced and the required size can be estimated using simulation software using PVyst software [6]. A number of researchers have used PVsyst to estimate the performance of the Bouhouras system [7], and using PVsyst for simulation of PV systems and generating power output from the PV. Kandasamy [8] simulates a photovoltaic system connected to the grid using PVsyst and discusses the feasibility of installing a 1 MW solar photo voltaic power plant by comparing solar energy, production costs and life cycle costs in several locations in the southern region of Tamilnadu, India. Karki [9] compared the electrical energy produced by the PV array and their losses in the tie-grid system in Kathmandu and Berlin using PVsyst. PVsyst has a very large database of popular solar battery and module companies. A very wide geographical database can provide precise information about solar radiation and insulating hours in certain areas of a country. Armstrong and Hurley [10] developed a methodology for determining optimal slope angles for locations with often cloudy skies using monthly sunlight duration data and hourly cloud observations.

In this study, the determining of the optimum value of the direction of the azimuth and tilt angle PV plant 300 wp model in the Bukit Jimbaran area of Bali is conducted by using PVsyst software simulation method.

2. Materials and methods

2.1. Azimuth, tilt angle and Software PV system

Figure 1 shows the direction of azimuth (γ) and tilt angle (β) in the setting of solar panel placement. In simple terms, the determination of tilt angle for the installation of solar panels in the southern part of the earth can be calculated using equation (1), as follows:

$$\beta\ = 180° - (90° + lat - \delta)(S\ hemisphere) \tag{1}$$

where lat is the latitude of the location of the solar panel placement and $\boldsymbol{\delta}$ is the sun declination angle |23.45° |.

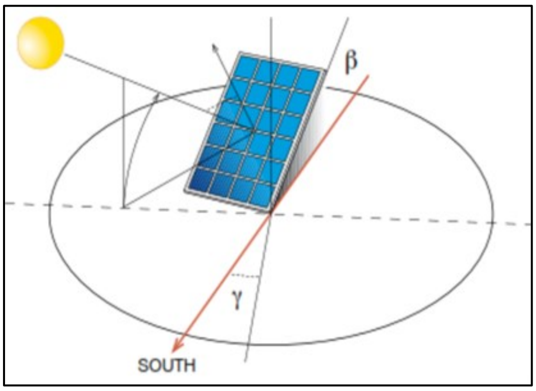

Figure 1. Azimuth direction (γ) dan tilt angle ($\boldsymbol{\beta}$) in placement of PV [11].

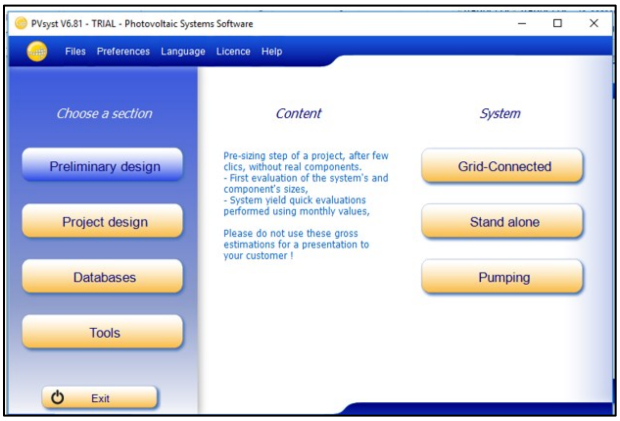

Figure 2. PVsyst V6.81 photovoltaic system software.

This azimuth and tilt angle optimization of the solar power plant on grid 300 Wp model uses PVsyst software version 6.81 as shown in Figure 2.

2.2. Selected point and geographical site parameter
Figure 3 shows selected points in the placement of solar panels in the area of Bukit Jimbaran Bali Indonesia, with coordinates latitude -8,805, longitude 115.1622, altitude 52 m. Geographic site parameters used to determine solar radiation using weather data contained in software meteonorm 7.2 as shown in Figure 4**.**

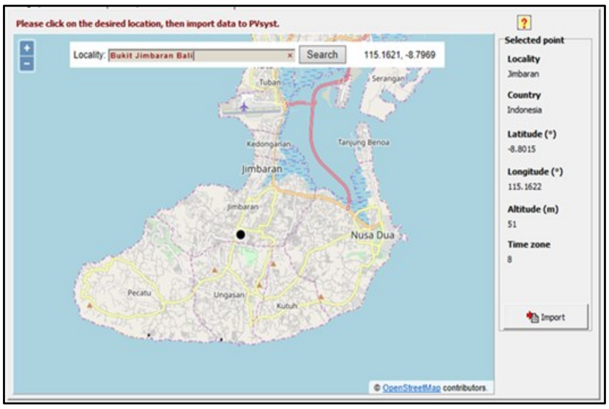

Figure 3. Selected point placement PV at Bukit Jimbaran Bali, Indonesia.

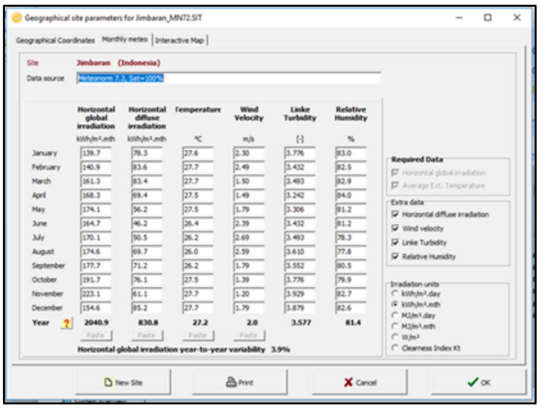

Figure 4. Geografical site parameter wheater condition using Meteonorm 7.2.

2.3. System specification
Figure 5 dan Figure 6 are the selection of system specifications. The type module is selected as a standard type system module, mounting ground base disposition, monocrystalline sell technology, ventilation property free standing, while the specific array has 0.3 kWp power.

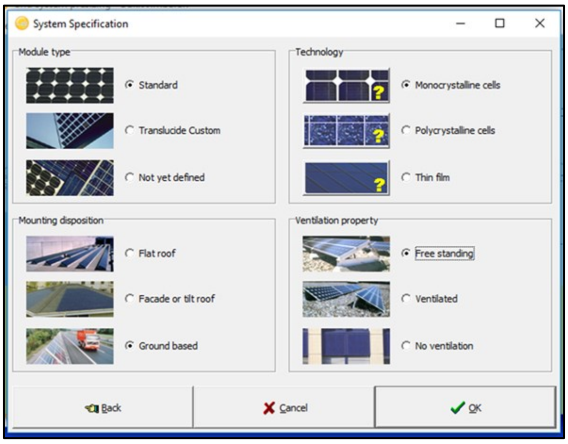

Figure 5. Selected system spesification modul type.

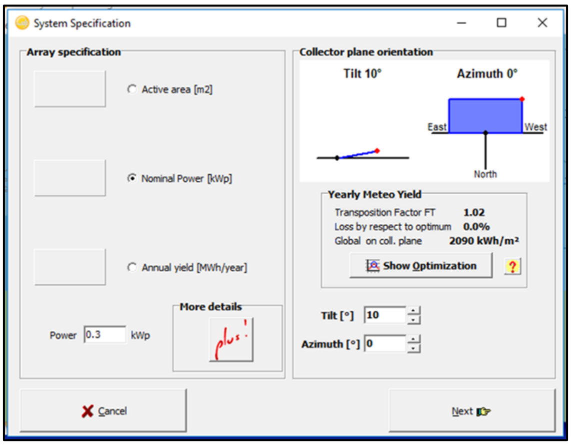

Figure 6. System specification array spesification.

2.4. Optimization the direction of the azimuth and tilt angle
In the PVSyst software after the location coordinates are determined, the meterology data is entered, then the design and system specifications are selected, and continued by determining the azimuth 0° and also the tilt angle values from 0° to 90° at 1° intervals. After that, continued by changing the azimuth

direction to 180°, with the same input tilt angle. In each condition, the output value (kWh) of the system will be searched, by entering this output value into tables and graphs, so, the optimum value of the azimuth and tilt angle can be determined.

3. Results and discussion

In this section the simulation results are presented firstly the optimation tilt angle at azimuth 0° and 180°, followed by monthly azimuth and tilt angle optimization, then six-month optimization and optimization for fixed systems throughout the year, and finally, the optimization of the three settings.

3.1. Optimization of tilt angle at azimuth 0° and 180°

In the azimuth 0° direction (solar panel facing north) the value of tilt angle optimization is 34° - 45° which occurs in July with an output system of 54 kWh, while in the direction of 180° azimuth (solar panel facing south), the tilt optimization value the angle is 10° - 30°, which occurs in November with a system output of 59 kWh that can be seen in Figure 7 and 8.

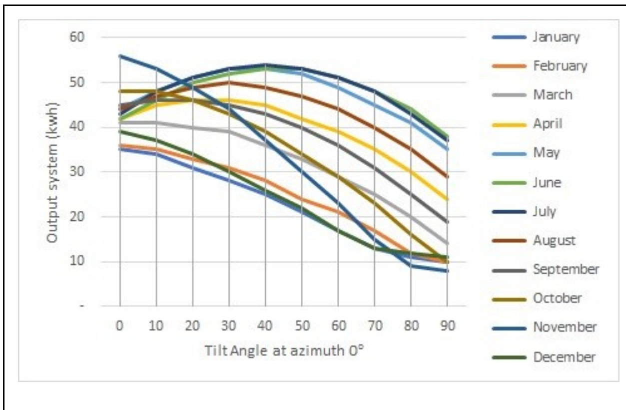

Figure 7. Graph the effect of tilt angle on the output system at 0° azimuth.

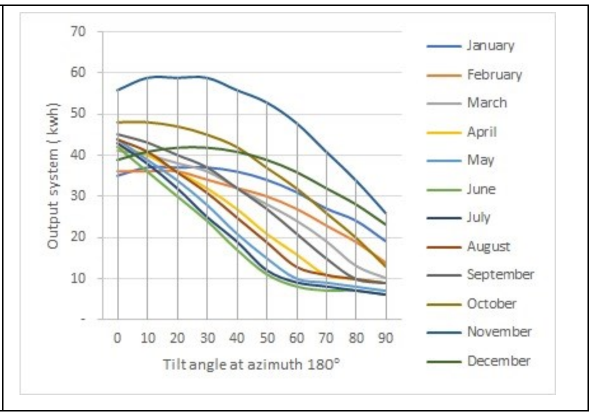

Figure 8. Graph the effect of tilt angle on the output system at 180° azimuth.

3.2. Optimization tilt angle per month

The optimum value of tilt angle per month is obtained as shown in Table 1. In November, December, January and February the optimum direction of azimuth for solar panel placement is 180° (southward), while in March, April, May, June, July, August, September and October, the optimum azimuth direction is 0° (northward). The highest system output per month is 59 kWh, which is in November with a tilt angle of 20 °, while the smallest system output per month is 36 kWh, which is in February with a 10 ° tilt angle. The total system output when the azimuth direction and optimum setting tilt angle each month will produce a system output of 565 kWh per year.

3.3. Optimization tilt angle per six month

In the optimization of the two azimuth and tilt angle directions, the PVSyst simulation obtains the maximum system output in the two groups of moon periods, as shown in figure 9. For the April to September periods, the optimum value is in the direction of azimuth 0° (nothward), with tilt angle 32°, and the output system of 300 kWh. As for the periods of October to March, the optimum value is in the direction of azimuth 180° (southward), with tilt angle is 24°, and the output system of 261 kWh. The total output of these two periods of setting is 561 kWh per year.

Table 1. Optimum azimuth direction, tilt angle and output system per month.

Month	Azimuth (°) / direction		Tilt Angle (°)	Output system (kWh)
January	180°	Southward	20	37
February	180°	Southward	10	36
March	0°	Northward	10	41
April	0°	Northward	25	46
May	0°	Northward	35	53
June	0°	Northward	42	53
July	0°	Northward	40	54
August	0°	Northward	30	50
September	0°	Northward	15	46
October	0°	Northward	5	48
November	180°	Southward	20	59
December	180°	Southward	25	42
Total per year				565

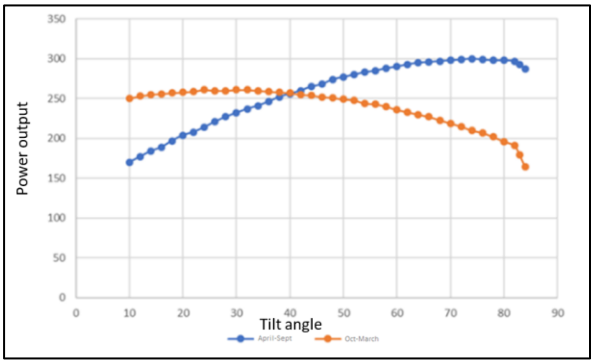

Figure 9. Graph of output system in two groups of month periods.

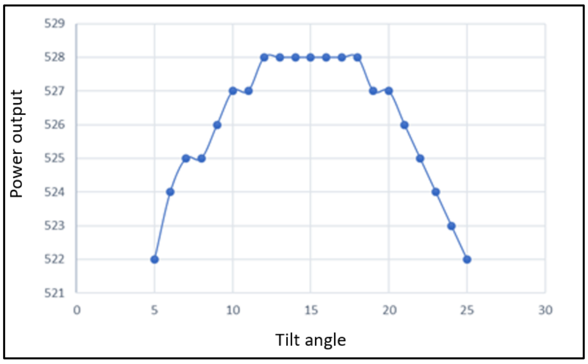

Figure 10. Graph of optimum tilt angle for fixed solar panel at Bukit Jimbaran.

3.4. Tilt angle optimization for fixed solar panel

Figure 10 is a graph of simulation results for determining the azimuth direction and tilt angle PV plant on grid 300 Wp fixed throughout the year, it can be seen that the optimization value is in the 0° azimuth direction (solar panel northward) with tilt angle 12° to 18°, that is producing the output system is 528 kWh per year.

3.5. Comparison of optimization values

From the three settings for azimuth and tilt angle optimization, namely optimization of the azimuth direction and tilt angle per month, six months and yearly tables can be made as shown in Table 2. Table 2 shows a comparison of the simulation results from three azimuth and tilt angle direction optimization settings in PV plant on Grid 300 Wp. Optimization of the azimuth direction and fixed tilt angle throughout the year resulting in an output system of 525 kWh per year (100%), while for optimization from the azimuth direction and the tilt angle which is fixed every six months produces an output system of 561 kWh per year or 106% of the system output. For azimuth and tilt angle regulated fixed system direction every month produces an output system of 565 kWh per year or 107% of the system fixed. This percentage shows that setting the azimuth direction and tilt angle both fixed throughout the year, fixed six months and fixed per month are only able to provide a difference output of 7% per year. These results can be taken into consideration in determining the fixed direction of the azimuth and tilt angle mounting solar panel.

Table 2. Comparison of optimization values.

Adjustment	Azimuth direction		Tilt angle	Output system (kWh/year)	Percentage (%)
Fixed	0°	(northward)	12°-18°	528	100
Adjusted per six months	0°	(northward)	32°	561	106
	180°	(southward)	24°		
Adjusted per month	0°	(northward)	10°, 25°, 35°, 42°, 40°, 30°, 15°, 5°	565	107
	180°	(southward)	20°, 25°, 20°, 5°		

4. Conclusions
In the azimuth 0° direction the value of tilt angle installation of solar panels is 34° -45° which occurs in July with an output system of 54 kWh, while in the direction of azimuth 180° the optimization of tilt angle is 10° -30°, which occurs in November with an output system of 59 kW. If a monthly arrangement is made, the optimization of tilt angle can be 10° in March, 25°, 35° in April, 42° in June, 40° in July, 30° in August, 15° in September, 5° in October with the direction of azimuth of 0°, and 20° in November, 25° in December, 20° in January, 10° in February in the direction of azimuth of 180°, with an output system at 565 kWh per year.For the direction of the azimuth and tilt angle of the solar panel which is changed every six months, the optimum value of azimuth and tilt angle for April, May, June, July, August, and September, are 32^0 in tilt angle with the direction of azimuth at 0^0, while for October, November and December, January, February, March, tilt angle is 24°, and the direction of azimuth is 180°, with an output system is 561 kWh per year. The optimum value of tilt angle for fixed position of solar panels is between 12^0 to 18^0 in the direction of azimuth 0^0 with an output system of 528 kWh per year.

5. References
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