



Performance Evaluation of On-Grid Solar Power Plant in PT.Syntek Automation Indonesia Building

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Abstract: Renewable energy, especially solar energy, plays an important role in creating a sustainable and environmentally friendly source of electrical energy. On-grid Solar Power Plant (PLTS) is one of the effective alternatives to utilize solar energy by converting sunlight into electrical energy, to reduce dependence on fossil energy and allow the supply of excess energy to the grid. This research evaluates the performance of the on-grid solar PV system installed in the PT Syntek Otomasi Indonesia building by assessing the performance of the existing system and redesigning it to increase energy production. The research methodology includes evaluation of the existing system performance, analysis of operational data, and comparison between various orientations and tracker types. Simulation results show that fixed tilt orientations of 3°, 5°, and 10° provide energy production of 7.47 MWh/year, 7.46 MWh/year, and 7.37 MWh/year, respectively, with an average performance ratio of 81%. This study also identified that the existing system is less than optimal in absorbing solar energy due to the variable movement of the sun's trajectory. Redesign using the E-W tracker showed a performance ratio of 80.99% and energy production of 7.88 MWh/year, while the N-S tracker resulted in a performance ratio of 80.75% and energy production of 7.84 MWh/year. These results indicate that the use of the E-W tracker is more optimal than the N-S tracker, with a difference in energy production of 0.055 MWh. These findings recommend the use of E-W trackers to improve the efficiency of the on-grid solar PV system at PT Syntek Automation Indonesia..

Keywords: renewable energy; performance ratio; energy production; on-grid PV; solar tracker

1. INTRODUCTION

Renewable energy plays a very important role in meeting sustainable electricity needs. The sun is an inexhaustible source of energy that can be converted into electrical energy using solar cells (Usman, 2020). A power plant that uses solar energy is a Solar Power Plant (PLTS), which converts solar energy into electrical energy (Sianipar, 2014). One PLTS system is the on-grid PLTS, which is connected to the main grid (PLN). This system allows users to reduce energy use from the main grid and supply excess energy to the grid if production exceeds demand (Radwitya & Chandra, 2020).

PT Syntek Otomasi Indonesia is a company that utilizes vacant land on its rooftop to build an on-grid PLTS system to reduce electricity bills. After the construction of a PLTS, a performance evaluation is needed to ensure that the power plant operates optimally and provides the expected results.

This research focuses on evaluating the performance of the on-grid PLTS at PT Syntek Otomasi Indonesia. The existing system with a fixed tilt is analyzed for its performance. However, this system has a weakness in optimally absorbing solar energy due to the varying trajectory of the sun each month. Therefore, this study also redesigns the

system using a solar tracker to maximize the energy produced.

The objectives of this study are evaluate the existing PV system at PT. Syntek Otomasi Indonesia, and redesign the PLTS to obtain maximum performance

2. MATERIALS AND METHODS

This research was conducted using simulation methods with PVSyst 7.2 and Meteonorm 7.3.1 software. The research object is the on-grid PLTS system at PT. Syntek Otomasi Indonesia. The solar panels used within the scope of this research are monocrystalline type. The research stages began with a literature study, then comparing the implementation results of the existing PLTS, identifying differences in results, and redesigning with several orientation options. The orientation options evaluated include a fixed tilt plane (existing system) and tracking (horizontal E-W and horizontal N-S). Meteorological data was taken from the Meteonorm and NASA databases.

2.1. System configuration

A grid-based PV system is a solar power generation system that is connected to the PLN (utility) or an

existing system, which is referred to as being "on-grid."

In an on-grid system, the solar power plant does not use batteries to store the energy produced by the solar panels. During the day, the solar cell modules act as the primary power supply for the load, and any excess electricity generation is fed into the distribution grid. When the solar modules are idle or at night, electricity is supplied by the PLN (utility grid). This is possible because the grid system is still connected to the PLN network.

The on-grid system scheme has the advantage of relatively low installation costs because it does not use energy storage components, such as batteries. Besides this advantage, this system scheme has a disadvantage: when the solar cell modules are not functioning and the PLN grid is disconnected, no electricity supply is sent to the load.

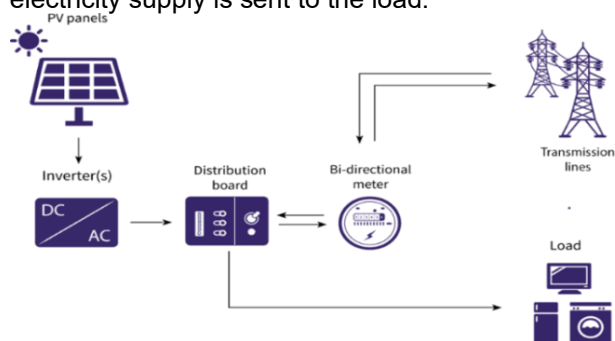


Figure 2.1 On-Grid PV System

As seen in Figure 2.1, the working principle of the on-grid system is that the solar cell modules convert sunlight into direct current (DC). This current is then sent to the inverter. The inverter then converts the direct current into alternating current (AC). The alternating current is used as the power source for household electronic devices. The resulting alternating current (AC) is used for self-consumption, and any excess can be automatically supplied to the PLN grid. Conversely, at night, when the load demand is high and the solar panels are not operating optimally, electricity from the PLN grid will be used.

2.2. Total solar radiation on a titled surface

Total solar radiation on a tilted surface is the total amount of solar radiation that falls on a tilted surface, such as a solar panel. This total solar radiation is influenced by several factors, such as the intensity of the sunlight, the relative position of the solar panel to the sun, and the ability of the solar panel's surface to absorb radiation. It can therefore be calculated with the following equation:

$$H_T = H_B + H_D + H_R \quad (1)$$

where,

- H_B : Beam radiation
- H_D : Diffuse radiation
- H_R : Ground reflection radiation

2.3. Beam radiation

Beam radiation is radiation originating from the sun that falls directly onto the Earth's surface without being scattered or reflected. This radiation

consists of sunlight focused directly on a point, the magnitude of which depends on factors such as the sun's position, the angle of incidence, and the surface tilt. Therefore, it can be calculated with the following equation:

$$H_B = (H - H_d) R_b \quad (2)$$

where,

- H_B : fill factor
- H : Radiasi horizontal global harian rata-rata bulanan
- H_d : Rata-rata harian total radiasi difus bulanan pada permukaan horizontal
- R_b : Radiasi langsung harian rata-rata bulanan suatu permukaan terhadap permukaan miring

2.4. Diffuse radiation

Diffuse radiation is radiation originating from sunlight that has been reflected and scattered by clouds, the atmosphere, and the Earth's surface. Diffuse radiation does not have a definite direction, and its amount depends on factors such as weather conditions, the presence of clouds, and atmospheric conditions. Diffuse radiation is an important source of energy in photovoltaic system modeling because it can provide electrical energy that helps improve the efficiency of the photovoltaic system. Therefore, it can be calculated with the following equation:

$$H_D = H_d R_d \quad (3)$$

where,

- H_D : diffuse Radiation
- H_d : monthly average daily total diffuse radiation on a horizontal surface
- R_d : Ratio of the monthly daily diffuse radiation on a tilted surface to that on a horizontal surface

2.5. Incidence Angle Modifier

The Incidence Angle Modulator (IAM) is a factor that accounts for the effect of the sunlight's angle of incidence on solar panel efficiency. When sunlight falls on the solar panel at different angles, the solar panel cannot collect the energy emitted by the sunlight as efficiently. IAM is a correction factor used to calculate the actual energy received by the solar panel based on the sun's angle of incidence. Therefore, it can be calculated using the ASHRAE parametrization equation as follows:

$$F_{IAM} = 1 - B_0 \cdot \left(\frac{1}{\cos i - 1} \right) \quad (4)$$

where,

- i : angle of incidence on the surface
- B_0 : Specific measurements on real crystalline modules actually indicate a B_0 value of 0.05

2.6. Performance Ratio

The main technical analysis used to evaluate system performance is the Performance Ratio (PR). The Performance Ratio (PR) is the ratio between the effective energy produced and the energy that the system would produce under standard test conditions (STC) (Marcelo, 2009). PR calculates the

overall effect of system losses. In PVSyst, PR is calculated using Equation (5):

$$PR = \frac{E \times 1 \left(\frac{kWh}{m^2} \right)}{D (kWp) \times A \left(\frac{kWh}{m^2} \right)} \times 100\% \quad (5)$$

where,

- E : AC Yield (kWh)
- D : DC installed capacity (kWp)
- A : Plane array irradiation (kWh/m²)

3. Results and Discussions

The performance analysis is divided into three parts: evaluation of the existing system, analysis of the redesigned system, and discussion of the underlying solar trajectory.

3.1. Meteorological Data

Table 3.1 Meteorological Data

Month	GlobH kWh/m ² /day	DiffH kWh/m ² /day	Temperature °C
January	120.9	86.8	26.6
February	121.8	80.9	26.6
March	152.8	89.9	27.1
April	151.8	73.5	27.4
May	142.3	73.8	27.9
June	121.2	66.6	27.5
July	150.4	64.2	27.1
August	152.8	75	27.3
September	160.2	77.4	27.6
October	157.5	91.8	28.1
November	130.8	89.7	27.5
December	141.1	90.8	27.3
Total	1703.6	960.4	
Average	141.967	80.033	27.333

Based on the table above, it is explained that the overall global horizontal irradiation (GlobH) obtained in a year averages 141.96 kWh/m²/day, while the diffuse horizontal irradiation energy absorbed by the solar cells (DiffH) in a year averages 80.03 kWh/m²/day. The average temperature (Temperature) obtained from the Meteorological simulation results over a year is 27.33°C.

3.1 Existing System Evaluation (Fixed Tilt)

The existing system was simulated at three different fixed tilt angles: 3°, 5°, and 10°. The annual simulation results are summarized in Table 3.2 until Table 3.4.

Table 3.2. PVsyst fixed tilt 3°

	GlobHor kWh/m ²	DiffHor kWh/m ²	T_Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray MWh	E_User MWh	E_Solar MWh	E_Grid MWh	EfrGrid MWh
Januari	120.9	86.8	26.55	119.9	116.2	0.546	4.253	0.479	0.051	3.774
Februari	121.8	80.9	26.63	121.5	118.1	0.552	3.739	0.496	0.04	3.243
Maret	152.8	89.9	27.1	152.7	148.6	0.687	4.121	0.581	0.08	3.539
April	151.8	73.5	27.37	151.4	147.4	0.685	3.949	0.587	0.08	3.362
Mei	142.3	73.8	27.85	142.3	138.5	0.648	4.253	0.549	0.061	3.704
Juni	121.2	66.6	27.5	121.7	118.5	0.558	3.949	0.491	0.052	3.458
Juli	150.4	64.2	27.09	150.3	146.6	0.686	4.121	0.558	0.085	3.563
Agustus	152.8	75	27.3	153.1	149.2	0.697	4.253	0.615	0.064	3.638
September	160.2	77.4	27.55	160.4	156.2	0.724	3.817	0.608	0.098	3.209
Oktober	157.5	91.8	28.1	157.2	153	0.711	4.253	0.635	0.057	3.618
November	130.8	89.7	27.53	130.7	127	0.595	4.082	0.529	0.05	3.553
Desember	141.1	90.8	27.3	140.5	136.5	0.64	3.988	0.537	0.086	3.451
Tahun	1703.6	960.4	27.33	1701.6	1655.9	7.73	48.778	6.666	0.804	42.113

Table 3.3. PVsyst fixed tilt 5°

	GlobHor kWh/m ²	DiffHor kWh/m ²	T_Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray MWh	E_User MWh	E_Solar MWh	E_Grid MWh	EfrGrid MWh
Januari	120.9	86.8	26.55	119.1	115.6	0.543	4.253	0.477	0.05	3.776
Februari	121.8	80.9	26.63	121.1	117.9	0.551	3.739	0.496	0.04	3.243
Maret	152.8	89.9	27.1	152.5	148.5	0.687	4.121	0.58	0.081	3.54
April	151.8	73.5	27.37	151	147.1	0.684	3.949	0.586	0.08	3.364
Mei	142.3	73.8	27.85	142.1	138.4	0.648	4.253	0.548	0.061	3.705
Juni	121.2	66.6	27.5	122	118.9	0.559	3.949	0.492	0.052	3.457
Juli	150.4	64.2	27.09	150.1	146.5	0.686	4.121	0.557	0.084	3.563
Agustus	152.8	75	27.3	153.1	149.3	0.697	4.253	0.615	0.064	3.638
September	160.2	77.4	27.55	160.3	156.3	0.724	3.817	0.608	0.098	3.209
Oktober	157.5	91.8	28.1	156.9	152.8	0.71	4.253	0.634	0.057	3.619
November	130.8	89.7	27.53	130.5	127	0.595	4.082	0.529	0.051	3.553
Desember	141.1	90.8	27.3	140.1	136.2	0.638	3.988	0.536	0.085	3.452
Year	1703.6	960.4	27.33	1698.8	1654.5	7.722	48.778	6.658	0.804	42.12

Table 3.4. PVsyst fixed tilt 10°

	GlobHor kWh/m ²	DiffHor kWh/m ²	T_Amb °C	GlobInc kWh/m ²	GlobEff kWh/m ²	EArray MWh	E_User MWh	E_Solar MWh	E_Grid MWh	EfrGrid MWh
Januari	120.9	86.8	26.55	116.8	113.2	0.532	4.253	0.455	0.044	3.798
Februari	121.8	80.9	26.63	119.9	116.3	0.544	3.739	0.461	0.038	3.278
Maret	152.8	89.9	27.1	151.4	147	0.68	4.121	0.581	0.08	3.54
April	151.8	73.5	27.37	149.5	145.5	0.676	3.949	0.579	0.079	3.37
Mei	142.3	73.8	27.85	141.3	137.4	0.643	4.253	0.565	0.061	3.688
Juni	121.2	66.6	27.5	122.1	118.7	0.558	3.949	0.49	0.052	3.459
Juli	150.4	64.2	27.09	149	145	0.679	4.121	0.578	0.083	3.543
Agustus	152.8	75	27.3	152.5	148.4	0.692	4.253	0.612	0.063	3.642
September	160.2	77.4	27.55	159.6	155.2	0.719	3.817	0.602	0.098	3.215
Oktober	157.5	91.8	28.1	155.5	151.2	0.702	4.253	0.627	0.057	3.626
November	130.8	89.7	27.53	129.7	125.9	0.59	4.082	0.507	0.05	3.575
Desember	141.1	90.8	27.3	138.5	134.3	0.63	3.988	0.529	0.084	3.459
Year	1703.6	960.4	27.33	1686	1638	7.643	48.778	6.585	0.789	42.194

Based on the simulation results, at a 3° fixed tilt orientation, the energy production is 7.47 MWh/year with a performance ratio of 81.30%. At a 5° fixed tilt orientation, the energy production is 7.46 MWh/year with a performance ratio of 81.34%. At a 10° fixed tilt orientation, the energy production is 7.37 MWh/year with a performance ratio of 81.00%. However, the weakness of this existing system is that it is not optimal in absorbing energy from the sun because the sun's path changes every month. Therefore, it is necessary to create a panel tilt that can follow the movement of the sun's path.

3.2 Redesign Results (Solar Tracker)

In the redesign using an E-W tracker, the performance ratio obtained was 80.99%, with the energy generated amounting to 8.183 MWh/year. This value is influenced by the global incident in the collector plane, which is the value resulting from the transposition of light from horizontal to the solar panel. The solar fraction was 14.33%.

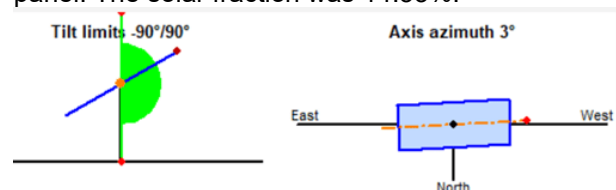
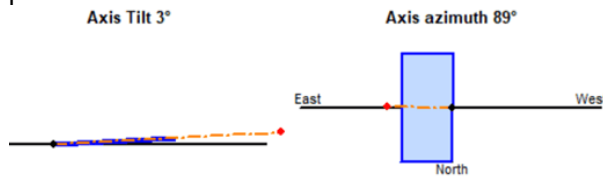


Figure 3.1 Orientasi horizontal E-W
Table 3.5 Horizontal E-W Simulation Results

	GlobHor	DiffHor	T_Amb	GlobInc	GlobEff	EArray	E_User	E_Solar	E_Grid	EfrGrid
	kWh/m ²	kWh/m ²	°C	kWh/m ²	kWh/m ²	MWh	MWh	MWh	MWh	MWh
Januari	120.9	86.8	26.55	124.8	121.8	0.57	4.253	0.496	0.058	3.757
Februari	121.8	80.9	26.63	122.9	120	0.56	3.739	0.503	0.042	3.236
Maret	152.8	89.9	27.1	153.5	150	0.693	4.121	0.593	0.082	3.528
April	151.8	73.5	27.37	159.7	156.2	0.723	3.949	0.568	0.077	3.381
Mei	142.3	73.8	27.85	159.4	155.9	0.723	4.253	0.628	0.077	3.626
Juni	121.2	66.6	27.5	139.1	136.1	0.633	3.949	0.545	0.071	3.404
Juli	150.4	64.2	27.09	174.2	170.5	0.789	4.121	0.655	0.114	3.466
Agustus	152.8	75	27.3	165.3	161.7	0.75	4.253	0.656	0.074	3.597
September	160.2	77.4	27.55	163.4	159.8	0.74	3.817	0.619	0.102	3.198
Oktober	157.5	91.8	28.1	158.6	155.1	0.72	4.253	0.643	0.058	3.61
November	130.8	89.7	27.53	133.3	130.2	0.609	4.082	0.54	0.053	3.542
Desember	141.1	90.8	27.3	147.6	144.3	0.673	3.988	0.543	0.084	3.446
Tahun	1703.6	960.4	27.33	1802	1761.7	8.183	48.778	6.988	0.893	41.79

In the redesign using an N-S tracker, the performance ratio was 80.75%, with energy generated at 8.141 MWh/year. This value is influenced by the global incident in the collector plane, which is the value resulting from the transposition of light from horizontal to the solar panel. The solar fraction was 14.21%.



Gambar 3.2 Orientasi Horizontal N-S

Table 3.6. Horizontal N-S Simulation Results

	GlobHor	DiffHor	T_Amb	GlobInc	GlobEff	EArray	E_User	E_Solar	E_Grid	EfrGrid
	kWh/m ²	kWh/m ²	°C	kWh/m ²	kWh/m ²	MWh	MWh	MWh	MWh	MWh
Januari	120.9	86.8	26.55	123.4	120	0.562	4.253	0.49	0.056	3.763
Februari	121.8	80.9	26.63	122.5	119.5	0.558	3.739	0.501	0.041	3.238
Maret	152.8	89.9	27.1	153.3	149.8	0.692	4.121	0.592	0.082	3.529
April	151.8	73.5	27.37	159.7	155.7	0.721	3.949	0.556	0.088	3.393
Mei	142.3	73.8	27.85	159.5	155.1	0.72	4.253	0.625	0.076	3.628
Juni	121.2	66.6	27.5	138.9	134.8	0.627	3.949	0.514	0.07	3.435
Juli	150.4	64.2	27.09	174.3	169.4	0.784	4.121	0.651	0.113	3.469
Agustus	152.8	75	27.3	165.2	160.9	0.747	4.253	0.654	0.074	3.599
September	160.2	77.4	27.55	163.3	159.5	0.738	3.817	0.617	0.102	3.2
Oktober	157.5	91.8	28.1	158.2	154.5	0.717	4.253	0.641	0.058	3.612
November	130.8	89.7	27.53	133.3	129.9	0.607	4.082	0.538	0.053	3.544
Desember	141.1	90.8	27.3	146.9	143	0.667	3.988	0.553	0.096	3.435
Tahun	1703.6	960.4	27.33	1798.5	1752.1	8.141	48.778	6.933	0.909	41.845

There is a difference of 0.055 MWh between the horizontal E-W and horizontal N-S orientations; this value is influenced by the sun's movement and also by the type and orientation of the tracker. Based on these data, the use of the E-W tracker is more optimal than the N-S tracker because the E-W tracker follows the sun's path.

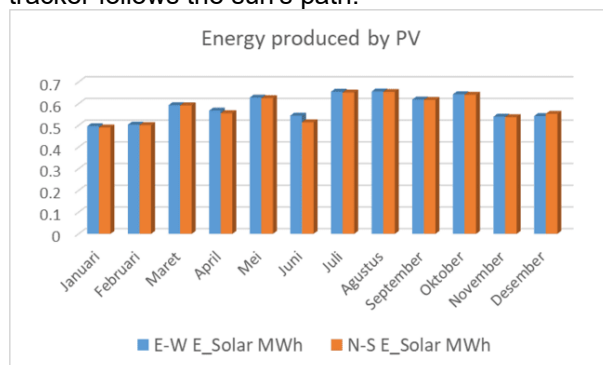


Figure 3.3. Comparison of Rebuild Results

3.3 Analysis of Solar Trajectory

The primary discussion point justifying the redesign is the significant variation in the sun's trajectory, which a fixed-tilt system cannot accommodate. Analysis of the sun's path data for the location (WGS84) reveals this variance, as shown in Figure 3.

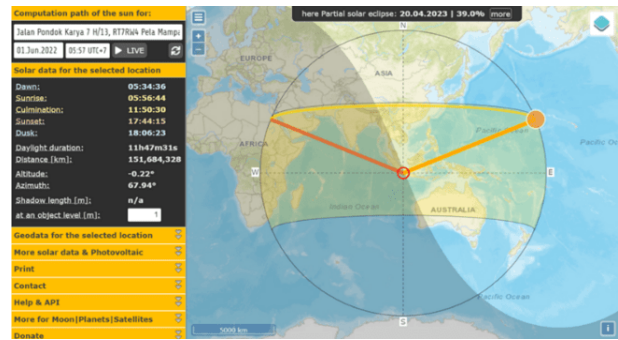


Figure 3.4. Sunrise point in June

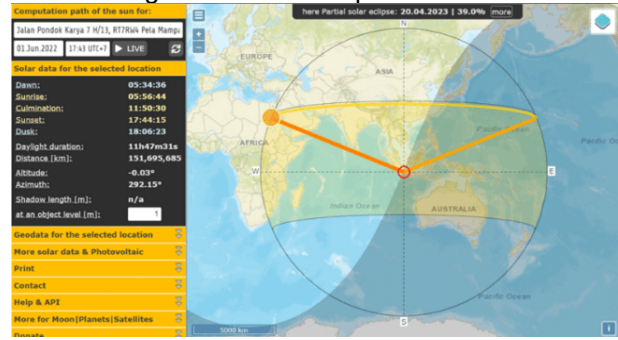


Figure 3.5 Sunset point in June

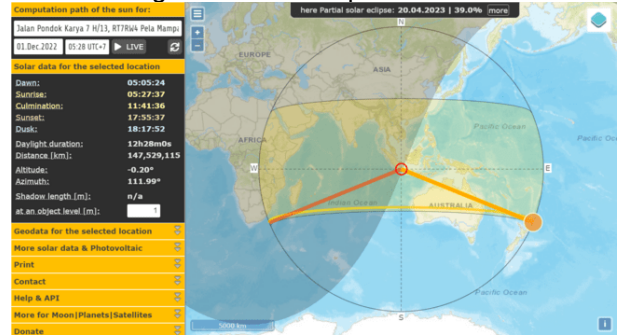


Figure 3.6 Sunrise point in June

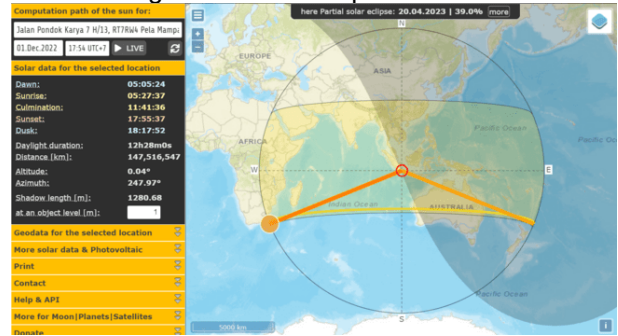


Figure 3.7 Sunset point in December

For example, on June 1, 2022, the sun's path is positioned more to the north, with sunrise at an azimuth of 67.94° and sunset at 292.15°. In contrast, on December 1, 2022, the sun's path shifts significantly to the south, with sunrise at an azimuth of 111.99° and sunset at 247.97°.

This daily and seasonal shift explains why the *fixed tilt* system's production is sub-optimal. The Horizontal E-W tracker (Section 3.2) yields higher energy (7.88 MWh/year) precisely because it is designed to follow this wide daily east-to-west trajectory, regardless of the north-south seasonal shift, thereby maximizing the *global incident in collector plane* throughout the year. The N-S tracker, which adjusts for seasonal (north-south) tilt

but not daily (east-west) movement, is less effective in this context.

4. CONCLUSIONS

Based on the simulation results and discussion, it can be concluded: The existing PLTS system (fixed tilt) at PT. Syntek Otomasi Indonesia produces optimal annual energy at a 3° tilt, amounting to 7.47 MWh/year with a performance ratio of 81.30%. The weakness of this system is its sub-optimal absorption of energy due to the varying path of the sun.

The redesign results using a solar tracker show a significant increase in energy production. The horizontal E-W tracker produces 7.88 MWh/year (PR 80.99%), while the horizontal N-S tracker produces 7.84 MWh/year (PR 80.75%).

The use of an E-W tracker is proven to be the most optimal configuration for the research location, producing 0.055 MWh/year more than the N-S tracker. This is because it effectively follows the daily E-W path of the sun, maximizing energy capture..

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REFERENCES

Darmawan, I. G. B., Setijadji, L. D., & Wintolo, D. (2015). Geology and Geothermal System in Rajabasa Volcano South Lampung Regency, Indonesia (Approach to Field Observations, Water Geochemistry and Magnetic Method).

Proceedings World Geothermal Congress, 12, 1-10.

Kananda, K. (2017). Studi Kasus Kampus Institut Teknologi Sumatera Menuju Smart Campus. *Journal of Science and Applicative Technology*, 1(2).

Marcelo, G. V. (2009). Comprehensive Approach to Modelling and Simulation of Photovoltaic Arrays. *IEEE Transaction on Power Electronics*, 24(5), 1198–1208.

Narayana, I. B. K. (2010). Incentive Instruments for PV Development. *International Workshop On PV Feed In Tariff*. Jakarta.

PT. PLN (Persero). (2021). *Statistik PLN 2021*.

Radwitya, E., & Chandra, Y. (2020). Perencanaan PLTS On Grid Dilengkapi Panel ATS di Laboratorium Teknik Elektro Politeknik Negeri Ketapang. *EPIC*, 3(1), 52–58.

Sianipar, R. (2014). Dasar Perencanaan Pembangkit Listrik Tenaga Surya. [Nama Jurnal Tidak Disebutkan], 11(2), 61–78.

Suyana, D., & Ali, M. M. (2016). Pengaruh Temperatur / Suhu Terhadap Tegangan Yang Dihasilkan Panel Surya Jenis Monokristalin. *Jurnal Teknologi Proses dan Inovasi Industri*, 2(1).

Usman, M. (2020). Analisis Intensitas Cahaya Terhadap Energi Listrik Yang Dihasilkan Panel Surya. *Power Elektron: Jurnal Orang Elektro*, 9(2), 52–57.