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DATA IN SUMMARY | ENGINEERING, MATHEMATICS AND STATISTICS

Observation of the Auto Tracking Process of 5 KWP PLTS at HKBP Nommensen University

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ABSTRACT
HKBP Nommensen University in 2022 received a Kedaireka Matching Fund-2022 Grant, and the research was carried out to build 3 PLTS units at UHN Medan, namely 10 KWP, 5 KWP and 2 KWP, with the title Prototype Autotracking PLTS UHN Medan. The research with the grant has been successfully implemented and has served UHN's electricity night lighting. The follow-up to the research is to provide opportunities for Lecturers and Students to conduct independent campus research internships for students of the Electrical Engineering Study Program and other study programs that require it. This research has joined student research conducted by special research by research lecturers with a lecturer and a student, with the title Observation of the Autotracking Process of 5 KWP PLTS at UHN Medan. This research was carried out together with the lecturer and the student. The autotracking observation aims to see several things including, can the autotracking movement reach a vertical position to sunlight? Next, the effect of autotracking on increasing the efficiency of the 5 KWP PLTS will be observed. The output of this research is planned to be in the form of a journal. From the observations, research data will be obtained for further analysis.

Keywords: Process Observation, Autotracking, PLTS, Research Data.

I. Introduction

The Electrical Engineering Study Program offers numerous courses involving various formulas and complex equations. In the 2020s, students have adopted computational and computer programming methods, replacing calculators as their primary means of calculation. This has evolved to include BASIC, QBASIC, Pascal (now Turbo Pascal), and finally, the most advanced, Matrix Laboratory, also known as MATLAB. Numerical computing is rapidly evolving, necessitating the use of these programs to analyze data on technological developments, such as solar power plants, which have flourished in the G-20 era. UHN received a Kedaireka MF-2022 research grant, resulting in the construction of three solar power plants (PLTS) at UHN, with capacities of 10 kW, 5 kW, and 2 kW. These solar power plants are now being used as part of the UHN Research Center plan. In line with this, researchers conducted a research study entitled "Observation of the Autotracking Process of a 5-KWP Solar Power Plant at UHN Medan." Researchers, along with one lecturer and one student from the Electrical Engineering study program, will investigate and observe the autotracking process of the 5-KWP solar power plant and gather the necessary data to analyze the autotracking process in monitoring the efficiency of the 5-KWP solar power plant.

The challenge in this research is how to analyze the results of the existing solar power plant autotracking design by observing its movement process, so that conclusions can be drawn about the power efficiency of the autotracking. Therefore, direct observations from student researchers who are also conducting MBKM research are needed to observe issues that will be useful for students' final assignments,

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particularly in design involving computation. This research will then produce guidance on the use of existing computing devices in the world of electrical engineering. Autotracking movements are currently analyzed daily, for example, every 30 minutes from morning to evening. However, this research focuses on collecting data for only two situations: a horizontal solar power plant and a tilted solar power plant, with no changes in the horizontal or tilted positions. The observation data are compared to analyze the impact of the autotracking movements, specifically on the 5-KWP solar power plant.

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II. Literature Review and Hypothesis Development

2.1. General Autotracking Method

The solar panel installation at UHN, a 5 kW solar power plant, uses a fixed (static) array. As the day progresses, the sun moves away from the panel's orientation, and thus the solar panel's power output is expected to increase or decrease over time. The simplest way to address this issue is to adapt the movable solar panels using a solar tracking or autotracking mechanism, assuming this system improves the efficiency of existing photovoltaic cells. Autotracking, or solar trackers, are devices used to orient solar panels or to focus their reflectors or solar lenses toward the sun. The sun's position in the sky varies both with the season and the time of day as the sun moves across the sky. Solar panels perform best when they are pointed toward the sun (perpendicular to the sun). Therefore, solar trackers are expected to increase solar panel efficiency if they are perpendicular to the sun, but at the cost of additional system complexity.

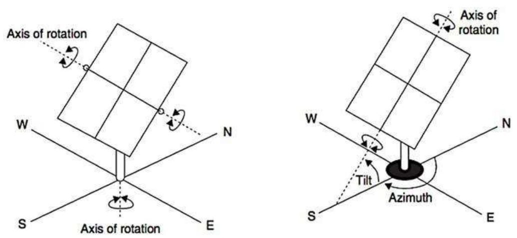

Figure 1. Dual Axis Geometry

Mounting structures for solar panels can be designed in several different ways. The two main categories for these structures are dual-axis and single-axis. Both types of structures have advantages and disadvantages. Dual-axis trackers, as in Figure 2.1, do a better job of keeping the sun's rays perpendicular to the solar panels, allowing for better energy absorption. However, these systems can be complex and expensive. Studies of dual-axis tracking systems show that annual improvements in solar performance range from 29-40%, and improvements for single-axis tracking systems range from 17-34%, depending on the system.

2.2. Solar Elevation Angle

Elevation angle is used interchangeably with altitude angle and is the angular height of the sun in the sky measured from the horizontal. Altitude and elevation are used to describe the height in meters above sea level. The elevation is 0 (zero) degrees at sunrise and 90 degrees when the sun is directly overhead. The elevation angle varies throughout the day and also depends on the latitude of a particular location and the day of the year.

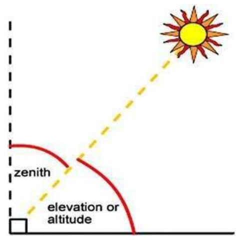

Figure 2. Elevation Angle and Zenith Angle

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Figure 2 shows the angle between the sun and the vertical. This is similar to the elevation angle, but is measured from the vertical rather than the horizontal. Therefore, the zenith angle is 90 degrees – the elevation angle. Active trackers use motors and gears to orient the tracker as instructed by a controller that responds to the direction of the sun, as shown in Figure 3. The sun's position is monitored throughout the day. The controller is used to control the motors and gears so they move accordingly and the panel faces the sun in the correct direction. This is achieved using a light-sensitive sensor such as an LDR. The voltage output is fed into a microcontroller, which then drives the motors to adjust the position of the solar panel.

Figure 3. Active Tracker

In this type of tracking system, a long horizontal tube, as in Figure 2.4, is supported on bearings with solar panels mounted on top. The tube then rotates on its axis to track the apparent motion of the sun throughout the day. Because they are not tilted toward the equator, they are not very effective during midday winter hours (unless located near the equator), but these tracking systems are very productive during the spring and summer.

Figure 4. Horizontal Axle Solar Tracker

In this type of tracking system, the panel is mounted on a vertical axle, as in Figure 5, at a fixed elevation angle. Such trackers with a fixed or (seasonally) adjustable angle are suitable for high altitudes. This is because at high latitudes, the apparent path of the sun is not very high, but it results in long days in summer, with the sun moving along a long arc.

Figure 5. vertical Axle Solar Tracker

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Here, the solar panels are mounted in such a way that they support the entire weight of the solar tracker and allow it to move in both directions and find a specific target. The horizontal axis (called the azimuth) allows the solar panels to move up and down, while the vertical axis (called the azimuth) allows the solar panels to swing in a circle parallel to the ground. This mechanism makes it easier because the telescope can swing in a circle and then lift to the target. Because tracking objects from Earth is more complicated due to the Earth's rotation, computer control is necessary.

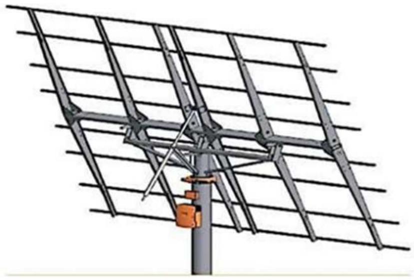

Figure 6. Altitude-Azimuth Solar Tracker

In a two-axis installation, one axis is a vertical pivot shaft or horizontal ring mount that allows the device to be swung to a compass point. The second axis is a horizontal elevation shaft mounted on an azimuth platform. Using the combination of these two axes, any location in the upper hemisphere can be oriented. Such systems require computer control or tracking sensors to control the motor drive that angles the panel toward the sun, as shown in Figure 6. Solar energy can be converted into electrical energy through solar cells, and the resulting energy is called photovoltaic (PV) energy. Solar energy primarily refers to the use of solar radiation for practical purposes. Solar technologies are broadly characterized as passive or active solar, depending on how they capture, convert, and distribute solar energy.

III. Research Method

The research methodology in this study consists of several systematic stages designed to ensure accurate data collection and robust analysis. First, the study determines an appropriate autotracking-based observation method to obtain reliable data over a one-week period (Monday to Saturday). Data are collected daily at 30-minute intervals, starting from 09:00 AM to 04:00 PM, resulting in 15 observations per day. This structured time-series observation approach is intended to capture variations in solar irradiation and system performance throughout the day. Second, the study selects the computational approach and algorithm to identify an efficient and optimal analytical solution. In this case, data processing and analysis are conducted using MATLAB, which is utilized to generate graphical representations and perform the necessary calculations for interpreting system behavior. Third, the study develops a conceptual framework for a larger-scale system design based on a multi-input, multi-output (MIMO) approach. This framework integrates multiple input variables and expected outputs simultaneously, enabling the development of a computational autotracking system that can be extended to other applications. Furthermore, the proposed model is intended to support future analysis and optimization of the existing solar power plant system at Universitas HKBP Nommensen (UHN) Medan, which has a total capacity of 618.8 kWp.

The research data observation process aims to obtain data on the electrical power generated by the solar power plant (PLT) and solar irradiation. Solar irradiation data is observed in two states at any given time. The first is when the PLT is level and the second is when the PLT is tilted, as shown in Figures 7 and 8. Both the level and tilt positions can be controlled at any time using an Android phone, as the 5 kWp PLT is designed to be manually controlled via an Android phone, as shown in Figure 9. PLT power is observed only once when the PLT is level, but irradiation is observed twice, each time, according to the specified direction. A flat position means that at all times the observed irradiation is perpendicular to the 5 KWP PLTS, while in a tilted position, the 5 KWP PLTS is made to face North (in this case towards the Building – L FT-UHN) as seen in Figure 7 and Figure 8.

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Figure 7. Leveled Solar Power Plant Position

In Figure 7, it is assumed that sunlight absorption is greater than in Figure 8. Figure 7 absorbs sunlight from all directions as the sun moves from East to West from 9:00 AM to 4:00 PM. In Figure 8, it is assumed that sunlight absorption is less than in Figure 7. Figure 8 absorbs less sunlight from one side, namely from the opposite direction, as the sun moves from East to West from 9:00 AM to 4:00 PM, because the 5-KWP solar power plant is focused in only one direction.

Figure 8. The position of the solar power plant is tilted

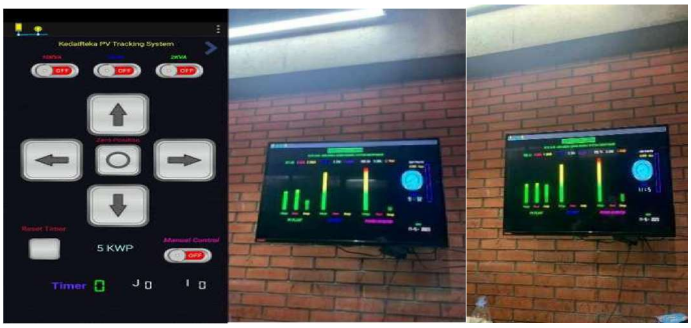

Figure 9. 5 KWP Solar Power Plant Control System

IV. Result and Discussion

4.1. Result of Observation Data

The results of this research activity consist of data from field observations for one week, from Monday to Saturday. Observations began from 9:00 AM to 4:00 PM, with 30-minute intervals. The data observed at the 5-KWP solar power plant (PLTS) included power and solar irradiation data generated by and for the 5-KWP solar power plant. Irradiation was observed in two sections: one section in a horizontal plane, referred to as the "PLTS PLANTATION" (FLATTENED PLTS POSITION), and the second section in a plane perpendicular to the sunlight, referred to as the "PLTS TILTED PLTS POSITION."

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The power from the 5-KWP solar power plant is used for three purposes: the first is power for the display lights, which are continuously turned on day and night to indicate that the PLTS is operational; the second is nighttime lighting in half of Building I, from the Rector's Office to the Faculty of Agriculture; and the third is power for the controller and the power used by four three-phase induction motors for autotracking. The data observations were conducted only during the day, from 9:00 AM to 4:00 PM. The data obtained are presented in Tables 1 through 6.

Table 1. Research Data Monday, September 11, 2023

Time	Power (W)	Light Intensity (W/m^2)		Weather
		Oblique	Perpendicular	
09.00	918,00	148,90	143,80	Drizzling
09.30	986,23	155,80	149,00	Drizzling
10.00	873,81	110,20	113,10	Drizzling
10.30	1969,44	439,40	562,90	Sunny
11.00	3268,86	691,10	979,7	Sunny
11.30	1142,64	351,10	476,70	Sunny
12.00	2826,26	510,80	962,20	Sunny
12.30	916,56	175,30	247,80	Overcast
13.00	898,80	152,00	233,50	Overcast
13.30	744,48	715,40	935,00	Overcast
14.00	744,48	730,20	932,5	Overcast
14.30	274,89	115,80	137,20	Overcast
15.00	280,80	102,90	98,80	Overcast
15.30	188,65	106,10	109,70	Overcast
16.00	183,60	77,10	118,70	Overcast

Table 2. Research Data Tuesday, September 12, 2023

Time	Power (W)	Light Intensity (W/m2)		Sunny
		Oblique	Perpendicular	
09.00	2400,0	75,60	79,20	Sunny
09.30	2409,0	290,10	218,90	Sunny
10.00	2410,0	376,56	288,50	Sunny
10.30	2411,0	179,00	199,30	Sunny
11.00	2647	372,89	532,00	Sunny
11.30	2875	549,43	1244,80	Sunny
12.00	2105	649,90	1112,90	Sunny
12.30	2422	768,10	1089,80	Sunny
13.00	2575	778,50	987,60	Sunny
13.30	2566,8	678,80	828,20	Sunny
14.00	1829,1	468,10	680,60	Sunny
14.30	2126,0	320,80	236,60	Sunny
15.00	1288,6	196,10	263,40	Sunny
15.30	844,5	734,20	534,15	Sunny
16.00	162,75	580,70	429,20	Overcast

Table 3. Research Data Wednesday, September 13, 2023

Time	Power (W)	Light Intensity (W/m2)		Weather
		Oblique	Perpendicular	
09.00	684,08	419,00	579,60	Sunny
09.30	1082,04	271,40	329,20	Sunny
10.00	2258,44	389,00	736,70	Sunny
10.30	2638,72	481,30	929,80	Sunny
11.00	1982,20	376,30	564,00	Sunny

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11.30	3210,89	529,50	1023,80	Sunny
12.00	3192,24	668,90	1039,90	Sunny
12.30	996,00	739,10	1127,80	Sunny
13.00	870,20	712,50	982,60	Cloudy
13.30	690,80	598,80	823,20	Cloudy
14.00	512,33	355,10	680,60	Cloudy
14.30	394,10	179,80	210,60	Cloudy
15.00	344,04	198,50	586,90	Cloudy
15.30	309,65	83,20	83,60	Overcast
16.00	287,13	231,00	151,50	Overcast

Table 4. Research Data Thursday, September 14, 2023

Time	Power (W)	Light Intensity (W/m2)		Weather
		Oblique	Perpendicular	
09.00	760,50	164,50	277,50	Sunny
09.30	829,67	251,60	550,10	Sunny
10.00	1187,64	196,90	310,40	Sunny
10.30	2245,02	566,80	874,40	Sunny
11.00	2828,80	490,10	817,90	Sunny
11.30	1479,36	572,60	885,20	Sunny
12.00	575,28	265,10	405,10	Cloudy
12.30	574,30	260,30	390,80	Cloudy
13.00	575,28	192,50	231,60	Cloudy
13.30	461,66	169,70	191,60	Cloudy
14.00	360,32	449,20	639,30	Cloudy
14.30	332,94	49,60	60,60	Cloudy
15.00	183,26	66,70	100,20	Overcast
15.30	172,48	79,80	103,20	Overcast
16.00	156,60	111,10	129,40	Overcast

Table 5. Research Data Friday, September 15, 2023

Time	Power (W)	Light Intensity (W/m^2)		Weather
		Oblique	Perpendicular	
09.00	2872,56	530,80	724,10	Sunny
09.30	2693,12	490,00	834,20	Sunny
10.00	1955,17	309,20	492,80	Sunny
10.30	3186,10	1260,3	1006,20	Sunny
11.00	1266,70	341,40	322,80	Cloudy
11.30	1656,72	318,80	285,00	Cloudy
12.00	147,90	24,50	46,80	Rainy
12.30	153,30	21,20	47,10	Rainy
13.00	122,40	20,50	48,40	Rainy
13.30	1523,20	284,20	382,00	Cloudy
14.00	1662,00	350,50	384,00	Cloudy
14.30	1821,72	402,40	508,30	Cloudy
15.00	698,12	196,10	233,40	Cloudy
15.30	291,60	700,00	567,10	Cloudy
16.00	285,67	575,70	429,20	Cloudy

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Table 6. Research Data Saturday, September 16, 2023

Time	Power (W)	Light Intensity (W/m²)		Weather
		Oblique	Perpendicular	
09.00	1213,44	300,50	516,80	Sunny
09.30	2357,25	1069,00	733,50	Sunny
10.00	2440,38	974,70	800,50	Sunny
10.30	2327,25	1024,60	901,90	Sunny
11.00	1293,20	315,90	314,00	Sunny
11.30	631,62	98,10	97,80	Overcast
12.00	106,80	101,70	111,90	Overcast
12.30	636,60	83,90	103,20	Overcast
13.00	646,98	103,20	101,00	Overcast
13.30	1017,42	175,90	177,00	Overcast
14.00	971,88	191,00	192,30	Overcast
14.30	1263,36	259,60	282,30	Sunny
15.00	551,74	237,40	409,60	Sunny
15.30	538,80	879,50	661,40	Sunny
16.00	320,91	100,70	112,00	Overcast

Analysis of Observation Data

The average irradiance was calculated in a fixed, horizontal position for one week, Monday through Saturday, from 9:00 AM to 4:00 PM, with 15 observations per day. The amount of irradiance per unit time is formulated and defined as follows.

$$\text{Average Irradiance } = \frac{Total\ Radiation\ one\ week}{Number\ of\ Observation\ data} = \text{ watts/m}^2$$

If the calculation is performed using MATLAB, the following is obtained:

Total Radiation for One Week = 42,529 watts / m2
Number of Observation Data = 6 x 15 = 90 data points.

Therefore, using the formula above, the following is obtained:

$$\text{Average Irradiance } = \frac{Total\ Radiation\ one\ week}{Number\ of\ Observation\ data} = \mathbf{472,5} \text{ watt/m}^2$$

For a FIXED SLIP POSITION observed 15 times per day from Monday to Saturday from 9:00 AM to 4:00 PM, the average irradiance was:

Total Radiation for One Week = 33,426 watts/m2.
Number of Observations = 6 x 15 = 90 data points.

$$\text{Average Irradiance } = \frac{Total\ Radiation\ one\ week}{Number\ of\ Observation\ data} = \mathbf{371,4} \text{ watt/m}^2$$

The average irradiance of the FIXED FLAT POSITION is better than the average irradiance of the FIXED SLIDING POSITION, with a ratio of 472.5 to 371.4, or 1.27 to 1. This means that the FIXED FLAT POSITION has a 27% advantage over the FIXED SLIDING POSITION. The average power generated by a 5 kWp solar power plant during the week, Monday through Saturday, was observed from 9:00 AM to 4:00 PM, 15 times per day, as defined below:

$$\text{Average Power } = \frac{Total\ Radiation\ one\ week}{Number\ of\ Observation\ data} = \text{ watt}$$

Total Power for One Week = 116,482 watts
Number of Observation Data = 6 x 15 = 90 data

$$\text{Average Power } = \frac{Total\ Radiation\ one\ week}{Number\ of\ Observation\ data} = \mathbf{1294,2}\text{watt}$$

If the total power of the PLTS used is 12 x 420 = 5040 watt-peak, and the average power generated is 1294.2 watts, then the efficiency of the 5 KWP PLTS is 25.68%.

V. Conclusion

Based on the results of the research and the analysis conducted, it can be concluded that the study was successfully implemented by defining two main observation objects, namely a 5 kWp solar power plant in a horizontal (level) position and a 5 kWp solar power plant in a tilted position. These two configurations served as the basis for evaluating the effect of panel orientation on solar irradiation and system performance. Furthermore, the analysis of solar irradiation data indicates a consistent difference between the two configurations. Based on the observed data, it was found that approximately 90% of the irradiation values in the horizontal position are higher than those in the tilted position. The comparative analysis shows a ratio of 1.27:1, which implies that the horizontal configuration provides a 27% higher irradiation advantage compared to the fixed tilted position. This finding demonstrates that panel orientation plays a significant role in maximizing solar energy absorption.

In terms of system performance, the total installed capacity of the solar power plant is 5040 watts-peak (12 × 420 Wp). The average electrical power output generated during the observation period was 1294.2 watts, resulting in a system efficiency of approximately 25.68%. This indicates that the system operates within an acceptable performance range, although there is still potential for optimization through improved panel orientation or tracking mechanisms. Overall, the results of this study confirm that the horizontal panel configuration is more effective in capturing solar irradiation under the observed conditions. These findings provide a practical foundation for the development of more advanced solar tracking systems and can be used as a reference for optimizing the performance of larger-scale solar power plants in future research.

References

Fauzi, Wirawan, Arfianto, Teguh, & Taryana, Nandang. (2018). Design and implementation of a solar tracking system to improve solar panel efficiency using Arduino Uno. TELKA Journal, 4(1), 64–67.

Gupta, B. R. (1985). Power system analysis and design. New Delhi: Prentice-Hall Wheeler & Co.

Kalogirou, S. A. (2014). Solar energy engineering: Processes and systems (2nd ed.). Academic Press.

Lubis, A. (2006). Photovoltaic solar power. Jakarta: BPPT Press.

Mandhu, K., et al. (2011). Microcontroller-based solar tracker. Department of Electronics and Communication Engineering.

Messenger, R. A., & Ventre, J. (2010). Photovoltaic systems engineering (3rd ed.). CRC Press.

Nakamura, S. (1991). Applied numerical methods with software. London: Prentice-Hall, Inc.

Ogata, K. (1994). Solving control engineering problems with MATLAB. London: Prentice-Hall, Inc.

Purwoto, B. (n.d.). Efficient use of solar panels as an alternative energy source. Jurnal Emitter, 18(1).

Sarker, M. R. I., Pervez, M. R., & Beg, R. A. (2010). Design, fabrication, and experimental study of a novel two-axis sun tracker. Department of Mechanical Engineering.

Simatupang, S., Susilo, B., & Hermanto, M. B. (2013). Design and testing of a solar tracker on an ATmega16 microcontroller-based solar panel. Jurnal Keteknikan Pertanian Tropis dan Biosistem, 1(1), 55–59.

Stagg, G. W., & Abiad, E. (1983). Computer methods in power system analysis. London: McGraw-Hill International Book Company.

GOLDEN RATIO
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Sun Energy. (2021). How solar panels work, benefits & installation. Retrieved July 29, 2021, from https://sunenergy.id/blog/panel-surya/

Masters, G. M. (2013). Renewable and efficient electric power systems (2nd ed.). Wiley.

Villalva, M. G., Gazoli, J. R., & Filho, E. R. (2009). Comprehensive approach to modeling and simulation of photovoltaic arrays. IEEE Transactions on Power Electronics, 24(5), 1198–1208.