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Design of actuator motor acceleration model in dual axis tracker movement for stand-alone PV system

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ABSTRACT

Stand-alone photovoltaic system or PV is a power generation technology with potential that is environmentally friendly and also one of the solutions for saving high electricity rates today. However, problems that often occur due to weather fluctuations that are always changing, especially North Sumatra, Indonesia result in the conversion produced by solar cells not being optimal. Therefore, it is necessary to do a new model with a dual tracker system and the development of accelerator motor actuators so that the resulting energy conversion is more optimal. The result of optimizing the reliability of the polycrystalline type solar panel which is designed with an additional photovoltaic tracker system to maximize the conversion of solar energy to solar panels is to obtain an output power of 303.72 volts DC and 267.52 volts DC in the position where the tracker is not used. Then the percentage increase in energy reached 29.80%. Dual axis tracker technology is able to maximize energy conversion in improving PV usage performance. The implementation of a stand-alone PV system will be beneficial if the installation is in Indonesian territory, especially in disadvantaged, frontier and outermost areas.

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1. INTRODUCTION

The high potential of the state of Indonesia in the management of renewable energy sources, one of which is by utilizing the use of photovoltaic (PV). This is because the climate in Indonesia is supported by a dense population so that a future in energy independence can be obtained [1]. Distributed generation installations from renewable energy sources continue to increase in various countries with the existence of renewable energy policies and reduced carbon emissions [2]–[4]. In addition to being environmentally friendly, PV can utilize existing land so that it will reduce land investment costs and can also reduce network losses due to its proximity to or being in a load center [5]–[7]. Therefore, PV installation with a stand-alone system (PV without a grid source) which will later be implemented in areas that have not yet had electricity is really needed [8]–[11]. Judging from the optimization modeling techniques, several installation models have been realized so that the potential for PV installation will be able to solve large-scale and small-scale economies, especially in isolated areas [12]–[14]. However, the problem that arises is climate change mitigation action, a regional energy model strategy is needed to represent the PV installation technique so that it becomes more optimal [15]–[17].

Previously, a projection method was carried out using the PV position in flat conditions or at one point on the solar cell where this condition has not been able to produce optimal energy conversion in converting solar energy into electricity [18]–[21]. Then another problem that occurs is weather fluctuations that occur such as the movement of clouds in covering the sun so that the conversion produced by solar cells into electrical energy drops dramatically [22]–[24]. The solution is to focus on increasing the development and installation of a stand-alone PV system with the concept of using actuator motor technology with two linear motor drives so that the power generated by PV is maximized. With modifications to various methods for more centralized tracking of the sun, it will later become a solution in the system reliability of the electricity supply system so that it is more maximized [25]–[27]. The addition of a tracking system taking into account the position of the sun will have an impact on the use of PV which will increase the output power in converting the energy produced to be greater [28], [29]. Then the tracker system technique that will be used uses a three-position system taking into account the angle of inclination using an actuator with a DC motor to support the optimization of the tracker torque to be greater [30]. The breakthrough of the stand-alone PV system technology on the dual axis tracker in the implementation of residential houses in underdeveloped areas is used to utilize the household electricity scale so that it will have an impact on optimizing the reduction of compensation for electricity bills which are increasing day by day. This stand-alone PV system is also based on where electricity automatically switches to battery use if the load does not allow it to back up all the electrical power used. In addition, data in the form of DC output recorded from photovoltaic stand alone will be processed using SPSS software. To support the accuracy of the intensity of the sun's light so that it is synchronized with energy conversion, a tool in the form of a smart luxmeter is added which can later be monitored in real time so that the data becomes more optimal.

2. METHODOLOGY

Utilization in maximizing the conversion of electrical energy produced by PV by installing PV parallel to the direction of the sun is still less effective. Therefore, a method is carried out using actuator technology as the prime mover where there is a linear DC motor which will later act as a tracker for the presence of the sun so that it stays on point using Arduino which has been integrated into several sensors. The stand-alone PV system used is a type of polycrystalline with a capacity of 410 Wp. The basic components supporting stand-alone PV installations are miniature circuit breaker (MCB), maximum power point tracking (MPPT) and also the solar charger controller (SCC) as a battery charging controller. The purpose of installing a DC MCB on PV to SCC is so that when bad weather occurs such as lightning or a short circuit, the MCB automatically disconnects so that the components are not damaged and burnt. In the installation system, especially the cable using pure copper cable measuring 16mm2 which will also be connected to the SCC. Then the stand-alone PV installation is supported by additional components, namely valve regulated lead–acid or VRLA batteries which will later act as a backup when the PV cannot supply energy, the battery will become backup energy. The use of a dual tracker system with the use of actuators will later become the main technique in increasing the performance of the resulting electrical energy conversion. in supporting the technology to be used using the PV specifications in Table 1.

Table 1. Characteristics and specifications for use PV model CS3W-410P

Characteristics	Specification
Nominal maximum power (Pmax)	410 W
Power Tolerance	0 - + 5 W
Optimum operating voltage (Vmp)	39.1 V
Optimum operating current (Imp)	10.49 A
Open circuit voltage (Voc)	47.6 V
Short circuit current (Isc)	11.06 A
Maximum series fuse rating	20 A

In Table 1, Canadian type polycrystalline solar panels are used with a power of 410 W DC. With a voltage when loaded (Vmp) of 39.1 V and also when loaded, the maximum current (Imp) generated by the solar panel is 10.49 A. So, to determine the surface angle of the panel at the position of the sun, the (1) is used.

$$\theta = arcos[cos\beta_c cos\theta_z + sin\beta_c sin\theta_z \, cos(\gamma_s - \gamma_c)] \quad (1)$$

β_c=slop angle, θ_z=zenith, γ_s=surface azimuth, and γ_c=azimuth.

To determine the sun's declination or the angle formed by the position of the sun, the (2) is used.

$$\delta = arcsin\,[0{,}39795\, cos\left\{2\pi \frac{n-173}{365}\right\}] \quad (2)$$

Then, to determine the hour angle the (3) is used.

$$\omega = \frac{\pi}{12}(t_s - 12) \quad (3)$$

t_s= solar time. Then, to determine the zenith angle from the sun the (4) is used.

$$\theta_z = \arccos\,(cos\varphi\ cos\delta\ cos\omega + sin\varphi \sin\delta) \quad (4)$$

φ= latitude, δ= declination, and ω= clock angle. Then, to determine the azimuth angle from the sun the (5) is used.

$$\gamma_{s=sgn\ (\omega)[\frac{cos\theta_z - sin\delta}{\sin\theta_z cos\varphi}]} \quad (5)$$

Then, to determine the actuator that is integrated with the use of a DC motor as a tracker to produce a large torque that must be calculated using the equation. The working principle of a torsion motor is that the torque is transferred by the object, so that the object rotates more easily. To obtain the DC motor torque can be calculated based on (6).

$$T = P/\omega \quad (6)$$

Furthermore, based on the description of the specifications of the actuator used, energy usage can be calculated by the actuator and to determine the power (power) of the motor, the (7) is used,

$$HP = (T * n/5250) \quad (7)$$

where HP = motor power, N = motor speed, T = torque, and 5250 = constant. To determine the magnitude of the increase in energy conversion in solar panels that use a tracker, the (8) is used.

$$\text{W total} = \sum \text{W} \quad (8)$$

The (8) is used to calculate the data from the two panels to be compared. After the total energy data is obtained, the difference and percentage increase of the two Photovoltaics can be calculated as in (9) and (10).

$$\text{Energy Difference} = (\text{E total PV Dual Axis tracker} - \text{E total flat PV}) \quad (9)$$

$$\%\text{Energy} = \frac{\text{Energy Difference}}{\text{E Total PV Flat}} \quad (10)$$

After all the equations to find the tracking of the sun have been obtained, a simulation of the implementation of the technology is carried out. The technology that will be simulated is by designing the movement of the polycrystalline PV assisted by the movement of two actuator motors. The simulation that will be displayed observes the movement of the sunrise and sunset. The design of the actuator motor is installed by moving two actuator motors at once which will later create a focal point for tracking sunlight. The technological design to be designed is shown in Figure 1.

Based on Figure 1, the movement of the polycrystalline PV is limited to a three-position movement so that energy efficiency is maximized and also the use of actuator movement is more efficient compared to continuous panel movement. Measurements that later data are obtained from the difference from the energy conversion produced by the PV dual exist tracker and the installation of flat positioning so that relevant data is obtained to determine the accuracy of using the most efficient control system used. Based on energy conversion using PV panel installation parallel to the incoming sunlight is maximized. Therefore, two DC motors integrated with the actuator are used so that the PV movement leads to sunlight so that the electrical energy produced increases compared to solar panels in a flat 90^0 state. Analysis of calculations in the use of electrical energy for actuators is very important so that energy conversion efficiency can be obtained maximally. Then the dual exist technology on the actuator has sufficient torque to drive the solar panels and use electrical energy from the battery. PV has a capacity of 410 Wp with a polycrystalline type. Other supporting components consist of a battery, inverter, motor actuator linear, lux meter, watt meter, solar charging controller, delay timer relay module, battery charge controller module, digital led voltmeter ammeter active power factor, and personal computer.

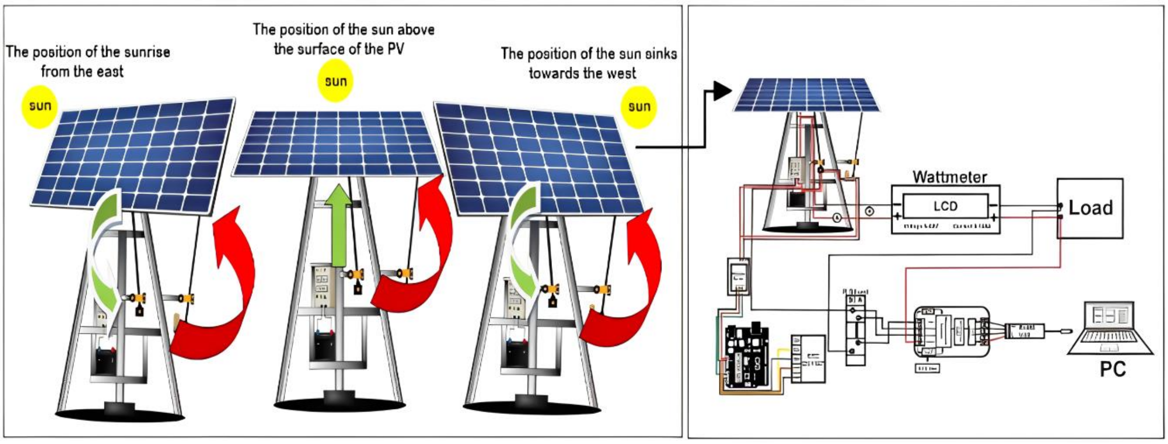


Figure 1. Illustration of dual axis hybrid PV solar tracker technology in tracking the sun's focus point

3. RESULTS AND DISCUSSION

The use of an actuator that is integrated with a DC motor as a dual tracker produces a large torque [31], [32]. Therefore, modifications to the use of a battery charge controller module are made to make it more efficient in the use of energy used. This battery module is set with a 1minute delay to minimize the motor power used. After the system works based on the settings of all components installed. then tested the Stand-alone PV system in real time in the field. The steps are carried out by analyzing data and conducting initial reliability tests, then integrating all the components of the dual axis tracker system tool for a stand-alone PV system by taking fluctuating weather. For clarity, the real field operating system of a stand-alone PV system on a dual-axis tracker is shown in Figure 2.

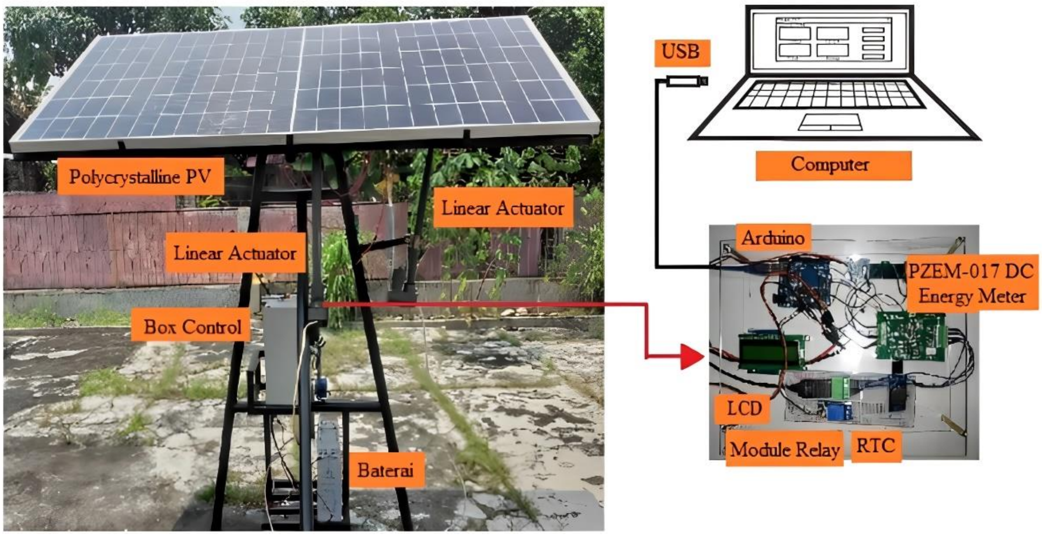


Figure 2. Model of two-liner motor actuator stand-alone PV system technology

3.1. Testing the intensity of sunlight in real time based on weather fluctuation

The need to test the reliability of sunlight intensity in measuring energy conversion resulting from PV output using luxmeter technology. Calibration is carried out using a manual luxmeter and also by comparing a digital luxmeter for better measurement accuracy. Digital luxmeter technology and the results obtained can be seen in Figure 3. Based on the graph of measuring the intensity of sunlight using a digital luxmeter, the measurement results show weather fluctuations so that the graph is irregular. Measurement of sunlight intensity at 9.00 am obtained lux data of 9458 with the peak value of sunlight intensity. Lux reading accuracy is still not optimal due to the limited reading of the measuring instrument.

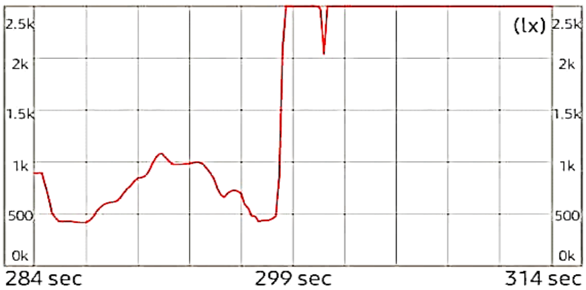


Figure 3. Graph of sunlight intensity measurements based on digital luxmeter performance

3.2. Linear actuator performance results on PV tracker dual axis and PV flat

The use of two linear actuator motors based on a dual axis tracker is able to optimize the energy conversion produced by PV compared to Flat PV. The measurement results yield a percentage increase in solar panel energy conversion with a dual axis tracker system in real terms compared to flat PV installations. Performance measurement data for the installation of a dual axis tracker PV system with two linear actuator motors and a flat PV can be seen in Figure 4.

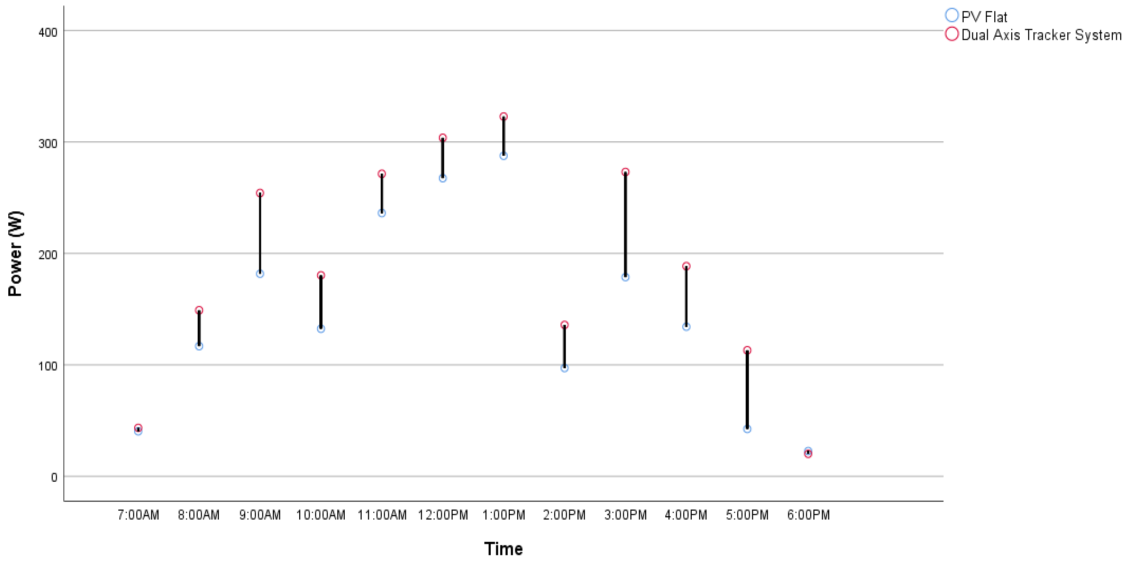


Figure 4. Performance of dual axis PV tracker based on actuator motors linear Vs flat PV

Based on the performance measurement results from the use of linear actuator motor-based PV with a comparison of flat-mounted PV, measurement results are obtained where solar-centered PV has a higher energy conversion compared to flat-mounted installation. Where the average DC energy produced by the dual axis reaches 187.95 W while the average flat PV installation is 144.81 W. Next, the calculation of the percentage increase in specific energy in PV is performed using a linear actuator motor by first looking for a comparison of the energy of both measurement results are based on the PV dual axis tracker and flat PV as in the (11) and (12).

Difference energy =Dual Axis − Average Energy PV Flat Tracker System Average Energy (11)

Energy difference = $187.95\ W - 144.81\ W = 45.13$ W.

For the percentage increase in energy = $\frac{Energy\ Difference}{E_{flat\ PV\ average}}\ x\ 100$ (12)

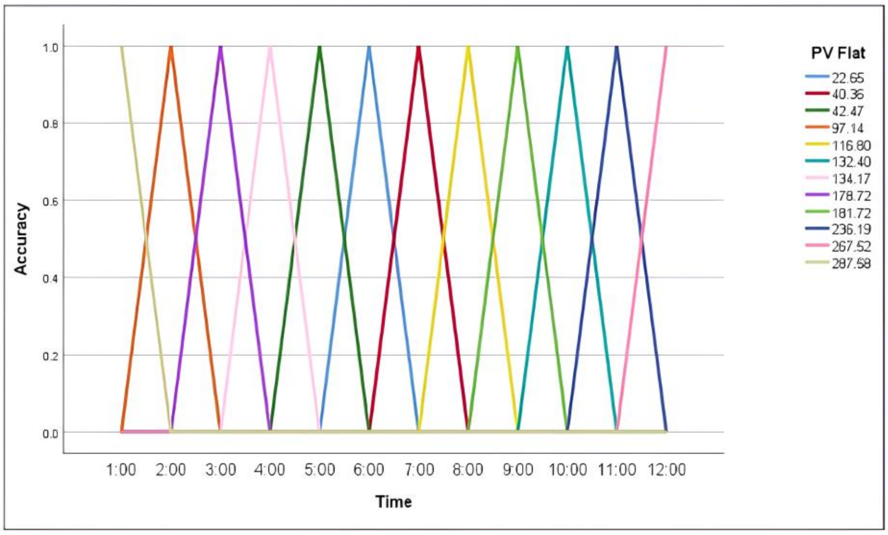
$= \frac{45.13}{144.81}\ x\ 100$

$= 29.80\ \%$

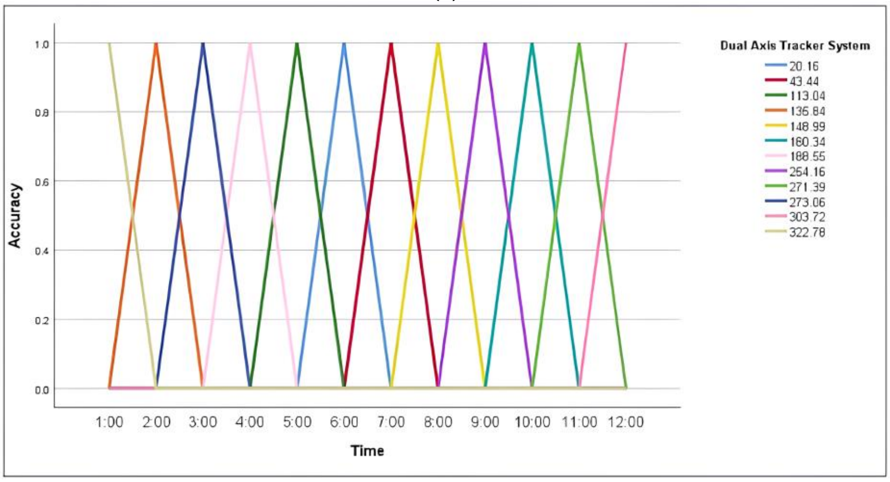
3.3. Accuracy data of dual axis and PV flat PV tracker simulation

Then the measurement results are displayed in graphical form to facilitate detailed data analysis. The data displayed is the resulting power accuracy in the form of a DC power graph. The simulation results using SPSS software by comparing the performance of the PV Tracker with two linear actuator motors and also a flat PV installation. Figures 5 are the results of the DC power from the lowest to the largest.

Based on Figure 5(a), the results of power accuracy on PV Flat, DC power data values are measured from the smallest to the largest with respect to time, while the 5(b), the measurement accuracy results on the dual axis tracker system also obtain DC power data accuracy values from the smallest up to the largest to simplify the analysis of the reliability of the flat PV installation system with the dual axis tracker system installation system. The data that has been recapitulated is then simulated using a bar graph to determine the performance of each DC power output produced.



(a)



(b)

Figure 5. Graph of flat PV usage power comparison with PV dual axis tracker measurement results of (a) power accuracy measurement results on flat PV, and (b) accuracy results on dual axis tracker system

The DC PV voltage produced will have the same value, but if conditions pass at 3.00 p.m, only the dual-axis PV will be centered on the sun, so the dual-axis tracking voltage will be greater than when PV is installed horizontally. Where the data obtained is the peak DC power of 322.78 W for the use of dual axis tracking linear actuators and for DC power in flat PV installations of 287.58 W. Then the data obtained is input data to see the frequency results of the voltage output DC, DC current and DC Power. To facilitate detailed and concise data analysis, the data is summarized by visualizing the data in the form of a histogram of DC power performance results from lowest to largest and DC power values from smallest to largest based on Figure 6.

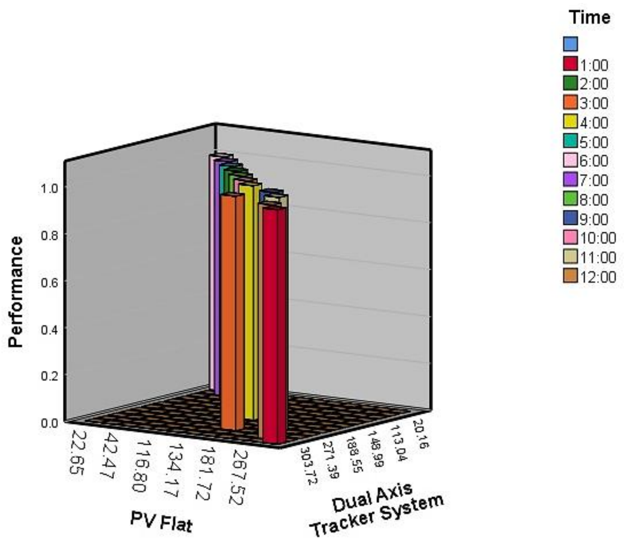


Figure 6. Comparison of PV tracker and PV flat power output results with histogram display

The results of all the simulated data are then described in the form of frequencies shown in Figure 7 (see Appendix). The display of all DC output is simulated in the form of a graph of the accumulated PV output frequency of a dual-axis tracking motor actuator installation with flat PV. The goal that will be achieved is to find out how far this performance can occur in analyzing the differences in value levels and several special aspects of converting a dual-axis PV tracking system to flat PV.

Based on the frequency of the DC voltage graph according to Figure 7(a), energy conversion is obtained using a dual axis tracker with the maximum condition occurring at 12.00 am at 303.72 Watt DC with a standard deviation of 1.178 and Figure 7(b) flat PV conditions of 267.52 Watt DC with a standard deviation 1.19. During the monitoring time, the output voltage on the PV shows irregularities. Then the data shown in Figure 7(c) and Figure 7(d) is a current graph which makes a graphical difference, there is a significant difference in the use of the two liner actuator motors. The peak current output results for the dual axis tracking installation system obtained a DC value of 9.17 A with a standard deviation of 2.793 and for the DC current for the flat PV installation system, a current output of 8.17 A with a standard deviation of 2,488 was obtained. Figure 7(e) is a source of DC energy conversion using a dual axis tracker with maximum conditions occurring at 12.00 p.m of 303.72 Watt DC with a standard deviation of 99.595 and flat PV conditions of 267.52 Watt DC with a standard deviation of 88.387. Based on real data in the field, during the monitoring time the output power on the PV shows irregularities when the PV is installed in a flat position. Meanwhile, the dual axis trackel has high energy conversion because it is focused on sunlight.

4. CONCLUSION

The design of the Dual Axis Tracker system uses actuator technology in optimizing the energy conversion produced by PV based on energy conversion which is obtained more optimally than from PV installations in a flat position. To operate the two actuators using a module, the automatic battery control system uses a battery charge controller so that the use of battery power to provide energy for the movement of the actuator motor is more efficient. The battery controller operates according to the system when full automatically the Hybrid PV will cut off. The results of measuring data on the PV output in converting the maximum energy obtained by the dual axis tracker, the maximum condition occurs at 12:00 PM when the PV is centered on the sun so that a maximum power of 303.72 Watt DC is obtained and the PV condition is in a flat position but not centered on the sun. solar power obtained 267.52 Watt DC. The actuators on the DC motors that are used only use very little energy so that after a comparative trial, the data on the increase in energy conversion of the dual axis tracker PV is able to produce greater power. Then the percentage increase in energy reached 29.80%. Dual axis tracker technology is able to maximize energy conversion in improving PV usage performance.

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APPENDIX

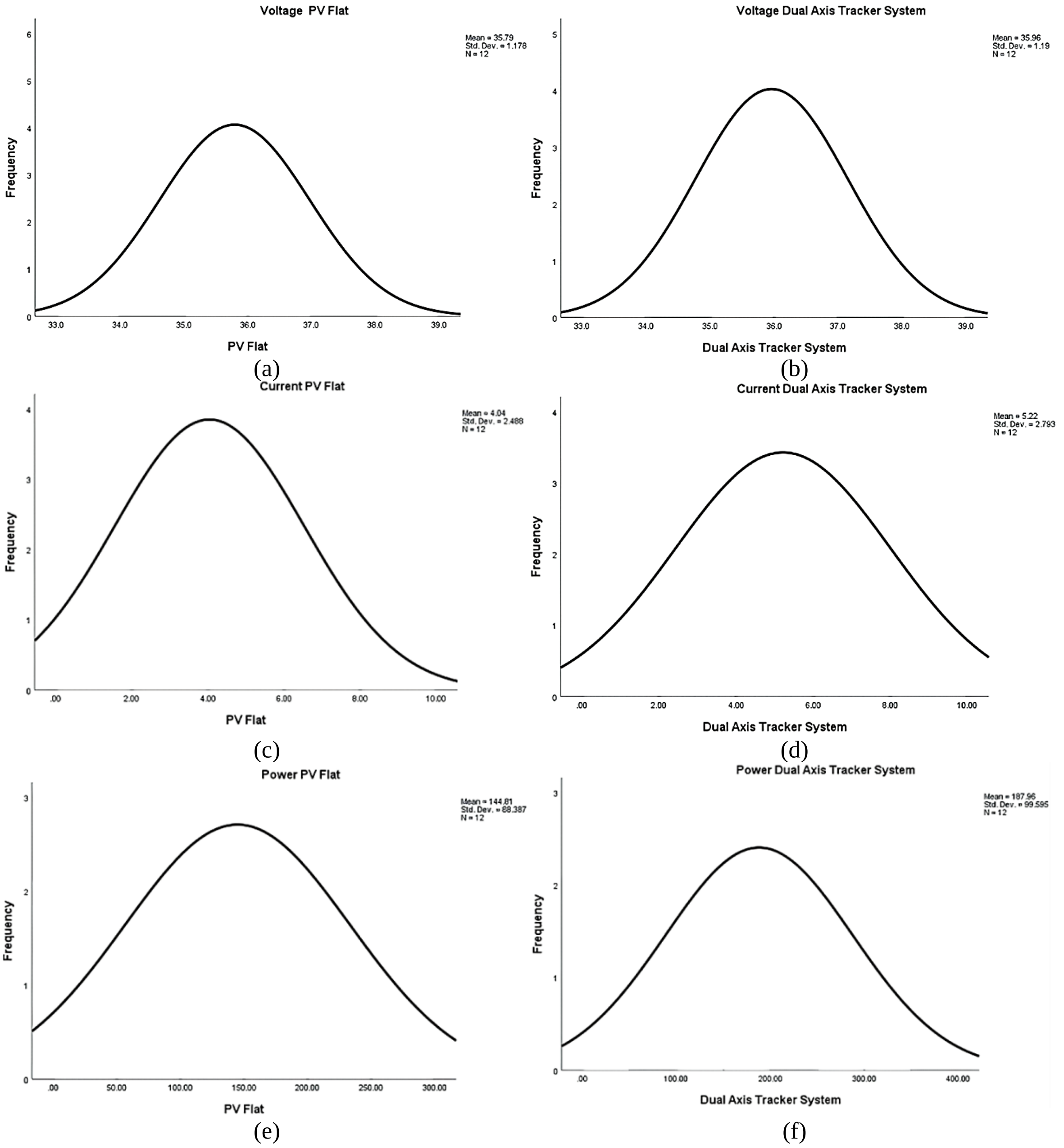

Figure 7. Graph of accumulated output frequency PV installation motor actuator tracker dual axis with PV flat (a) before preprocessing frequency voltage PV flat, (b) after preprocessing frequency voltage PV dual axis tracker, (c) before preprocessing current frequency PV flat, (d) after preprocessing frequency current PV dual axis tracker, (e) before preprocessing power frequency PV flat, and (f) after preprocessing power frequency PV dual axis tracker

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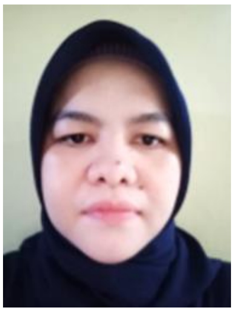

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