International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Design and Implementation of Sun Tracking Solar Panel Using Microcontroller

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***Abstract**— This study is associated with using the Photovoltaic conversion panels attached to the fabricated solar tracker system. Solar cell efficiency is affected by temperature, maximum power point tracking (MPPT), and energy conversion efficiency. One of the most innovative solar panel improvements is to attach a solar tracker to the solar panel board. This system provides a panel to tilt a solar panel to follow the sun's position to improve solar energy collection. This tracker system assures the optimization of electrical power conversion from solar energy. It is an experimental design based on the Microcontroller that triggers the linear actuator when the panel receives signals from the controller to tilt the solar panel according to the sun's movement in precisions. This research expected that it would give an innovation for advocating solar energy and the transitions of renewable energy to prevent the global warming of the environment.*

***Keywords**— Embedded System, Fabrication, Microcontroller, Solar Panel, Sun Tracker*

I. INTRODUCTION

In our modern days, technology is building a stable ground for its development where power generation is a big concern to keep track of our evolving way of life [1][10][11][12][13][14][15]. Sun energy is considered to be one of the most promising sources to address the world energy crisis. Sun energy also is the best idea for a transition of renewable energy to prevent global warming [2][12][13][14][15][18].

Solar energy was introduced to the people by the year 2011 as an alternative source of energy. Due to the fixed installation of the panel, the power output decreases. As the angle of the sunlight on a solar panel deviate from the perpendicular. Because, on a flat surface area, the light's average intensity decreases as the angle decreases from 90 degrees [1][2][11][13][14][15].

On a solar panel, less light equals less power generated. The study utilized and employed the manufacturing process of a single-axis linear actuator tracker device by using photovoltaic conversion panels to supply much more energy [3][12][16].

After the system in a specific device, a sun is controlled to move the PV (Pick Voltage) modules, so they regularly face the Sun to boost the PV display's light. A sun fueled after the structure made out of three particularly isolated parts: the framework, the driving motors, and the accompanying controller [3][4][12][13][17][18].

Installing a solar tracker system assures the conversion optimization of electrical power output from the source. It is an experimental system based on the DC Linear Actuator's function that is controlled by a microcontroller to move the PV panel by following, per, under the sun rotations.

The researcher developed a single-axis linear actuator with a metal frame and a stand to carry the solar panel following the sunlight to create more efficient power charging than the typical solar panel installation at 45 degrees based on the roof position. The system is called sun tracker, wherein the solar panel follows the Sun's movement using a Microcontroller [13][14][15][17][18]. The central controller would follow the Sun's direction on an hourly basis, embedded into its microcontroller memory to perform repetitive tasks in real-time. The sun tracker started to track at 6:00 AM at -45 degrees to the ground until 6:00 PM at +45 degrees allowing the solar panel attached to the linear actuator to move in the sun direction.

With this setup, the efficiency of charging to the solar panel is very expected, and it is proven to increase the stored power compared to the conventional structure. Figure 1 shows the conceptual framework of the study.

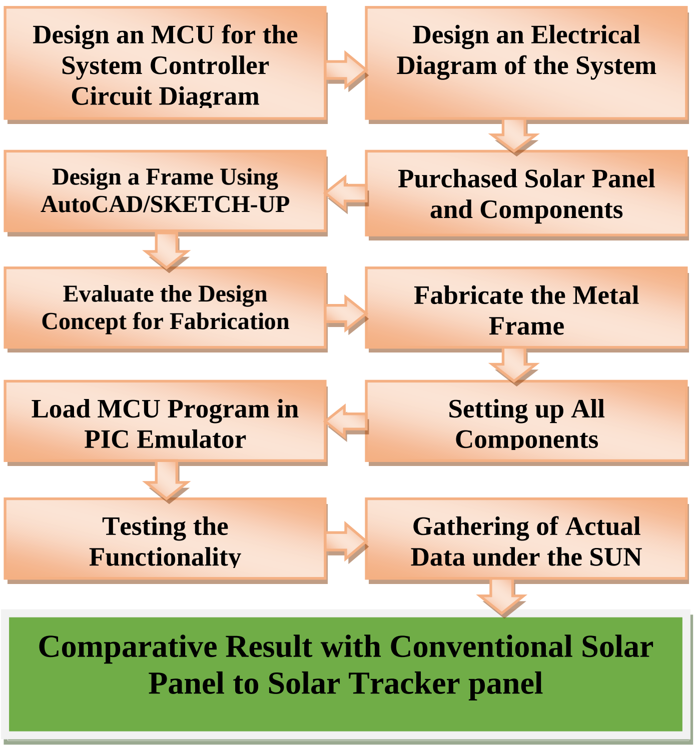


Fig. 1. Conceptual Framework of the Study

The ultimate goal of the study is to fabricate a single-axis linear actuated solar tracker system that uses in carrying solar panels following the movement of the sun. As proof, the acquired voltage in a solar panel at the right position of the sun is more efficient than a conventional setup.

The study focused on the following:

1. Fabricate a single axis tracker system to increase the power rated output of the installed solar panel.
2. Testing and gathering of data on how reliable the system is, and how it would increase the efficiency of the power rated output of the panel.
3. The comparison of fixed mounted solar panel and a solar tracker data, to know the difference in the effectiveness of both systems.

II. METHODOLOGY

The researchers deal with fabricating a model that used the PLAN-DO-CHECK-ACT (PDCA) scheme to investigate and approve that the single-axis solar tracker will be more efficient than the fixed solar panel conventional use. First, the researchers gathered information about the energy supply rate and its usefulness for applying the solar tracking system. Then, they conducted an experiment using the system to differentiate the changes and the difference between the fixed mounted and a solar tracker. Finally, after gathering the data and knowing the contrast in the efficiency between the two experiments, the researchers compare how it will be more efficient if the system to solar panels. Figure 2 shows the schema of the study conducted by the researchers.

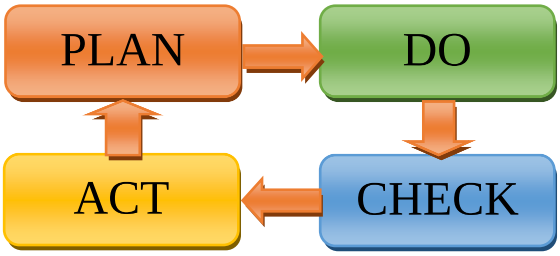


Fig. 2. Schema of the Study

Plan

Design

Sun-powered energy generator synchronizes a battery pack, charge controller, and an inverter into a conventional system to transform sun-powered energy into an electrical current. Every segment is intended to harmonize the power rating of the gadget getting power. Standard voltage collected for solar-based generators are 12, 24, and 48 volts [5].

The researchers use an 80W Solar Panel to generate electricity and function the solar tracking system. Then, they use a 12 Volts Battery to store the collected energy from the solar panel and a voltage regulator to prevent the overcharging of the battery. Also, install an inverter to convert the DC energy to AC energy for general purposes. The researchers also use the RS Pro Linear Actuator for the tilting motion of a Solar Panel (Push and Pull Movement of the Actuator).

The Microcontroller was tapped into the battery to control the linear actuators automatically. The versatility of the Microcontroller is what makes it one of the essential tools in modern design. Lastly, researchers use a pillow block to mount a shaft directly connected to the solar panel. This component will allow the linear actuator to do a tilting movement of the solar panel. Figure 3 deflects the system's running block diagram. At the same time, Figure 4 shows the circuit diagram of the central controller using the PIC16F62 Microcontroller [6][7][8][9][19][26][24], and Figure 5 shows the drawing of the metal frame created in AutoCAD software.

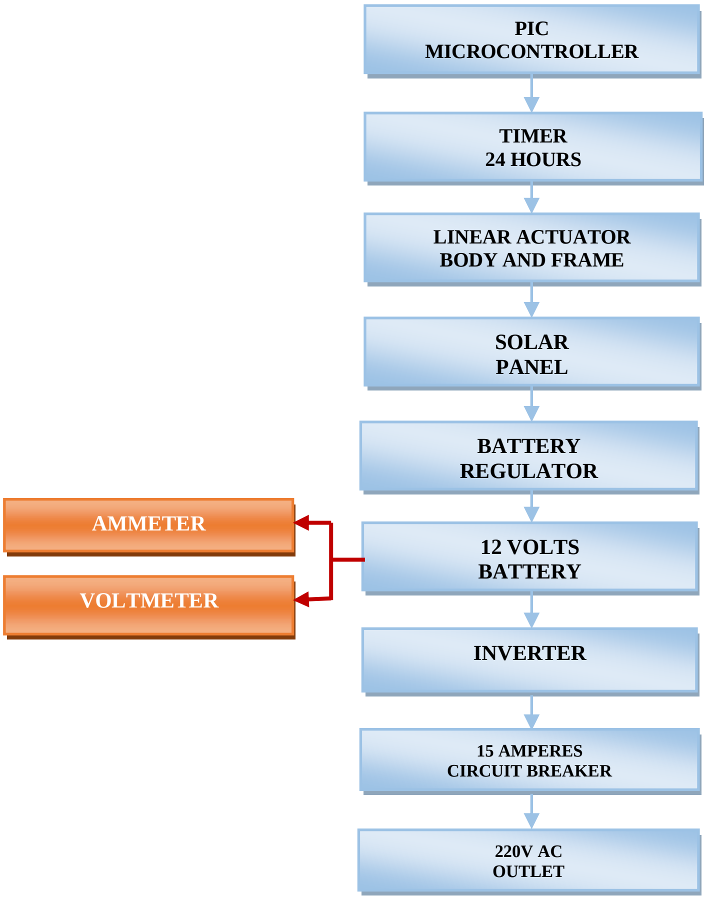


Fig. 3. Block Diagram

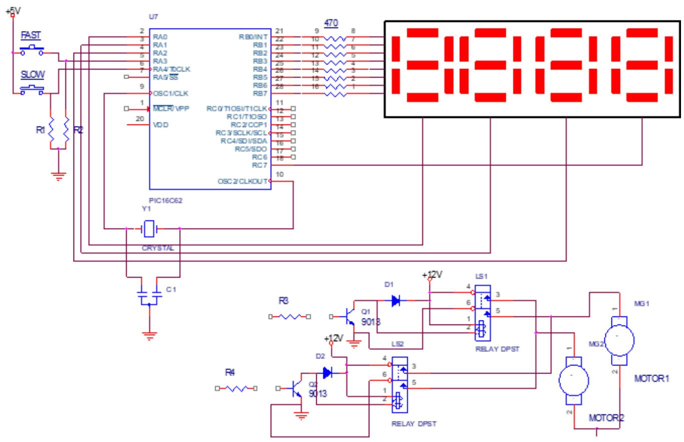


Fig. 4. Schematic Diagram of the System

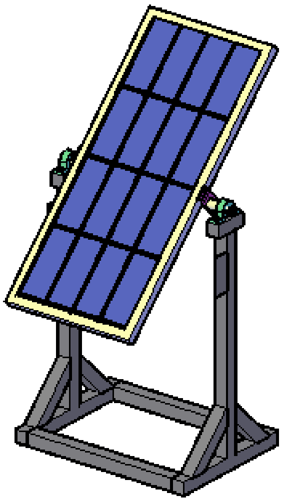


Fig. 5. Design of Metal Frame

Do

Assembly and Fabrication

The researchers utilize a 2x2 inch level metal bar for creating the edge of the board. Subsequently, introduce the two pad squares to interface the shaft associated straightforwardly to the solar panel board. Finally, they fit the linear actuator to control the changing point of the solar panel board. Figure 6 the completed result of the metal frame.

Fig. 6. Metal Frame

After the fabrication of the frame, the solar panel is attached to the frame with a two (2) single-axis linear actuator motor to carry the solar panel in angular motion following the movement of the sun. Figure 7 shows the actual mounting of the solar panel in a frame with a single axis linear actuator. After the fabrication of the structure, the solar panel is attached to the frame with a two (2) single-axis linear actuator motor to carry the solar panel in angular motion following the movement of the sun. Fig 7 shows the actual mounting of the solar panel in a frame with a single axis linear actuator.

The researcher created the microcontroller board in the Express PCB software for the easy layout of the whole circuitry. Figure 8 shows the design of the PCB.

After creating the layout, the researcher processed the PCB into the actual board by etching copper, drilling the holes to place the parts, and soldering it. Figure 10 shows the basic assembled Microcontroller unit of the system.

Fig. 7. Mounted Solar Panel in a Frame

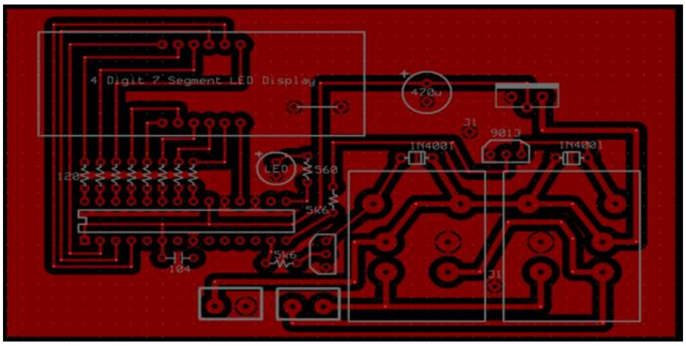


Fig. 8. Lay-out of the Microcontroller

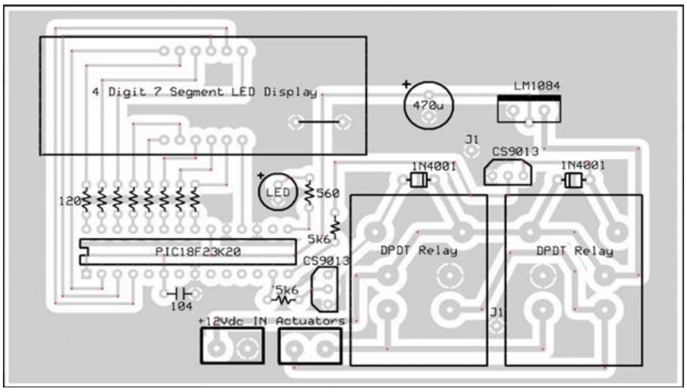
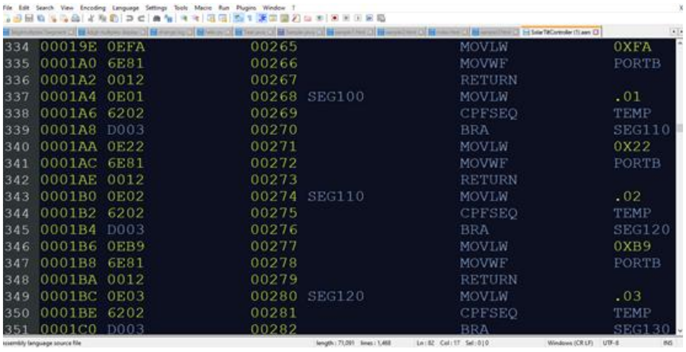


Fig. 9. Placement of parts in PCB Lay-out

Fig. 10. Microcontroller Main Board

The researchers created a code for the Microcontroller to activate. Then, it is programmed embedded into its memory using assembly language programming based on the instruction set given by the datasheet of Microchip Corporation. Figure 11 shows the Notepad++ editor for the source code of the system.



```
334 00019E 0EFA   00265          MOVLW   0XFA
335 0001A0 6E81   00266          MOVWF   PORTB
336 0001A2 0012   00267          RETURN
337 0001A4 0E01   00268 SEG100   MOVLW   .01
338 0001A6 6202   00269          CPFSEQ  TEMP
339 0001A8 D003   00270          BRA     SEG110
340 0001AA 0E22   00271          MOVLW   0X22
341 0001AC 6E81   00272          MOVWF   PORTB
342 0001AE 0012   00273          RETURN
343 0001B0 0E02   00274 SEG110   MOVLW   .02
344 0001B2 6202   00275          CPFSEQ  TEMP
345 0001B4 D003   00276          BRA     SEG120
346 0001B6 0EB9   00277          MOVLW   0XB9
347 0001B8 6E81   00278          MOVWF   PORTB
348 0001BA 0012   00279          RETURN
349 0001BC 0E03   00280 SEG120   MOVLW   .03
350 0001BE 6202   00281          CPFSEQ  TEMP
351 0001C0 D003   00282          BRA     SEG130
```

Fig. 11. Notepad++ Environment

Check

System Testing

According to the time setting, the researchers conduct system testing to see if the microcontroller can tilt the solar panel. The tilt angle of the solar tracker system will depend on the time of the day instead of installing sensors to detect the position of the Sun. The two (2) linear actuators also function generally by the controller to tilt the solar panel concerning time. Figure 12 shows the testing of the system.

Fig. 12. Testing Tilting Solar Panel

The researcher tests its functionality after installing all the parts needed in the solar generator system based on the earlier block diagram. Figure 13 shows the result of the testing procedure.

Fig. 13. Testing Setup

After successful testing of the system, the researcher's also conducting experimentation to gather data to compare the efficiency of the solar panel with a solar tracking system.

Act

Implementation

During the first day of the experiment, the researchers connected the system to the solar panel to identify the gained energy and the efficiency of the power acquired after charging the solar panel. The researchers attached the solar tracking system to the solar panel on the second day. Also, the solar tracker gathered data that gained energy from the solar panel. Figure 14 shows the data gathering with the different results under the sun's heat.

Fig. 14. Gathering of Data

After conducting experiments, the researchers did a computation and comparison on the difference between the two systems—the scope of the comparison was based on the gained energy by getting the percentage difference between both experiments. Finally, the researcher used compass apps from the smartphone to measure the solar tracker's actual angle movement per hour. Figure 15 shows the exact setup of the angle measurements.

Fig. 15. Angle Measurement using Apps

III. RESULTS AND DISCUSSION

The researchers finally had come up with the final output of the study, wherein it is functionality based on the desired outcome of the study. Fig 16 shows the running setup of the solar energy power based on the solar tracker and without the solar tracker setup.

Fig. 16. Running Setup of Solar Power

The researchers conducted experiments in the open ground from morning to afternoon by getting the given voltage and the current to identify the supplied power in the solar panel. The researchers use the formula *Power = Current x Voltage or P=IV* to identify the Solar Panel's Power Output. Figure 17 shows the graph comparison between fixed solar panels and solar trackers.

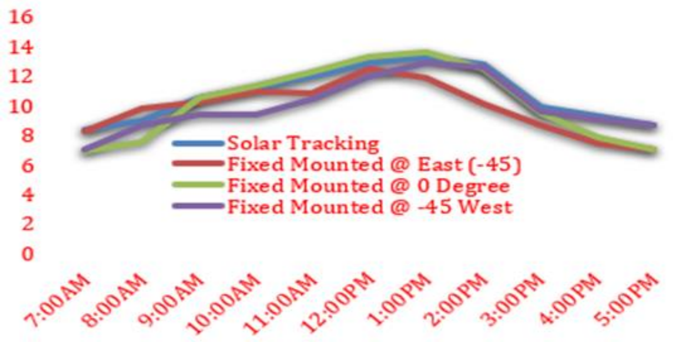


Fig. 17. Graph Result

Based on the graph presented in Figure 17, the reading of the power, the researchers noticed that the higher energy collected was during the off-peak hours from 10:00 am to 2:00 pm at all elevation angles.

TABLE 1. Gathered Data Using Solar Tracking System

WEATHER	FAIR			
TYPE	SINGLE AXIS SOLAR TRACKING SYSTEM			
DATE	02/22/20			
TIME	VOLTAGE	CURRENT	POWER	ANGLE
7:00 AM	8.31V	0.35A	2.91W	-45 °
8:00 AM	9.01V	0.42A	3.78W	-45°
9:00 AM	10.53V	0.51A	5.37W	-33°
10:00 AM	11.27V	0.63A	7.10W	-22°
11:00 AM	11.93V	0.65A	7.75W	-11°
12:00 PM	12.85V	1.03A	13.24W	0°
1:00 PM	13.25V	0.92A	12.19W	-11°
2:00 PM	12.76V	0.87A	11.10W	-22°
3:00 PM	9.87V	0.61A	6.02W	-33°
4:00 PM	9.29V	0.55A	5.11W	-45°
5:00 PM	8.65V	0.39A	3.37W	-45°
TOTAL POWER			77.94W	
POWER EFFECIENCY GENERATED			97%	

And based on the result, the researchers noticed that using a solar tracker collects much more energy for more than 20 percent compared to the fixed mounted solar panel. The researchers also noticed that the selected mounted solar panel decreases its power output during the afternoon because the solar board is not facing the sun.

The solar tracker can make the battery fully charge for less than two hours compared to the fixed mounted panel, which needs two and a half hours to complete the battery.

The researchers gathered data and tabulated it from 7:00 am to 5:00 pm as deflected in Table 1 for results of voltages, current, and power with the respective time and date using a single axis solar tracking system.

TABLE 2. Gathered Data Using Fixed Mounted Solar Panel @ -45 Degrees (East)

WEATHER	FAIR		
TYPE	FIXED MOUNTED SOLAR PANEL		
ANGLE	@-45 DEGREES (E)		
DATE	02/23/20		
TIME	VOLTAGE	CURRENT	POWER
7:00 AM	8.22V	0.33A	2.71W
8:00 AM	9.76V	0.40A	3.9W
9:00 AM	10.25V	0.52A	5.33W
10:00 AM	10.98V	0.59A	6.48W
11:00 AM	10.85V	0.65A	7.05W
12:00 PM	12.47V	0.89A	11.1W
1:00 PM	11.82V	0.83A	9.81W
2:00 PM	10.12V	0.68A	6.88W
3:00 PM	8.63V	0.52A	4.49W
4:00 PM	7.45V	0.44A	3.28W
5:00 PM	6.98V	0.31A	2.16W
TOTAL POWER			62.28W
POWER EFFECIENCY GENERATED			77%

TABLE 3. Gathered Data Using Fixed Mounted Solar Panel @ -0 Degrees (East)

WEATHER	FAIR		
TYPE	FIXED MOUNTED SOLAR PANEL		
ANGLE	@ 0 DEGREES		
DATE	03/04/20		
TIME	VOLTAGE	CURRENT	POWER
7:00 AM	6.88V	0.29A	2.00W
8:00 AM	7.58V	0.37A	2.80W
9:00 AM	10.48V	0.46A	4.82W
10:00 AM	11.30V	0.53A	5.99W
11:00 AM	12.27V	0.68A	8.34W
12:00 PM	13.26V	0.97A	12.86W
1:00 PM	13.58V	0.94A	12.77W
2:00 PM	12.45V	0.79A	9.84W
3:00 PM	9.45V	0.52A	4.91W
4:00 PM	7.83V	0.49A	3.83W
5:00 PM	6.98V	0.29A	2.02W
TOTAL POWER			70.18W
POWER EFFECIENCY GENERATED			87%

In Figure 18 below, based on the graph, the tracker collects more power than fixed-mounted solar panels, especially in the morning from 7:00 AM to 10:00 AM and from 3:00 PM to 5:00 PM.

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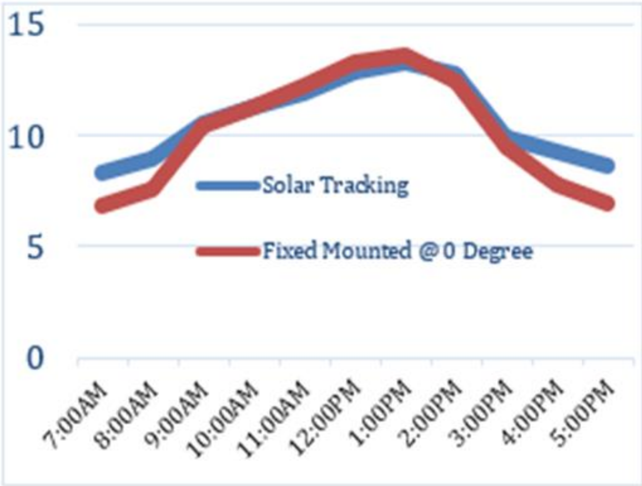

Fig. 18. Solar Tracking vs Fixed (0^0)

TABLE 4. Gathered Data Using Fixed Mounted Solar Panel @ -45 Degrees (West)

WEATHER	FAIR		
TYPE	FIXED MOUNTED SOLAR PANEL		
ANGLE	@ -45 DEGREES (W)		
DATE	03/05/20		
TIME	VOLTAGE	CURRENT	POWER
7:00 AM	7.01V	0.34A	2.18W
8:00 AM	8.67V	0.37A	3.21W
9:00 AM	9.43V	0.39A	3.68W
10:00 AM	9.43V	0.43A	4.21W
11:00 AM	10.37V	0.55A	5.70W
12:00 PM	11.98V	0.91A	10.90W
1:00 PM	12.84V	0.98A	12.58W
2:00 PM	12.59V	0.79A	10.14W
3:00 PM	9.61V	0.60A	5.77W
4:00 PM	9.11V	0.52A	4.74W
5:00 PM	8.71V	0.41A	3.57W
TOTAL			66.68W
POWER EFFECIECY GENERATED			83%

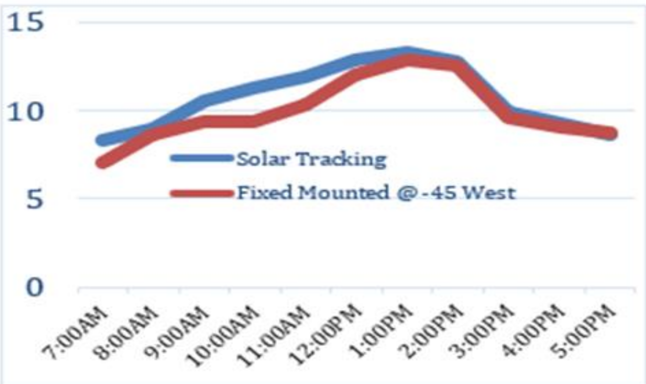

Fig. 19. Tracking VS Fixed (@West)

In Figure 19, the graph shows a significant variation in the morning while the sun is behind the solar panel. Solar tracking is more effective than a fixed solar panel.

Tables 1, 2, 3, 4 presented above with the specified data of total power gained and power efficiency generated with the formula given below:

TOTAL POWER = Summation of All Acquired Power
POWER EFFECIENCY = ACTUAL MEASURED / RATED POWER

As a result, charging a solar panel using a solar tracker much higher power acquired, a total of 77.94 watts, and a power efficiency generated at about 97 % compared to the fix mounted solar panel, as reflected in Table 1. While in the fixed installed, there were three (3) angle positions being tested and gathered the data as indicated in Tables 2, 3, and 4, respectively. The total power generated at different angles was not the same result as stated in Tables 2, 3, and 4 due to the sun's position that the panel is away from a focal spot. The highest acquired voltage angle is at zero (0) degrees concerning the ground from 11:00 AM to 2:00 PM, in which the position of the solar panel is at zero (0) degrees angle when the sun is in-line with the solar panel.

Summary

Based on the result that gathered data from the experimentations and differentiating, it proves that applying a sun tracker to the solar panel is much more efficient than the fixed mounted. Based on the experiments, using the implementation of the system increases the gained energy by 20 %. The test was conducted from 7:00 AM the morning up to 5:00 PM.

IV. CONCLUSION

The researchers concluded that the Microcontroller is the primary brain of the system wherein the program/machine coded is embedded into its memory to perform repetitive applications. Without a Microcontroller, it is tough to develop a solar tracker that will last for a longer time using metal gears because of corrosion issues. The researchers finally came up with the finished product that can acquire more power than the conventional solar energy panel without the solar tracker.

Using a microcontroller in the system was applied for the automation of the tracking system. The system's operational program is based on the inputted time in the Microcontroller. The solar panel tilts by the Microcontroller through the real-time sun positioning based on the time. Also, the solar panel alone is massive. So the researchers use low-speed high torque linear actuators for the solar tracking system to operate smoothly and avoid any possible problems.

Recommendations

For the development and improvements of this study, the researcher recommends the following:

1. An additional Linear actuator will install to support the solar panel's larger load capacity, producing a vast amount of power in the storage battery.
2. The whole operation, including the electrical output components, will become waterproof so that the system can be helpful during the entire, complete season.

ACKNOWLEDGMENT

The researcher sincerely thanks the involved person during the experimentation and assembly of the entire study, especially the researcher's family, for the unending support. And finally, our more powerful Lord Jesus Christ, who is on a

high, always protects and gives good judgment when doing this study.

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