Portable Solar Powered Outdoor Charging Station With The Application Of Servo Motor In Sunlight Tracking System With Light Detection Relay Sensor

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Abstract.
The use of renewable sources of power has been greatly encouraged since the turn of the century owing to the limited source of fossil fuels. The richest fuel source in the area of renewable energy is solar energy. This experimental-development study focused on the fabrication and testing of a portable solar powered charging station with servomotor and light sensor and testing its acceptability in terms of functionality, aesthetics, durability and safety. This also focused on the determination of the effectiveness of the solar tracking system in the output voltage and current of the prototype. Moreover, efficiency in charging was also tested. Locally available materials were used in constructing the prototype which as equipped with a solar energy harvesting system and sunlight tracking system using Arduino uno to program the sunlight tracking module. Results of the study indicate that the prototype consisted of a harvesting system and a tracking module which enabled the rotation of the solar panels to the angle where solar energy harvest is maximum throughout the day. The Historic Data Chart of the Climate in the Philippines for the daily sunshine hours was used to determine the exact energy that can be harvested in one sunny day and the factors that will be affecting the On and Off condition of the LDR sensor for the lights. Results also suggest that the prototype is highly acceptable with a rating of very good in all the indicators of functionality, aesthetics, durability and safety. Further, there was a 7.62% and 33.39% increase in the voltage and ampere after installing the sunlight tracking system. Furthermore, it was found that the maximum number of gadgets that can be charged by the solar portable charging station is three laptops with 45 watts poer input in three hours and nine mobile phones with 5 watts power input in two hours or a combined full charge capacity of 575 watt-hours

Keywords: *solar-powered charging station, servo-motor*

I. INTRODUCTION

The province of Occidental Mindoro belongs to the Small Power Utilities Group (SPUG) of the National Electrification Administration and is mainly serviced by Occidental Mindoro Electric Cooperative, an electric cooperative that is dependent on power produced by diesel generators. While most of the province is already energized, there are still unenergized areas which are located in remote areas. The province is also not exempted from frequent power interruptions caused by line faults and other technical reasons. Due also to its geographical location, Occidental Mindoro is often visited by typhoons and other extreme weather conditions which result to damage of power transmission and distribution lines and consequently, to massive power outages. In the aftermath of these disasters, communication is indispensable. In December 2019, super typhoon Ursula wreaked havoc to the province of Occidental Mindoro taking down 70% of the distribution lines in the SAMARICA Area (OMECO Annual Report, 2019). Power was only fully restored after two months. At the interim , alternative sources of power, mainly gas and diesel generators were used to charge cellular phones and other communication equipment, and to provide lighting during the night.In situations like these, alternative sources of power aside from gas power generators can be tapped like solar or wind energy. The use of renewable sources of power has been greatly encouraged since the turn of the century owing to the limited source of fossil fuels. The richest fuel source in the area of renewable energy is solar energy. Two methods exist by which sunlight can be converted into directly usable energy are: conversion of sunlight based on rankine cycle and conversion of electricity based on photovoltaic (PV) effect. The former is the conversion of solar energy into heat by absorbing sunlight into a blackened surface while the latter uses solar cells to harvest energy which is converted to DC electricity. (Udayalakshmi & Mohammed, 2018).

To convert the sun's energy, the photovoltaic (PV) cells capture photons; create free electrons that flow across the cells to produce current (Schuss & Rahkonen, 2012) Today, there is a widespread use of photovolatc and solar-thermal installations primarily in space application where every satellite is equipped with solar photovoltaic as power source . Solar photovoltaic technologies have been deployed for varius off-grid and on-grid applications such as solar street lighting, solar water pumping, rural electrification, commercial power projects and solar building technologies (Sheik Mohammed & Ramasamy, 2010). In 2018, Udayalakshmi & Mohammed designed a solar powered mobile phone charging station and cited that the two main parameters which had noticeable effect on the solar PV output were temperature and irradiation with the other factors ontributing to the variation of the output power being cloud cover and angle of the sun. They found that the PV panel output was directly proportional to the light intensity and the chnge in temperature has an inverse effect on the panel voltage. The angl at which the panels are placed in their mounts also determine the power collected by the panels (Schuss & Rahkonen, 2012,; Schuss, Eichbergert & Rahkonen, 2014). Of all the designs previously made for outdoor solar-powered charging stations, obtaining the greatest amount of sunlight to optimize the output was a challenge. A solution to this constraint was proposed by Kondackri, Collins and Habbab (2014) by integrating a solar tracker circuit in the design which will allow constant alignment towards the sun and can potentially increase the production of electricity by the solar panel up to 60%..

Consequently, an increase in output allows for a reduction in panel array size which helps with overall cost and size of the design.It is proposed that same design concept can be applied to a portable charging station which local government units can place in a public place for the public's accessible phone charging needs.. The charging station will also automatically illuminate when the sensor does not detect light from any source especially during night time, Unlike alternating current charging stations, the proposed design will use an entirely renewable source of power with the added features of a servo motor for sunlight tracking system to maximize solar energy harvest as well as provide light source during the night. The proposed design in this research incorporates the use of servo motor for sunlight tracking as well as the integration of a solar lighting system which uses light detection relay sensor which enables the prototype to be both a cellphone charging station and lighting system expected to provide 600-1000 lumens of light.The proposed beneficiaries of this research project are those off-grid constituents or those not connected to the power utility by virtue of their distant location. Moreover, the portable cellular phone/laptop charger will be indispensable during pandemics like the CoVID 19 especially since classes are conducted online and hence the need to charge cellular phones and laptops is heightened.

II. OBJECTIVES

The main objective of this study is to design and construct a Solar Powered Outdoor Charging Station with the application of Servo Motor in sunlight tracking system with Light Detection Relay sensor. Specifically, the study aims to

1. Determine the material and system specification for the fabrication of the solar-powered charging station
2. Construct, test and evaluate the Solar Powered Outdoor Charging Station with the application of Servo Motor in sunlight tracking system with Light Detection Relay sensor.in terms of:

a. functionality;
b. durability;
c. aesthetic; and
d. safety;

3. assess the percentage difference in the output voltage reading before and after installing the sunlight tracking system
4. Test the performance efficiency of the product in charging cellular phones and laptops

III. MATERIALS AND METHODS

Research Design

The study was undertaken using an experimental development research design by fabricating a prototype on the technology of harvesting energy from the sun and testing it in terms of functionality, durability, aesthetics and safety. Consequently, its charging efficiency was also measured.

Construction Materials

The following materials were used in the construction of the solar-powered charging station with sunlight tracking system and light sensor:

Table 1. Construction Materials

Quantity	Item Description	Unit
1	100-Watt Solar Panel	Piece
1	12V Battery 70Ah	Piece
1	Charger Controller	Piece
1	1000-Watt Inverter	Piece
4	Convenience Outlet	Pieces
4	Outlet Casing	Pieces
1	Servo Motor	Piece
1	Arduino Uno	Piece
1	Electrical Tape (big)	Piece

1	USB Cable	Piece
8	Connecting Wires	Meters
1	12V DC Bulb	Piece
2	Resistor	Pieces
1	Capacitor	Piece
1	Aluminum Stand	Piece
1	Charging Station's Roof	Piece
1	Metal Table Base	Meter High
5	Bolts and Screws	Pieces
1	Padlock	Piece
1	Paint	Quart Transportation

B. Methods

1. Collection of Solar Energy

The set-up for sunlight collection is presented in Figure 1 where the sunlight falls on solar array. The sun's power emitted to the Earth (prototype) is composed of "photons" that carry energy. Photons hit the solar panel "Photovoltaic" (PV), then photons cause the electrons in the PV material to move. Moving electrons are direct current electricity which can be stored in a battery and converted by a DC 12V inverter to become the standard 230/220 volts convenience outlet source.

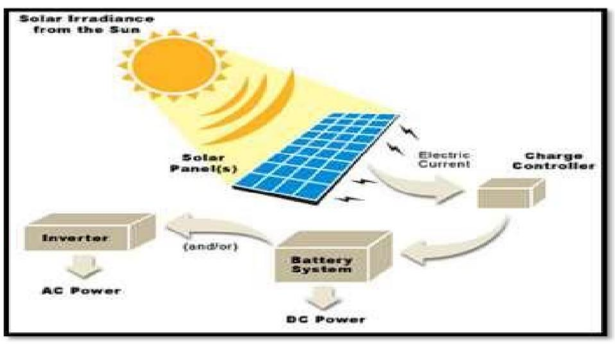

Fig 1. Collection of Solar Energy

2. Storage and conversion of solar energy to electrical energy

The diagram shows the different parts of the Solar Powered Outdoor Charging Station with the application of Servo Motor in sunlight tracking system with Light Detection Relay sensor. In Figure 2, , the solar panel or the module of the system is connected to the solar charger controller, the charger controller is in turn connected to the battery and inverter to supply a DC power supply for the convenience outlets and the led light bulb.

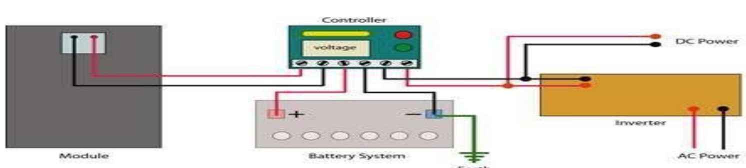

Fig 2.

A. Charger Controller will regulate or limit the rate or range of distribution of electric current. Also it will help to prevent overcharging and may protect against overvoltage. It will reduce the battery performance and it also lifespan. Lastly, it may pose a safety risk.

B. Storing collected electrical energy in 120 AH rated battery.

C. Converting Electrical Energy from Direct current (DC) to Alternating current (AC). The collected electrical energy will be sent to inverter as DC electricity will be converted to AC.

D. The design of the project is based on the existing individual models of IoT-based power meter with light detector relay for the bulb and AC light dimmer using ESP8266 when combined. Also light detector relay (LDR) serves as the source function of the light bulb installed in the prototype. This sensor will limit the energy consumption of the light bulb, in the morning it will automatically turn "Off" as it senses the sunlight and when it gets dark it will automatically turn "On".

The biggest constraint in the project was maximizing the solar efficiency in providing the best amount of energy to the system generated by solar panels. Weather and solar patterns will be accounted during the calculations of the efficiency and output of the solar panels. Climate factors, such as clouds, moisture, haze, dust, and smog were considered in on the amount of output power produced. Obtaining the greatest amount of sunlight throughout the day will be needed for optimum output. The prototype used a 1200W inverter, to be able to theoretically charge eight laptops (with 45 watts) and three dc led light bulb (12 volts, 10 watts) connected to the LDR sensor. The researchers utilized the Historic Data Chart of the Climate in the Philippines as baseline data on the average of daily sunshine hours to determine the energy that can be harvested in one sunny day and the factors that would affect the On and Off condition of the LDR sensor for the lights. Since the solar panel of this project is rated 120 Watts and the average daily sunshine hours in the Philippines is 5.75 hours, a total of 690 Watt-hour will be theoretically harvested in the system.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Sunlight Hours/ Day	05:42	07:00	07:17	08:36	07:11	05:24	04:17	04:17	04:24	05:05	05:06	04:54	05:45
Average Daylight Hours & Minutes/ Day	11:21	11:38	12:01	12:26	12:47	12:57	12:53	12:35	12:11	11:46	11:25	11:16	12:00
Sunny & (Cloudy) Daylight Hours (%)	51 (49)	61 (39)	61 (39)	70 (30)	57 (43)	42 (58)	34 (66)	34 (66)	36 (64)	44 (56)	45 (55)	44 (56)	48 (52)
Sun altitude at solar noon on the 21st day (°)	55.4	64.6	75.5	87.2	84.4	81.1	83.9	87.4	76.1	64.5	55.4	52	72.3

Fig 3. Historic Data Chart of the Climate in the Philippines.

3. *Testing of the Prototype*

The prototype was tested in terms of functionality, safety, durability and aesthetics. The instrument used measured these qualities using a likert scale of one to five with five as maximum. Moreover, the charging efficiency and the voltage output difference was also measured to test whether the servomotor helped in maximizing the solar energy harvest.

IV. RESULTS AND DISCUSSION

1. Material and system requirements

The prototype used a 1200W inverter, to be able to charge eight laptops (with 45 watts) and three dc led light bulb (12 volts, 10 watts) connected to the LDR sensor. The researchers utilized the Historic Data Chart of the Climate in the Philippines for the daily sunshine hours to determine the exact energy that can be harvested in one sunny day and the factors that will be affecting the On and Off condition of the LDR sensor for the lights. Since the solar panel of this project rated 120 Watts and the average daily sunshine hours in the Philippines is 5.75 hours, a total of 690 Watt-hour will be consumed in the system. The operation starts from the battery to convenience outlet that is connected to the solar panel where the sunlight tracking system is installed. The module is required to take energy from the sun generated by solar panels while the controller regulates the power from the solar panels to the batteries, the inverter converts the DC voltage generated from the solar panels to an AC voltage.

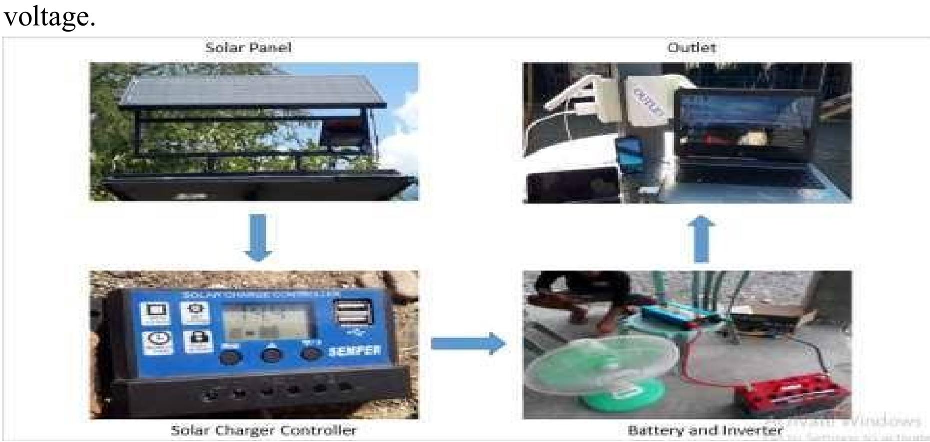

Fig 4. Pictorial diagram of the components of the Portable Solar Charging Station

The solar panel will harvest energy from the sun and the solar charger controller regulate the power going from the solar panels to the batteries. The inverter will convert the DC voltage generated from the solar panels to an AC voltage to charge up devices

2. Schematic Diagram of the Harvesting Part

In Figure 5, the solar panel or the module of the system is connected to the solar charger controller then the charger controller was connected to the battery and inverter supply a DC power

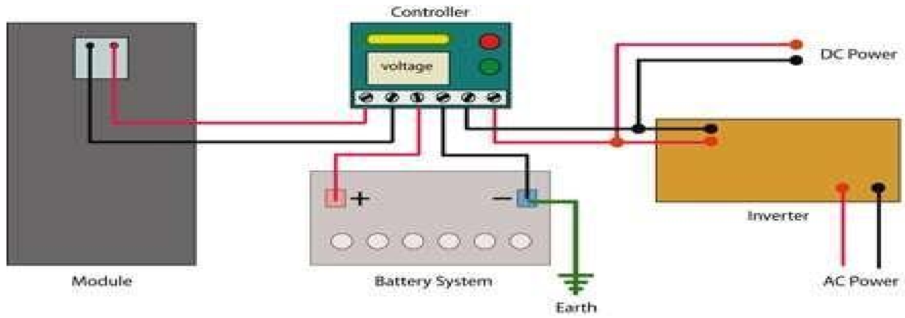

Fig 5. Schematic Diagram of Harvesting Part

Schematic Diagram of the Tracking Part

The Arduino is programmed to store the data gathered from the power analyzer and also it controls the function of the Servo Motor as actuator of the system. It initiates movement of the solar panels towards the direction where the sun shines the brightest to maximize solar energy harvest.

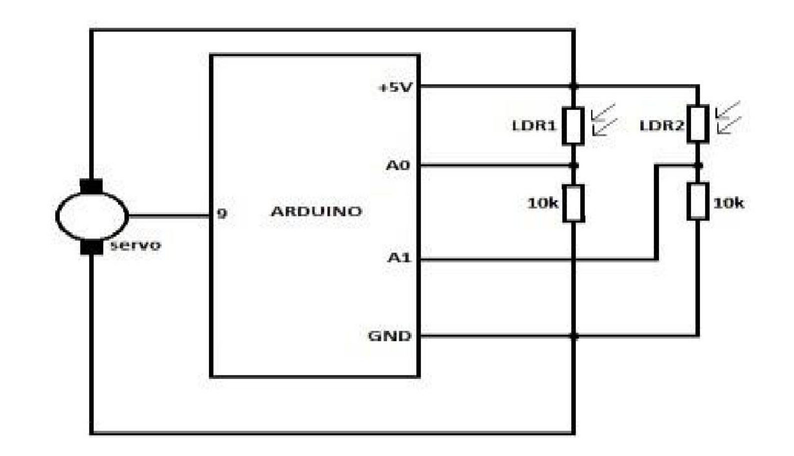

Fig 6. Schematic Diagram of the Tracking Part

Wiring Diagram of the Harvesting Part

The figure shows the wiring diagram of the proposed product. The operation started from the battery to convenience outlet that was be connected to the solar panel where the sunlight tracking system is installed

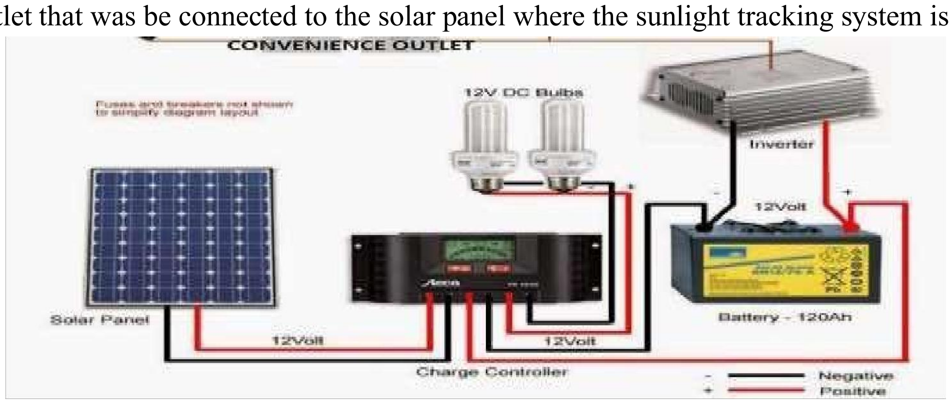

Fig 7. Schematic Diagram of the Solar Charging Station

Wiring Diagram Sunlight Tracking System

The Arduino is programmed to store the data gathered from the power analyzer. It is also programmed to controls the function of the Servo Motor as actuator of the system.

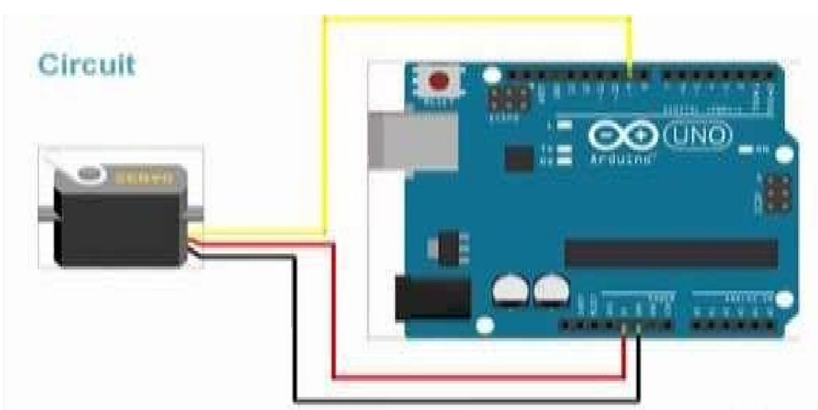

Fig 8. Sunlight Tracking System

3. System Block Diagram of Harvesting Part

The diagram in Fig 9 represents the systematic process of the operation of the developed product. From the battery that is connected to the solar panel going to the charger controller and inverter to produce an AC output; battery is supplied with power by solar panel enabling the charger controller to operate.

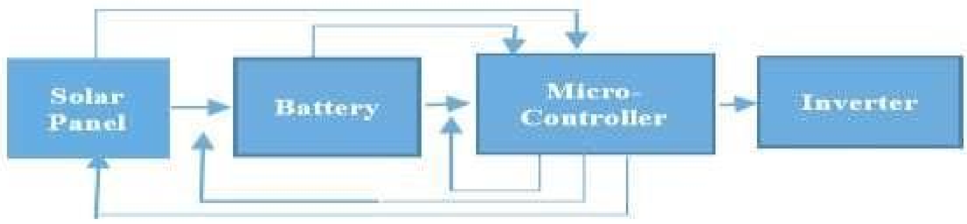

Fig 9. System block diagram of harvesting part.

4. Testing of the Prototype

After construction of the prototype and integration of its solar energy harvest system and the tracking system, it was tested in terms of functionality, aesthetics, durability and safety. Table 2 shows the mean score in terms of functionality as 4.00 and interpreted as 'very good'. The indicators of functionality essentially reflects the prototype's usability and delivery of the features as provided in the design concept.

Table 2. Mean score of acceptability in terms of functionality.

Functionality	Mean	Interpretation
Ease of operation	4.00	Very Good
Provision of Comfort and Convenience	4.00	Very Good
User friendliness		
	4.00	Very Good
Total	4.00	Very Good

Legend: Excellent-4.50-5.00; Very Good- 3.50-4.49; Good- 2.50-3.49; Fair- 1.50- 2.49; Poor- 1.00-1.49

The respondents evaluated the Aesthetics or the artistic design and fabrication of the trainer in terms of ease of size, design and color which yield an overall mean of 4.00 interpreted as very good. This indicates that the prototype had pleasing in appearance.

Table 3. Mean score of acceptability in terms of aesthetics.

Aesthetic	Mean	Interpretation
Size	3.50	Very Good Excellent
Design	4.50	Very Good
Color	4.00	
Total	4.00	Very Good

Legend: Excellent-4.50-5.00; Very Good- 3.50-4.49; Good- 2.50-3.49; Fair- 1.50- 2.49; Poor- 1.00-1.49

The overall mean score of 4.00 described as very good as evaluated by the respondents to the durability and quality of the prototype in terms of design and materials implies that the product will last over a long period of time.

Table 4. Mean score of acceptability in terms of durability.

Durability	Mean	Interpretation
Design Materials	4.00	Very Good Good
	3.00	
Total	3.50	Very Good

Legend: Excellent-4.50-5.00; Very Good- 3.50-4.49; Good- 2.50-3.49; Fair- 1.50- 2.49; Poor- 1.00-1.49

Generally, safety evaluation gained a mean score rating of 3.50 interpreted as very good as evaluated by the respondents in terms of smoothness of the surfaces, installed protection device and provisions of warning sign which ensured its safe use.

Table 5. Mean score of acceptability in terms of safety.

Safety	Mean	Interpretation
Smoothness of the surfaces	4.00 3.50	Very Good
Installed Protection Device	4.00	Very Good Good
Provisions of Warning Signs		
Total	3.83	Very Good

Legend: Excellent-4.50-5.00; Very Good- 3.50-4.49; Good- 2.50-3.49; Fair- 1.50- 2.49; Poor- 1.00-1.49

The acceptability Solar Powered Electric Charging Station of as evaluated by the experts in terms of functionality, aesthetics, durability/quality, safety and instructional applicability had a mean rating of 3.83 interpreted as very good. The result denotes that the Solar Powered Electric Charging Station can be useful in augmenting the intermittent power supply in outdoors.

Table 6. Mean score of acceptability.

Acceptability	Grand mean	Interpretation
Functionality	4.00	Very Good
Aesthetics	4.00	Very Good
Durability/Quality	3.50	Very Good
Safety	3.83	Very Good
Total	3.83	Very Good

Legend: Excellent-4.50-5.00; Very Good- 3.50-4.49; Good- 2.50-3.49; Fair- 1.50- 2.49; Poor- 1.00-1.49

5. Voltage Difference before and after installation of Sunlight Tracking System

To test whether the servomotor was effective in maximizing solar energy harvest, output voltage reading was done before and after installation of the servomotor. Table 7 reflects the output voltage reading before installation of the servomotor. Testing was done on the same day with interval of attaching the wires to the harvesting system. Table 7 shows a collected data of the output voltage that reads in the 10 Ampere charger controller display connected from the 100-Watt solar panel (Stationary array) without the tracking system. The table shows that the five trials being done results to an average output voltage data of 13.12 Volts.

Table 7. The output voltage reading from the solar panel without solar tracking system.

Trial	Time	Output Voltage
1	08:00 AM	12.6
2	10:00 AM	12.9 14.4
3	12:00 NN	12.7
4	02:00 PM	12.6
5	04:00 PM	

In the third trial, solar panel was facing straight directly to sun, so that we meet the peak output voltage of the 100-Watt Solar panel. When sunlight strikes a solar panel, it comes in at an angle, called the angle of incidence. The normal angle to the cell is perpendicular to a PV cell's face and this normal is necessary to achieve the panel's proper alignment towards the sun.Table 8 shows a collected data of the output voltage that reads in the 10 Ampere charger controller display connected from the 100-Watt solar panel with the tracking system. The table shows that out of five trials being done results to an average output voltage data of 14.12 Volts.

Table 8. The output voltage reading from the solar panel with solar tracker system.

Trial	Time	Output Voltage
1	08:00 AM	13.7
2	10:00 AM	14.4
3	12:00 NN	14.4 14.4
4	02:00 PM	13.7
5	04:00 PM	

Solar trackers provide a precise tracking of the sun by tilting the solar panels towards the sunlight as it moves throughout the day.

- Voltage Difference = Average Voltage (Table 6) - Average Voltage (Table 5)
- Voltage Difference = 14.12 Volts – 13.12 Volts
- Voltage Difference = **1 Volt**
- Percentage Increase = Voltage Difference / Average Voltage (Table 5) x 100 %
- Percentage Increase = 1 Volts / 13.12 Volts x 100 %
- Percentage Increase = **7.62 %**

The integration of a solar tracker circuit into the design allowed constant alignment towards the sun and can potentially increase the production of electricity by the solar panels by as much as 7.62%. In the third trial, solar panel was facing straight directly to sun, so that we meet the peak output current of the 100-Watt Solar panel. When sunlight strikes a solar panel, it comes in at an angle, called the angle of incidence. The normal angle to the cell is perpendicular to a PV cell's face and this normal is necessary to achieve the panel's proper alignment towards the sun.

Solar trackers provide a precise tracking of the sun by tilting the solar panels towards the sunlight as it moves throughout the day.

Ampere Difference = Average Ampere (with) - Average Ampere (without)

- Ampere Difference = 3.004 Amperes – 2.252 Amperes
- Ampere Difference = **0.752 Ampere**
- Percentage Increase = Ampere Difference / Average Ampere (Table 7) x 100 %
- Percentage Increase = 0.752 Amperes / 2.252 Amperes x 100 %
- Percentage Increase = **33.39%**

One solution to the aforementioned constraints is to integrate a solar tracker circuit into the design, which allowed constant alignment towards the sun and can potentially increase the production of electricity by the solar panels by up to 33.39 %.

6. Charging Efficiency

Table 9 shows the total watt-hour of the prototype that was calculated by number of wattage of gadgets multiply by the number of hours to be full charge. The result indicated that 575Watts-hour is the maximum rating of the system with respect to the quantity of the gadgets.

Table 9. The total number of gadgets can be charge from the system in one day.

Quantity	Gadgets	Watts	Hours Use	Watt-hour
3	Laptop	45.0	3.0	405
9	Mobile Phone Tablet	5.0 7.2	2.0 2.0	90
4	Pocket Wi-Fi	5.6	1.0	57.6
4				22.4

Therefore, the maximum number of devices that can be charge in the system was 3 laptops with 45 Watts power input in 3 hours; 9 mobile phones with 5 Watts power input in 2 hours; 4 tablets with 7.2 Watts in 2 hours; and 4 1500mAh pocket Wi-Fi with 5.6 Watts in an hour. The total watt-hour consumed was 575Watt-hour in a full charge battery.

V. CONCLUSION

Based from the findings of the study, the following conclusions are drawn:

1. The prototype consisted of a harvesting system and a tracking module which enabled the rotation of the solar panels to the angle where solar energy harvest is maximum throughout the day. The Historic Data Chart of the Climate in the Philippines for the daily sunshine hours was used to determine the exact energy that can be harvested in one sunny day and the factors that will be affecting the On and Off condition of the LDR sensor for the lights.

2. The prototype is highly acceptable with a rating of very good in all the indicators of functionality, aesthetics, durability and safety.

3. There was a 7.62% and 33.39% increase in the voltage and ampere after installing the sunlight tracking system.

4. The maximum number of gadgets that can be charged by the solar portable charging station is three laptops with 45 watts poer input in three hours and nine mobile phones with 5 watts power input in two hours or a combined full charge capacity of 575 watt-hours

VI. RECOMMENDATIONS

I view of the findings and conclusion of this study the following are proposed:.

1. A dual axis system solar tracker may be used to provide additional 6% increase of efficiency on solar power generation.
2. Two or more solar panels connected in parallel maybe used to increase solar energy harvest
3. High rating batteries to power the system should be used as these last over a long period of time.
4. A bi-directional stepper motor maybe chosen for this application because of their speed and torque yet low power and current consumption.

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