

Increasing the Output Power and Efficiency by Concentrating the Solar Flux Effectively Using a Dual Axis Solar Tracker

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Abstract—The dependency of electric power generation on conventional resources is high in any country as we all know the conventional resources of energy will not sustain for a long time thus, we must switch our resources of energy. The alternate is renewable energy, which is abundant in nature and will never exhaust. One such example is to get the required amount of energy from the Sun by using solar panels. It is an example of clean energy, but the efficiency is very low compared to conventional sources. Some research shows that the Sun's radiance, which falls on the earth in one hour, exceeds the total energy consumed in an entire year, proving the scope of highly efficient solar energy usage. This paper defines the possibilities of using different types of lenses of different focal lengths to improve the efficiency of the integrated photovoltaic model. Also, there can be fluctuations in the output power due to renewable uncertainties. Thus, it will be a target to keep the output power constant. [1]

Index Terms—Fresnel lens, Solar Tracking, Photo-Voltaic

I. INTRODUCTION

Due to global climate variation, conventional fossil-fuel-based energy sources are being replaced with non-conventional energy sources. A photovoltaic array is a collection of several photovoltaic modules. Each photovoltaic (PV) module consists of multiple interconnected PV cells [2]. The cells convert solar energy into direct current electricity. A convex lens is an optical device used to concentrate the incoming light onto a spot or a line. The temperature at this point will be high. Some research has been done previously, which shows that the total energy spent in an entire year is less than the solar energy falling on the earth within one hour on the earth. It will be helpful for solar thermal power plants to show their potential [3]. Photoelectric cells were used in the first experiment for generating electrical energy from solar energy, which was later supplanted by photovoltaic cells, found by Alexander Edmond Becquerel.

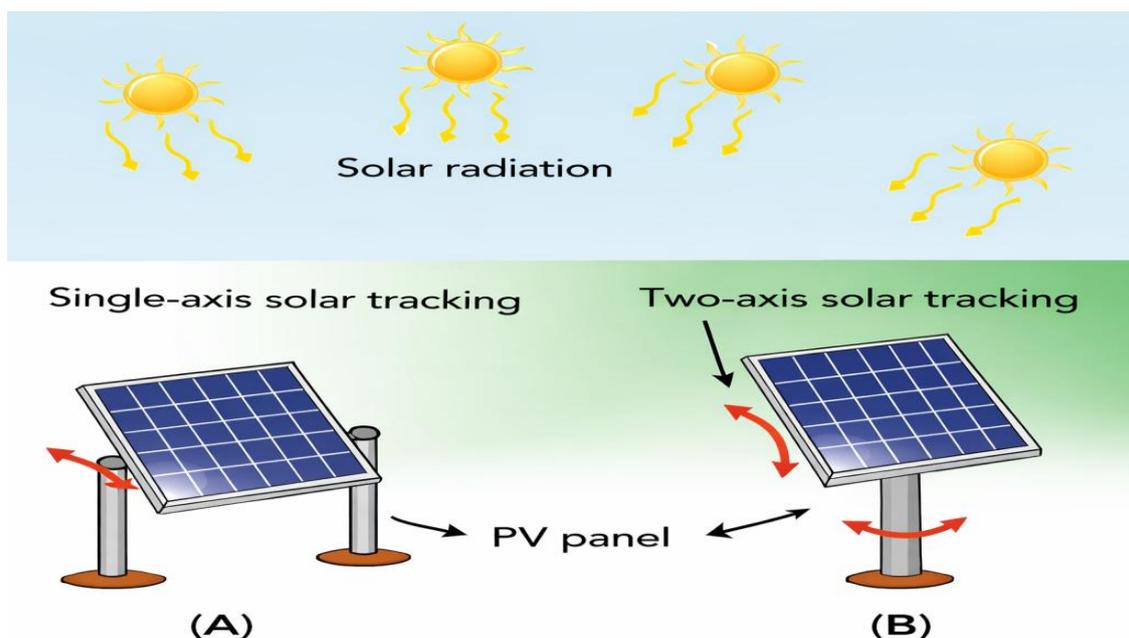


FIGURE 1. Solar Tracking System

Based on his research, he claimed that putting light on an electrode submerged in a conductive solution would generate an electric current. The concept of solar energy remained ineffective despite multiple research studies due to its expensive cost and low efficiency. Nowadays, power generation and its application are bending towards solar energy as a weapon to enhance society technically. Hybrid solar PV module for power generation comes in practice from which we can not only generate electricity, but we can supply them to the grid for which we can get subsidies from the government [4].

The installation of solar panel systems in high-rise buildings has gained pace in the last two decades. Solar panel systems, used to generate electricity and installed on roofs, are called rooftop systems.

Concentrating and building integrated photovoltaic thermal systems is gaining scope and increasing rapidly. Both electricity and heat can be generated using two types of concentrators: parabolic-trough and parabolic-dish and Fresnel lenses. In 1960, the first Fresnel lens for Concentrated Photovoltaic (CPV) power generation systems were built and tested. For achieving maximum power extraction from PV array, different experiments had performed in which one is by using simulation software named TRNSYS software in which additional readings are taken to observe the graph of kWh generated. These readings are taken for the PV array's 30, 45, 60, and 90(degree) orientation concerning the lens. The acrylic plastic was used to make a Fresnel lens and it proved to be an effective solar concentrator. The intended setup's highest mean efficiency was 34.82 percent [5]

II. METHODOLOGY

The main components of a concentrated photovoltaic (CPV) functionality include solar cells, concentrators, solar tracking systems having dual Axis to rotate, lenses, or concentrators. The working of each component is described here. Solar cells work on the phenomenon of the Photoelectric effect, which is when light radiation strikes the surface of the solar panel. The surface accepts an electron resulting in the formation of current. A concentrator is defined as the type of solar cell which operates under the illumination of Sun. It corresponds to a standard illustration that if 1 KW/mt. sq of the light is focused and steered by an optical device, it results in a high-intensity beam on a small solar cell. A solar panel's

short circuit current is in proportion to the intensity of light; hence a device operating under ten suns will have ten times the short circuit current compared . However, because incident power increases with concentration, this effect is not efficient. The efficiency improvement is provided by the logarithmic dependence of the open-circuit voltage on the short circuit [6]

Many efforts have lately been made to increase the efficiency of concentrated solar photovoltaic systems so that they may be manufactured at a lower cost. This solar tracking system is designed to get the maximum rays of Sun, so that maximum irradiance can be achieved [7]. The Solar tracking system used in this research is a dual-axis solar tracker that moves with the Sun on the y axis and on the x-axis. Solar Tracker, which is used here, is a microprocessor-based solar tracker. the solar panel moves on the x-axis and y-axis with the help of Servo Motor. When it comes to improving the efficiency of a solar panel, its orientation is crucial as solar panels use the radiance of the sun to generate the maximum power output [8]. The logarithmic dependence of the open circuit voltage and the radiance of the light is shown by the equation given below.

$$V_{oc}' = (nkT/q) \ln(XI_{sc}/I_o) = (nkT/q) [\ln(I_{sc}/I_o) + \ln X] = V_{oc} + (nkT/q) \ln X \quad \text{----- Eq [1]}$$

Where n, k, T denote solar constants, X is a concentration of sunlight and V is the open-circuit voltage. The study was bifurcated into two parts: dynamic simulations of PV module experiments in different conditions (performed via TRNSYS software) to have the orthogonal incidence angle. Keeping in mind some relevant experiments (carried out using a dedicated set-up). It had to do with the fact that traditional Fresnel lenses are designed to focus sunshine rays into a point or a line that is spread across a planar or curved surface.

III. EXPERIMENTAL SET-UP

The experimental part of this study was performed with a dedicated set-up having the following specifications:

- Fresnel lens having dimensions of 70 × 45 cm.

- 25 W PV cell with an open-circuit voltage of 10V and a short circuit current of 1.5 A having dimensions 50 × 30 cm
- pyranometer has a measuring range from 0 to 2000 w/m² and resolution of 1 w/m² (located close to the tested PV cell).
- RTD (Resistance Temperature Detector) sensor measuring the temperature of each cell on the PV panel.
- LDR sensors (4) for tracking the movement of sun rays falling on the panel.
- PV cell directly connected to the electric load to observe I-V and P-V characteristics.
- Data from LDR sensors and an inductive load are retrieved by a pfc200 plc controller.
- Computer with TRNSYS software.

The entire setup was installed on the roof of the AGH VST Energy and Fuels building. The PV modules and Fresnel lens were oriented southward (a PV module's tilt angle was 90° and its azimuth was 0°). Figure 1 depicts the rig's configuration. The TRNSYS program was used to examine the simulation diagram while retaining the Fresnel lens at varied orientations and rotating it simultaneously in both the x and y axes using LDR sensors. The next step was to see if a Fresnel lens could improve the performance of PV modules operating. Finally, the collected data were incorporated into the model, and additional analysis was conducted to maximize solar irradiation. The HPV-EVB system's efficient energy management method is derived from a variety of settings. Based on the highest PV power generation and load demand curves, these modes are efficiently differentiated. The HPV system's peak power generation occurs between 9 a.m. and 3 p.m. EVB should be fully charged at maximum speed during this time, and the residence should be powered by HPV electricity as well. Any excess HPV power can be fed into the grid during this time. This electricity is insignificant when compared to the total HPV power injected into the grid without the EVs. Of course, this eliminates the issue of too much HPV power being fed into the same feeder. EVB energy can be used to power the home load and fed into the grid if necessary during peak load demand, which occurs between 5 and 8 p.m.

The first step in modelling is to arrange, assemble and connect the components according to our circuit on a breadboard or a solar panel.

We will be using light-dependent resistors (LDR) or photoresistors which are sensors that are used for

detecting the intensity of light. Their resistance changes with the change in the intensity of light. With an increase in the intensity of light, the resistance of LDR decreases and vice versa. The LDR's will be sending the signals to the Arduino. Arduino UNO is a microcontroller that has been used for controlling the entire process. Arduino has fourteen input/output pins. Out of those, six pins are meant for Pulse Width Modulation (PWM). The Arduino sends the output signals to the servo motor which will help in moving and adjusting the solar panel according to the movement and direction of the sun.

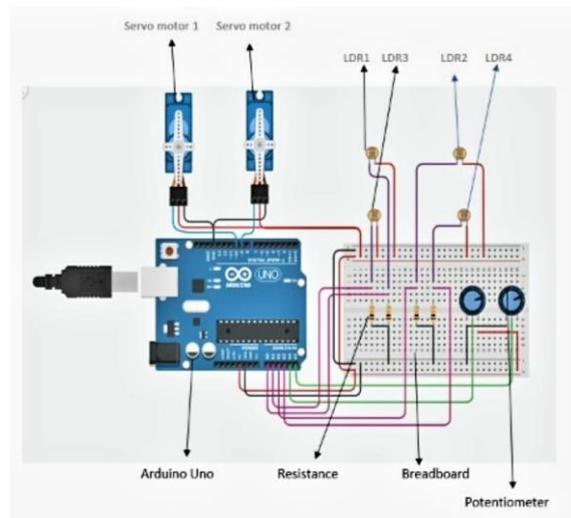


FIGURE 2. Schematic modeling of Solar tracking System

A basic circuit of the model has been developed on tinker-cad, which is shown in the figure 2. In this circuit, the resistors which are used, that is R1 and R2 are each of 4.7kohm. The two LDR's in the circuit are shown as PR1 and PR2. For our project, we will be installing the model in such a way that the components are fixed and not loose.

This system absorbs solar energy, stores it in a battery, and then transforms it into an alternating current of some value. The Energy which we will be stored can be used as a stand-alone power source. This system is created in a way that it can respond to its surroundings in the lowest time possible. Any type of error either hardware or software. Our system is put through its paces in terms of real-time responsiveness, dependability, stability, and security. The basic factors which our model can withstand are weather, temperature, and mild mechanical stresses.

IV. COMPONENT

TABLE 1: VARIOUS RESULTS FROM WATTMETER IS TAKEN FOR CALCULATING POWER.

S.no	Component	Quantity	Rating
1.	Solar panel	1	5 volt
2.	Fresnel lens	1	
3.	Resistance	4	10k-ohm
4.	Resistance	1	220 ohm
5.	LDR sensor	4	5mm
S.no	Component	Quantity	Rating
6.	Motor driver IC	1	L293D
7.	Geared motor	2	9volt, 150 rpm
8.	Arduino uno	1	Atmega328
9.	Diode	2	1N4007
10.	Battery	1	7.4Volt
11.	Switch	1	
12.	Wire		

Solar panel - A solar panel is made up of solar cells that can convert light directly into electricity. A vast number of tiny solar cells spread out over a big area can create enough electricity to be useful. Because the more light that strikes a cell, the more power it produces, spacecraft are typically designed with solar panels that can be directed at the Sun at all times, even while the rest of the spaceship moves around.

Fresnel lens - Concentric grooves engraved onto the plastic make up Fresnel lenses. They are helpful in a wide range of applications due to their thin, lightweight structure, availability in small and large sizes, and outstanding light-gathering ability. The design allows lenses with big apertures and short focal lengths to be created without the mass and volume of material required by traditional lenses. A Fresnel lens can be much thinner than a typical lens, often adopting the shape of a flat sheet.

Resistance - Resistance is defined as the property of element to oppose the current flow in an electrical circuit. Resistance is measure in ohm; it is denoted by omega. In this project, five resistances are use 4

resistance of 10k-ohm and one resistance of rating 220 ohm.

LDR sensor A photoresistor, commonly known as a cadmium sulphide (CdS) cell, is a light-dependent resistor (LDR). A photoconductor is another name for it. It's simply a photocell that works on the idea of photoconductivity. The passive component is essentially a resistor with a linearly decreasing resistance value as the light intensity increases. This optoelectronic component is commonly found in light-varying sensor circuits as well as light- and dark-activated switching circuits.

Motor driver IC - One of the simplest and least expensive ways to control DC motors is to connect the L293D Motor Driver IC to an Arduino. It can control the speed and direction of two DC motors.

- It is possible to use the same IC to power two DC motors.
- It is possible to control the Motor's speed and direction.
- 100 ns is the transition time.
- There is an option for an automatic thermal shutdown.
- 16-pin DIP, TSSOP, and SOIC packages are all available.

Geared motor - A geared motor is a component whose mechanism adjusts the motor's speed, causing it to operate at a specific speed. Because the gearhead acts as a torque multiplier, geared motors can deliver high torque at low speeds, allowing small motors to generate higher speeds.

Arduino UNO - The Arduino Uno is a microcontroller board that is open-source and developed by Arduino that is based on the ATmega328P microcontroller from Microchip. The board has analog and digital I/O pins that can be used for connecting various expansion boards and other circuits. A bootloader is preprogrammed into the ATmega328 board, allowing fresh code to be uploaded without the necessity of an external hardware programmer.

- The Operating voltage is 5volt.
- Input voltage is 7volt to 20volt.
- Digital input /output pins are 14.
- PWM pins are 6.
- Analog input pins are 6.
- Flash memory is 32KB.
- The Clock speed is 16MHz.

- SRAM is 2KB.
- EEPROM IS 1KB.
- Length is 68.6mm, Width is 53.4mm and weight is 25g.
- The Power sources are DC power jack & USB Port.

Diode- A diode is an electrical component that enables just one direction of electricity to pass. In the current limiting device, a diode is used. In an electronic circuit, a diode can also be employed as a switch. The most typical purpose of a diode is to allow an electric current to pass in one direction (the diode's forward direction) while blocking it in the other (the reverse direction). As an electronic check valve, the diode can be thought of. Rectification is the term for this one-way behaviour, which is used to convert alternating current (ac) to direct current (dc) (dc). In radio receivers, rectifier varieties of diodes can be used to extract modulation from radio signals. A semiconductor diode's current-voltage characteristic can be adjusted by choosing the semiconductor materials and doping impurities that are injected into the materials during production.

Battery- A battery is an electric power source made up of one or more electrochemical cells that are connected to the outside world and used to power electrical devices like flashlights, cell phones, and electric cars. When a battery is supplying power, the positive terminal is known as the cathode, and the negative end is known as the anode. The negative terminal is the source of electrons that will flow to the positive terminal via an external electric circuit. When a battery is connected to an external electric load, a redox reaction occurs in which high-energy reactants are converted to lower-energy products, with the free-energy difference being sent to the external circuit as electrical energy. The term "battery" used to refer to a device made up of multiple cells, but it has increasingly come to refer to single-cell devices.

Switch - A battery is a type of electric power source that consists of one or more cells. A switch is an electrical component that can interrupt or divert electric current from one conductor to another by disconnecting or connecting the conducting channel in an electrical circuit. The most common sort of switch is an electromechanical device that consists of one or more sets of moveable electrical contacts coupled to external circuits. Current can flow

between two contacts while they are in contact; when the contacts are separated, no current can flow. Power is supplied through electrochemical cells that are connected to the outside world.

V. CONCLUSION

This paper concluded about the extraction of maximum solar insolation by comparing results by placing convex lenses of different focal lengths and a special type of Fresnel lens. The minimum efficiency concluding from the vertical orientation and dual axis tracking of PV modules can be mitigated from the use of solar energy maximum extraction from the concentrated solar system. When the case was utilised to test and experiment with a PV module, the energy performance rose by 8% when a Fresnel lens was used.

Domestic use and rooftop-mounted solar panel power make an environmental difference by reducing the liberation of carbon dioxide, for example, a typical 5KW solar power system reduces almost close to 200,00 pounds of carbon dioxide within 20 years. See Table 1.

The energy extracted from the PV module is now fed to the grid to get the advantage from the government on electricity usage. For this simple solar Power is converted into a hybrid solar power system by using the inverted DC output of the solar PV module. See table 2.

Keeping in mind the distribution and balance of the stored energy about 10 percent of the energy is stored in utilizing a water pump and the remaining 90 percent of the energy produced is given to the power grid.

The renewable uncertainties could be minimized by having a proper storage system so that during maximum demand power shortage will not affect the integrated solar system. The output power of PV power plants is managed and levelled using PI controllers and power converters so that it does not negatively impact the power system during times of high frequency deviation. On the other hand, the suggested system can be made to operate under the circumstance when the controller receives the signal for reaching the maximum maximum solar insolation at periods with a tiny frequency deviation. See table 3.

The readings of voltage and current to analyze the power outputted from the panel by placing the lenses at different orientations corresponding to the solar panel which is moving along with the movement of the sun from east to west. The readings were taken at different orientations at 30, 45, 60, 90-degree orientation of solar PV panel and then mounted a Fresnel lens and convex lens on it so that the sun rays start converging on the panel. The solar insolation and the power generated in the different intervals of time are listed below in the table. PV power plants are controlled with the help of PD control and electronic circuits and power converters to maintain the voltage profile. The most effective and efficient angle of inclination for a solar PV module in the summer is close to 30 degrees, while it is around 60 degrees in the winter (in Polished conditions). When we examine and evaluate the actual amount of power generated over the course of a year, we find absolutely no differences. In the vertically oriented PV module, the amount of electricity generated is only around 10% lower than in the summer season. Finally, experimental findings were analysed in order to assess the proposed system and regulate the fixed solar system's performance. The performance of the biaxial solar tracking system in terms of generated power may be quantified (on average) in the order of 37 percent, with a tendency to rise when the azimuth of the sun changes dramatically. In recent decades, the field of renewable energies has witnessed substantial expansion due to cost reductions and better efficiency, with photovoltaic applications being one of the most active research topics. Research has recently been conducted all over the world, and several exciting breakthroughs have been reported in the literature from a variety of complementing areas to improve efficiency and extract the maximum power from PV systems.

TABLE 2: VARIOUS RESULTS FROM WATTMETER IS TAKEN FOR CALCULATING POWER.

NOTE: THE ORIENTATION OF THE SOLAR PANEL IS 45 DEGREES.

Orientation (degree)	Time Interval	Power generated(W)
30	11:20 - 12:30	3.4
45	11:20 - 12:30	4.6
60	11:20 - 12:30	2.6
90	11:20 - 12:30	1.5

TABLE 3: VARIOUS RESULTS FROM WATTMETER IS TAKEN FOR CALCULATING POWER.

S.No.	Voltage (V)	Current (mA)	Power (mW)
1	0.985	16.89	19.94
2	1.965	34.86	68.49
3	3.023	51.96	157.07
4	3.984	72.47	288.72
5	5.231	89.64	468.90
6	5.985	108.76	650.40
7	6.983	124.56	869.80
8	7.986	142.87	1140.95
9	8.587	181.43	1557.94
10	9.242	201.45	1861.80
11	9.841	225.47	2218.85
12	10.567	250.86	2650.83
13	11.045	287.65	3177.09
14	12.03	308.56	3711.9

For future scope following should be analyzed and research needs to be done in the following areas:

- By using Fresnel lens heating phenomenon occurs inside the solar panel which needs to look upon.
- After some time when maximum efficiency reaches it starts deteriorating and to maintain the temperature of the panel cooling system needs to be employed.
- Use of tandem cells which are blended and stacking kinds of solar cells. For a long-term basis, that's only been done for satellites but now we're looking for more viability, particularly using it with fluorescent.

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