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Performance of A CPV unit with a Dynamic lens

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Abstract – Using a lens to concentrate sunlight and focus it on smaller sized solar cells increases the system's output power and in the same time decreases the cost by replacing much of the expensive semiconductor photovoltaic cells with the cheaper optics. But the concentrated light will raise the temperature of the photovoltaic cell and that may affect the performance hence, will affect the output power of the CPV unit[1]. A CPV unit with a dynamic lens has been developed and manufactured. Light dependent resistors (LDR) were used to collect data then according to the electrical circuit the dynamic lens moves in a way that makes sure that the optimal intensity of the sunlight falling on the photovoltaic cell is achieved, hence we can gain an enhanced electrical output power. The developed CPV unit with the dynamic lens has been used for evaluating the voltage in the open circuit case and compare it with a fixed lens CPV unit under the same conditions.

Keywords – Concentrated Photovoltaic CPV, Dynamic lens ,Solar Energy, Photonics

I. Introduction

Environmental pollution and the growing needs for clean energy resources have stimulated the global effort to exploit renewable energy as a replacement to the conventional fossil fuel energy. Solar energy is the most abundant renewable energy and is recognized as an ideal alternative energy source. In the field of renewable energy, solar energy conversion is considered as one of the most addressed topics. Radiation that comes from the sun is usually converted into two forms of energy: thermal and electrical energy[2]. The electricity is generated from the sun by the use of Photovoltaic cells (PV).

Photovoltaic cells are made up of semiconducting materials, such as silicon, which are doped with different impurities. The doping of semiconductors produces unequal distribution of free electrons (n-type) on one side of junction and excess of holes (p-type) on other side of junction. The light falling on the solar cell consist of photons. These photons excite the loosely bound electrons which are designed to move only in one direction in photovoltaic cells and thus electron-hole pairs are created in respective junctions and electricity is obtained in external circuit[3] .

Although the cost of the common PV cells is getting cheaper year by year, the highly efficient PV cells such as multi-junction PV cells are still quite expensive. It is more convenient economically to use a small size of the multi-junction PV cell with a focusing lens to produce a certain amount of power instead of having big sized multi-junction PV cell. The focusing of light into the PV cell is referred to as Concentrated Photovoltaic (CPV).

CPV technology makes use of mirrors and lenses in order to intensify the light . When it comes to lenses Fresnel lenses have been one of the best choices because of the numerous advantages such as small volume, light-weight, mass production with low cost as well as effectively increase the energy density [4]. The basic idea of concentrated photovoltaic using lenses is shown if figure 1 .

For the suggested design a regular lens was used as the overall cost was not a critical factor.

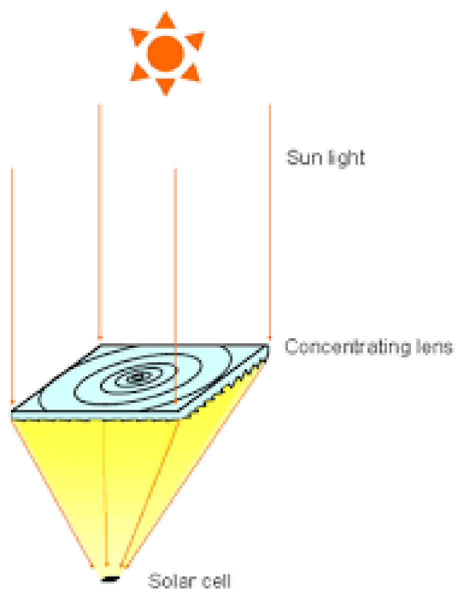

Fig. 1 Basic Idea of CPV using lens

In this design, the performance of the CPV unit with dynamic lens was analyzed. It was separated into three parts which were input, controller and output. The input was from the LDRs, the electrical circuit as the controller and, the DC motor as the output.

II. Materials and Method

As stated before, the goal of this project is to analyze the performance of the CPV unit with dynamic and fixed lens .

The overall system block diagram is presented in Figure 2.

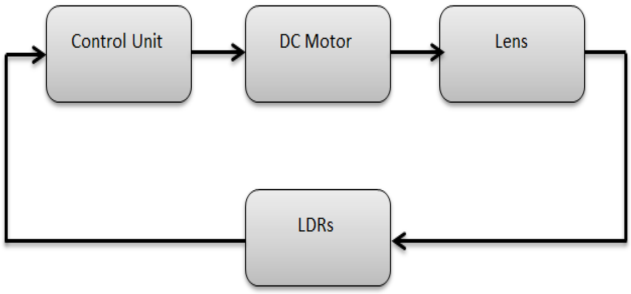

Fig. 2 CPV unit Block Diagram

According to the electrical circuit design ,as long as the both LDRs are under the same illumination level , the motor does not move . When the light position is changing so does the illumination level on the LDRs and the input voltage for the comparator is no longer half of the supply voltage thus the output of the comparator causes the motor to rotates until the illumination level is satisfied in both LDRs again.

A. Electronic components

1) LDRs
In our project the LDRs which is a resistor whose resistivity decreases with increasing of light intensity. Were used as inputs to the electrical circuit.

2) DC Motor with the following specifications :
Type: 22CL-3501PG
Stall Torque: 1.6Nm (16Kg · cm)
Continuous torque: 0.5Nm (5Kg · cm)
Voltage: 12VDC
Diameter: 22mm
Length: 67mm
Stall Current: 1.8A
Reduction ratio: 80: 1 (metal planetary reducer)
Output speed: 120 r / min (input voltage DC 12V)
Encoder: 2 pulses per revolution.

Fig. 3 The DC Motor used in the project

3) Variable Resistors
Two variable resistors with 100k ohm and 15k ohm are adjusted in such way that the motor stands still when the LDRs get the same amount of solar light.

4) Battery
12 voltage regular battery was used

5) PV cell with the following specifications :
Open circuit voltage of 4.2 V
Short circuit current of 100 uA
0.55 watt

B. Experiment approach

An artificial light (bulb light) were used in a dark room ,the bulb was installed in a vertical position (90 degrees) to the PV cell , then the reading were taken at 60,45,30 and 0 degree . The two LDRs were placed at the edges of the solar cell .When the illumination level is not equal on both LDRs the motor rotates in clockwise (pushing the lens up) or anticlockwise (taking the lens down) .

The CPV unit used for the project is shown in the next figure

Fig. 4 The CPV unit

III. Results and Discussion

As mentioned earlier The experimental data presented in this paper were taken by the use of artificial light , in the case of the fixed lens it was fixed 10 cm away from the PV cell.

Table 1. Readings Of the CPV with Fixed lens

Position Of The Light Source(degrees)	Open Circuit Voltage (V)	Illuminance on the lens(lux)	Illuminance on the cell(lux)
90	3.25	380	440
60	2.65	312	265
45	2.57	373	252
30	2.07	214	176
0	1.76	186	150

We notice from the obtained data of the illuminance that the illuminance on the lens is always higher than the cell's due to the closeness of the measurement device to the light source ,except the 90 degree case where the illuminance of the cell is higher .

Table 2. Readings Of the CPV with Dynamic lens

Position Of The Light Source(degrees)	Open Circuit Voltage (V)	Illuminance on the lens(lux)	Illuminance on the cell(lux)
90	3.57	763	677
60	3.03	282	260
45	2.35	150	171
30	1.47	38	75
0	1.25	53	65

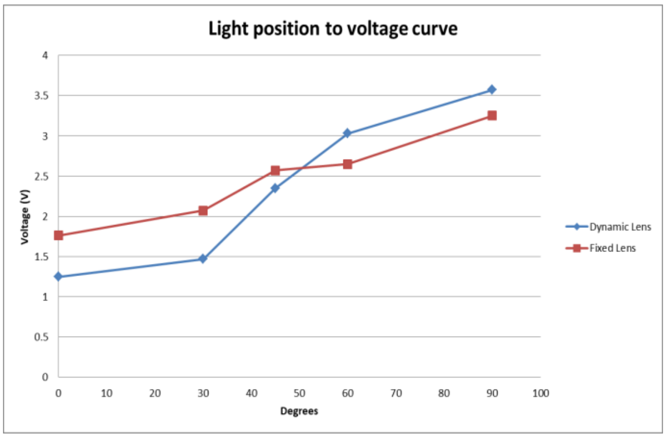

Fig. 5 Curve of the light position vs. voltage

Figure 5 shows that using a dynamic lens in this particular design when the light source position is above 50 degrees can produce more voltage that because when the bulb is placed under 50 degrees the design structure on the sides of the PV cell along with the lens structure work as isolators for light to pass , the illuminance on the cell drops remarkably as table 2 states making it hard to the PV cell to produce in such dark surroundings .

IV. CONCLUSION

In conclusion, the performance of a CPV unit system was analysed. Based on the data collected ,it can be said that the CPV unit with dynamic lens is more affective when the light source is placed at 50 degrees and above , in order to improve the produced voltage under 50 degrees some changes must be applied to the design structure to ensure that the light is falling on the PV cell from all directions.

For further research once can collect data using the sun's radiation as the source of the light instead of bulb light.

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