Increasing the solar cell efficiency using glass balls

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Abstract. Solar cells lose high percent of their capacity as a result of insufficient solar radiation, due to changing of the solar angle of projection during the day. Thus this research aims to increase the cell efficiency by a novel method which is based on collecting rays in the convex focus and dispersed in the concave lens, to make the rays always perpendicular on cells. To achieve this purpose, glass balls with a diameter of 10 mm were used and arranged on the cell area. This work found an obvious increasing in the cell efficiency, where it is possible to have an increasing in generating voltage by an estimated 7.53%, and the current 1.086% by this novel method.

1. Introduction

The Sun is a permanent source of light and thermal energy production. Over the last 50 years, there was a rapid increasing in its utilization to generate energy as a promising green alternative source to fossil fuels.

Solar energy coming from sunlight is converted by a cell panel into electrical energy called Photo Voltage (PV). These cells are made by trade of various semiconductor materials using P-N dipole technology [1]. These materials are preferred to be made from silicon due to several advantages such as its moderate cost comparing with other materials.

Silicon used several types such as monocrystalline, polycrystalline, and copper indium selenide (CIS)[2]. It also possible to add some materials such as Chlorophyll-A to the cells to increase their efficiency [3]. Falling sunlight on the cell induces the thin board to make an electronic polarity which could be positive or negative through which the electricity flow.

For high working efficiency and standard cell operation, standards of radiation and temperature (STC) are required. The standard lighting, temperature, and reference spectrum are 1000 w/m², 25 °C and 1.5Am, respectively.

2. Reasons of reducing the efficiency of solar cells

Several parameters can cause decreasing in the cell efficiency such as temperature, intensity of light, incident light angle, as well as acid rain, ozone depletion, emission of radioactive substances [4].

2.1. Dust

As a result of dry weather conditions in some regions of the world, which reduces vegetation and increase the dust, in addition to smoke from large factories as well as other pollutants, the air is polluted by several solid particle which cover the outside surface of the PV cell. This led to reduce the glass's light transmittance, which in turn reduces the cell’s efficiency [5].
There are also several factors associated with the presence of solid pollutant particles on the surface of the cell board, such as cell slip angle, climate conditions, exposure time, wind movement, and particle properties. Note that deposition of particles of 0-22 g/m² leads to a reduction power from 0-26% of the efficiency of the cell [6].

2.2. Temperature
Ambient temperature plays an important role in cell efficiency due to its impact on the conductivity of materials used in the cell manufacturing [7]. As the temperature increases, the gap of the internal semiconductor tape shrinks and leads to a decrease in the voltage of the open circuit (OCV). Low output power produces the same amount of current due to the decreasing of the released charges. Conversely, lower temperatures can produce a higher voltage to allow shipments on both sides of the chips.

2.3. Light Intensity
The constant rays of the sun on the ground with the same intensity make it possible to use this energy permanently. However, this intensity varies depending on different parameters such as the angle of fall of solar radiation, which is related to the places, seasons, and daylight hours [8]. This variation in the intensity is due to the orbit of the earth, which changes the angle of radiation and that leads to a huge variation in energy production.

Several axes and angles are used to calculate the position of the sun such as solar azimuth (ψ), solar altitude (α), declination angle (δ) and zenith angle (υz) as shown in figure 1.

3. Solar tracking system
The Earth's orbit makes it difficult to keep the panels in front of the sun and get a steady output of energy, which is one of the main causes of reduction in cell efficiency. The solar tracking system can be a solution to overcome this obstacle. Solar tracking system can provide the highest possible light intensity to the cell throughout the day [9]. The tracking system is more efficient than the fixed system as shown in figure 2.
Figure 2. The production power of different tracking systems [10].

Many solar tracking systems are designed to maximizing the received solar radiation [9] as shown in figure 3. The improving in the tracking systems can be done by using different ways such as using two tracking axes instead of one, using tracking algorithms [11], light sensing [12], or using automatic solar tracking system (ASTS) [13]. However, most of these methods rely on the using of motors to rotate the cell, which increases the manufacturing and maintenance costs of the solar cell system.

4. Type of Lenses

Lens is a glass material with similar center and sides. When its thickness is neglected comparing to the diameter of the curvature of its faces, then it called thick lens. On the other hand, if the thickness of the axis is small compared to the amount of radius of curvature, then it called thin lens [15].

The main task of the lenses is the process of collecting or dispersing light through the lenses called Converging Lenses and Diverging Lenses, respectively, and have several types [16].

The position of the Ball Lenses used in this research enable to collect the light falling from different angles inside the lens, and transfer light to the opposite direction to a specific point according to the value of the angle of the lens as in figure 4.
5. Experimental methodology and materials

The experiments were conducted using commercial polycrystalline silicon panels with a size of 31.8 x 24.8 mm and a thickness of 20 ± 180 micron as shown in figure 5.

Cell performance was measured in sunny weather conditions in five days, at various times throughout the day. Glass balls with a diameter of 10 mm were added along the cell surface. It was exposed to sunlight and for different times throughout the day, as shown in figure 6.
Voltage was calculated as shown in figure 7, and current was calculated as shown in figure 8.

![Figure 7](image-url)

**Figure 7.** Comparison Voltage measured per time for two panels (with and without glass balls).

![Figure 8](image-url)

**Figure 8.** Comparison current measured per time for two panels (with and without glass balls).

Calculated the amount of incident solar radiation as well as the intensity of light produced after sunlight penetrates the glass balls. It turned out that this type of balls passes light intensity by 80% of the intensity of solar radiation arriving.

The temperature of the two cell types (with and without balls) was measured and shown in figure 9.
6. Conclusions

This work approve the ability of increasing the cell efficiency by adding glass balls to the solar cell panel. The results shows that using glass balls increases the effectiveness of light intensity on the surface of the solar panel. However, the greater the purity of the glass used in the manufacture of balls, the greater of the intensity of light received by cells.

As shown in figures 8 and 9 which demonstrate increasing the generating of voltages and amperes by the panel with glass ball comparing to the panel without glass balls along the day, except at middy (12pm). The results show that the increasing in the voltage and current is about 7.53% and 1.086%, respectively. This indicate the high efficient of the glass balls in collecting light due to increasing the collecting surface area. In addition to that, more light is collecting as a result of existing of convex and concavity.

In the middle of the day the solar effect is at the great point where the radiation transfers directly to the panel. Thus, in the ball panel case, only the purity of the glass would play an important role in transferring the radiation completely to the plate.

Figure 10 refers to the temperature of the board, where there is an increase in the temperature of the board temperature in which glass balls are used by an estimated 3.647% throughout the day. This is due to increase the exposure surface area to heat [17], the heat transfer through the cells, and the heat storage by the surface of the board.

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Figure 9. Determine Temperature of cell per time.
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