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The Effect of Solar Sphere Thickness on the Fluid to Generate Power

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Abstract – The high demand for renewable energy sources has given rise to many innovative systems that utilize natural resources to generate energy and supply electricity. The solar sphere system is an innovative system that collects the solar radiation incoming from the sun and concentrates it at a focal point on a multijunction device. The multijunction device consists of a high-efficiency solar cell that converts solar radiation into electricity. Many parameters in the solar sphere system affect the amount of power output and the associated efficiency leading to the improved overall performance of the system thus the aim of this paper is to examine and investigate the thickness of the sphere on the performance of the solar sphere filled with sunflower oil. The results obtained from the experiments showed that the thickness of the sphere significantly changes the value of power output and the associated efficiency of the system. From this result, it is found that decreasing the thickness of the sphere did increase the power output. Hence, the efficiency of the sphere increases when using a lower acrylic sphere thickness. The results can be interpreted as the thickness of the acrylic layer of the sphere getting lower, the more the sunlight is absorbed by the acrylic photons which subsequently leads to higher output power generation and higher system efficiency as compared to the conventional solar panel.

Keywords**:** solar, concentrated energy, thickness, power.

1. Introduction

Societies worldwide are combating various hazards spread out in categories like environment, food, and water. Technological developments and enhancements have grown to help these societies survive these hazards. The exponential growth of research activities in the energy sector has been demonstrated by studies over the past decade and by the years 2016-2040 a big energy peak is expected. [1-3].

Different energy topics are being investigated by organizations on international and national levels including challenges related to energy generation, conservation, and storage. On top of these challenges, the utmost challenge remains to be the generation of energy that is able to meet the world’s demand for energy. Most of this energy demand is directed towards the supply of electricity which is currently being supplied by conventional nonrenewable sources. Hence, the challenge to meet the rise in energy demand is also coupled with the challenge of providing the same with renewable resources. [4-6].

Theoretically, the different sources of available renewable energy can solve the worldwide increase in demand for energy over the coming years. By this, the negative effect and the depletion of the nonrenewable energy sources will be minimized in addition to the reduced cost of energy production. Amongst the different renewable sources, solar energy, which is collected effortlessly from the sun, is one that is accessible to many regions and can be the solution to cover and keep up with the current rate of electricity consumed. [7-10].

Since the discovery of the solar energy collection concept, various developments in solar energy collection and conversion to electricity were introduced. One of these developments is the solar sphere, as this new innovative system has proven higher efficiency than conventional solar panels. Besides the higher efficiency, the solar sphere is able to directly convert the collected energy from the sun into electrical energy. Also, it can overcome the challenges of conventional solar panels such as the large surface area required for the installation as well as the need for a sun tracking system to ensure the panel is always facing the sun, especially since the sunlight beams angles varies throughout the year. Hence the solar sphere system can overcome the conventional solar panel's challenges and limitations. [11 and 12].

Briefly, the solar sphere system uses a liquid to fill a sphere that is eventually kept under direct sunlight. The solar energy collected is then focused by a special configuration of a set of lenses into a spot over a high-efficiency solar cell which converts the concentrated energy into electricity. The electrical energy generated is measured by a multimeter and the incoming solar irradiance is measured by a pyranometer.

In the previously published research, many aspects of the solar sphere system were experimented with and documented including the sphere parameters and the liquid parameters. The sphere parameters included the different shapes, designs, and sizes and the liquid parameters included different fluid mediums and different volumes within the sphere itself. The different parameters were experimented with at various conditions throughout the year through which the efficiency and output power were compared amongst the parameters with the conventional solar panel. The results of these experiments supported the fact that the solar sphere system can indeed produce electrical power with higher efficiency than conventional solar panels. The overall summary and conclusion of the previous experiments are documented below:

1. Shape: for this parameter, the complete sphere was the best shape and was able to produce 4 times additional output power for the equivalent area.
2. Size: it was also demonstrated that as the size of the sphere increased the output power, as well as efficiency, increased as well.
3. Fluid medium: Amongst the different fluids used, oil was able to produce one and a half additional output power compared to alcohol. Alcohol on the other hand was also able to produce double its output power compared to water with air being the least output power-producing medium. [13-17].

The applications involving liquids filled in spheres are already in use in different engineering fields and applications. In order to complete the investigation of the solar sphere system the effect of the thickness of the sphere on the overall performance of the system should be carried out. Therefore, the next parameter to be experimented with is the thickness and the degree of effect it can have on the solar sphere system performance [18-34].

The objective of this study is to understand the effect of the thickness of the solar sphere filled with fluid on the power output. Furthermore, to clearly improve the performance of the system to generate electricity and then optimize its efficiency.

2. Experimental Apparatus And Methods

In Figure 1, a schematic representation of the experimental setup of the solar sphere system is shown. The material used for the sphere is Plexiglas acrylic as this material showed the best ability to collect solar energy. Moreover, the best liquid based on the previous experiments that were carried out was used which is sunflower cooking oil. A Stainless-Steel stand is used to lift and hold the sphere from the ground surface in order to place the multijunction device underneath it. The multijunction device is also held on a smaller stainless-steel stand that was made adjustable and rotatable to allow capturing the focal point at various solar radiation angles. The multijunction device is further connected to a multimeter to read the voltage and current. These two measured parameters will be used to calculate the power output of the solar sphere system after collecting the solar energy and concentrating it on the focal point of the multijunction device. The solar radiations collected by the sphere will be focused on the multijunction device at the special lenses configuration, consisting of layered junctions that maximize the energy collection from the light, and aid in further concentration of the solar energy on the concentrated solar cell that is attached to a heat sink. This type of multijunction device was used in this solar sphere system experiment as it is able to handle high temperatures resulting from concentrating solar radiation. In addition to the complete experimental setup of Figure 1, figure 2 represents the individual components of the solar sphere system.

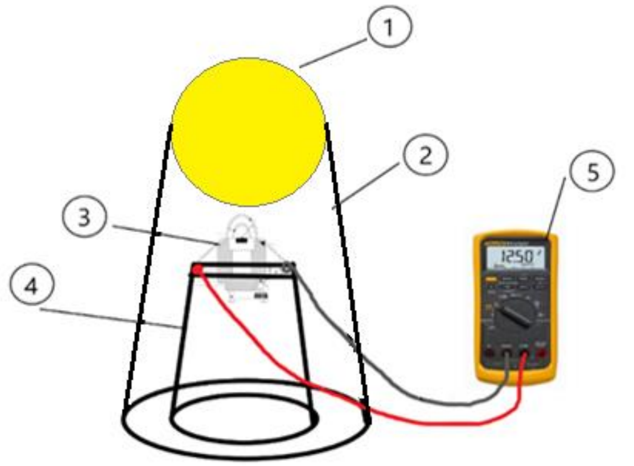

Fig. 1: The setup of the solar Sphere system experiment

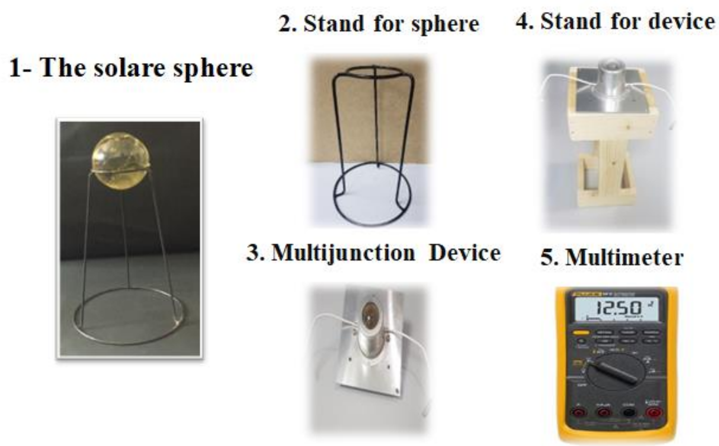

Fig. 2: Individual components of the solar sphere experiment

Further details related to the multijunction device are presented in Figure 3 including the primary optic, the secondary optic, the multijunction photovoltaic cell, and the improved thermal performance for cooling the system. Finally, figure 4 demonstrates the actual outdoor experimental setup used to carry out this experiment.

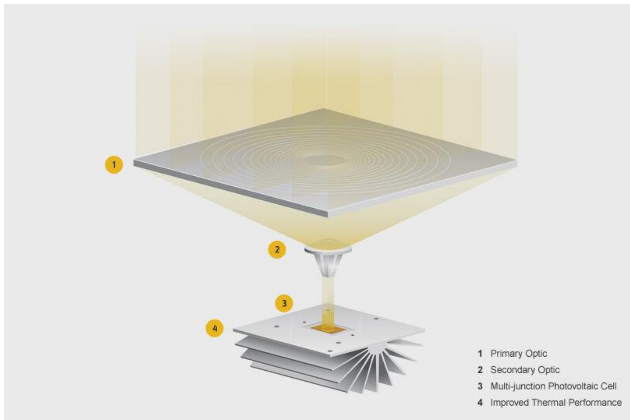

Fig. 3: Schematic of the multijunction internal components.


Fig. 4: The actual outdoor experimental setup.

3. Results of the Solar Sphere Thickness Effect Data Analysis

The experiments for exploring the effect of the thickness of the solar sphere and measuring the power output and the efficiency are conducted for a sphere of 15 cm diameters, and for different thicknesses. The thicknesses are 3 mm, 4 mm, 6 mm, and 8 mm. As shown in Figures 1 and figure 4 the sphere is set over the stand above the multijunction device, the multijunction device is connected to the voltage and current ampere meter. The focal point was found under the sphere and adjusted to be directly over the lens of the multijunction device by controlling the stand of the multifunction device which can be adjusted and controlled by moving it in all directions and levels. Then experiments were conducted for each mentioned sphere and for the 4 thicknesses. The voltage and the current ampere were measured for all these experiments and cases. In order to calculate the power output of the solar cell (w), the following equations are used:

$$P_{out} = I \times V \quad (1)$$

Where I and V are the current and the voltage respectively which are measured by the multimeter.

The efficiency of normal photovoltaic solar panels (PV) is usually measured by the ability of a panel to convert sunlight into usable energy for human consumption. Knowing the efficiency of a panel is important in order to choose the correct panels for the photovoltaic system. For smaller roofs, more efficient panels are necessary, due to space constraints.

$$\eta_{max} = \frac{P_{max}}{E_{s,y} \times A_c} \quad (2)$$

Where η_{max} is the maximum efficiency.
P_{max} is the maximin power output.
$E_{s,y}$ is the incident radiation flux.
A_c is the area of the collector.

The incident radiation flux could better be described as the amount of sunlight that hits the earth's surface in W/m^2. The assumed incident radiation flux under standard test conditions (STC) that manufacturers use is 1000 W/m^2. However, the standard test conditions STC includes several assumptions and depends on the geographic location.

Whereas, in concentrated photovoltaic systems like our system, the produced power is higher than that of conventional solar systems. The solar collector focuses more sunlight on the receiver, which is the solar cell in our system. To get an overview of how much solar radiation is concentrated and to get the power input of the solar shapes, some parameters are defined to be used in the following equations.

CR is the geometrical concentration ratio which is the amount of solar radiation incident on the receiver, and it is obtained from the area of the collector and the receiver. Therefore, the ratio between the areas of the collector and the receiver is called the geometrical concentration ratio (CR) [35].

$$CR = \frac{A_{collector}}{A_{receiver}} \quad (3)$$

The optical concentration ratio is the ratio between light intensities at the collector to the receiver. The optical concentration ratio is less than the geometrical concentration ratio since it includes the losses that are due to light intensities (solar radiation). For concentration technologies, the higher the concentration ratio is, the preferable the system is.

$$CR_{optical} = \frac{A_{collector} \times I_{collector}}{A_{receiver} \times I_{receiver}} \quad (4)$$

The solar radiation on the receiver, which is the multi-junction solar cell in our system, is:

$$G_r = G \times CR \ (W/m^2) \quad (5)$$

Where G is the solar radiation (W/m2) and Pin is the input power of the solar ce

$$P_{in} = Gr \times A_{cell} \quad (6)$$

Electrical efficiency:

$$\eta = \frac{P_{out}}{P_{in}} = \frac{I \times V}{G_r \times A_{cell}} \quad (7)$$

Moreover, the efficiency was computed for each thickness. Figure 5 demonstrates a sample of the current-voltage characteristics for a 6 mm thickness solar sphere, while Figure 6 shows a sample of the current-voltage characteristics for a 3 mm thickness solar sphere. For the 6 mm thickness solar sphere, the current is maximum at short-circuit (i.e., Zero circuit resistance/Zero voltage potential across PV terminals), nearly 10 Amps. Current is stable up to 2.5 V. Then as voltage increases it falls off to zero Amps at 2.8 V (open circuit). The optimum operating point is at the maximum power point, equivalent to V = 2.5 V. While for the 3 mm thickness solar sphere the current is maximum at short-circuit (i.e., Zero circuit resistance/Zero voltage potential across PV terminals), nearly 13 Amps. Current is stable up to 2.5 V. Then as voltage increases it falls off to zero Amps at 2.8 V (open circuit). The optimum operating point is at the maximum power point, equivalent to V = 2.5 V.

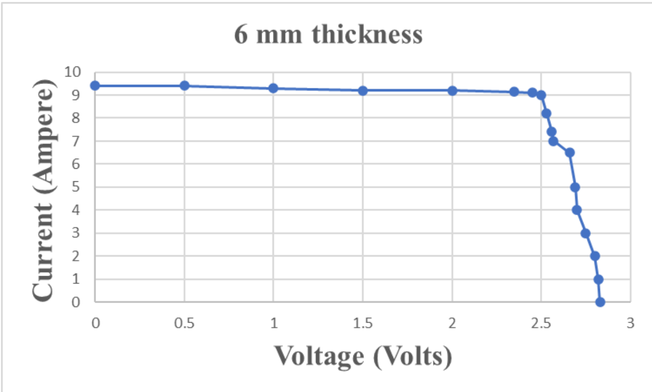

Fig. 5: a sample of the current-voltage characteristics for a 6 mm thickness solar sphere

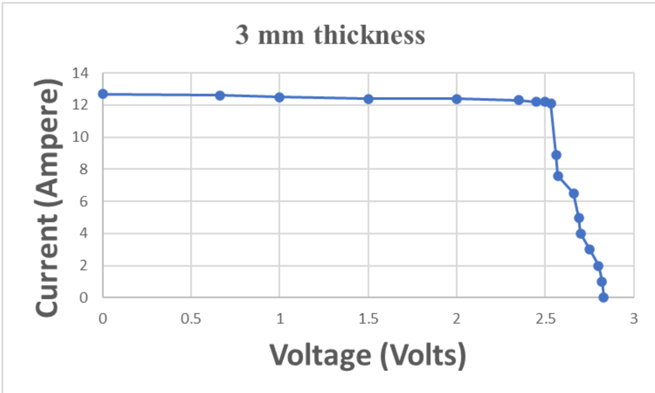

Fig. 6: a sample of the current-voltage characteristics for a 3 mm thickness solar sphere

Figure 7 illustrates the relationship between the acrylic solar sphere thicknesses (3 mm, 4 mm, 6 mm, and 8 mm) and the maximum output power compared to the normal PV that has the same cross-sectional area of our system.

Figure 8 shows the relationship between the acrylic solar sphere thicknesses (3 mm, 4 mm, 6 mm, and 8 mm) and the efficiency compared to normal PV which has the same cross-sectional area as our system.

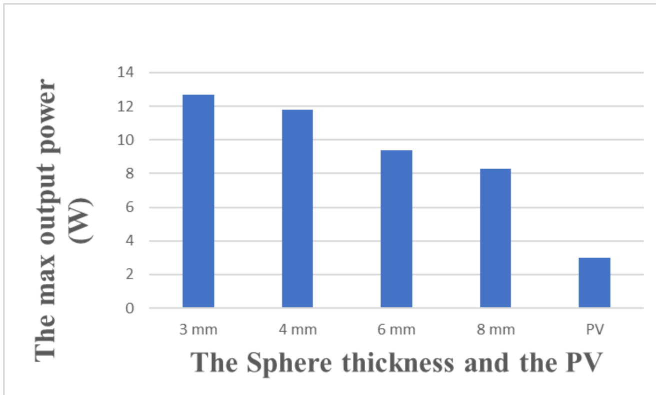

Fig. 7. The relationship between the max output power and the sphere thicknesses compared to PV

Fig. 8. The relationship between the efficiency and the sphere thicknesses compared to PV

It is clear from the above figures that when the acrylic solar sphere thickness decreases the output power of the system increases. It is recognized that the output power of the 3 mm thickness sphere is higher than that of the 4 mm thickness sphere by about 1 w and the output power of the 4 mm thickness sphere is higher than that of the 6 mm thickness sphere by about 2 w, while the output power of the 6 mm thickness sphere is higher than the that of the 8 mm thickness sphere by about 2 w. The output power increases by about 1 w when decreasing the thickness by 1 mm. Moreover, it is clear that the output power of this system (the concentrated acrylic solar sphere) is almost about 4 times more than the normal solar panel PV that has the same cross-sectional area. This kind of compression is very important because it leads to the conclusion that this system does not need more area for installation compared to the area of installing the solar panel. It will reduce the installation area at less by 25% to 50%. Moreover, this conclusion is similar to that shown in our previous research papers [13-17].

In fact, when the thickness of this acrylic solar sphere increases the received amount of solar radiation is affected and limited, it becomes less. And hence, the output power is reduced. So, the larger acrylic thickness impedes sun radiation and produces lower output power. Whenever the thickness is less, higher power is produced hence higher efficiency. Therefore, the thinner the thickness of the acrylic layer, the higher the sunlight absorbed by the acrylic photons. Subsequently, the higher the output power, which results to get higher the efficiency.

In conclusion, the effect of the thickness of the solar sphere is examined in order to achieve better performance for power generation hence, in order to improve the performance of the system and optimize its efficiency. The results showed that the thickness of the sphere significantly changes the value of the output power. Hence, in order to improve the efficiency of the solar sphere, a lower thickness should be used. Moreover, the thinner the thickness of the acrylic layer, the higher the sunlight absorbed by the acrylic photons. Subsequently, the higher the output power, which results to get higher the efficiency.

4. Conclusion

The effect of the thickness of the acrylic solar sphere filled with oil fluid is carried out in order to improve the applicability of power generation. The effect of the sphere thickness is computed. The results illustrate a significant effect of the sphere thickness on the output power, hence the efficiency. The main conclusions can be summarized as follows:

1. The obtained output power was increased with decreasing solar sphere thickness. Thus, the lower thickness allowed more sunlight to be absorbed by the acrylic photons. Subsequently, the higher the output power.
2. The output power increases by about 1 W when decreasing the thickness by 1 mm.
3. The obtained efficiency was increased by decreasing the solar sphere thickness. The thinner the thickness of the acrylic layer, the more sunlight is absorbed by the acrylic photons. Subsequently, the higher efficiency.
4. The output power of our system (the concentrated acrylic solar sphere) is almost about 4 times more than the conventional solar panel having the same cross-sectional area. This conclusion is the same conclusion shown in our previous research papers [13-17].

Finally, the concentrated acrylic solar sphere system requires less installation area compared to installing the conventional solar panel. The reduction of the installation area is around 25-50%. This conclusion is the same as the ones shown in our previous research papers [13-17].

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