

# Enhancing Photovoltaic solar panel

## Raising efficiency of photovoltaic solar panel by preventive actions

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**Abstract**—this document describes the main factors responsible for the reduction of the efficiency of photovoltaic (PV) solar panel. Those factors are: type of material used, accumulated dust on solar panel, higher temperature, position of the panel, and low area for photon capturing. To achieve higher efficiency, this paper investigated several ways to reduce the effects of the affecting parameters: reducing the temperature of the PV panel, eliminating the dust, controlling the position of the panel and adding a mirror to collect more photons. Those modifications were applied on a laboratory-scale prototype in order to enhance the performance of the (PV) to deliver higher efficiency.

**Keywords**— efficiency of PV; Photovoltaic solar panel; renewable energy.

### I. INTRODUCTION

Electrical energy forms a major source of comfort to human. Numerous activities would have been impossible without the aid of electrical energy. Without it, our current living standard cannot be maintained. In order to solve the issue of energy crisis facing the world nowadays, conversion of solar energy into electricity is introduced as a technique to be applied [1]. There are many types of the solar cells. Serious efforts are ongoing to improve their performance to the stages of practical applications [2].

Different techniques and processes have been applied through the years to improve the performance of the photovoltaic solar system and thus, increasing its efficiency. This paper aims to study the different parameters affecting the performance of photovoltaic (PV) solar system. Some modifications in the parameters were examined for this reason: type of material used, the environment which is a major contributing factor that includes the external resistances, and the geographical locations [3]. Recommended to achieve higher efficiency, more innovative design is presented in more advanced technique, taking into consideration solutions to the limitations of certain of the parameters that may affect the system's performance.

### II. INFLUENT PARAMETERS AFFECTING THE PV EFFICIENCY

#### A. Material Vs. Efficiency

##### 1) Selecting cells type

Selecting the chemical material is the main importance for higher productivity with less cost. Table 1 summarizes the top materials used and their characteristics.

**TABLE 1: EFFICIENCIES OF SOLAR CELLS: ONLY CELLS WITH A CELL SURFACE LARGER THAN 1 CM<sup>2</sup> HAVE BEEN CONSIDERED [4].**

Material	Type	Lab efficiency %	Manufac efficiency %
Silicon	monocrystalline	24.7	14.0-18.0
Polysilicon simple	polycrystalline	19.8	13.0-15.5
MIS inversion layer (silicon)	monocrystalline	17.9	16.0
Concentrator solar cell (silicon)	monocrystalline	26.8	25.0
Silicon on glass substrate	Transfer technol	16.6	
Amorphous silicon, simple	Thin film	13.0	8.0
Tandem 2 layers, amorphous silicon	Thin film	13.0	8.8
Tandem 3 layers, amorphous silicon	Thin film	14.6	10.4
Callium indium phosphate	Tandem cell	30.3	21.0
Cadmium-telluride	Thin film	16.5	10.7
Copper indium di-selenium	Thin film	18.4	12.0

##### 2) Choosing the right Specifications of the material.

Crystalline Silicon is usually used for photovoltaic cells due to the fact that Silicon is a semiconductor with the largest market penetration, it has been theoretically understood, and is the simplest to deal with [4]. On the other hand, amorphous - Silicon is cost-efficient and has good absorption features which allow it

to be used as a base material for a thin solar cells film. Yet in the end Crystalline Silicon dominates as base material [5].

Regarding the high cost of the material by which the PV is made, polycrystalline type material is used in the design, which is not expensive and it provides close properties of the advanced PV materials, to perform many experiments.

### B. External resistances

#### 1) influence of dust

The dust accumulation on the PV's surface, the bird droppings or the water stains (salts), can play an important role of obstruction or distraction of the light energy to reach the solar cells, and this minimizes the efficiency [3]. All these types of external resistances could be referred to as "soiling". The surface of the PV is a major contributing factor in the soiling phenomenon. If a PV surface is rough, sticky, furry and not smooth, that would provide the best conditions for dust accumulation.

Describing the phenomenon of dust deposition is a must. By definition, the dust is a term applied to solid particle having a diameter less than 500  $\mu\text{m}$ . It is present in the air and occurs in the atmosphere coming from many sources like dust lifted up by wind, vehicular movement, volcanic eruptions, and pollution [3]. There are two primary factors concerning the dust settlement on PV systems: the qualities of the dust and the indigenous surroundings. The property of dust that includes the type, the chemical - biological and electrostatic property, in addition to the size, shape and weight, is at equal importance of its accumulation or aggregation. It is also very known that the dust accumulations promote dust. In other word, with the initial onset of dust, it would have the tendency to attract or promote further settlement. Which means that the amenability of the surface to dust collection increases [6].

As for the local environment, it implicates site-specific factors affected by the nature of human activities, built environment characteristics such as surface finishes, orientation and height of installation, vegetation type and weather conditions (the geographic location is at major importance in the section) [7].

Thus, the purpose of this work is to access the impact of the accumulation of dirt on the efficiency of solar PV panels. The study was operated indoor. It involved artificial lighting, instead of the sunlight, by mean of spotlights to neglect the variation that may be occurred under the sunlight.

As a solution: a proper maintenance for the solar panels would be of a high importance. Some particles like dust and sand can be eliminated when washed away. Washing can be done naturally in the winter season when it rains, but this is not efficient for a long term since the seasons change through the year. For this reason, there is a need for water to provide a permanent cleaning of the PV surface and thus ensuring an optimum power generation.

To solve this problem, two techniques could be applied: the manual cleaning or mobile cleaners.

The manual cleaning method follows the same concept as cleaning the windows of a certain building. To prevent the

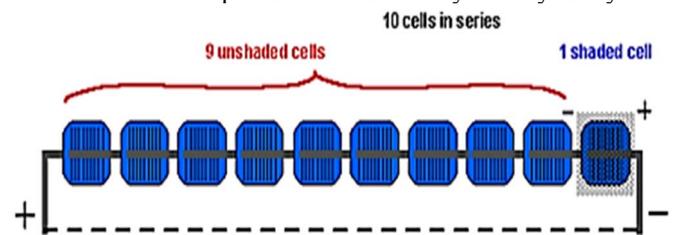
scratches of the module, scrubbing of the soil off from the surface and brushing it with special bristles were both applied. It must be mentioned that this method requires a long ladder and a scrub [7].

When it comes to the mobile cleaners, this technique uses machinery to perform the mission in addition to a water storage supply to clean the PV's surface [7].

Thus, to mitigate the impact of dust, a cleaning cycle must be recommended. This is why, in this design, a spraying water system made of pressurized water nozzles was used to remove the accumulation of dirt and dust especially in the dry seasons and in the case of intensive dust accumulation. It is a simple and a cheap solution.

#### 2) Influence of shading

Some of the patches caused by the deposition of leaves and other dirt that covered some of the PV cells reduce the energy production. They have a sever effect on PV performance. The *figure 1* below shows a PV model composed of 10 successive cells in series with one shaded cell among them [3]. The shaded cell is considered as a resistance that blocks the flow of the current generated from the other cells, so it is unable to produce electricity like the others. The problem is that dust stops the current cell from producing energy. Also it blocks energy produced by previous cells from passing through this cell. This fact causes a heat up of the shaded cell and leads to the occurrence of a hot spot that will ultimately destroy the system.



If the terminals of the module are connected, the power from the unshaded cells is dissipated across the shaded cell.

Figure 1: Current Flow across the Shaded Cell [3].

In order to minimize the impact of partial shading on PV, bypass diodes could be used especially when a single unit is involved in a series string. It must be mentioned that when dealing with a sequence of cells connecting in series, the same amount of current flow through every single cell.

Thus, in a similar case of the one represented in *figure 1*, the shaded cell will not be able to produce an amount of current equivalent to the unshaded cells' current.

Two options are possible for this problem:

The solution would be by inserting a bypass diode between each 4 cells, this diode will by-pass the shaded cell, the current will pass around the shaded area, reducing by that the voltage losses through the module. *Figure 2* shows that if the partial shading takes place, the current produced from the unshaded cells passes across the bypass diode rather than the shaded cell. The most important advantage gained is that the amount of local heating at the shaded area will be drastically reduced by the use of bypass diode, preventing the formation of hotspots. This is a

good solution but presents several inconveniences: it is expensive, and it doesn't prevent shading, it only bypasses shaded cells. This technology could not be used for this work, but it will be presented in another paper.

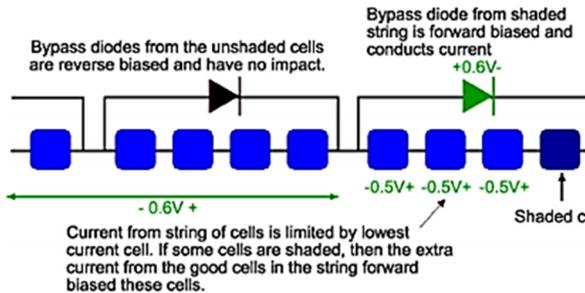


Figure 2: Introduction of Bypass Diode in PV Modules for Hot Spot Avoidance [3]

### 3) Effect of the temperature

Temperature is one of the most important factors that must be taken into consideration when dealing with a PV design. Examining the effect of the ambient temperature on the efficiency of a solar photovoltaic panel is a must. Recently, there has been a huge increase in the understanding of the operational system of photovoltaic apparatus, leading to an increase in the power conversion efficiencies of such devices. Solar cells vary with the variation of the temperature because it will affect the power and the voltage output from the cells [8]. Therefore, PV panel is influenced by varying weather conditions. Since the weather is not at constant permanent conditions, and the solar panels are installed all over the world in different climate regions, most solar panels are not operating under ideal conditions. This is why, it is crucial for engineers to know the operating system of the panels and how they react to different weather conditions [9].

Temperature affects the electron activity, which means how electricity can flow through an electrical circuit by changing the speed needed by the electrons to travel. It must be cited that an increase in the temperature is a result of an increase in resistance of the circuit. Thus, resistance is decreased with decreasing temperatures which leads to higher efficiency [10].

As it was mentioned previously, the power output from the cells is affected by the change of the temperature. Which means that the voltage depends on the temperature change: an increase in the temperature leads to a decrease in the voltage. The results obtained by Vahid *et al.* (Figure 3) show the variation of the current vs. the voltage at different temperature values [9]. It could be noticed that the output voltage of the PV increases when operating the cell at a lower temperature. A similar interpretation applies for the power delivered (figure 3), the output power of PV module increases with decreasing temperature.

Needless to say that the power output from the cells is affected by the change of the temperature: an increase in the temperature leads to a decrease in the voltage [9]. It must be cited that the efficiency differs by changing the material of the PV since the efficiency of various materials has varied levels of dependence on temperature. This is why, a PV system must be

also engineered based on an understanding of the materials used in the PV panel [4].

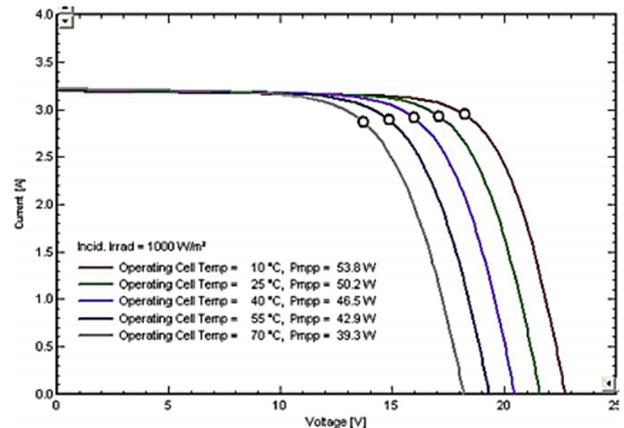


Figure 3: Output current and voltage of the PV module at different temperatures [3].

In this design, the work is done by keeping the panels as cool as possible by introducing an active cooling system by pumping water behind the panels to pull the heat away. The increase in the temperature of the cooling fluid depends on the flow of water sent through the pump.

### 4) Effect of the PV position

One of the main causes for low efficiency in PV cell is that the PV solar panel is putted in a fixed angle on the roof, and that the light coming from the sun is not sufficiently intense. The angle of the solar panel has a very important role in increasing the output current. That's why the efficiency changes between the day hours and differ between different months.

Putting many solar panels may be a solution to collect more photons and it will function. But it is not feasible because of the high cost of PV solar panels. So an innovative solution is needed to makes the solar panel collect more photons in less cost possible.

In this design, to solve the problem of the low collection of photons, a mirror was added facing the panel. The introduction of the mirror, which is considered a cheap material, increases the collection of photons and provides more energy. Also, as a solution for the sun position changing, a screw is put on the back of the panel and on the back of the mirror. In this way, the position of the panels will be modified to capture the maximum amount of energy coming from the sun.

## III. EXPERIMENTAL DESIGN

### A. How this design helps solving efficiency problem

In the design, several preventive solutions were introduced for the main "efficiency decrease" in a normal PV solar panel. Figure 4 shows a realistic photo of the invented prototype. It has the shape of an open book in which in one of its sides the photovoltaic cells is fixed and, on the other side, the mirror is fixed. When it is closed, it looks like a box having a certain width. Both of the sides are surrounded by wood frames. The

wood is coated by paints to prevent its corruption in the case of water leakage. The mirror is used to increase the sunlight absorbance.

The photovoltaic solar system is made up of silicon since it was proved that silicon has provided the maximum achievable efficiency up to these days.

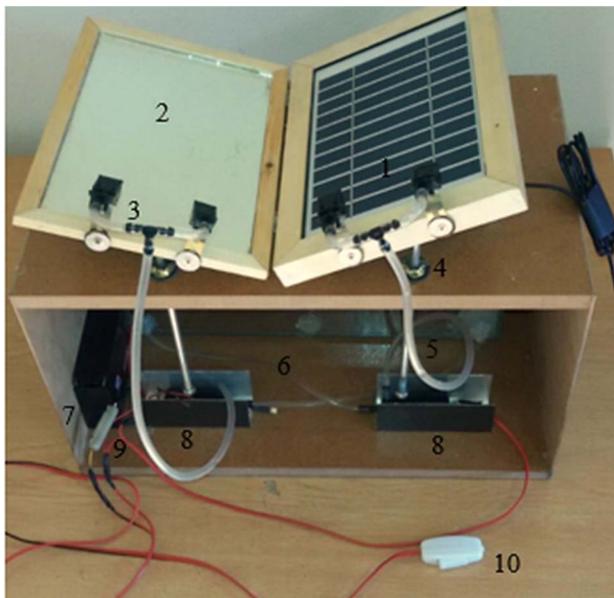


Figure 4: Picture representing the different parts of the prototype: 1) PV solar panel 30cm\*15cm, 2) Mirror; 3) Nozzle; 4) Screw to control the PV angle 5) Connection tubes; 6) tank; 7) battery; 8) pumps; 9) protective fuse; 10) switch.

Removing the dust accumulated on the PV surface is of a major importance, that's why a spraying water system is provided to get rid of dust settlement. The spraying system is made up of a sequence of nozzles fixed on the wood frame on both sides: the PV side and the mirror side. Its responsibility is to clean the system surface in the case of dust accumulation. Those nozzles have been fixed on movable screws where they can change the direction of the water split. The nozzles are connected by pipes made of PVC to two powered pumps present in the box under the PV surface side. They will remove the dust by the pressure water jet system. By applying this technique, another important factor is included: cooling. The water has the ability to cool a system four times more than the air. Thus, the water here has double functions: cleaning and cooling.

Controlling the angle by which the PV system should be set is another contributing factor. It is meant by the angle the degree of inclination with reference to the ground surface. For this reason, two screws are implemented, they are attached to a railway to fix the position of the solar panel and the mirror, according to the direction of the sun, in a way that they can collect the maximum quantity of photons.

A cooler in the back of the panel is introduced to reduce the effect of the heat by the sun. The cooler was made of galvanized metal because it has a good heat transfer coefficient and is easy to be shaped on a small scale. The cooler has an "S" shape water canalized pipes for a better cooling configuration design and the tank has a volume of 275ml.

Also the reflecting light is being prevented by introducing an anti-reflective layer at the bottom of the PV solar panel. This will help the 30 % of light that will be reflected by default to be captivated by the solar cells and used instead of being dispersed. Noting that the water won't be considered as a reflecting agent, because the width of the water layer is small enough and won't be always present on the top of the protective coating layer.

Finally the battery used in the system is a GT4B-5, AH: 2.3, size: 4.4 x 1.5 x 3.2 cm and it is made in China.

It must be mentioned that the experiment was done in a laboratory where the light source used was a 30 Watts Neon lamp. Several measurements of the output current (mA) and voltage (V) vs. Time (minutes) were applied on two systems to compare their performance: a normal panel put one week outside on the balcony in El Koura, North of Lebanon (PV<sub>1</sub>) and our prototype (PV<sub>2</sub>).

#### IV. EXPERIMENTAL RESULTS

In this study, preventive actions were done for the main factors that enhance the resistance of the solar cell: by decreasing the shading effect by dust, and putting an anti-reflective layer on the top of the solar panel, and putting nozzles to eliminate dust, and increasing the photons quantity absorption.

The voltage was measured and given by the prototype (PV<sub>2</sub>) and compared it to the normal panel (PV<sub>1</sub>). The figure 5 shows that the prototype designed is more efficient since it delivers higher voltage range and the normal PV panel has a lower voltage.

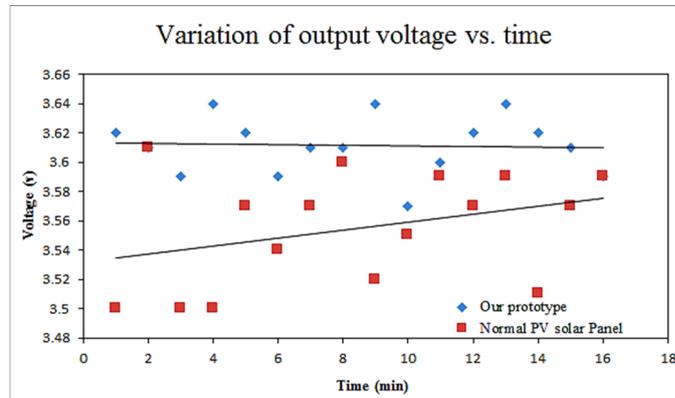


Figure 5: Variation of the Output Voltage of both PV<sub>1</sub> (prototype) and PV<sub>2</sub> (normal PV solar Panel) vs. Time

Another experiment is introduced in order to compare the current charging power of a phone's battery from different electrical sources. Four sources were used to charge a Samsung Galaxy grand 2 cell phone as it is shown in the figure 6 below: charging from a socket charger, from the normal PV, from the prototype, and when it is unplugged. The purpose of this experiment is to compare between the electricity produced from the two system PV<sub>1</sub> and PV<sub>2</sub> when it is needed to charge a cell phone.

This measurement was done using an application called battery graph from the play store. It measures how the battery

is being used and how much energy is being lost or added during time (figure 6).

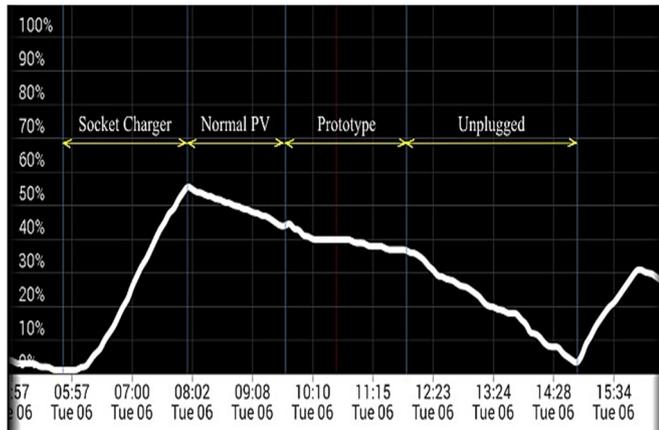


Figure 6: The current variation curve of the phone battery from different electric resources

The first section of it represents the current variation curve of a phone charging from the wall socket, the second section shows the current variation curve of a phone being charged by the PV<sub>2</sub> using a neon lamp of 30 watts, the third section indicates the current variation curve of a phone charging by the electricity produced from the prototype designed (PV<sub>1</sub>) with the same neon lamp, and the last section represents the variation curve of a phone when it is unplugged.

In figure 6, when the curve decreases, it means that the battery is consuming electricity, and thus the phone is consuming more than it is charging. When the curve increases, it means that the phone is charging. When the phone is plugged in a socket charger, the curve starts to increase which means that the phone is charging. It takes electricity more than consuming to supply its usage. When the phone is charged by the electricity produced from the PV<sub>2</sub>, the curve decreases slowly which means that even the system is charging the phone but its consumption is higher than the electricity delivered to it from PV<sub>2</sub>. Moreover, when the phone is charged from the electricity produced from the prototype PV<sub>1</sub>, an approximately constant line appears in the graph which means that the electricity received from the prototype is equal to the electricity needed for the phone to function normally. Finally, when the phone is unplugged from any source of electricity, the curve decreases rapidly indicating that the phone is not charged anymore and it consumes all its stored electricity.

Needless to say that the slope in the section of the normal PV<sub>2</sub> is decreasing, but the slope of the curve resulting from the prototype is almost constant, with small variation. This

experiment shows that the electricity produced from the prototype is more efficient than that from PV<sub>2</sub>, so the purpose of the experiment is verified.

From those two graphs, we can conclude that if those changes were done on a larger scale, this will increase the production of energy and decrease the resistivity in a feasible cost.

## V. CONCLUSION

The results obtained from the experiments examined on the advanced prototype show that all the changes added to the new design enable it to increase the production of energy and to decrease the resistivity effects.

In the future works, the water flow rate must be optimized to have the best cooling of the photovoltaic panels. The latter should be studied while optimizing the energy consumption of the cooling system.

Furthermore, the quantum dot technology can be implemented in the prototype. This new technology would not only help to eliminate the resistances, but also to increase the capacity of the cell to take more wavelength and benefit of the entire solar wavelength.

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