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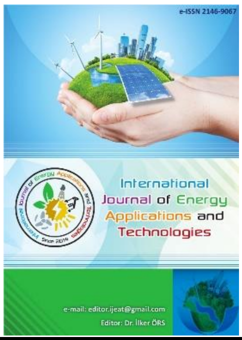


Original Research Article

# Comparison of innovative and traditional method for optimizing the efficiency of photovoltaic panels

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## ARTICLE INFO

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## ABSTRACT

Obtaining energy with high efficiency from solar panels, which are an endless source of energy, is one of the important research topics today. There are many methods applied both in manufacturing and after manufacturing to increase efficiency in solar panels. One of the methods that affect the efficiency of solar panels is the removal of dirt from the panels. The method is preferred since it does not affect the manufacturing cost and is for old panel users. Innovative panel cleaning method affects maintenance costs. This article presents a new approach to improving the efficiency of solar panels versus traditional method cost analysis. In this study, which includes an experimental approach, 10W solar panels with equal parameters were used. The correlation between the gain and the cost of the efficiency increase in the solar panel coated with rain-slip solution, which is a new approach, has been examined. Cost benefit analysis in this study will guide both small-scale and large-scale solar panel users.

*Keywords:* Cleaning PV; Cost-benefit; Efficiency; Solar panel

## 1. Introduction

Non-fossil energy sources are innovative and environmentally friendly energy sources that should be given importance in energy production. Renewable energy sources have a very important scale in energy production in the world in recent years. Solar energy is one of the most preferred ones in energy production because it is easier to install and the cost of installation is lower than other sustainable energy sources. It is estimated that the sun, which is an inexhaustible and costless energy source, will have a large share in energy production in the future [1-3]. Photovoltaic (PV) cells are used to generate electricity from solar energy. These cells are designed to convert the radiation coming from the sun to the earth's surface into electrical energy [4]. One of the most important problems of PV systems is efficiency. Efficiency problem is a problem caused by the inability to use the sun effectively. The reasons that affect the efficiency in the PV system are caused by the problems that arise during both manufacturing and operation. Manufacturers try different PV panel production methods for the efficiency problem caused by manufacturing. There are many manufacturing techniques that have succeeded today. Among the reasons arising from use, the sun angle is not the same every hour of the day or the panel is not as clean as it was in the first production [5-8]. Like other surfaces in the external environment and constantly exposed to environmental conditions, solar panels are also polluted. The main ones of this pollution are dust, sand and bird droppings. The result of this pollution causes a decrease in the amount of sunlight transmitted to the panel, and therefore the efficiency of the solar panel is low. This efficiency decrease is around 35-40%, which causes a decrease in the power produced by the solar panel [9]. Periodic maintenance is required to minimize these disruptive effects on efficiency. This process increases operating and maintenance costs. In recent years, researchers have focused on methods to reduce the effects that reduce the efficiency of solar panels [10]. These methods are about the different self-cleaning coating materials used in the manufacture of PV panels and the cleaning of the panel with a mechanical tool [11-13].

The researches carried out in recent years are on the production of new panels and they are far from providing solutions to the already installed systems. However, studies on installed systems are mechanical or human-powered cleaning systems. These operations are the most important expenses that affect the maintenance costs of existing systems.

This study focuses on the comparison of traditional PV panel with coating the panel with a special solution, which is a simple and inexpensive method to improve the efficiency of existing solar panels. The effect of using with the rain-slip solution on PV panels was examined and its effect on maintenance cost was analyzed. In this study, 10W polycrystalline panels were used. It was carried out on PV panels with the same power and electrical parameters.

## 2. Technology of PV Cells

Photovoltaic panels are semiconductor materials that convert solar radiation from the sun into electrical energy. Semiconductors are materials that are the subject of electronics. These materials are substances that can transmit electrical energy and control the current under suitable conditions. Silicon and germanium materials are examples of semiconductor materials. Silicon material is the most widely used semiconductor in photovoltaic cells. It is also used in semiconductor materials such as gallium phosphite, gallium arsenide, aluminum phosphite, aluminum arsenide and indium phosphide. These semiconductors are two types, p and n types. p type is called positive charge carrier and n type is called negative charge carrier. A PV cell consists of a combination of p-type and n-type semiconductors [14-16]. Today, energy and energy planning are very important. In addition, energy efficiency is an important issue. The efficiency of photovoltaic systems has been a prominent research topic in recent years. Research both in the manufacturing process and in the installed systems is aimed at increasing efficiency. The efficiency of the energy produced by a photovoltaic cell; wavelength of sunlight, panel surface temperature, surface reflectivity, and recombination of electron holes and holes. PV cell efficiency;

$$\eta_{PV} = P_{PV}/(G.A) \tag{1}$$

$$P_{PV} = U_m I_m \tag{2}$$

where $P_{PV}$ is PV module power, $G$ is solar radiation, $A$ is PV array area, $U_m$ is maximum PV module voltage and $I_m$ is maximum PV module current [17, 18].

Factors affecting PV cell efficiency are PV module design, environmental factors, and PV installation design. Material selection, self-cleaning glass and glass transmittance are PV module factors. dust, precipitation, bird droppings, ambient temperature and humidity are environmental factors. Solar reflector, water sprinkler and solar trackers are PV installation design factors [15].

Conditions caused by environmental factors are the most affecting the maintenance cost of PV panel users. All kinds of outdoor pollution such as dust effect cause a decrease in the electrical energy produced by the PV panel. Pollution is a negative effect on the total energy production from the solar panel. Therefore, solar panel cleaning is important. There are manual or automatic systems for PV panel cleaning. Both automatic systems controlled by mechanical electrical-electronic systems and manual systems based on human power affect the maintenance cost. However, it is very difficult to determine the correct time intervals for panel cleaning. Because the situation that creates this pollution depends on many unpredictable parameters. In addition, the weather conditions are constantly changing and the effect on the panel cannot be determined. Panel cleaning scheduling directly affects the gain from solar panels. Therefore, the panel cleaning interval changes the cost per unit energy. The total cost of this lost energy of the solar panel is found by adding the cost of the cleaning process to the cost of the lost energy. The cleaning interval can be defined as $t_{clean}$ and the value of the energy lost due to contamination during this interval can be defined as $W_{clean}$ [19, 20]. According to this;

$$W_{clean} = \int_0^{t_{clean}} R\,(t)P(t)L_s(t)dt \tag{3}$$

where $R(t)$, $P(t)$ and $L_s(t)$ are tariff of electricity, power produced by the panel at time interval $t_{clean}$ and the power loss due to soiling, respectively [19, 20]. The sold value of the energy generated by the solar panel is

$$W_{sold} = \int_0^{t_{clean}} R\,(t)P(t)[1 - L_s(t)]dt \tag{4}$$

## 3. Experimental Setup

The test setup is located in Electrical Engineering Department at Istanbul Technical University in Istanbul, Turkey (at coordinates 41°06'17.1"N 29°01'29.2"E). The test setup consists of 2 solar panels. The solar panels in the experimental setup are 10W polycrystalline silicon panels as seen in Figure 1.

The electrical properties of the solar panels used in the experimental setup are as in Table 1. Rain-slip solution was applied to the surface of one of the panels used. The other solar panel does not have any coating. This panel was used as the reference solar panel.

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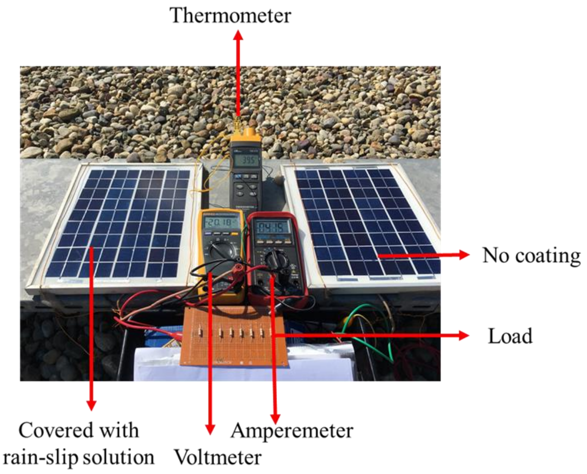



**Figure 1.** Test bench

**Table 1.** Specifications of the solar panels

| Parameters | Value |
|---|---|
| Rated Maximum Power ($P_{max}$) [W] | 10 |
| Open Circuit Voltage ($V_{oc}$) [V] | 22.10 |
| Maximum Power Voltage ($V_{mp}$) [V] | 18.00 |
| Short Circuit Current ($I_{sc}$) [A] | 0.67 |
| Maximum Power Current ($I_{mp}$) [A] | 0.56 |
| Maximum System Voltage [V] | 1000 |
| Dimensions length (L)×width (W)×thickness (T) [mm] | 300x300x20 |

Experimental studies were started in June and measurements of the solar panels were made periodically at the same time every day. These measurements continued for four months. The uncoated solar panel was taken as the reference panel and the other coated panel was used for comparison. Before starting the measurement studies, the high pollution time of the panels in the Istanbul Technical University Ayazağa Campus, where the study was carried out, was determined. This period is set as two weeks. These solar panels, which were specified on the roof of the Faculty of Electrical and Electronics of Istanbul Technical University, were placed side by side and the condition was provided to be exposed to the same external effects.

In addition, the effect time of the rain-slip solution was determined. It was determined that this period corresponds to approximately two weeks. During the measurement studies of the panels, the rain-slip solution was renewed by paying attention to the specified times.

During this experimental study, which continued for 4 months, it was tried to ensure that the panels remained at high efficiency. At the same time, the amount of rain-slip solution consumed was calculated.

## 4. Results

At the beginning of the experimental study, the reference and solution-coated panels were cleaned to produce the highest power. Then the panel without reference solar panel was covered with rain-slip solution. After this specified process, electrical measurements were carried out on both panels. In order to make the measurements more precise, electrical measurements were made at the same time and at the same time of day. The data considered as the initial state of the solar panels are as in Table 2. The panel called PV 1 is a solar panel covered with rain-slip solution, and the panel called PV 2 is solar panel without any coating.

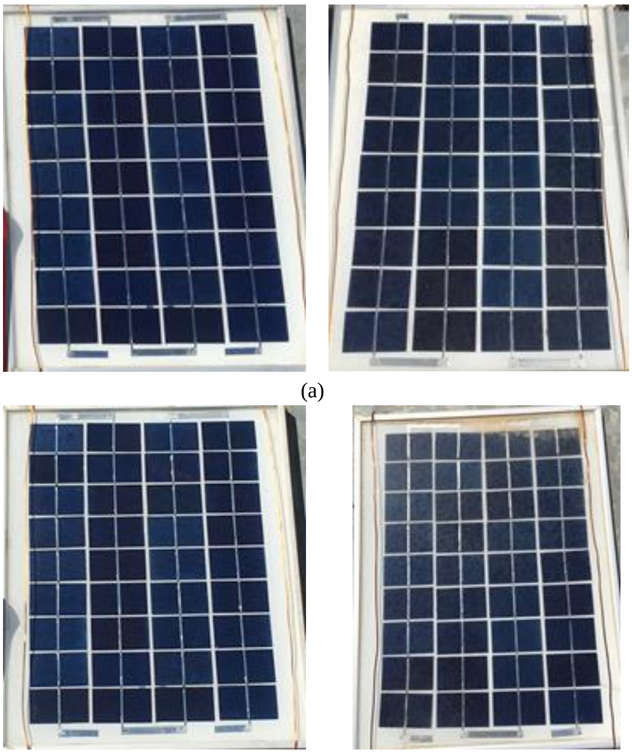
**Table 2.** Initial state data of the solar panels

| Solar Panel | Open Circuit Voltage [V] | Voltage with Load [V] | Current with Load [mA] | Temperature of Solar Panel [ºC] |
|---|---|---|---|---|
| PV 1 | 21.1 | 20.35 | 1.02 | 38.4 |
| PV 2 | 21.15 | 20.7 | 1.05 | 38.4 |

The time interval when the panels could be the dirtiest was predetermined at two weeks. Therefore, measurements were made at the end of two weeks. The data at the end of the second week are as in Table 3. This period is when the pollution on the solar panels is at the maximum level. The initial states of the solar panels and the states after two weeks are shown in Figure 2.

**Table 3.** Results of solar panels for dirty-clean situation

| | Solar Panel | Open Circuit Voltage [V] | Voltage with Load [V] | Current with Load [mA] | Temperature of Solar Panel [ºC] |
|---|---|---|---|---|---|
| Dirty | PV 1 | 20.56 | 20.5 | 1.03 | 37.2 |
| | PV 2 | 19.93 | 19.17 | 0.96 | 37.2 |
| Clean | PV 1 | 21.1 | 20.9 | 1.05 | 37.2 |
| | PV 2 | 20.54 | 20.45 | 1.04 | 37.2 |



(a)

(b)

**Figure 2.** State of the polluted PV modules (a) rain-slip coated (b) no coated

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It is seen in Figure 2 that the panel on which the rain-slip solution is applied is slightly soiled and the pollution is at the maximum level on the uncoated solar panel. The change and comparison of the measured voltage values under load with the contamination of the solar panels due to weeks is as in Figure 3.

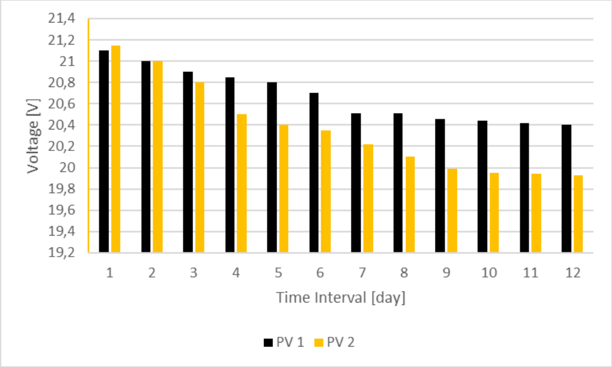


**Figure 3.** Compare voltage value of solar panels

The efficiency change obtained according to the measured electrical values of the solar panels is as seen in Figure 4.

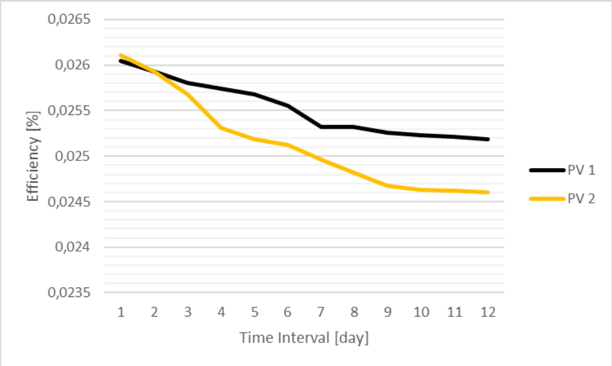


**Figure 4.** Compare efficiency of solar panels

As seen in Figure 4, the efficiency difference at the end of the twelfth day is 0.00058%. The panel is cleaned again and returns to its initial condition at the end of the twelfth day. The efficiency change can be taken as approximately 0.00047% for this twelve-day period. The rain-slip solution used in the experimental study was used as 10 ml on the 0.9 $m^2$ solar panel surface. In Turkish market conditions, the approximate cost of using rain-slip solution in this panel is 0.2 Euro Cent. The energy production difference between the rain-slip solution coated solar panel and the uncoated panel is approximately 3.25mW for the twelve-day period. Assuming that the solar panels produce an average of 10 hours of energy per day, energy difference is about 4Wh for the twelve-day. In Turkey, the unit cost price of energy is 0.0887 Euro as kWh. Accordingly, the energy difference cost for the twelve-day time interval is 0.036 Euro Cent for the 10W panel used as an example in the study.

## 5. Conclusion

This study is on the comparison of two solar panels with the same electrical parameters in different coating conditions. The electrical output data and optimal efficiency of two solar panels were investigated. In order to provide the most efficient solar panel working condition, the cost calculation has also been examined. Two solar panels were examined using different coating materials. One of the panels is covered with rain-slip solution and the other panel does not have any coating. These two solar panels were exposed to the same ambient conditions and efficiency values and operating parameters were compared. It is seen that the voltage value obtained from the solar panels using rain-slip solution is much better than the uncoated solar panel. When the solar panel without any coating material is exposed to pollution, its efficiency decreases by approximately 5.77%, and the rain-slip solution solar panel, which is exposed to the same pollution conditions, is 3.32%. In order to increase the efficiency value of the uncoated panel to the panel with rain-slip solution, around 6.2 Euro Cent value of this solution should be used annually. The annual energy gain is around 1.116 Euro Cent with this process. The method proposed for panel efficiency in this article does not seem cost-effective. Nevertheless, more positive results can be achieved for solar panels with big power values. It is planned to examine these economic values in detail in future studies for powerful solar panels.

## Conflict of interest

The author(s) declares that he has no conflict of interest.

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