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Assessment of Solar Panels using an Auto/Self-Cleaning System: Case Study at Al-Khobar City

Nader A. Nader[1]

[1]Mechanical Engineering Department, Prince Mohammad Bin Fahd University, P.O. Box 1664 Al Khobar 31952 KSA

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Abstract

There is no denial that renewable energy is considered to be the most cost-competitive source of clean power in many parts of the world. Saudi Arabia's vision 2030 aims at achieving the best by using different sources of renewable energy such as solar energy, wind energy, and others. The use of solar energy in particular for power generation will decrease the dependency on oil and thus decrease the greenhouse gasses. Solar panels efficiency tends to decrease with the accumulation of dust on their surface. Thus a cleaning process requires assigning and employing labor which increases the cost of running as well as high cost of machinery. The current study focuses on assessing and designing a simple auto self-cleaning system in order to improve the efficiency of the solar panel. The results showed that for the Al-Khobar region, Eastern Province, Kingdom of Saudi Arabia, the efficiency of the solar panels after cleaning was increased from 6% to an average of 12% at nominal temperature of 27 oC. In addition, the average power output was increased by 35% during the day time

I. INTRODUCTION

Renewable energy is the continuous and alternative energy to the fossil fuels. It is mostly abundant for example within the Kingdom of Saudi Arabia where the sunshine is 365 days. Harvesting energy from the sun has become a vital source of energy in the United States. The advancement in the technologies has made it useful in generating electricity without generation of green gasses. The urgency for clean environment and reducing global warming have become major requirements for clean air and healthier life. As a matter of fact, the total installed photovoltaic panels in the United Stated is expected to double in capacity over the next five years. In particularly it is expected to reach 14 GW by the year2023 [1].

The Kingdom of Saudi Arabia has a promising future in utilizing the solar and wind power. It is expected to increase in local electrical consumption by 2030. However, there is still a lack of study cases

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and data on the performance of existing systems in the harsh desert weather that has a detrimental effect on efficiency. Saudi Arabia holds great potential in harvesting solar energy as sun shine available all year round. The challenge of moderating power misfortune in solar photovoltaic system because of dust has become critical in the economical feasibility of using solar panels in dry areas. These territories experience the ill effects of high airborne focus levels and incessant dust accumulation that lead to find an engineering solution to remove the layer of dust from the solar panels surface.

1.1 Comparative Study

Solar panel gather clean sustainable power source in form of sunlight where the energy is harvested and converted to electrical power. In general, solar panels are made mostly of multiple layers of silicon embedded with phosphorous materials which gives the negative charge. Others are mix of silicone and boron materials which generate the positive charge. By connection the n-p layers, and with the photons from the sun, a flow of electrons will be induced. This will enable the panels to generate electricity. This whole setup is very common in industries and it is well known as the Photovoltaic Effect.

The main point of this study is to design a cleaning system to remove dust in order to improve efficiency of the solar panel. In most of the cases, cleaning was often done physically by labors. The manual cleaning has many disadvantages such as accidents generated by minor mishaps, damaging of the panel surface, development challenges, poor support and so on. The programmed residue cleaning arrangement of solar panels has been taken to defeat the troubles emerge in the customary cleaning. Furthermore, it delivers a compelling, non-erosive cleaning and avoids the inconsistencies in the efficiency because of the collection of dust.

Worldwide there an immense need of utilizing renewable energy as we are rapidly depleting the fossil fuels, there will soon come a time where we will be left with none to use. This gives us a challenge to look for other resources to generate electricity. One of the most reliable renewable energy source is sun and the energy it emits. The technological advances are becoming more effective in converting the solar energy into electricity using solar panels. However, more improvements are needed in order to enhance the efficiency and decrease the cost of operation and maintenance. of just slight and periodic rainfall.

1.2 Previous Work

Several researchers conducted a research on the viability of cleaning solar panel, utilizing a mechanized automated cleaning system [2]. The automated cleaning framework is a piece of an examination program identified with robotic dust relief advancements for solar panel. It uses different kind of brush that is delicate to the silicone elastic froth folds mounted onto an aluminum center. The investigation found that the robotic system, utilizing this silicone elastic froth brush, could adequately limit the effect of dust on the solar panel capacity yield, giving an expansion in power yield versus the

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week after week cleaned controls. The method used in removing the dust particles from the surface of the panel using this new brush will result in clean surface and low cost. .

More studies were carried on that led to an exploration of various advancements utilizing programmed cleaning systems for solar panels in various weather conditions. Solar photovoltaic systems have for some time been utilized to create vitality for various applications since 1990s. The efficiency of solar photovoltaic model is dictated by the accessible Sun's irradiance alongside different natural components like humidity, temperature, dust, snow, flying creature stool and so forth. The investigation showed that ecological factor did in fact diminishes the execution of the photovoltaic modules [3].

1.3 Comparative Work

Previous comparative study of solar photovoltaic arrangements was completed in various settings. In their investigation, execution parameters of photovoltaic modules are checked continually in electrical terms, for example, voltage, flow, and power. In the interest of the acquired outcomes, an examination under various courses of action is made and it is seen that the photovoltaic system with cleaning and sun tracking system demonstrates best outcomes as compared to the stationary arrangement and sun following states of solar photovoltaic system. Overall study is valuable in residential based independent photovoltaic system [4].

Another comparable research was conducted in this the new cleaning component utilizing dew was tried indoor with various kinds of wipers, distinctive cleaning angles and with various surface wetting time. The cleaning productivity with this instrument was exceptionally high; it achieved 99.3% for ordinary single wiper, 98.9% for industrial wiper and 98.3% for normal vehicle wiper. This system can spare huge amounts of water therefore lead to decrease in task and support cost. In any case, it must be viewed as that the system relies upon dew potential of the CSP plant area which is exemplarily researched for one solar site [5]. Other researchers have showed that whenever there is a dust accumulation on the surface of the solar photovoltaic module, this will tend to block the photons that comes from the sunlight. As a result of that, the electrical power generation will be reduced as much as 50% especially when the module is not cleaned for a month [6]. Further studies showed that in designing a self-directing system and in order to sense the physical parameters like dust and temperature of the solar panel,

Sensors were used to activate the wiper and dust is removed [7]. Further studies have revealed that the power output is reduced by 50% if the module is not cleaned for a certain duration of time. In addition, a regularly clean surface and with the assistance of a sun tracking-cum-cleaning system will not only track the sun but also clean the module automatically [8].

Other study was done by researcher within the kingdom focused on increasing the efficiency of the

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photovoltaic panel for residential units. The design system provides enough energy by cooling the solar panels with pumping cool water from the refrigerator to the direct system. The results showed that for the Dhahran region, Saudi Arabia, the normal efficiency of the solar panels before cooling was between 10 to 15 % at 42 oC. After cooling, the temperature of solar cells decreased to 20 °C and the efficiency increased by 7%. Moreover, the output power was increased by 31% with maximum efficiency of 32% at noon time [9].

II. THEORETICAL CALCULATIONS

Solar Panel Calculation:

The overall performance of a Photovoltaic cell can be defined by the use of IV-curve (Fig. 1). The current inside the solar panel changes is dependent on the voltage for a given direct normal irradiation (DNI). The current is very well influenced by the DNI at a given temperature.

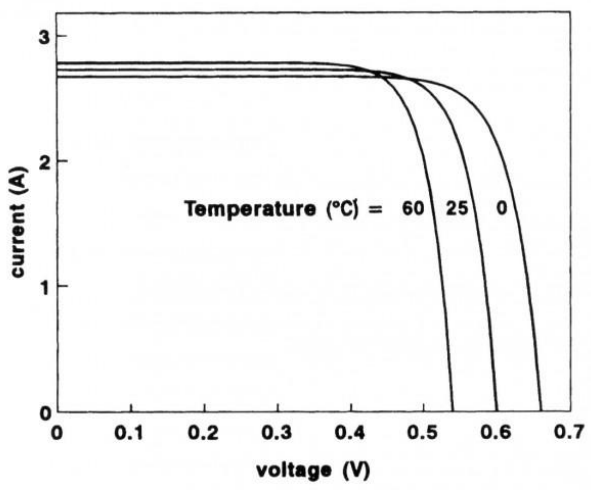

Fig.1. IV-curves for different Temperatures [10]

Power output:

$$P = V \times I \quad (1)$$

Heat input:

$$Q_{solar} = \Phi \times A \quad (2)$$

where Qin is the amount of heat transfer from the solar panel to the cooling water and Qsolar is the amount of heat transfer from the solar energy during the day. Φ is the t of heat transfer coefficient (W/m²); A is the Area where the heat transfer is taking effect of the heating device (m²); and ΔT is the difference in temperature in (°C) [11].

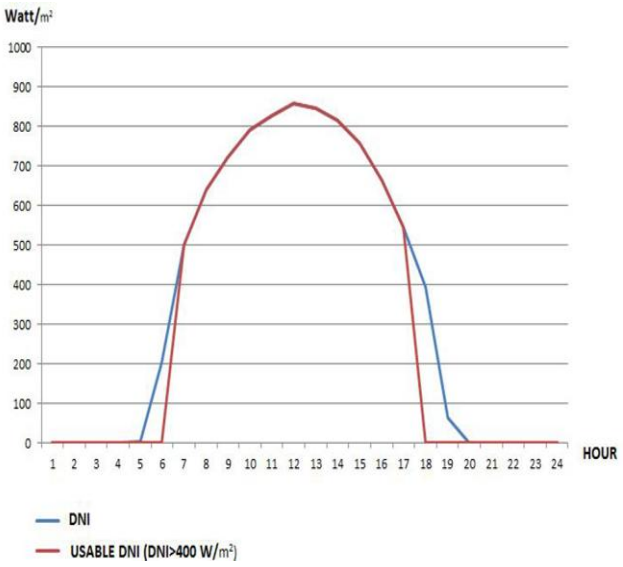

Fig. 2. Coefficient of radiation in Dhahran [12]

Figure 2, shows the coefficient of radiation that have been done in Dhahran, Saudi Arabia for 24 hours on a summer session, because the problem which the project solves happens in summer more than any other sessions.

III. DESIGN METHODOLOGY

For automatic self-cleaning solar panel system in order to be effective, there are some constraints

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which should be taken under consideration. The major constraint first is the weight. New parts and apparatus such as brush, water sprinklers, batteries, pipes and AC motor attached to the solar panel will add weight to the whole system. A waterless brush design was chosen for simplicity and light weight and for the purpose to clean the tough dust adhered to the panel we will be adding sprinklers which will be spraying very fine water droplets all over the panel. The system framework is constructed of aluminum to reduce the overall weight of the device. Second, the design system is required to function during the life of a solar panel. To make the system more cost productive, it needs to function for longer duration of time. Moreover, the device must be weatherproof and thus improving the battery life. Third, the sun has significant potential to generate energy at an tremendous amount of energy rate. Moreover, it is abundant and available all year round in the dessert areas in the Arabian Peninsula. Just imagine that all solar energy can be converted into usable forms, it will be able to supply the whole universe with electrical power. However, this is not practical since there are many variables that effect the efficiency such as environment and extreme weather conditions. A direct of energy conversion from solar to electrical can be utilized using the photovoltaic panels. Nowadays, it can be seen in many research on the importance of improving the technology and production at less cost keeping in mind the clean environment sustainability. Fourth, the existing cleaning system is done mostly by hand using expensive labors. There are many disadvantages for manual cleaning such as the occurrence of dangerous accidents that results in significant damage to the solar panels or loss in human life at higher elevation. In addition, the difficulties in cleaning mobility that ends in degradable maintenance. The advantage of using the automatic self-cleaning system is to solve all these persisting issues and thus enhancing the performance of the solar panel module. ies The need for automated self-cleaning solar panel system can be utilized on a larger scale for industrial plants or residential housing units. Fifth, the economic considerations are very vital for any future implementation of this cleaning system. A need for more manufacturing plants with reduce operational costs will result in considerable savings of power generation that is affordable to all users. Furthermore, the government and private industries must get involved in subsidizing the sector initially to make it attractive and affordable to the public. A huge investment is already implemented by the government of Saudi Arabia as part of the vision 2030. The system is expected to operate for minimum of twenty years. During this time, the system must maintain durability and cost effectiveness throughout the lifespan of the operations. Sixth and last, the safety of any system plays an important role in applying the standards and regulation of the wellbeing of humans. The system should be secured from any condition that might endanger lives such as earthquake or any severe weather conditions. A controller and sensors should be installed on any system to ensure

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credibility and safety enhancement. The weatherproof material can be used in any extreme weather conditions in order to reduce any damage to surface of the solar panels.

IV. EXPERIMENTAL WORK

The prototype setup consisted of a stand, solar panel, battery, controller, inverter, coil, compressor, condenser, expansion valve, evaporator, and refrigerator case. The first step was to calculate the internal heat coming from the sun and second to find the voltage and current for the current power output. Second step was to install additional parts such as wipers, water filter, new tank, chains, humidity sensors, water jets, and a fan. The wipers were attached above the above the solar panel and move in vertical motion. At the edge of the solar panel, a sensor was installed to control the movement of the wiper. The system also had a humidity sensor in order to activate the cleaning process when the humidity is abnormal.

In order to collect data from the self-cleaning solar panel system, evaluation of all important parameters was required to assess the systems performance. The voltage was being produced by the solar panels at three different stages when the sunlight was incident on the solar panels. First, the voltage was measured when the solar panel was cleaned with hand with no dust or humidity. Then water was sprayed as to simulate the humidity and the voltage was recorded. Finally, dust was placed on the panel and new measurement were found. The same procedure was carried on and repeated for five times at different hours of the day. In addition, the amount of power output from the voltage and current measured for each trial (Pout = V x I), the power being produced power input using (P_IN=∅ x Area), and thus the efficiency of the system can be determined

V. RESULTS AND DISCUSSION

Figure 3 and 4 shows the assembly drawing of the system. It can be noticed the amount of dust covering the solar panel in which will trigger the cleaning system to start.

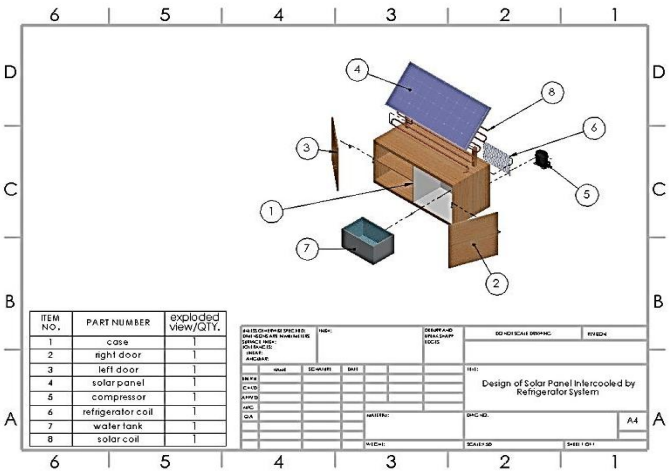

Fig. 3. Assembly drawing of major parts used in this experiment

Fig. 4. Dust covering most area of the solar panel.

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Table 1. System Power & Efficiency at 11 AM

	Hand cleaned	Humid	Dust	Mechanism
P_{out}	108	105.6	57.3	102.8
P_{solar}	823	823	823	823
η (%)	13.1	12.8	6.95	12.5

The data for system power and efficiency were calculated at four different time from 9 am to 2 pm. The results showed discrepancies among four different conditions, hand cleaned, humid, dust and when cleaning mechanism was initiated. As expected the worst condition came along with efficiency of 6.95 % for the dust conditions. The cleaning mechanism was very effective in removing the dust and thus improving the efficiency to 12.5% (Table 1).

Table 2. System Power & Efficiency at 2 PM

	Hand cleaned	Humid	Dust	Mechanism
P_{out}	94.26	93.53	66.7	97.02
P_{solar}	793.2	793.2	793.2	793.28
$\boldsymbol{\eta}$	11.82	11.79	8.21	12.29

Table 2 shows sample calculations of efficiencies at 2 PM. Again the cleaning mechanism results showed an effective cleaning technique as efficiency was improved to 12.29%. Example of calculation is shown below for the solar power input and efficiency.

$$Q_{solar} = \emptyset \cdot A = 800 \times 0.9916 = 793.28 \text{ Watts}$$

Efficiency (η): Efficiency is defined as ratio of energy output from solar cell to input energy from sun [9].

$$\eta = \frac{Q_{Solar}}{Q_{in}} \quad (4)$$

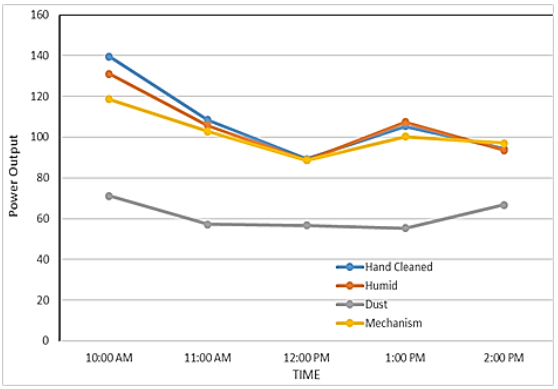

Fig.5. Electrical power generation versus time at different cleaning conditions

Calculating all four condition at different times were plotted in figure 5. In general, as time passed by during the day, the power generated by the solar panel was decreased. The cleaning mechanism showed an excellent result in improving the power especially when it was partially covered with dust. The hand cleaning result was close to the mechanism output data. This confirms the success of the cleaning system which is recommended for any future solar panel installation within the Kingdom.

Table 3. System Voltage and current at 2 PM

	Hand cleaned	Humid	Dust	Mechanism
Voltage	19.41	19.65	19.7	20.08
Current	4.65	4.6	3.09	4.6

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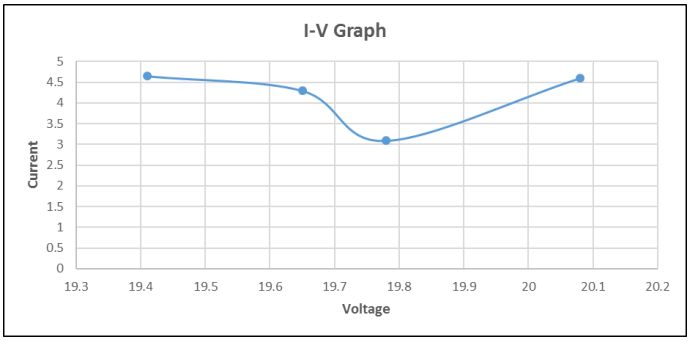

Fig. 6 System Voltage and current at 2 PM

In addition, the voltage and current for all the conditions were monitored and registered (Table 3), The trend shows from figure 6, that there was slight variation in the current as voltage was increased at 2 PM. In general, the trend was the same throughout the daytime measurements (9 AM-2 PM).

From all the data collected and the calculations done, a summary of the results showed that the dust on the panels effect greatly on the efficiency of the electrical output. The maximum efficiency was obtained at 10 AM, since this time the sunlight has the highest coefficient of radiation. The best improvement happened when the automatic solar cleaning system was used. The system is suitable in any commercial and domestic use.

Finally, the performance of a PV cell is defined by the IV-curve, which shows how the current inside the cell varies as a function of the voltage at a specified temperature and for a given solar irradiance.

V. CONCLUSION

The objective of this research was to design an effective cleaning system for the PV panels using water. The cleaning mechanism was chosen taking into consideration the cleaning cost in terms of materials and maintenance. It is recommended to be installed and used on all existing and new panels for numerous commercial and industrial sectors within the Kingdom. In general, the results showed that for the Al-Khobar region, Eastern Province, Kingdom of Saudi Arabia, the efficiency of the solar panels after cleaning was increased from 6% to an average of 12% at nominal temperature of 27 oC. In addition, the average power output was increased by 35% during the day time.

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