SOLAR PANEL PERFORMANCE ENHANCEMENT USING SMART CLEANING COOLING SYSTEM

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Abstract: This paper introduces two efficient, not expensive, easy, portable ways for rising the solar panels electric power production through a dedicated cleaning process embedded by a cooling process threw proposing, designing, and implementing a cleaning and cooling solar panels system in order to solve the problem of degradation in electrical power generation in hot zones territories using solar cells where the systems of renewable resources, clean energy, and environment friendly depending on. Temperatures rising above 45 °C, up to 55 °C for more than 4 months in the year in the Middle East area are the most important problems facing the electrical generators due to the physical obstructions which affect the physiological path of generation. While desertification, which is the main source for the dust layer, decreases the efficiency of the power cell production due to the solar radiation absorption limitation. Both cases cause production loss that may reach up to 50%. The proposed system overpasses these problems on both, test and real operational environments to achieves efficiency rising by 26% from 54% to 80% with minimal operating energy losing and system costing, while system easy use is present due to the availability of the LCD display where all necessary information's are displaced directly with online updates.

Key words: Solar Cell, Cleaning & Cooling, Heat Sink, Thermal Compound.

1. INTRODUCTION

Exposure to sun ray is high in the Middle East (Figure 1), because the sun is vertical or nearly vertical to those areas where the sun may last for 10 hours in winter and 16 hours in summer [1].

Winter on these areas is mild cold so the fall in temperatures not exceeds a single digit below zero in most occasions [2]. Therefore, the systems do not need to raise the temperature of the solar cells (because semiconductors tend to be conductors due to the changes in its physiological behavior in very low temperatures that exceed -100C^0) [3], but the system is in need to cool these panels to increase energy productivity especially in summer [1, 2]. Second highest temperature recorded worldwide was in the middle east region which is 73C^0, so, negatively affected due to high temperatures on solar panels is one of the reasons why the Middle East moving away from using solar energy to generate electricity, while fossil fuels (oil, coal, etc.) rise in efficiency with such conditions [3]. This paper focuses on the cleaning process since cleaning is implemented using a relatively small amount of ordinary water (no need for specially treated kinds of water) & wipes with soft rubber tubes. Hence, the cooling process will be embedded inside the cleaning process, this leads to reduce the system size, cost, while system performance will be achieved as perfect as possible.

Heat effects are an important factor that is reversely proportional to the open circuit voltage of the solar cell (Voc).

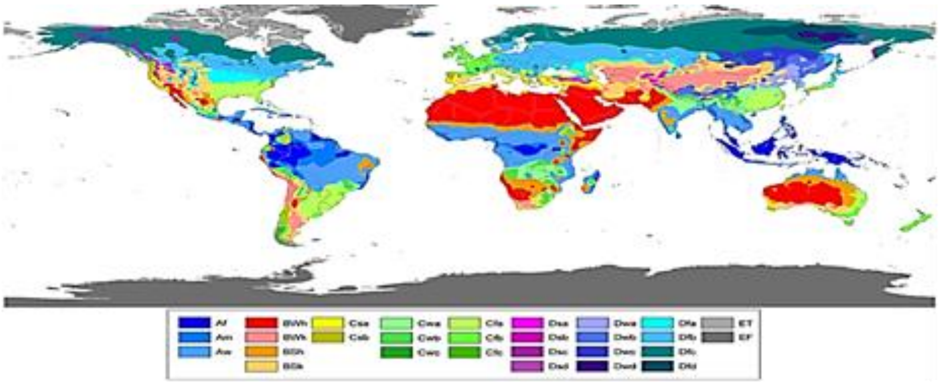

Fig.1. Illustration of temperatures of the Middle East area

This factor affects the physical path of generation, side by side the solar radiation is also strongly affected as Voc is a sign of panel temperature and the intensity of solar radiation, equation (1), [4, 5]:

$$Voc = f(S, Tc) \quad (1)$$

Where: Tc= Solar cell temperature.S= Solar radiation in W/m^2 (Watt/meter^2).
The temperature of the solar cell is taken by the average of the temperature of the upper surface T-top and the bottom surface temperature T-bottom for the cell where it is, equation (2), [4, 6]:

$$Tc = T - ac = (Ttop + Tbottom)/2 \quad (2)$$

The temperature of the lower surface is used to represent the temperature of the solar cell where a thermal sensor placed on the bottom surface of the solar panel to avoid direct exposure of the sensor to light rays from the sun which will be higher than the actual and hence the system is in need for a heat sink to guarantee best heat dissipation and distribution at the same time [7].
The temperature of the solar cell can seriously and effectively affect the output capacity of the photovoltaic (PV) cell [6, 7]. The temperature of the solar cell depends on cell packaging and on environmental conditions such as ambient temperature (or ocean) and wind speed, which works by increasing the area that is relatively exposed to air, or increasing airflow over the surface of the element to be cooled or both where an optimal point between the system surface area and wind speed must be evaluated so that the system kept away from what is called wing effect which destroys the system [7, 8].
There are some ways to maintain the temperature of electronic systems within permissible limits [9]. Air cooling is the main method and the simplest in controlling heat widely for a variety of electronic systems starting from Portable electronic devices to large business systems. The advantages of an air cooling system are its reliability, availability and its ease of application [10, 11]. Herein, a heat sink which is normally used to cool electric devices, integrated circuits and microprocessors, is used to cool a solar cell and study the effect on the panel temperature and performance as a stage one in the cooling system, while stage two in the cooling system is to use water from the cleaning system to cool the solar panels.
The proposed system is divided into two independent parts, the first part is the cleaning system while the second part is the cooling system. The cleaning system is more frequently used through the year than the cooling system since cleaning process must be applied continuously all over the year in different seasons due to the lake of the green areas and the possibility of using the water of the cleaning process in the cooling process is also applicable specially if there are no dust storms.

2. SYSTEM COMPONENTS

The system components that are listed in Table 1, represent the electronic devices and the microcontroller used in implementing the system to achieve the system operations where the system simplicity, easiness, and cost-efficient are very clear.

Table 1. The system`s components

No.	Component	No.	Component
1	Two Arduino Micro Controller	9	Digital screen display
2	LCD Display	10	Heat Sensor
3	Electric adapter and boards	11	Moisture Sensor
4	Two nozzles	12	Small water pump
5	Waterproof box	13	Remote Control Unit
6	two end motion sensor	14	Relays
7	Two stepper motor railway	15	Radio Frequency Receiver RFC
8	GSM chip	16	Stepper Motor

3. SYSTEM CONFIGURATION AND OPERATION

These components which are shown in Figure 2, with their RFC are connected to the Arduino board, where optical motion sensors are also connected to that Arduino to ensure that the stepper motor motion works correctly and continuously [12].

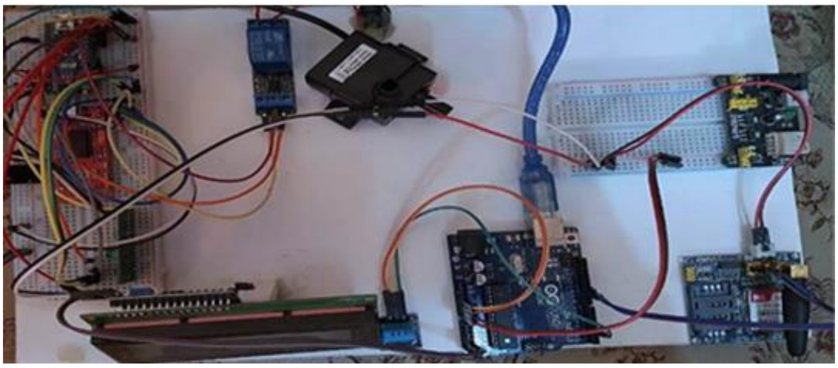

Fig. 2. The connection of the system parts

These parts are powered by Arduino's power adapter, taking a positive part directly from the Arduino pin and the other connected with the GND pin, while the control signal is triggered from the Arduino. These Arduino's are programmed using C ++ language due to its effective, direct, powerful operation and the most important is the huge size of the on-shelf, free programming operation libraries available on the web that make the implementation is much easier and more acceptable.

The first microcontroller will start action in case of getting a signal from the transceiver through the remote control to the system then to the RF receiver which will translate the order and give the command to the stepper motor to start its action. This means that the process will enter a loop, through which the stepper motor will work in a certain direction depending on the sensing signal received from the optical motion sensors on board the rail fixed to the plain surface of the panel. For example, the movement of the stepper motor from the right to the left, hence when the motor arrives at the other end of the track which is the left end, there is an optical sensor which may called EAR sensor that is used to detect that the motor has reached its highest value in the movement (end of the track) where this will activate a command to reverse the motion direction. At this moment the second microcontroller is activated where the optical sensor will give a signal to the microcontroller to convert the direction of motion to the new value of the rotation, hence the stepper motor will move tower its original position which is right. This process is done four times in a normal day, where each time it's activated, a full system checkup is performed to ensure the temperature of the cell, side by side, cleaning the cells from the accumulated dust. However, the system is not in need to run the pump always, which means that the water pump will not run unless the stepper motor is activated while the water pump may not be functional even if the stepper motor is activated since the first function is for cleaning-cooling while the second one is for cleaning only.

The second microcontroller contains a temperature and humidity sensors where in case of high temperature and humidity, which may affect the surface of the solar cell, the action must be taken to trigger the water pump and the stepper motor simultaneously to clean and to cool the panel surface more than four times a day until the panel temperature be under 45^{o}C in order to keep the system in the safe margin. These results will be displayed on the screen of the digital display on the system where a copy of all information's, messages, activities, and results will be sent to the GSM chip then the latter sends that information's to the mobile phone to keep the owner updated each time the system takes an action.

4. SYSTEM TESTING ENVIRONMENT

4.1 Heat test environment

Testing environment with temperature control is prepared for testing the solar panels to demonstrate the heat effect where this environment is supplied by a light source stands for the sunlight while the heat is increased to reach 60^{o}C where most of populated areas on earth do not pass over that limit. 8 panels where involved, each panel of (130.5cm * 80.5cm) and thickness of 0.6cm with a rated output of each panel is 115-120 watt, in the test to generate maximum output electric power of 1200 watt and rated output power of 950 watts. For the purpose of panel-temperature measurement, a double thermal sensor attached to the lower surface of the solar cell (type k-thermocouple), while a voltmeter is connected to the two ends of the solar panel to record the change of the panel response to heat effect. The increase in the panel temperature reduces Voc and vice versa, so rapid changes in Voc due to heat change may cause unstable generation and hence reduces system efficiency. Therefore, heat sinks and cooling systems must be attached.

4.2 Actual atmosphere test environment

Two months in for each season, summer and winter, the system was tested while for one month only in both Spring and Autumn. The output varies depending on the exposure angle (which depends on the season), the atmosphere heat, and the usage of heat cooling and heat radiating systems to keep Voc within the acceptable values. An important point is taken in the consideration is that the heat dispersion is attached to the system continuously since the middle east territories are always suffering from high temperatures and this action increases the overall system performance. Highest performance is achieved in spring & autumn. The use of the system raises the solar system efficiency where the increasing lies between 10% in winter to reach more than 25% in summer comparing with the system output power production when the system is not used and hence the system rate rises from 55% to reach up to 80%.

5. PRACTICAL READINGS AND MEASUREMENTS ACQUIRING

The results were obtained on two independent phases, where the first one applied using the heat test environment to obtain (Voc) versus temperature to specify the system boundary conditions that effect the production process while the second phase applied on the actual atmosphere environment on all seasons to cover the atmosphere conditions and effects as much as possible.

The first phase measurement steps were implemented as follows:

First: - Recording the values of the open circuit voltages and the temperature of the bottom surface of the cell every twenty minutes for 12 hours from the moment of turning the light source on, where the heat dispersion is not attached. The results of the system as shown in Figure 3, two cases where presented, with no cooling system in the first one (the system become unstable within 10 hours only and the measuring process couldn't be continued to reach the 12 hours as in the second cases), and with the cooling system (where the production process reaches to its upper bearing limits) where this temperature represents the atmosphere temperature in most of the summer times.

Second: - A dispersion is installed and attached to cool the panel where the dispersion used was the same as in the computer's processor heat sink after changing its shape to match the shape of the cells used in this research, and maintain the position of the heat sensor in the same place as in the previous phase of measurements (without dispersion). The values of (Voc) and the temperature of the bottom surface of the cell as shown in Figure 4, were recorded as in the First step with and without using the cooling system. It was clear that the system operates within the active stable reign of the system to guarantee the highest system performance in order to rise up the overall system efficiency.

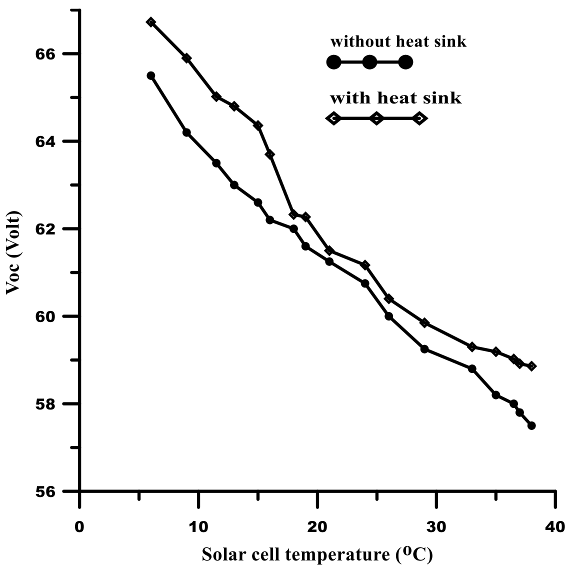

Fig. 3. The voltage change with the solar cell temperature while no heat dispersion

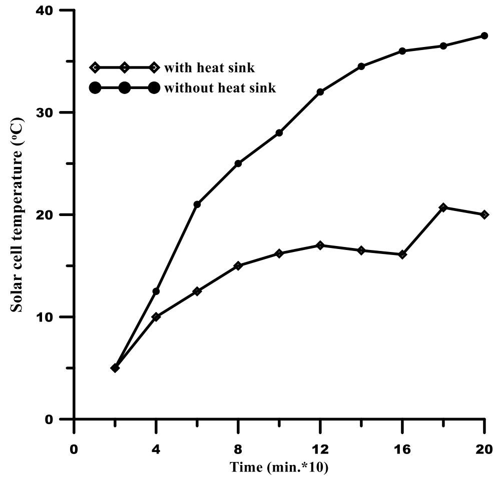

Fig. 4. The solar cell temperature versus operation time

While the second phase measurement steps were obtained and recorded in a period of one year where the results of testing vary because first, the system is tested with and without the proposed system. Second, due to the variation of weather in the middle east area where the temperature variation may reach to 10 degrees in the morning while the variation may reach up to 20 degrees between night and day especially in summer times. Third, dust storms may last for more than three days continuously especially in Summer, where some system parts are not allowed to be used as water pumps since water will change dust to mud (where mud represent an obstruction for the cleaning process) and an out action must be taken. Side by side, when the atmosphere temperature drops below 4 degrees down to a single digit below zero, the proposed cleaning system process will not use water while cleaning but wipes the solar cells only specially if it's windy because this may cause what is called " icing effect " which is harmful to the PVC shield protector of the solar panel. In such conditions, an out action must be taken too.

This process is handled by the second microcontroller and activated by the temperature sensor. The cleaning system in summer uses water which is the best for the solar panels and hence acts as a cleaning - cooling process to increase the panels productivity to reach more than 800 watts (if and only if the temperature does not exceed 50°C). The highest productivity obtained in spring and autumn where it's nearly about 950 watts with using both systems.

This system is implemented for homes and small electricity demands where no batteries are needed and the systems are directly attached to the panels, so all devices will be functional through the daylight period and will be dysfunctional threw nights, so if its desired to keep the systems functional all day long then a back-up system is needed at nights, hence the system at daylight must support, supply, and charge the system in the morning to work at night. The amount of power used or produced majorly depend on the weather (clear, smoky, or dusty), or the season (winter, spring, summer and winter where this depends on earth axes that are tilted by 23.5°C). Table 2, demonstrates the system output power with and without operating the proposed system in all seasons of the year with max system power of 1200 watt's & rated productive power is 1000 watts and the heat sink is fully attached in all seasons and cases.

Table 2. The system output power with and without attaching the proposed system

The season	System in summer	System in winter	The system in spring & autumn
Without the proposed system	550 watt	680 watt	900 watt
With the proposed system	825 watt	780 watt	950 watt

6. CONCLUSIONS

Table 2 and Figure 3, where the dispersion is not attached, it's obvious that the open circuit voltage Voc of the panel drops as the temperature of the solar cell increases where the drop increases dramatically when the temperature crosses 45°C and the system becomes unstable if it crosses 50°C since the heat affects the physical path of energy production because the heat effect increases the depletion region in the P-N junction of the semiconductor and hence increases the internal resistance of the system which reduces Voc. This effect is reduced when the proposed system is used because the system starts to fight the temperature increase and keep the system as fit as possible in the operational region where it was clear that the system reaches its upper limits but still functional.

Table 2 and Figure 4, where the dispersion was attached, the system passes the critical margin due to providing the necessary conditions for keeping the system functions within the active area where excessive heat is radiated through the dispersion and the radiation efficiency is increased when the proposed cooling system is used which its clear from the recorded results where the panels heat never pass the 40C° limits which keep the system in the safe side.

The rate of improvement in solar cell performance can be seen in Figure 3 and Figure 4, which shows the rate of rising in voltages, and hence the rise of the system performance, and the retention of voltages during the same period of time when using the heat sink. This improvement in performance is evident when comparing a value ($|\Delta Voc|$) and ($|\Delta T|$) according to equation (1) and equation (2), in both cases where the value is ($|\Delta Voc|$= 0.089V) and ($|\Delta T|$= 3.65°C) when the dispersion does not exist while ($|Voc|$ = 0.049 V) and ($|\Delta T|$ = 1.62°C) when the dispersion exists.

An improvement may be forced if the dispersion of the panel changed from passive to active where air circulation can be achieved if there will be cooling fans installed on the desperation which lead to increase the heat exchange, hence reduces the panel temperature.

While from the atmospheric environment it's very clear from the results shown in Table 2, that:

1-The system can't reach its rated production in summer due to heat effect where the proposed system tries to fight this effect and reduce it as much as possible where the system efficiency rise by 25% to reach 80% when the proposed system is activated.

2- The system can't reach its rated production in winter due to the tilted earth axis by 23.5 °C which reduces the panel exposure to sunlight, hence reduces the system production where the proposed cooling system effect is limited.

3- The system reaches near its rated production in spring & autumn because the earth axes are nearly orthogonal and the atmosphere heat within the safety margins of the panels, hence maximum production achieved with and without the proposed cooling system.

From all the above cases the cleaning system is turned on in all cases and steps since the middle east area suffering from dust storm most of summertime and this may obstruct the process of production (does not reduce the rate of production).

An additive technology may be adapted "wherein such cases it's desired to generate electricity during nights too" in solar panel manufacturing technology by turning towards the double layered technology where this will rise up the overall system`s cost and hence rises the system complexity.

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