Effects of Temperature and Dust on the Behavior of Photovoltaic Systems

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Abstract - *This work presents the study of the effects of temperature and dust on the performance of Photovoltaics Systems (PVS) during power generation. The control of temperature and cleaning of the Photovoltaic Modules (PVM), was realized through an Automatic Cooling and Cleaning System (ACCS), using water as work fluid.*

The test was realized using 3 PVS, with Polycrystalline Silicon Modules of 255 Wp each one: the first one, was coupled at the ACCS (PVM1); the second, was evaluated with the clean Surface, but without the ACCS (PVM2); and the third, was evaluated with the dusty Surface (PVM3). Measuring was realized each 10 minutes during 5 hours, with the next configurations: A) The PVMs disconnected; B) PVM's connected to off grid system to 24V. In each configuration, ACCS was programmed to maintain the Temperature to 40 °C. The results obtained from effect of the temperature and dust on the behavior of PVS, show us that: to the reduce in 15 °C the Surface temperature of the PVM (keeping it at 40°C) during peak radiation hours, the energy generation increase 26.17%

Key Words: Photovoltaic, Module temperature, Dust, Cleaning, PV water cooling, Efficiency improvement.

1. INTRODUCTION

In recent years, the demand for electrical energy worldwide it has increased, consequently the increased use of fossil fuels and environmental problems, such as global warming [1]. For this reason, look for new energy alternatives for to solve this demand, and thus, reduce the negative effects caused to the environment.

Renewable energy is part of this new concept of energy production, to reduce the use of the fossil fuels. According to the recent studies, the energy sources that have had greater participation, are: Hydraulics, Wind and Photovoltaic Energy [1-2]. Considering that the Photovoltaic energy is the most promising in the following years [2]. One of the problems associated with photovoltaic conversion process, is the work conditions are different to the standard conditions (SCT): 25 °C; 1,000 W/m^2; 1.5 AM [2]. In this condition, the PVM reach the maximum efficiency.

SCT is very difficult to obtain under real operating conditions, since radiation and ambient temperature are directly related, i.e. an increase in the magnitude of radiation causes an increase in the temperature on the surface of the PV module, which reduces the energy production (about 0.5% less for 1 °C of increase) [3]. On the other hand, the accumulation of dust on the surface of the PV modules reduces the intensity of radiation reaching the solar cells [4-6].

It has been observed that the electric energy production in the PVM increase if the Surface temperature is reduced, as well as keeping it dust free.

Many researchers have focused their interest on improving the electrical energy production of PVS, and in turn, taking advantage of the heat generated [7]. Other research refers to air cooling with forced and natural ventilation systems with ducts, as well as water cooling as a working fluid [7-31].

This paper reports on the analysis of the effect of temperature and dust on the performance of PVS under actual operating conditions. This analysis was realized with a control system that allows to maintain constant the temperature of the surface of the PVM, as well as, to maintain it free of dust, using water as working fluid. It is considered that with this method a better production of electric energy is obtained, and therefore, the energy production costs are reduced.

2. MATERIALS AND METODS

2.1 Description of the PVS

The off-grid photovoltaic systems (figure 1 and figure 2) used to study the influence of temperature and dust on power generation consist of:

a) The first one is integrated by: the ACCS, 1 polycrystalline PVM of 255 Wp, 2 batteries of photovoltaic application (deep cycle) of 95 Ah and 12V, 1 solar controller of 30 A and 12/24V, 1 24V-DC to 110 AC inverter with 1kW power and 2 incandescent lamps of 75 W.

b) The second, it is clean and consists of: 1 polycrystalline PVM of 255 Wp, 2 batteries of photovoltaic application (deep cycle) of 95 Ah and 12V, 1 solar controller of 30 A and 12/24V, 1 24V-DC to 110 AC inverter with 1kW power and 2 incandescent lamps of 75 W.

c) The third PV system is dusty. This dust was accumulated during 6 months in the site where the measurements were realized during the dry period. It consists of: 1 polycrystalline PVM of 255 Wp, 2 batteries of photovoltaic application (deep cycle) of 95 Ah and 12V, 1 solar controller of 30 A and 12/24V, 1 24V-DC to 110 AC inverter with 1kW power and 2 incandescent lamps of 75 W.

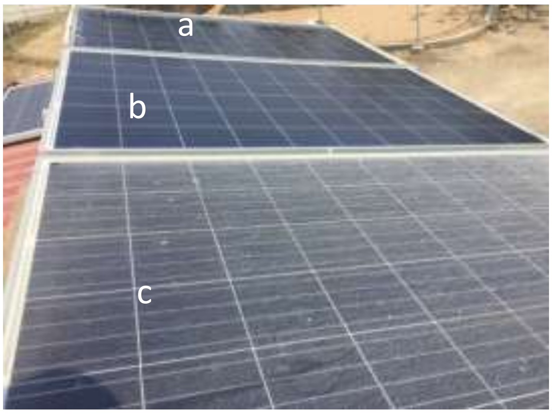

Figure – 1: Photovoltaic modules: a) With ACCS; b) Clean Surface and without ACCS; c) Dusty.

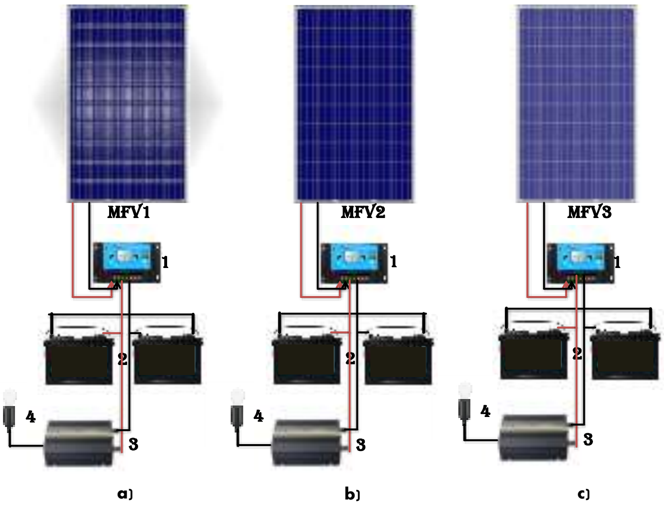

Figure – 2: Photovoltaic systems: a) With ACCS; b) Clean surface and without ACCS; c) Dusty.

2.2 Functioning of the ACCS

The ACCS is essential for the control of water needed to maintain the desired temperature level. The pumping system draws water from a 50 liter container to the front surface of the PV module. The water falls by gravity onto the front surface of the PV module, and extracts the heat generated in the module. The water is returned to the container for further use by means of a PVC pipe that is attached to the bottom of the PV module.

The pump system consists of a 12 V off-grid PV system, integrated by a 100 Wp PV module, a 10 A 12/24 V solar controller, a 12 V deep-cycle battery, Arduino platform control system and a 12 V DC surface pump with 700 liters per hour flow.

Figure – 3: Components of the ACCS.

2.3 Evaluation procedures

The Arduino platform was programed to cool at 40°C the PVM Surface. The Arduino platform was programmed to maintain the surface temperature of the module at 40°C.

The measurements are taken every 10 minutes, during a period of 6 hours, with the following configurations:

a) The 3 PV modules are disconnected. Short Circuit Intensity (Isc) and Open Circuit Voltage (Voc), were measured.

b) 3 Autonomous PVS to 24 V (figure 2). In this case, Maximum Power Intensity and Maximum Power Voltage were measured.

In both configurations, the incident radiation and the temperatures (of the water, of the environment and on the surface of the PV modules) were measured. The measurements were performed during periods of the day with conditions of stable sunshine.

3. RESULTS

3.1 Energy production and efficiency of PVM disconnected

Figure 4 shows the temperature variation during the measurement period for PVM1, PVM2 and PVM3 solar modules, as well as the variation of the ambient temperature and water used in this experiment. As it can be seen from the figure, there is a significant variation of the temperatures between the different solar modules, reaching a maximum difference of temperature of 13 °C between PVM1 and PVM2, and 18 °C between PVM1 and PVM3, around 13:00 hrs.
Also, an increase in the water temperature can be observed, up to 7°C, as a result of the heat absorption from the PV module (PVM1).

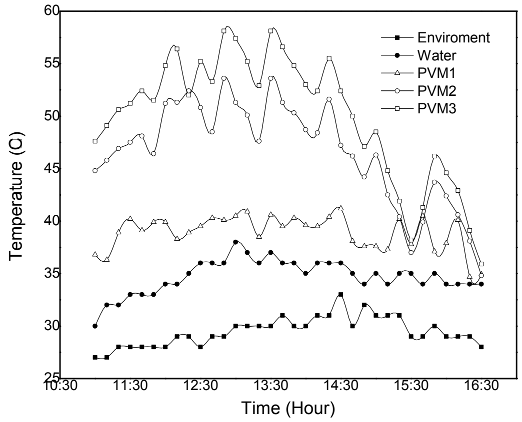

Figure – 4: Temperatures variation vs time.

Figure 5 shows the variation of the Voc, of the three PV modules and the variation of the irradiance during the measurement period. As shown in the figure, the Voc of PVM1 is higher than the other two (PVM2 and PVM3). The difference between them remains in the range of 3 to 5 units.

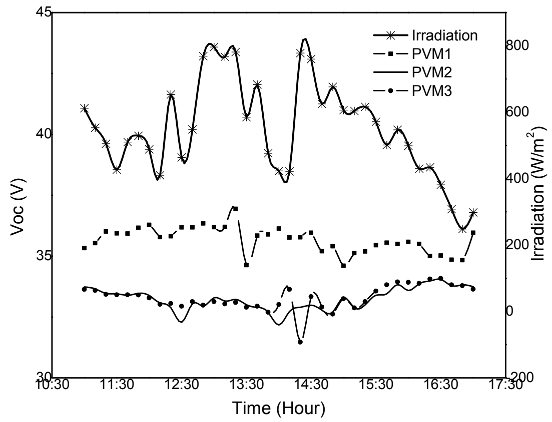

Figure – 5: Voc and Irradiation variation during the measurement period.

Figure 6 shows the variation of the Isc of the PV modules, as it can be seen that the current intensity of PVM1 is higher than the Isc of PVM2 and PVM3 during the whole measurement period. However, it is important to mention that the Isc variation between PVM2 and PVM3 is higher than the difference between PVM1 and PVM2.

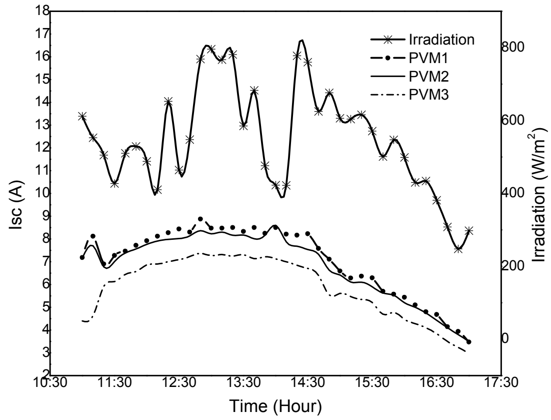

Figure – 6: Isc and Irradiation variation vs time.

These results are in correspondence with those obtained by M. Moreno [15], where he mentions that at 1,000 W/m2 of radiation, the values obtained by a PVM of 250Wp, are 242 W and 202 W, in operation temperatures of 31 ℃ and 64 ℃, respectively. Compared to our results, with values of 244 W and 183 W, to operation temperatures of 40 ℃ and 58 ℃, respectively, in this case with a incident radiation of 770 W/m2. So, if we reduce the operation temperature of the PVM at 30 ℃ and that the incident radiation of 1,000 W/m2, we would achieve greater energy production.

3.2 Energy production and efficiency of Autonomous photovoltaic system at 24 V

Figure 7 shows the variation of ambient temperatures, water and PV modules, as well as the variation of irradiation. From the figure it can be seen that there is a significant difference between the temperature of PVM1 and those of PVM2 and PVM3 modules, which varies between 10 and 15 degrees centigrade. The temperature of PVM1 does not exceed 40 ℃ due to SEL. In the case of PVM2 and PVM3, the temperature difference is in the order of 3 degrees Celsius, due to the influence of the dust layer that covers PVM3, which reduces the incident radiation on the module.

On the other hand, it can be observed that the temperature in the water increases with time, this is due to the heat it extracts from the PV1 module. This increase in water temperature is up to 10 degrees Celsius in relation to its initial temperature (25 ℃).

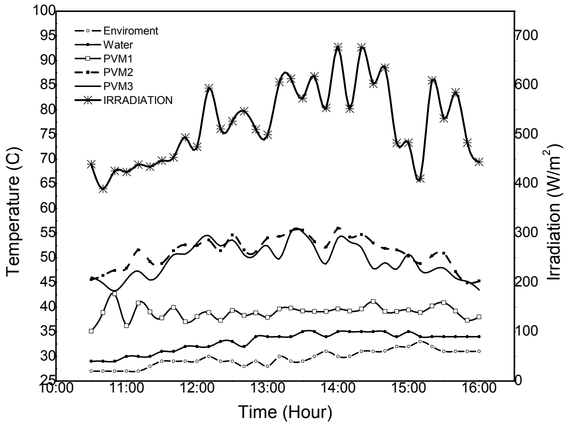

Figure - 7: Temperatures and irradiation variation during measuring time.

Figure 8 shows the power variations over time for each PV module.
In the period of time analyzed the energy production of PVM1 is 1,062.74 Wh/day, while that of PVM2 is 863.91 Wh/day and finally the energy produced by PVM3 is 784.61 Wh/day. This shows that PVM1 generates 18.71% more energy than PVM2 and 26.17% more than PVM3. The difference in production between PVM2 and PVM3 is 9.18%.

Figure 9 shows the variation of the efficiency of the photovoltaic systems, in the period of time analyzed. As can be seen from this figure, the efficiency of PVM1 is always higher than the efficiency of PVM2 and PVM3.

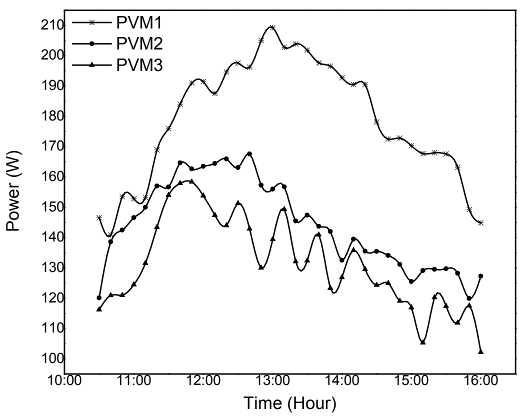

Figure - 8: Power variation during measuring time.

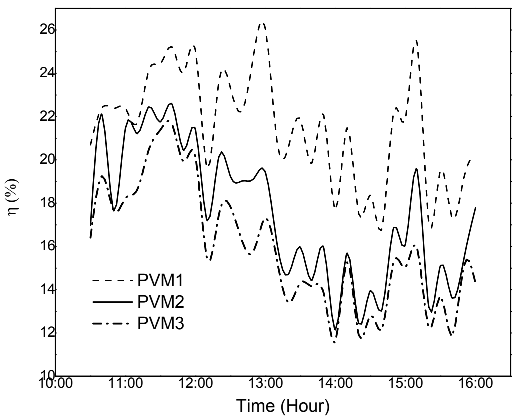

Figure – 9: Efficiency variation during measuring time.

The results found, are similar to the presents by S. Mekhilef, et all [4], who affirm a reduction of the 11% of energy production by dust effect.

On the other hand, K. A. Moharran, et all [32], show us a equivalent production when the PVM temperature is maintained to 45 °C.

Shaharin A. et all [6], study the effect of dust on the performance of PV panel. They found that the reduction in the peak power generated can be up to 18%. It was also shown that under greater irradiation, the effect of dust became slightly reduced but not negligible.

3.3 Energy production balance

In relation to the analysis of temperature and dust effect on the behavior of PVS, the following parameters are considered for the energy production balance:

- The energy production using ACCS is 26.17% greater.
- Water pumping capacity of the ACCS is 10 m.

- Width length of the PVM of 255 Wp is 0.99 m. In this part, is where the water comes out to the whole solar module.

It is considered that the ACCS has a capacity to clean and could 10 PVM arrangement, equivalent to 2.55 kWp installed. This allows us to obtain 11.99 kWh/day energy production, considering 4.7 PSH (Peak Solar Hours – average solar radiation at 1000 W/m2).

The 26.17% of excess energy production equals to 3.14 kWh/day. The ACCS, according to measures, consume 100 Wh/day, if we consider that to supply water at 10 PVM more time is required to cool and is projected as a lineal form according to the proportionality pressure and water flow, then this system consumes 1 kWh/day. Therefore, net energy production of the 10 PVM arrangement, is 2.14 kWh/day.

4. CONCLUSIONS

Based on the results obtained, the following conclusions are drawn:

- Cooling in 15 �C of the PVM Surface increases 18.71% the energy production, compared to the PVM without cooling.
- Presence of dust on the PVM surface, reduces 9.18% of energy production compared to dust free PVM.
- ACCS increments 26.17% of energy production of the PVS. Keeping at 40 �C and dust free.
- The net production of electrical energy of PVS with an arrangement of 10 PVM using the ACCS, is 2.14 kWh/day.

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