



The reliability of the photovoltaic utilization in southern cities of Libya

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Abstract

Solar energy can be converted to electrical energy by means of two methods: the first one is a direct method with photovoltaic (PV) systems and the second is an indirect one by solar thermal power generation. The main disadvantage of the PV systems is the high sensitivity of the output electrical characteristics to their temperature surface. The increase of the surface temperature leads to reduce the power output according to its power temperature coefficient. For this purpose we have to locate the zones where the PV systems can work efficiently as high as the standard test condition (STC) efficiency. The aim of this research is to determine the surface cell temperature of a working PV system under real operational and environmental conditions (Load, Solar radiation and ambient), further to evaluate the electrical behavior of PV systems and to estimate the failure of their function. The experiment has been carried out in order to measure the following parameters: output power, surface temperature, solar radiation, ambient temperature and wind speed. An experimental model has been designed and built up in the Solar Energy Laboratory at the Department of Mechanical Engineering, in Brack. Brack City is located at 27.6°N and 14.2°E, 600 km away to the south from Tripoli (Capital). According to the results of the experiment, the maximum cell's surface temperature reached 125.4°C in 6/5/2003 at 2:30 PM. The solar radiation was around 896 W/m². The percent of the failure of the power was found to be 69% of the nominal power at STC. This is why we have to be careful concerning the use of PV cells for Multi-Mega-Watts power generation, especially, which classified as hot regions, in most of the Arabic countries, especially in those which are classified as hot regions, such as North Africa and South Asia.

Keywords: Photovoltaic; Libya

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1. Introduction

The sun presents the main and safe source of energy on the earth. As we know, the energy produced by fossil fuels causes environmental pollution and contamination, furthermore the risk of their depletion in the near future. Electrical energy, due to its characteristics, is the most favorable, and it is easy to convey and convert it to other forms of energy. The electrical power can be extracted from solar energy directly with PV cells and indirectly by means of solar thermal generation. Solar thermal and PV electricity generation are two promising technologies for climate compatible power. They have such an enormous potential, that theoretically they could cover much more than just the present worldwide demand for electricity consumption. Both technologies provide an important contribution to climate protection. PV systems have advantages for low-power demand, stand-alone systems and building integrated grid connected systems.

The relative high cost of the PV technology is the main obstacle for their global utilization and it is only restricted to the rural and faraway electrical network regions. Because of the well developed PV production technology, the costs are reduced, which help to adopt this technology in lots of applications.

The aim of this research is to study the electrical and thermal characteristics of PV cells under real conditions of load and weather. To achieve this purpose, an experimental model was designed and connected to the measuring instruments to monitor both the electrical and the thermal characteristics of the model, such as voltage, current, and cell temperature, and also, the climatic parameters, such as, solar radiation, ambient temperature, and wind speed. This experiment has been carried out by the Solar Energy Laboratory of Sebha University in Libya.

2. Parameters affecting the performance of PV cells

The response of the PV cells is affected by many factors, such as the intensity of incident solar radiation, the surface cells temperature, the load size connected to the system and the manufacturing characteristics of the PV cells.

From the experiment's observations it was found that a small increase in the voltage and an augment in the current occurred with increasing of solar intensity, and this causes the increase of the power of the PV system. Contrarily, the increasing of temperature surface cell, which is

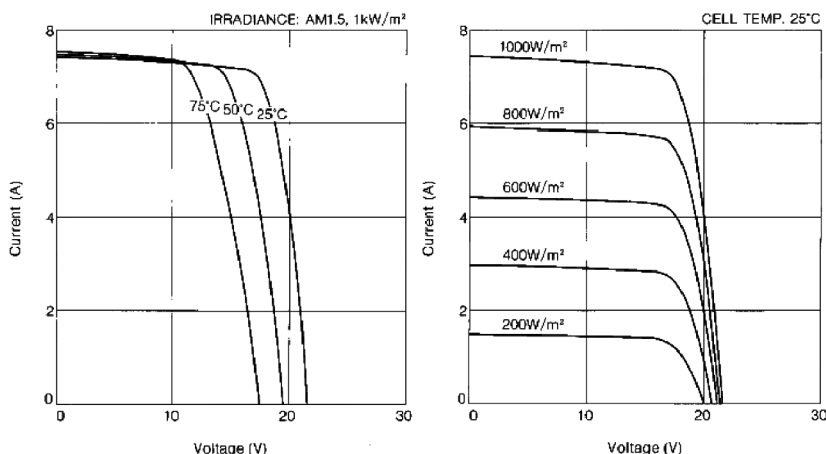


Fig. 1. Voltage - Current characteristics of PV module KC120-1 at various solar radiation levels [1].

due to absorption of solar radiation, and the conversion process causes the reduction of voltage and increase of current and as a result, the power output will be reduced (as indicated in Fig. 1).

The main aim of this work is to get to know the average working surface cell's temperature, which leads to becoming acquainted with the deviation from the nominal characteristics of the PV system. The comprehension of the behavior of the PV systems gives us a real view about the quantity, quality and the cost of production.

3. Experimental approach

3.1. Experiment description

Because of the difficulty of attaching the measuring sensors on the PV surface, it is difficult to determine the thermoelectrical characteristics of the PV panel, therefore we have designed the experimental model presented in Fig. 2.

3.2. Experiment steps

- 1) Calibration of the measuring instruments.
- 2) Connection of six PV cells in series.

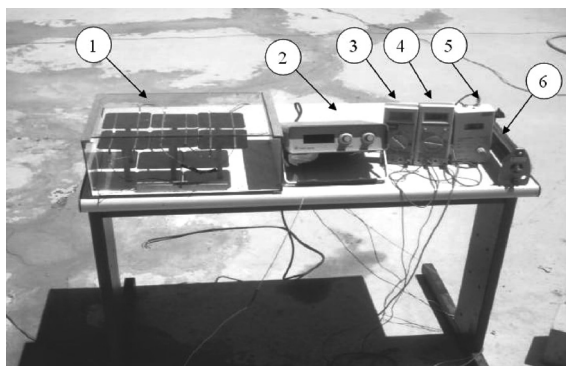


Fig. 2. The experimental model and the instruments used in the work; 1, the experimental model; 2, the temperature measurement device; 3, 4, Ammeter and voltmeter; 5, the solar radiation measurement device and 6, the variable resistance.

- 3) Fixation of the thermocouple ends on the PV cell surface.
- 4) Assembling the cells in a box, to allow to change the temperature of assemblies, by passing air flow (hot or cold) for heating or cooling the model, respectively.
- 5) Connect the experimental model by Volt-Ampere meter.
- 6) Monitoring and tabulating the data and tabulating in tables for treatment.

3.3. Experiment results

The experiment was achieved by Solar Energy Laboratory during the interval from 24th April to 20th May 2003. The following data has been monitored:

- 1) Climatic data: Ambient temperature, wind speed and solar radiation intensity.
- 2) Electrical data: Voltage and Ampere.
- 3) Thermal data: PV cell surface temperature.

The obtained results were presented graphically. Fig. 3 presents the relation between the PV cell surface temperature and the output power. The difference between the surface cell temperature, the ambient temperature and the solar radiation intensity were plotted in Fig. 4.

From experiment observations, we can remark the following notes:

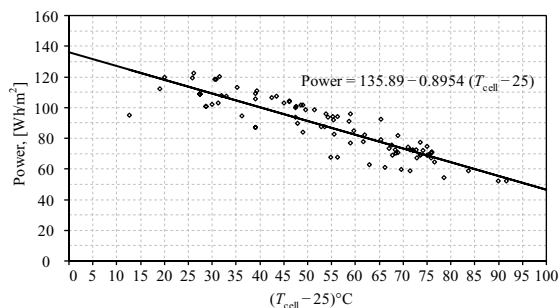


Fig. 3. Power behavior related to the change of the temperature difference between cell's surface temperature 25°C.

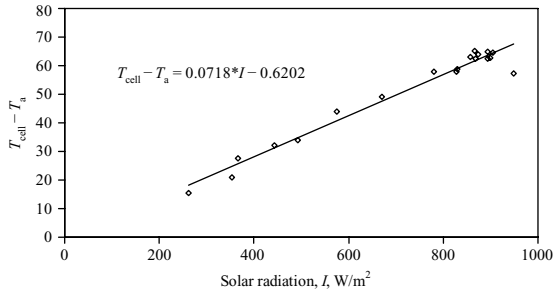


Fig. 4. Correlation fitting of the surface cell temperature as a function of the solar radiation intensity.

- 1) The surface temperature of the PV cells is strongly affected by the output power of the PV cells, and the shortage in the power was high as $-0.9\text{W}/^\circ\text{C}$.
- 2) The greatest surface cell temperature is 125°C that is occurred in 6th May at 14:30 (Libyan Time), the ambient air temperature is 39°C and the solar radiation is found to be $836\text{ W}/\text{m}^2$.
- 3) The experimental model is working at average surface cell temperature of 80°C , the average ambient temperature is about 30°C and the average solar radiation around $600\text{ W}/\text{m}^2$.
- 4) From the experiment observance we note that the cell never return back to the initial state when the climatic conditions are the same at morning and evening on the same day, but it starts in the next day with the initial nominal characteristics.

4. Results and discussion

The experiment has been carried out during April and May in Brack city. These months are not the hottest, and not the coldest ones.

The discussion will cover the two questions, the first question is related to the power, and the second one is dealing with the surface PV cell temperature.

4.1. Power generation question

From Fig. 3, we can remark that, the PV cell is operating at a relatively high temperature with

average value about 80°C , which causes a shortage in the power around 57% of its nominal value. This value can not be neglected.

The nominal electrical characteristics are often evaluated at standard test conditions (STC). These characteristics are maximum power [Watts], maximum power voltage [Volts], maximum [Amps], open circuit voltage [Volts] and Short-circuit current [Amps], which are evaluated at STC as: surface cell temperature of 25°C , solar radiation of $1000\text{ W}/\text{m}^2$, and air mass of 1.5.

The electrical behavior can be evaluated from the manufacturing data by using the following general equation:

$$X = X_{\text{STC}} + \beta_X (T_{\text{cell}} - T_{\text{STC}}) \quad (1)$$

where X , the electrical parameter, power [Watt], Voltage [Volt], current [Ampere], or efficiency [%];

X_{STC} , the value of electrical parameters at STC; β_X , the temperature coefficient of the electrical parameter, so there are four coefficients, temperature coefficient of voltage β_V , [Volt/ $^\circ\text{C}$], temperature coefficient of current β_I , [Amp/ $^\circ\text{C}$], temperature coefficient of power β_P , [Watt/ $^\circ\text{C}$], and temperature coefficient of efficiency. T_{cell} , the surface PV cell temperature [$^\circ\text{C}$], and T_{STC} , the standard test condition temperature [$^\circ\text{C}$].

All the terms in the right side of the aforementioned equation must be given in the passport data of the PV system, except the surface cell temperature, which have to be estimated.

4.2. Surface cell temperature question

As presented above, the surface cell temperature presents a very important, essential parameter for economic evaluation of the PV system.

It is not easy to determine the surface PV cell temperature, because it depends on many other

factors, such as climatic, operations, and manufacturing. Nassar and others [2] presented a mathematical expression for determination of the surface cell temperature. Practically, for this purpose, experimental correlation can be relied on calculating the surface temperature of the PV cell, these correlations often reliable for a certain location within limit of temperature and solar radiation variation. For our location we found this relation as different from that one offered by others:

$$T_{\text{cell}} = T_{\infty} + 7.8 \times 10^{-2} I \quad (2)$$

where I is the solar radiation intensity [Watt/m²], T_{∞} , T_{cell} are the ambient air and the surface cell temperatures [°C], respectively.

4.3. Conclusion of the approach

As we have described above, the area field of the solar PV system will be geminated to cover the shortage of the power generation in the field, because of the growth-up of the surface temperature of the PV cells. Which, of course, will be unfavorable to reflect on the investment capital and on the price of the productivity, so it becomes not economical and not competition comprising with other types of renewable power generation.

5. What is the alternative

Most of the Arabic countries are located in warm or hot zones, therefore, these zones are indicated by most of scientific works [2,3] as the

most favorable areas for thermodynamics solar power generation plants. Unfortunately, the exploitation of this gigantic available power is still underprivileged, especially the thermal electrical solar power can be generated in the scale of several hundreds of Megawatts and the excess exported to the neighbors through the Arabic electrical network.

6. Conclusions

The present study presents the disadvantage of the PV system's utility as a strategic source of electrical energy generation, in Southern region of Libya. It is because of the failure which occurred during its performance caused by the increase of its surface temperature during the operation. The utilization of PV systems can be restricted on mini and micro PV systems (e.g. watches, calculators), small PV island systems (e.g. solar home systems), large PV island systems (e.g. village power supply), and small PV grid-connected systems.

References

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