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Determination of suitable types of solar cells for optimal outdoor performance in desert climate

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Abstract

To choose the most suitable solar cell for desert climate, measurements and analysis of the integrated spectral response (ISR) and the electrical power over 32 spectral bands for monocrystalline, polycrystalline and amorphous solar cells have been carried out in Helwan during several seasons under different environmental conditions. The results of ISR show that while the amorphous silicon solar cell is sensitive in the visible part of the spectrum with maximum sensitivity at wavelength ($\lambda = 0.522$ μm), the polycrystalline silicon solar cell shows remarkable sensitivity in the infra-red region with maximum sensitivity at ($\lambda = 0.922$ μm) and the monocrystalline silicon solar cell is more sensitive in the near infra-red spectrum with maximum value of sensitivity at ($\lambda = 0.704$ μm). Deviations were found in the behavior between the ISR and the electrical output power in the measured bands.

Keywords: Integrated spectral response; Solar cells; Desert climate

1. Introduction

Questions about the sensitivity to spectral solar irradiance variations for specific

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solar cells have been addressed in an earlier study [1]. The thermal description and temperature effect [2], of photovoltaic performance have been studied in real outdoor conditions [3], for different types of silicon solar cells. Air pollutants, which are another factor that affects the performance of the solar cells have been found [4], to vary the solar radiation in Cairo between 20% in summer and 10% in winter. These air pollutants are found to decrease the spectral sensitivity of polycrystalline silicon solar cells more than amorphous silicon solar cells [5]. The objectives of this study are to find out the most suitable type of solar cells for desert climate through measuring the integrated spectral response (ISR) and electrical output power over several spectral bands in four clear days representing the year's four seasons. The winter is represented by two days, one of which is a full cloudy day.

Since environmental parameters are necessary for determining the spectral power distribution, which is an important factor in determining the ISR, it is important to calculate the effective variation of each of them on its value. Through this study, information can be obtained about the sensitivity with which each parameter has to be measured in order to choose for each a suitable measuring instrument.

2. Experimental setup and measurements

The experimental setup consists of three main parts:

1. A movable table which enables the system to be tracked.
2. Four filter frames each of which contains eight filters that can slide parallel to the solar cells.
3. Metallic frame contains three circular holes of the same diameter as the used filters, in which the three solar cells are installed.

The experiment for determining the integrated spectral response (lSR) for the solar cells over defined spectral bands was carried out with thirty two interference glass filters from Carl Zeiss Jena (Germany) covering the range from ultra-violet to infra-red. With these filters, the ISR of three types of solar cells, namely (1) a polycrystalline silicon solar cell from Telefunken System Technique (Germany), (2) an amorphous silicon solar cell from Chronar (UK) and (3) a monocrystalline silicon solar cell from Mobil Solar Energy Corporation (USA), was investigated.

The reflectance of the top surface of the amorphous and monocrystalline silicon solar cells as a function of wavelength $R(\lambda)$ has been measured using a spectrophotometer. The measurement of reflectance of the polycrystalline silicon solar cell is very difficult because each grain has a different orientation, area and reflectance. For its measurement, either the whole area of the solar cell has to be illuminated with a monochromatic light and the reflected radiation has to be measured, or an image analyzer or any compatible system has to be used to measure the area and orientation of each grain. The measurement of the reflectance of each grain gives, after the integration of the obtained results over all the grains, the total reflectance of the cell. Since neither of the latter systems was available, the reflectance measurement of polycrystalline silicon cell in this study was excluded.

The solar cells under investigation were connected to a voltmeter to measure the open circuit voltage. An ammeter enables the short circuit current for each of the three solar cells to be measured. The measurement of the current and voltage in the thirty-two spectral band ranges for the three solar cells takes about 15 min. To estimate the error resulting from the automatic untracked system during the measuring time, the normal global radiation at the beginning and the tilted global radiation at the end of the voltage-current measurements were measured using a thermopile pyranometer. The difference between these two measurements was taken as a reference for the error estimation of the air mass.

In order to use the theoretical model [6] for determining the spectral power distribution of the incident radiation, which is necessary for determining the ISR of the cells, the measurements of temperature, humidity and air pressure were also carried out.

3. Results and conclusions

It is evident that from the obtained results:

1. The monocrystalline solar cell has the greatest ISR in the visible range of the spectrum.
2. In the near infra-red region of the spectrum, the monocrystalline solar cell has practically the same ISR as the polycrystalline solar cell.
3. The amorphous solar cell has the smallest ISR all over the investigated range of the spectrum. Thus; it can be concluded that the monocrystalline solar cell is more efficient than the other types. Since in the desert climate, visible radiation is reduced and the price of the monocrystalline cell is much higher than that of the polycrystalline solar cell, it is advisable to use it in such climate polycrystalline cells in PV applications.
4. Increased humidity causes more absorption of the solar irradiance in the near infra-red region of the spectrum, and the polycrystalline cell will be more affected than the monocrystalline cell; therefore the last one will be suitable for PV applications in the regions characterized by a high percentage of perceptible water vapor.
5. The comparison between the internal and external ISR curves of the amorphous cell shows a gap between the two curves in the range (350–750 nm) which means that the use of selective antireflective coating can increase the efficiency of that kind of solar cell by about 1.38%.
6. The comparison between the internal and external ISR curves of the monocrystalline cell shows a deviation between the two curves in the range (400–700 nm) and coincidence in the range (700–1100 nm), so a selective

antireflective coating can increase the efficiency of that kind of solar cells by about 0.95%.

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