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Series Connection Effect on the Current Shunt Measuring Technique for Large Area Multicrystalline Silicon Solar Cells

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Abstract

The series connection effect on the electrical performance of a large area multicrystalline Silicon solar cell (21 cm × 21 cm) with back contact technology has been considered in a desert area. Short circuit current, open circuit voltage and output power are the major electrical parameters normally characterise the solar cells.The current shunt measuring technique has been used to avoid the problems encountered with traditional measuring methods. Achieving the optimum electrical short circuit current has been investigated. For this reason, two similar cells have been connected in series and their short circuit current has been measured. Then, the short circuit currents of the three cells and four cells have been obtained as well. These different connections short circuit currents have been studied to determine the most suitable number of cells that compiles with the used shunt resistance value. Furthermore, the correlated open circuit voltages and output powers have been illustrated for all cases.

Keywords: Large Area Multicrystalline Silicon Solar Cell, Current Shunt Measuring Technique, Optimum Short Circuit Current, Open Circuit Voltage, Output Power.

Introduction

There are many types of solar cells that are used in different life applications. Multicrystalline silicon is a very smart substrate for solar cells due to its low production cost and readily abundance [1,2]. Hence, it is presently the dominant solar cell material for commercial applications [3,4]. It is expected to be remain an important material in photovoltaics over the next years, due to its well recognized properties [5,6]. In addition, back contact technology solar cells have several advantages over conventional solar cells [7-11] due to their improved performance [12,13]. . The electrical performance is mainly described by measuring the cell short circuit current and open circuit voltage. These parameters are usually measured using digital multimeters (DMMs) but in case of the large area solar cells some problems appeared. This is due to the high current intensity with low output voltage of these cells. Even though, the hall sensor technique was applied in order to overcome these problems; this technique is still facing some limitations and it needs a lot of precautions [14,15]. Nowadays, current shunts are playing a vital role in measuring the large area solar cells' high short circuit currents in the desert area by measuring the voltage developed across their known very low resistance. They are very stable under a wide range of ambient temperatures from 5ºC up to 50ºC with the same linearity equation. Consequently, it is safely used in the desert area without any temperature effect on the cell measurements due to its negligible temperature coefficient [15,16]

In this paper, current shunt measuring technique is used to measure the short circuit current of a 21 cm × 21 cm multicrystalline Silicon solar cell with back contact technology. Then, the series connections of two, three and four units of the same cell have been studied respectively to get the most suitable number of cells which produce the optimum short circuit current. Consequently, the open circuit voltage and the output power have been investigated for all series connections. The comparison between the electrical behaviour due to series connections has been discussed.

Experimental Work

A 21cm × 21cm multicrystalline silicon solar cell with back contact technology has been installed at the optimum tilt angle [17]. The cell current is collected by the fine finger grid which is led to the back side through 25 holes. On the back side there are 25 soldering pads for each polarity. One of the methods of increasing the efficiency of the solar energy system is using the optimum orientation for the considered location [18]. Using the predicted and experimental values in degrees

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given by Table 1 the optimum tilt of a photovoltaic collector for use during the winter season is approximately 43.33^{o} for the chosen site. The optimum tilt of a photovoltaic collector used during the summer months is 15^{o} for the same site. Finally, the optimum tilt angle of a photovoltaic collector continuously mounted at a fixed angle throughout the year is 28.75^{o} and oriented towards the south [17,19].

Table 1 Predicted and experimental values of the optimum tilt angle in degree for Helwan [17,19]

Month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Predicted	55	45	30	15	5	5	5	15	25	40	50	55
Experimental	51	48	35	21	4	4	7	20	32	48	53	55

The incident radiation is recorded by using CMP3 Kipp &Zonen pyranometer. The CMP3 is a pyranometer that measures solar radiation with a high quality blackened thermopile. The blackened thermopile provides a flat spectral response for the full solar spectrum range, which allows the CMP3 to be used even when the sky is cloudy. It is also used for the reflected radiation measurements.

In this work, the current shunt measuring technique has been applied to measure the cell short circuit current to avoid the other measuring techniques' problems. 20 Amps - Holt HCS-1 current shunt has been used to obtain the equivalent voltage drop across its known resistance. Subsequently, this equivalent voltage is applied to a 14 bit data logger which is directly connected to a PC to compute the corresponding short circuit current using the shunt input-output linearity equation. The computed short circuit current values are obtained from the shunt voltage signals transferred to the PC through the data logger. The output voltage is linearly proportional to its input current with approximately the same linearity equation at all temperatures [16].The linearity equation that relates the input current to the output voltage is:

$$V_{out} = 0.0517 \times I_{in} + 8 \times 10^{-5} ....(1)$$

Where V_{out} is the output voltage drop in volts across the current shunt resulted from applying input current source I_{in} in Ampere. The cell short circuit current is obtained using the previous linearity equation with the voltage drop across the current shunt, V_{out}. Moreover, the open circuit voltage of the cell is received by the data logger to be transmitted to the PC.

The block diagram of a one 21cm × 21cm Multicrystalline silicon solar cell measuring system using current shunt is illustrated in Fig. 1

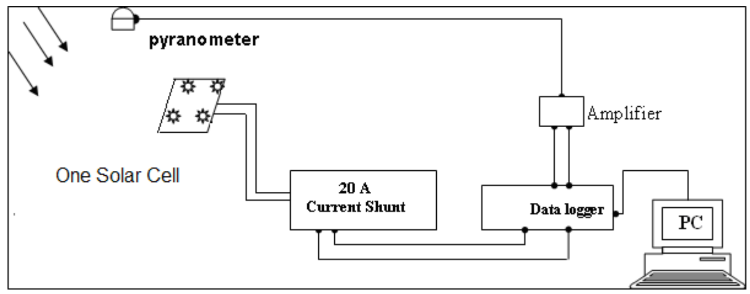

Fig. 1: Block Diagram of a one 21cm × 21cm Multicrystalline silicon solar cell measuring system using current shunt

The data has been recorded on 14th September 2013 at optimum tilted angle of 32° at this location. Nominally, the maximum open circuit voltage value of this cell is about 0.5 V while its maximum short circuit current is about 14 A. When one cell was examined it produced a short circuit current of 3.4 A (much smaller compared to the short circuit current optimum value), and an open circuit voltage of 0.55 V. The daily profile of a one solar cell short circuit current, open circuit voltage and electrical power is illustrated in Fig. 2 showing an output power of 1.87 W.

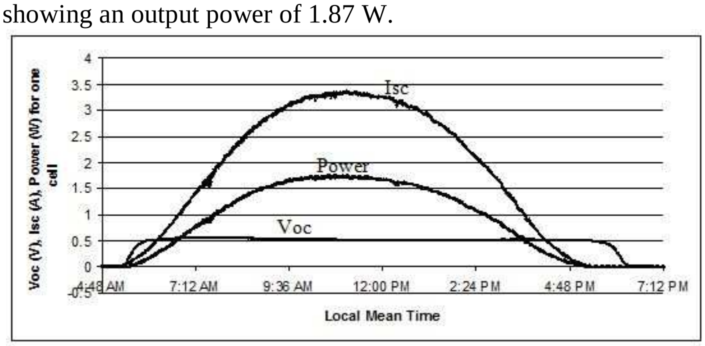

Fig. 2: Daily profile of the one solar cell short circuit current, open circuit voltage and output power

Series Connections Analysis

In order to attain the optimum short circuit current of this cell using the same current shunt value, the series connection of similar cells has been studied. Firstly, two similar cells have been connected in series. Fig. 3 shows the block diagram of two similar cells

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connected in series while the short circuit current, open circuit voltage and the output power daily profile of this connection is presented in Fig. 4.

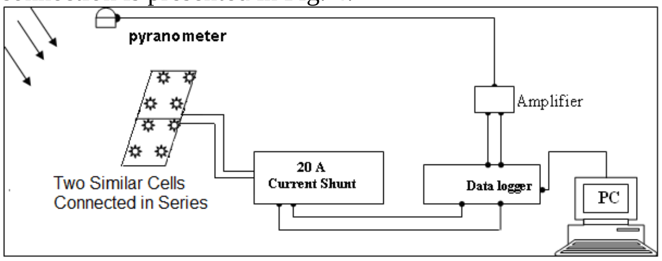

Fig. 3: Block Diagram of the measuring system using current shunt for two similar 21cm × 21cm Multicrystalline silicon solar cells connected in series

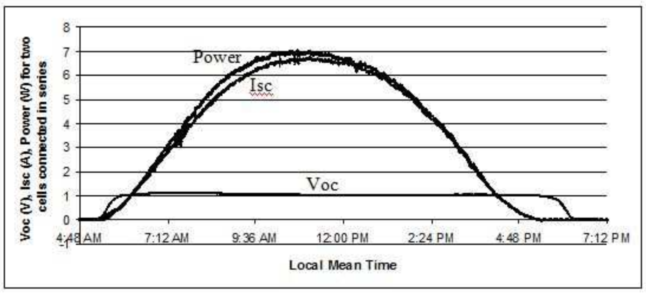

Fig. 4: Daily profile of the short circuit current, open circuit voltage and output power for the two similar cells connected in series

As shown in Fig. 4, the short circuit current of this connection is about 6.6 A (smaller compared to the short circuit current optimum value) while the open circuit voltage is about 1.1 V, thus increasing the output power to about 7 W.

Secondly, three similar cells have been connected in series as shown in Fig.5. The electrical parameters have been studied for this connection. Figure 6 shows that the short circuit current for the three series cells is about 10 A (less than the short circuit current optimum value) with about 1.6 V open circuit voltage and about 16 W.

Finally, four similar cells have been connected in series and the electrical parameters have been measured. Figure 7 illustrates the block diagram of the four series cells while the electrical parameters measurements are plotted in Fig.8. As clearly shown in Fig. 8 the short circuit current is about 14 A (equal to the short circuit current optimum value) with about 2 V open circuit voltage which produces about 28 W output power.

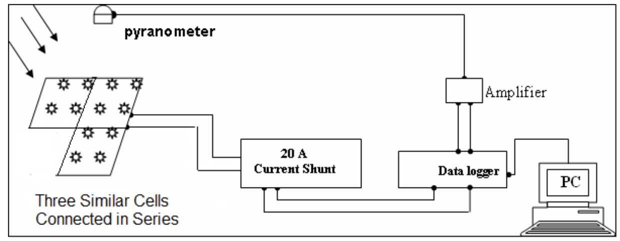

Fig. 5: Block Diagram of the measuring system using current shunt for three similar 21cm × 21cm Multicrystalline silicon solar cells connected in series

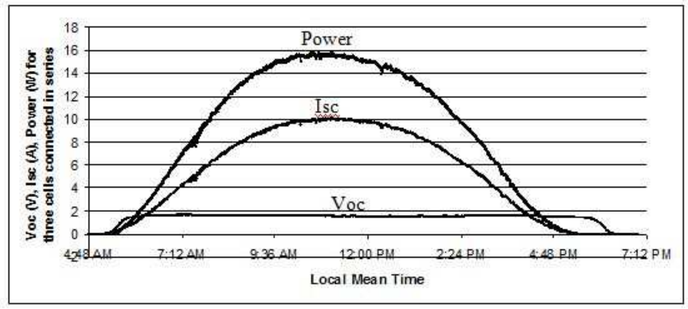

Fig. 6: Daily profile of the short circuit current, open circuit voltage and output power for the three similar cells connected in series

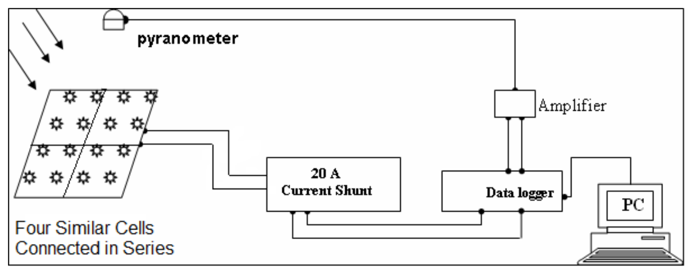

Fig. 7: Block Diagram of the measuring system using current shunt for four similar 21cm × 21cm Multicrystalline silicon solar cells connected in series

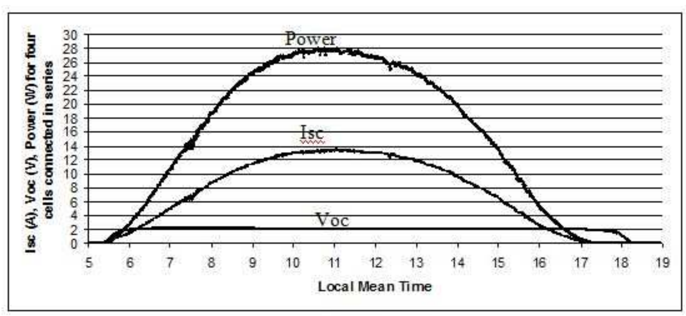

Fig. 8: Daily profile of the short circuit current, open circuit voltage and output power for the four similar cells connected in series

Figure 9 clearly shows that the short circuit current, open circuit voltage and consequently the output electrical power are proportionally increasing with the number of solar cells connected in series. Furthermore, it is fairly demonstrated that the four cells are the most suitable cells number to be connected in series for obtaining the maximum short circuit current of this type of solar cell using this shunt resistor. Besides, this connection increases the output electrical power by about 14 times which perfectly enhances the solar electrical performance.

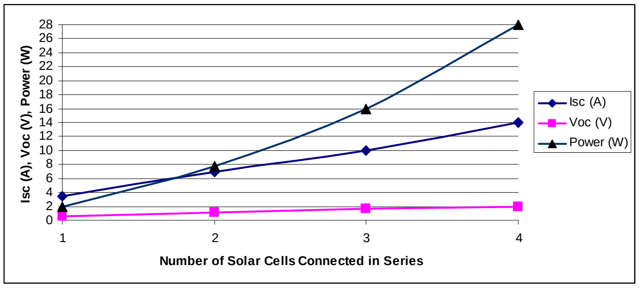

Fig. 9: Effect of the number of series cells on the short circuit current, open circuit voltage and power

Conclusion

The practical results of using the current shunt technique in measuring the short circuit current of a multicrystalline Silicon solar cell (21 cm × 21 cm) with back contact technology have been discussed. Different series connections have been tested including two, three and four cells. The results indicate the possibility of measuring the short circuit currents for the possible series connections, where the value of the measured current increases with the increase of the series cells; however full success in measuring the optimum short circuit current value takes place for the four series connected cells. In the same time, the open circuit voltages and output powers have been analyzed for the different connections. Improved electrical behavior has been achieved using the series connections especially in the case of four series cells.

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