Performance Evaluation of solar cells after 31 Years of Work

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Abstract

Crystalline silicon photovoltaic modules are being used for long time in many photovoltaic applications. It was not expected that photovoltaic modules of old technology will last for twenty years. In contrast, a photovoltaic system which was installed in 1979 in the Libyan Desert is still running with a little decrease in the output power and small changes in its designed parameters. The study goal is to evaluate the performance of thirty-year old crystalline silicon cells under Standard test condition. Some of the solar cells were dismantled from one of the photovoltaic modules which have been working for more than thirty years in order to test and measure their current-voltage curve. This paper presents the measuring results of indoor measurements on the thirty-year old solar cells.

Index Terms standard test condition, Qualification and Testing, solar cells

1. INTRODUCTION

Crystalline PV cells encapsulated in front glass modules have been used for long time in many applications [1]. Long period of run is one of the major technical strengths of the photovoltaic (PV) modules [2]. Manufactures continue to search for new materials in order to reduce cost and improve performance of both solar cells and modules. Many Crystalline silicon module manufacturers offer warranties that their products will survive for certain duration of time [3]. Even though old technologies of crystalline silicon was not expected to last for more than twenty years, solar modules have still been running more than thirty years and they are expected to run for more. [4].

Isolated PV systems have been used in Libya for more than thirty years in microwave repeater stations which are located in Libyan Desert. In this study, a number of solar cells was removed form one of the thirty-year old PV modules and tested to measure their performance "current-voltage curves (I-V carves)".

2. APPROACH AND METHODOLOGY

The performance of the solar cell is determined by measuring the I-V curve which can tell a lot about the cell performance. The I-V curve is a plot of the current versus voltage. The big challenge in this part is how to remove the solar cells from its module since there is encapsulation liquid around the cells between the front and the back glass. Any a small wrong movement, it will cause to break the cell. Eventually a solution was made to pass this obstacle. The indoor I-V curves of the cell were measured in the laboratories of the Solar Energy Research Center in Tajoura City using Sun Simulator – Solsim see fig. 1. Solsim (Sun Simulator) enables accurate measurement of solar cells and measures the short circuit current I_{sc}, the open circuit voltage V_{oc}, the fill factor FF, the maximum power P_{mpp} with its voltage V_{mpp} and current I_{mpp}, the current density J_{sc} and the efficiency eta. In addition, it can calculate I_{sc}, V_{oc}, and J_{sc}. Furthermore its xenon lamp produces 1000 W/m light intensity which meets standard test condition. The Solsim is also able to change the temperature of measuring cell between 20°C and 60°C.

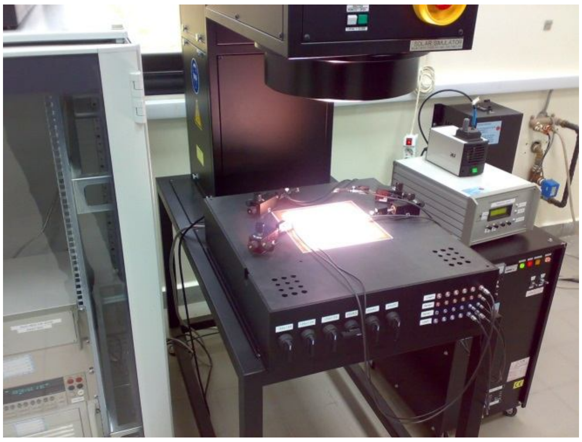

Fig. 1 Sun Simulator – Solsim

3. PREVIOUS WORK

In the paper [2], Visual Inspections and performance measurements were done only for the twenty seven year old PV module. In this paper, the authors indicated that this was one of the longest, if not the longest, exposed and operated arrays ever evaluated in the world, but it will definitely not be the longest one anymore.

4. FIELD OBSERVATIONS

The modules, PQ 10/40/02, were installed in Libya in the late of seventies as stand-alone system as shown in fig. 2. The cells are made of Multicrystalline silicon. In addition, the encapsulation of the PV modules is front and back glass with polyvinyl butyral (PVB), and the frame is made of stainless steel. The dimensions of each module are (459 mm × 1076 mm) with 40 cells (10 cm × 10 cm) each.

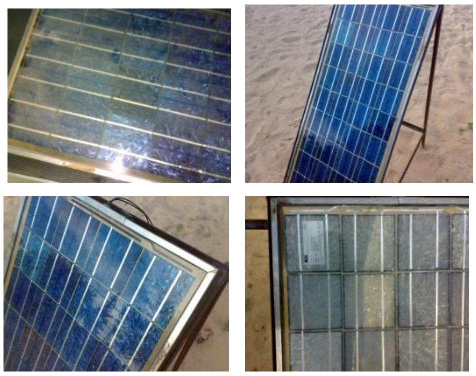

Fig. 2. The module PQ 000876 and 000877

5. MEASUREMENTS AND RESULTS

The table 1 summarizes the indoor measurements for solar cells under standard test condition.

Table (1): performance parameters of solar cell

Temperature [°C]	25
$I_{sc,meas}$ [mA]	2231.940
$J_{sc,meas}$ [mA/cm^2]	22.319
$V_{oc,meas}$ [mV]	541.222
$I_{sc,korr}$ [mA]	2229.600
$J_{sc,korr}$ [mA/cm^2]	22.296
$V_{oc,korr}$ [mV]	540.518
I_{mpp} [mA]	1973.755
J_{mpp} [mA/cm^2]	19.738
V_{mpp} [mV]	422.974
FF [%]:	69.274
P_{mpp} [mW]:	834.848
eta [%]:	8.348

Korr: calculation, Meas: measurement

The fig. 3 shows the I-V carve of solar cell.

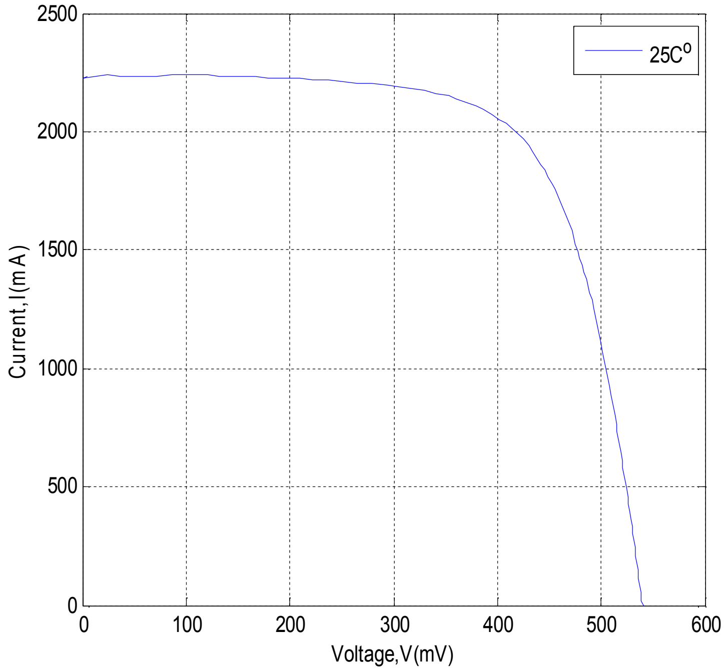

Fig. 3. The I-V carve of solar cell

6. TEMPERATURE EFFECT ON SOLAR CELL PERFORMANCE

During the measurement, the temperature is changed using a temperature controller to get different values of the temperature in order to see the effect on the performance of the solar cell. The table (2) presents the performance parameters for different values of temperature.

Table (2): temperature effect on the solar cell

Temperature [°C]	25	30	35	40
Isc,meas [mA]	2231.940	2248.905	2260.097	2276.202
$I_{sc,meas}$ [mA]	22.319	22.489	22.601	22.762
$J_{sc,meas}$ [mA/cm^2]	541.222	528.337	524.127	503.010
$V_{oc,meas}$ [mV]	2229.600	2251.440	2262.432	2277.774
$I_{sc,korr}$ [mA]	22.296	22.514	22.624	22.778
$J_{sc,korr}$ [mA/cm^2]	540.518	527.847	523.507	502.498
$V_{oc,korr}$ [mV]	1973.755	1974.984	1969.569	1948.262
I_{mpp} [mA]	19.738	19.750	19.696	19.483
J_{mpp} [mA/cm^2]	422.974	402.134	390.660	360.492
V_{mpp} [mV]	69.274	66.829	64.964	61.362
P_{mpp} [mW]: [mW]:	834.848	794.208	769.432	702.333
eta [%]:	8.348	7.942	7.694	7.023

Korr: calculation, Meas: measurement

The fig. 4 shows the temperature effect on the I-V carve of the cell. In addition, the fig. 5 illustrates s the temperature effect on Power-voltages carve.

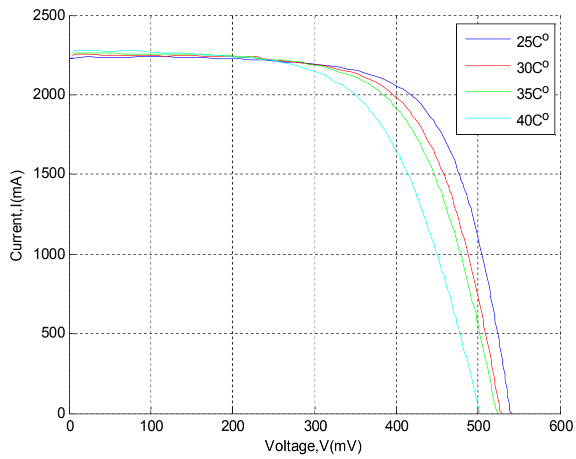

Fig. 4. Temperature effect on I-V carve of solar cell

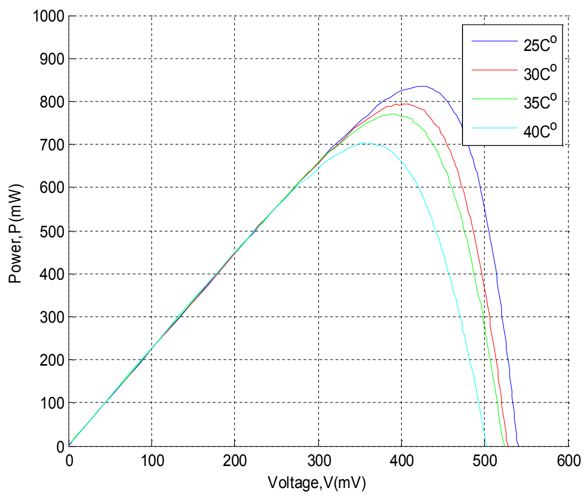

Fig. 5. Temperature effect on power carve of solar cell

7. VISUAL INSPECTION

The module and cells are still in good condition as shown in Fig. 6. From visual inspection, it is clear that not only the cells seem to be unaffected but also no cells have been turned into a yellowish color [1].

Fig. 6. Visual inspection of solar cell

8. CONCLUSION

In this paper, the I-V carve of solar cells which were removed from thirty year old PV module was measured under standard test condition.

In conclusion, the results show a peak power of 834.848 mW for thirty-year old solar cells with 8.348% efficiency. According to the temperature effect, the power degrades each time the temperature goes higher. Furthermore, the solar cells is still in good condition and no a yellowish color.

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