A Study of Cooling Effect on the Operation of a Polycrystalline Silicon Solar Cell

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Abstract- Temperature effect is one of the most significant factors on the operation of solar cells. A polycrystal Si solar cell was utilized in the experiment. The solar cell was illuminated by the constant light flux and typical electrical values were obtained. It was later cooled by the thermoelectric cooler system and the experimental values were obtained. The behaviour of the solar cell at two different temperatures ($\Delta T=15°C$) was examined and the cooling effect on the performance of the solar cell was determined in terms of Voc.

Index Terms- **Mono crystal Si solar cell, polycrystalline silicon solar cell, thermoelectric converter**

I. INTRODUCTION

One of the most important parameters affecting the working conditions of the solar cells is temperature effect. When incident light comes to the surface of the solar cell, some part of the incident light flux is absorbed by the body of solar cell and thus light energy is converted to the heat energy and temperature of the solar cell rises depending on the absorbed photons.

As a conclusion, rising temperature also causes decreasing efficiency of the solar cell. For this purpose, some techniques such as active and passive methods are used to decrease the ambient of temperature. As a significant parameter I_{sc} values of the solar cells increase linearly with the increasing solar intensity as given in Eq. (1) [1, 2]:

$$I_{sc} = C\int qAF(\Lambda)T(\Lambda)SR(\Lambda)d(\Lambda) \qquad (1)$$

where the symbol of **C** is light concentration ratio, **A** is the solar cell area, $F(\Lambda)$ is the incident solar intensity, $T(\Lambda)$ is the transmission, and $SR(\Lambda)$ is the response of the solar cell. Moreover, the values Voc of the solar cell increases logarithmically with illumination as given in Eq. 2 [1, 2]:

$$V_{oc}=(nkT/q) \ln (CI'_{sc}/I_o) \qquad (2)$$

Meanwhile, the fill factor changes slightly with respect to the incident light concentration [1]. These two equations provide the basic relations for the solar cells.

Thermoelectric cooling technique to improve the performance of the solar cells was examined as a different technique in this work. So far, many researches about temperature effect on the solar cells have been performed and it has been seen that temperature is one of the most significant parameters on the performance of the solar cells [3]. Meanwhile, light concentration and temperature effect on the performance of the GaInP /GaAs [1] solar cell and the GaAs/Ge solar cell [4] have been studied and significant results have been reported.

Particularly, increases in the temperature of the silicon solar cells caused decreases in the output power [5, 6]. Thermoelectric converters have recently been used in high-tech goods as a cooler [7-11]. In this work, the behaviour of a solar cell cooled by the thermoelectric converter was compared to that of other identical solar cells and the cooling effect on the behaviour of solar cells was explored.

II. EXPERIMENTAL PROCEDURE

A polycrystalline silicon solar cell illuminated by the constant light flux was utilized in the experiment. For the illumination of the solar cell, the triac-controlled illuminator (Lucas-Nülle, OSRAM, 120W) was used. The incident light fluxes on the surfaces of the solar cell were increased gradually and response of the solar cells was obtained. In the cooling processes, a thermoelectric converter (TEC1-12708) and a digital controlled voltage supply were used. A MacSolar model of radiometer was used to measure of the light flux. A polycrystal Si solar cell cooled by means of the TE cooler was utilized (see Figure-1.

As known, elevating temperature of the solar cell results in decreases of the efficiency and, therefore, to increase the efficiency new different techniques have been concerned in this field. Thus, a typical method in this work was examined to decrease the temperature of the solar cells utilized. A new type cooling system based on TEC unit for the solar cell was employed in the experiment as seen in Figure-1. Utilizing the arrangement with and without TE cooler system, the experimental results were obtained and the data were evaluated to examine the effect of thermoelectric cooler on the operation of a polycrystal Si solar cell.
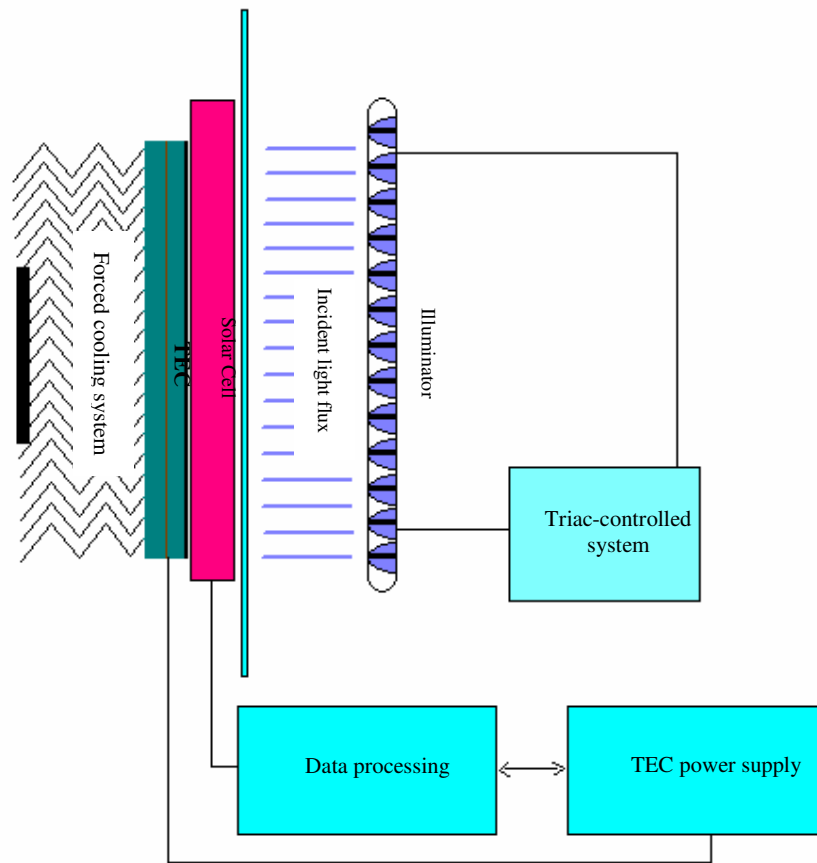
Figure-1. The thermoelectric cooling arrangement used in the experiment.

In the second step of the experiment, the solar cell was cooled by means of TEC in the constant light flux. In order to cool the surface of the solar cell, the unit of TEC was mounted and the generated heat was transferred by both the conduction and convection methods in the system. As seen in Figure-1, a special glass, which has less reflection properties than the common glasses, was used in front of the solar cells.

EXPERIMENTAL RESULTS

In the first step of the experiment, the TEC unit (TEC1-12708) was mounted on the solar cell for the cooling process. The parameters of the thermoelectric converter are: V_{dc} : 10V, I_{sc} : 4,5A and P_{input} : 45W.

Temperatures of two surfaces of the solar cell were measured periodically and the needed voltage and current were applied according to the temperature. Concerning the temperatures of two surfaces of the solar cell, V_{oc} values at two different temperatures were obtained (see Table-1). A total of five measurements were performed with a constant temperature difference ($\Delta T=15°C$) between T_1 and T_2. via the TEC system. V_1 and V_2 values for various incident light flux were tabulated in Table-1.

	Incident light flux (W/m^2)	V$_1$ (Volt)	V$_2$ (Volt)
The Polycrystal Si Solar Cell	27	2.13	2.14
	112	2.39	2.43
	239	2.60	2.61
	426	2.69	2.70
	503	2.74	2.76

Table-1. Comparing the data of a solar cell at two different temperatures ($\Delta T=15°C$).

The variation of potential differences with the incident light flux is given in Figure-2.

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Potantial Difference-Incident Light Flux

$V_2 = 2{,}1581\varphi^{0,1609}$
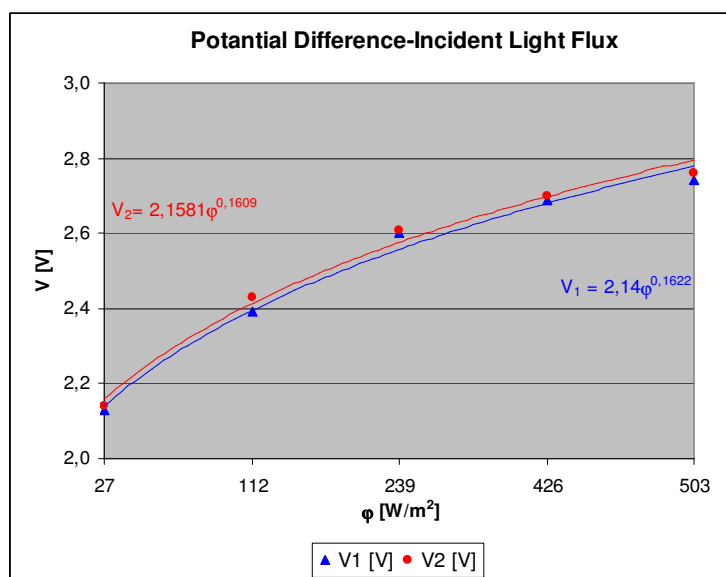
$V_1 = 2{,}14\varphi^{0,1622}$

▲ V1 [V]   ● V2 [V]

Fig.2. The potential difference V (Volt) versus the incident light flux I (W/m^2)

IV. CONCLUSION

A polycrystal solar cell illuminated by the five different incident light fluxes was utilized in the experiment. The responses of the solar cell to the incident light flux were measured in terms of voltage V_1. The light flux was increased gradually and two measurements were done in the special circumstances. Later, temperature of the solar cell was decreased by the thermoelectric cooler at the second step of the experiment. Temperature difference was kept constant at 15 °C in each experiment. As seen in Table-2, a sharp increase in the intensity of light flux cause a gradual increase in the voltage values of the solar. Meanwhile, when the measured V1 and V2 values of the solar are compared, it has been seen that ΔV is roughly equal to 0.01 Volt. The experiment was conducted using a small sized solar cell (4cmx4cm). As small as 0.01V increase in the voltage values of the cooled solar cell was obtained. In conclusion, it is thought that this system can be applied to relatively larger sized photovoltaic modules and more electrical energy can be generated. The variation of obtained voltage values with the same incident light flux at two different temperatures is seen in Figure-3. When the solar cell is cooled, the measured voltage is higher than that of lower temperature at the same light flux as seen in Figure-2.

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