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Investigation the Effect of Series Resistance on the Electrical Parameters of Solar Cell using Multisim Software

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A R T I C L E I N F O

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A B S T R A C T

In this paper, a theoretical investigation to the effect of the series resistance (R_s) on the solar cell output parameters, such as efficiency (η), open-circuit voltage (V_{oc}), output maximum power (P_{max}), fill factor (FF) and short circuit current(I_{sc}) was performed. Multisim software was used to achieve the investigation. It is reproduced by using the current-voltage (I-V) characteristics in accordance with double-diode modeling of the solar cell. The results showed that there is a change in the characteristic curve form due to the variation of series resistance values between (0.01-0.5) Ohm. Moreover, it was found that the fill factor, short circuit current, and open circuit voltage decreased linearly when the value of the series resistance increased. Consequently, the conversion efficiency of the solar cell declined. In other words, the series resistance has a significant effect on the performance of the solar cell.

1. Introduction

A photovoltaic PV cell, or photoelectric cell, is a semiconductor device that transforms light into electrical energy [1].The R_s of the PV module contains resistive elements, such as cell solder bonding and emitter and base regions, as well as bus bars for cell interconnections and terminations at junction boxes [2, 3]. The solar cell series resistance is a parasitic, power-consuming characteristic. It softens the I–V characteristics of a solar cell in the fourth quadrant by lowering the highest attainable output power. It denotes a decrease in the solar cell's fill factor. The fill factor and FF of the solar cell is found to drop by around 2.5 percent for every 0.1 increased in series resistance [4]. One of the most critical aspects influencing PV module performance is series resistance. Some researchers are discovered that the series resistance is affected on the FF and power output of PV modules due to the series resistance has a greater impact on the solar cell's output power than any other parameter [3, 5, 6]. Also, the R_s is reduced the short-circuit current but it didn't influence on the V_{oc} [7]. This R_s is raised as the base doping density increasing. Therefore, the ability of the materials to resist the passage of electric current is increased as a result of this phenomena. As a result of the base doping density gradient, the semiconductor material's resistivity raised [8]. Commercial solar cell has least FF than ideal, owing to R_s, which is grown as the substrate size grows. However, the FF in both laboratory and production cells is restricted not only by the R_s, but as well by factors, such as the low parallel resistance and non-ideal diode parameters [8, 9].The voltage output and fill factor ($1/4\ P_{max} = I_{sc}\, V_{oc}$) of the module, as well as its performance quality are reduced as the R_s is increased. The module I_{sc}starts to fall at increasingly greater R_s

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levels pacing, and finger area must all be adjusted [9]. So a rectangular device shape and tin busbars on conductive substrate effectively reduce the R_s . Meanwhile, an additional hot-pressed highly conductive low-temperature carbon layer on the back carbon electrode also reduces the R_s [10]. In Fig. 6 (e) it can clearly be seen that the electrical efficiency improves with increasing solar concentration and decreasing series resistance. The lower the series resistance the higher the optimum solar concentration under which the device can operate [11].A number of publications investigated the effect of series resistance on performance of solar cell. Dyk and Meyer (2004) [2] discussed the detrimental effect of series resistance on the performance of a PV device. The I–V characteristics were simulated buy the use of PV simulation software (PVSIM). This software uses the two-diode model and calculates I–V characteristics based on typical solar cell parameters. The simulations were performed with 1000 W/m^2 irradiance and a temperature of 25 °C. Wafaa et al (2013) [12] studied theoretically the effect of series resistance on solar cell parameters including I_{sc} , V_{oc} , P_{max} and FF. The simulations have been performed using the one-diode model of PV modules in MATLAB/Simulink environment. The study considered light intensity of 1000 W/m2, and a temperature of 25 °C. Fahmi et al (2017) [13] concluded that there is a variation in the I-V characteristic curve of the solar cell due to the increase in the series resistance. In their simulation, a software multisim10 was utilized to simulate the single-diode model. In current study, Multisim12 software is used in the simulation of double-diode model. Massaki et al (2018) [14] characterized the effects of series resistance on performance of like an ACM tandem through solar cell simulations and indoor experiments. M. S. Ahmed *et al* (2020) [15] investigated the impact of series resistance on various parameters by using PC1D software simulation. Daiyu et al (2021) [10] demonstrated that the increased series resistance is the main restriction that limits the PCE of large- area p-MPSCs. series resistance was greatly influenced by the charge transport distance in the less-conductive electrodes and the conductivity of the electrodes themselves. Hongliang et al (2022) [16] developed and applied the numerical two- dimensional methods to study the effects of the series resistance in solar cells .The simulations were performed using the MATLAB software.

2. The double - diode model.

The effects of series resistance can be sufficiently described and revealed by a p-n junction solar cell's double-diode equivalent circuit model. The model is demonstrated in Fig. 1, which is displayed the R_{sh} and R_s, together with the photon-generated current, I_{ph} , the optimal recombination current in the bulk region, I_{D1} , the non- optimal recombination in the depletion region I_{D2} and V_T are the thermal voltage defined as $V_T = (K_B T)/q$ where (K_B) is the Boltzmann constant (1.38× 10^{-23} J/K). Fig. 2 shows that the (I–V) and (P-V) output characteristics of a double exponential can be defined using the equations below [2] :

$$I = I_{ph} - \left[I_{01}\left(e^{\frac{q(V-IRs)}{n1K_BT}} \right) + I_{02}\left(e^{\frac{q(V-IR_s)}{n2K_BT}} \right) \right] - \frac{V-IRs}{Rsh} \quad (1)$$

Where I_{ph} denotes the photogenerated current, I_{01} and n1 indicate the first diode's saturation current and ideality factor,I_{02} and n2 indicate the second diode's saturation current and ideality factor, R_{sh} and R_s account for parallel and serial resistances and T is the p-n junction’s absolute temperature, and (q) is the elementary charge (≈1.6×10^{-19}C), V is the applied voltage [17, 18].

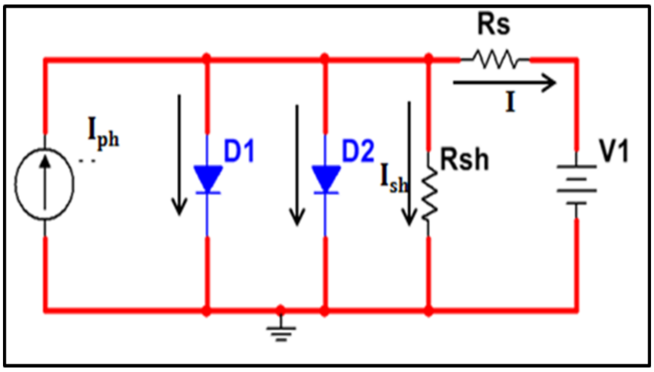

Fig. 1. Solar cell's two-diode equivalent circuit model.

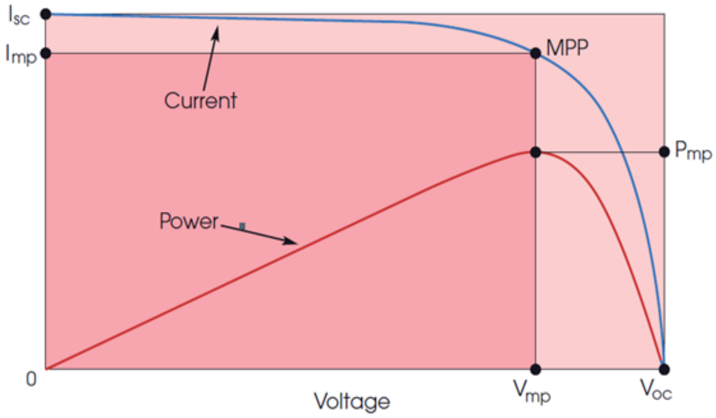

Fig. 2. Shows I-V and P-V output characteristic of solar cell [19].

The photogenerated current I_ph can be found as follows [20, 21] :-

$$I_{ph} = \left(\frac{G}{G_{stc}}\right)\{I_{ph,stc} + K_i(T - T_{stc})\} \tag{2}$$

Where G is the solar radiation, $G_{stc}$is the solar radiation under standard temperature conditions, $I_{ph,stc}$ is the photogenerated a current is the current coefficient, and $T_{stc}$is the temperature under standard temperature conditions (stc). The parameters at open-circuit voltage V_{oc} short -circuit current I_{sc} and short circuit current I_{sc} can be calculated as [20]:

$$I = I_{01}\left\{e^{\left(\frac{V_{oc}}{n1Vt}\right)} - 1\right\} + I_{02}\left\{e^{\left(\frac{V_{oc}}{n2Vt}\right)} - 1\right\} + \left(\frac{V_{oc}}{R_{sh}}\right) \tag{3}$$

$$I_{sc} = I_{ph} - I_{01}\left\{exp\left(\frac{I_{sc}Rs}{n1Vt}\right) - 1\right\} - I_{02}\left\{exp\left(\frac{I_{sc}R_s}{n2Vt}\right) - 1\right\} - \left(\frac{I_{sc}R_s}{R_{sh}}\right) \tag{4}$$

The fill factor reduced as (FF) is used to calculate the solar cell's top power output. The fill factor is the ratio of the top power of a solar cell to the production of .V_o and I_{sc} as below [9]:

$$FF = \frac{P_{max}}{I_{sc}V_{oc}} \tag{5}$$

Where P_{max} the maximum out power of solar cell ,the relationship between I_{sc} and R_s, which is derived from Eq. (1).

$$I_{sc} = I_{ph} - \frac{I_{sc} R_s}{R_{sh}} \quad (6)$$

The solar cell's conversion efficiency is defined as [7]:

$$\eta = \frac{P_{max}}{P_{in}} = \frac{FF\, V_{oc} I_{sc}}{P_{in}} \quad (7)$$

The input power (P_{in}) is specified by the features of the light spectrum incident (kW/m^2) on the solar cell, therefore, the input power for efficiency equal the product to (1 kW/m^2 and solar cell's Area) . So, the input power for a (160 * 80.4) cm is (1.286 W).

3. Result and Discussion

To investigate the effect of the series resistance on the behavior of the electrical parameter of a solar cell by using the double-diode equivalent circuit model for a p-n junction solar cell, which understudy by using the simulation software multisim. Multisim includes a broad set of SPICE analysis to study the circuit behavior. These analysis range from basic to advanced. Each analysis is provided with beneficial information, such as the implications of component tolerances and sensibilities. To do the analysis, some pieces of information are required to specify the parameters. This will assist the used software (Multisim) what and how to analyze the required parameters. Fig. 3 shows the flowchart of the simulation process as DC weep and Table 1 explains the impact of series resistance increase on the performance parameters of a solar cell.

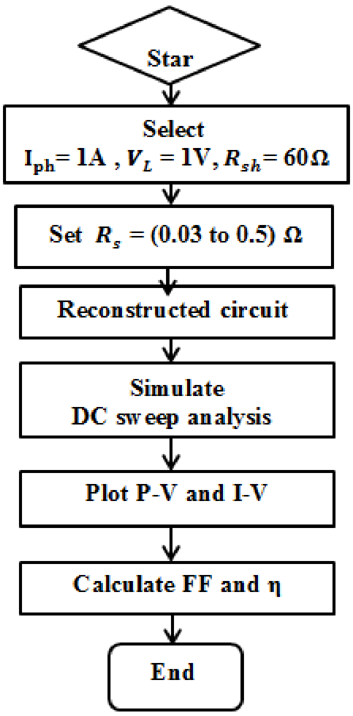

Fig. 3. A flowchart of the simulation process.

Table 1. Impact of series resistance on performance parameters.

R_s Ω	I_m(A)	) V) V_m	P_{max}(W)	I_{sc} (A)	V_{oc} (V)	FF	η %
0.03	0.904	650.6	0.601	0.9995	0.8435	0.7	46
0.06	0.900	0.0631	0.568	0.999	0.8435	0.68	44
0.09	0.879	610.0	0.536	0.9985	0.8435	0.64	42
0.12	0.885	0.588	0.520	0.998	0.8435	0.62	40

3.1. Output characteristic of the solar cell via DC sweep analysis.

It is apparent from the results shown in Fig. 5 and Fig. 6 that the I-V and P-V characteristics of solar changed due to the effect of series resistance which equal to (0.03 ohm and 0.5 ohm) respectively, by using the DC sweep Analysis which is simulated in Multisim. Clearly, there is a decrease in the area under the properties of the I-V curve which is in agreement with findings of Fahmy *et al* [14] .

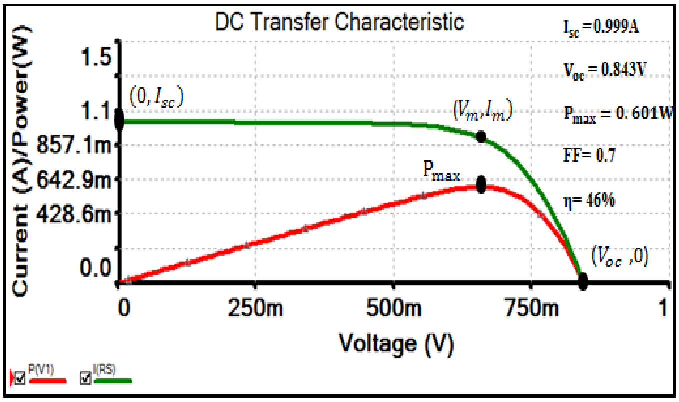

Fig. 5. P-V and I-V curve at series resistance $R_s = 0.03\Omega$.

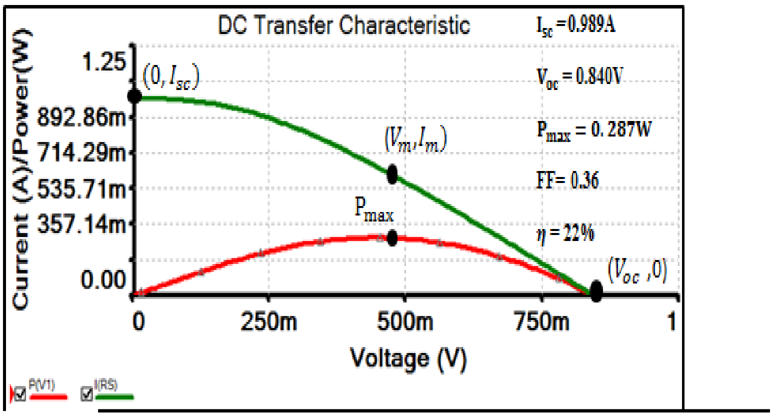

Fig. 6. P-V I and I-V curve at series resistance $R_s = 0.5\ \Omega$.

3.2. Effect R_s on the performance of output a solar cell

The I–V and I-P characteristics curves of the solar cell for different values of series resistance (0.03 Ω to 0.5 Ω) are illustrated in Fig. 7 , Fig 8, respectively. Fig. 7 shows that the increase in the series resistance leads to a reduce in the area under the curve. This means that the curve shifted to the left. Consequently, the impact of the series resistance is more significant on the shape of the I-V curve. This findings agree with the results of Koffi *et al* [17].

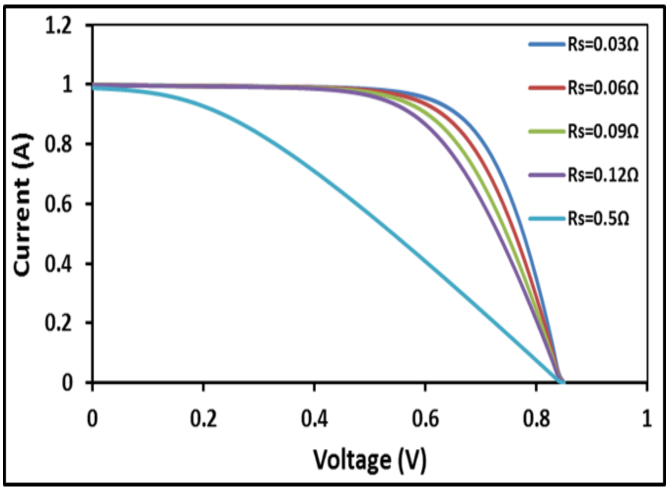

Fig. 7. I-V curves with the impact of increasing series resistance.

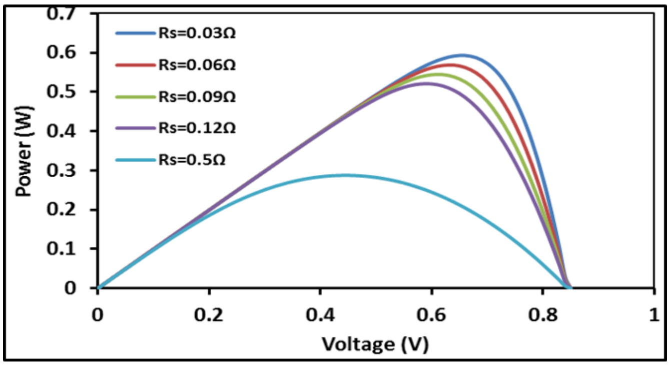

Fig. 8. P-V curves with the impact increasing series resistance.

3.3. Variation of I_{sc}, P_{max} , V_{oc} and FF with R_s

Parameters of V_{oc} , Pmax, Isc are extracted from the characteristic curve in Fig. 7 , Fig. 9 shows the open-circuit voltage V_{oc} which is nearly constant. Thus, it decreases slightly by ~0.0032 V when the series resistance is increased from (0.12 Ω to 0.5 Ω). This is because the series resistance (R_s) has no effect on the open-circuit voltage, but the short-circuit current decreased from 0.999 to 0.989 A. This might because the power loss which leads to a decrease in the maximum value of voltage and electrical current as shown in Table 1. The conducted results are consistent with the results reported by Dyk and Meyer [2].

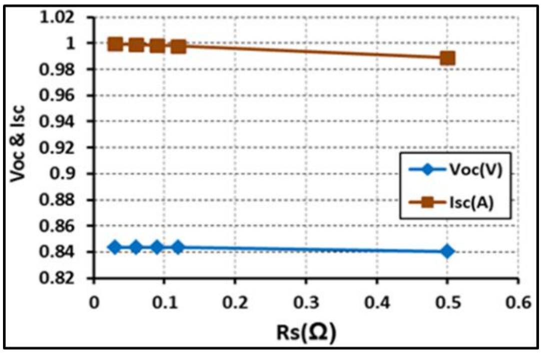

Fig. 9. Variatio of n V_{oc} , I_{sc} with R_s .

The effect of series resistance on all of P_{max} and FF of a the solar cell is shown in Fig. 10. The results revealed that the maximum power and fill factor decreased as series resistance increased. Therefore, the performance of the solar cell degraded. These results are in line with the results of Deepthi *et al* [22], Damian. G and Y. Galagan [22] and Alfredo and Rune [23].

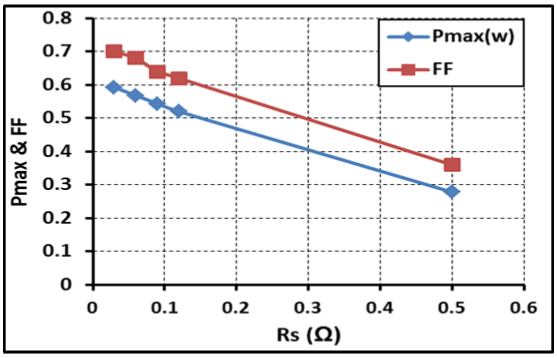

Fig. 10. Variation P_{max} , FF with R_s

3.4. Efficiency

According to Eq. (7), the efficiency of the solar cell was calculated and the values of efficiency are listed in Table 1. The simulation results suggest that R_s remarkably affects the value of η of the solar cell. It can be observed from Fig. 11 that the calculated efficiency decreases with increasing R_s and accordingly there is a decrease in the output power of the solar cell due to the ohmic resistance. The collected results agree with the results reported by Masaaki *et al* [14] and Hongliang *et al* [16].

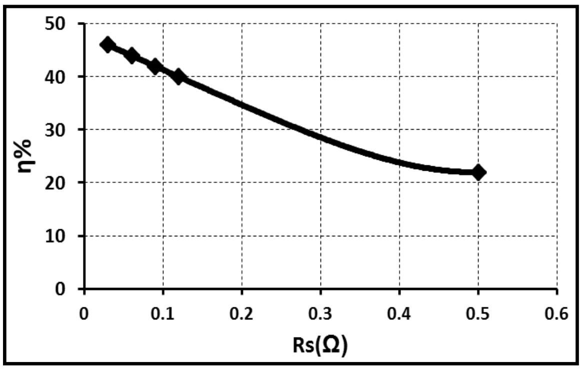

Fig. 11 . Variation efficiency η with R_s.

4. Conclusion

In the present study, the influence of series resistance on the performance of solar cells was investigated utilizing the simulation performed by Multisim software. The DC Sweep Analysis was used to estimate V-I Characteristics and P-V curve for the double diode model. The results show that further increase in R_s has a direct effect on the solar cell's electrical parameters. At room temperature, the short-circuit current, fill factor FF, maximum power P_{max} and efficiency decrease linearly with the increase of series resistance, but it has no effect on the open-circuit voltage. This work illustrates effectively and decisively that series resistances can be detrimental to the performance of the solar cell. Based on the collected results, it is recommended to use Multisim simulation software to investigate the performance of solar cells.

References

[1] A. N. Tuaimah, S. A. A. AL-Saidi, Univ. Thi-Qar J. Sci **7,** 12 (2019).
[2] E. E. van, E. L. Meyer, Renew. Energy **29**, 3 (2004).
[3] H\. A. Koffi, A. A. Yankson, A. F. Hughes, K. Ampomah-Benefo, J. K. A. Amuzu, African J. Sci. Technol. Innov. Dev **12**, 6 (2020).
[4] M. Dadu, A. Kapoor, K. N. Tripathi, Sol. Energy Mater. a Sol. Cell **71,** 20 (2002).
[5] B. Bora, O. S. Sastry, R. Singh, M. Bangar, S. Rai, Energy Procedia **90**, 33 (2016).
[6] M. S. Ahmed, S. M. Ahmad, M. Subhyaljader, J. Ovonic Res **16**, 2 (2020).
[7] A. Luque, and S. Hegedus, West Sussex: John Wiley & Sons Ltd **33** 2 (2011).
[8] H. Alma, Results Phys. **7,** 42 (2017).
[9] K. S. Duggimpudi, MSc thesis, Rochester Institute Of Technologynew **60**, 14 (2016).
[10] G. Dost, H. Höffler, J. M. Greulich, Phys. Status Solidi Appl. Mater. Sci **218**, 6 (2021).
[11] H. Baig, H. Kanda, A. M. Asiri, M. K. Nazeeruddin, T. Mallick, Sustain. Energy Fuels **4**, 2 (2020)
[12] W. EL-BASIT, Leonardo J **23**, 20 (2013).
[13] F. F. Muhammad, PLoS One **12**, 8 (2017).
[14] C. Technique, and M. Baba, IEEE J. Photovoltaics **8**, 2 (2018).
[15] M. S. Ahmed, S. M. Ahmad, M. Subhyaljader, J. Ovonic Res **16**, 2 (2020).
[16] H. Guo, AIP Adv **12**, 1 (2022).
[17] G. Sulyok, J. Summhammer, Energy Sci. Eng **6**, 5 (2018).
[18] P. A. Lynn, Electricity from Sunlight: An Introduction to Photovoltaics **20**, 22 (2010)
[19] R. Dash, S. M. Ali, Int. J. Res. Eng. Technol **3**, 10 (2014).
[20] W. Shinong, M. Qianlong, X. Jie, G. Yuan, L. Shilin, Sol. Energy **199**, 90 (2020).
[21] J. K. Deepthi Jayan, B. Varkey Sebastian, Sol. Energy **221**, 30 (2021).
[22] D. Glowienka, Y. Galagan, Adv. Mater **34**, 2 (2022).
[23] A. S. Garcia, R. Strandberg, Appl. Sci **11**, 22 (2021).

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دراسة تأثير المقاومة التسلسلية على المعاملات الكهربائية للخلية الشمسية باستخدام برنامج المحاكاةMultisim

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القبول ٨ حزيران ٢٠٢٢
النشر ٣١ تموز ٢٠٢٢

الكلمات المفتاحية

المقاومة التسلسلية ، برنامج Multisim، الخلية الشمسية، الكفاءة، المعاملات الكهربائية.

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الملخص

العمل الحالي عبارة عن دراسة نظرية لتأثير المقاومة التسلسلية R_s على المعاملات الكهربائية للخلية الشمسية وهي جهد الدائرة المفتوحة, V_{oc} تيار قصر الدائرة , I_{sc} عامل الامتلاء FF وكفاءة تحويل الخلية الشمسية η باستخدام برنامج المحاكاة.multisim حيث تم اعتماد نموذج الدائرة المكافئة للخلية الشمسية التي تحتوي على دايودات اثنان في عملية المحاكاة للخلية من اجل التحقق من تأثير المقاومة التسلسلية على اداء الخلية الشمسية تم اختيار قيم للمقاومة بين$(0.03\Omega - 0.5\Omega)$.
ومن المحاكاة تم الحصول على منحنيات الخواص I-V وبعد ذلك تم استخراج وبشكل مباشر قيم المتغيرات الكهربائية للخلية الشمسية ومن ثم الاستعانة بالمعادلات النظرية لحساب الكفاءة وعامل الامتلاء ومن النتائج عند زيادة قيمة المقاومة التسلسلية تم ملاحظة انخفاض في تيار القصر للخلية وبالتالي حصول تناقص خطي في عامل الامتلاء والكفاءة للخلية الشمسية ويكون هذا التأثير واضح عند قيم الكبيرة للمقاومة التسلسلية ولكن لم يكن هناك تأثير واضح للمقاومة التسلسلية على جهد الدائرة المفتوحة. لذلك نستنتج ان المقاومة التسلسلية ذات تأثير ضار على عمل الخلية الشمسية نتيجة انخفاض تيار وقدرة الاخراج للخلية وايضا نستنتج ان برنامج المحاكاة multisim ذات فعالية وكفاءة عالية في عمل المحاكاة.

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