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Effect of atmospheric parameters on the silicon solar cells performance

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***Abstract*--** In this paper, the global and diffuse solar radiation incident on solar cells are simulated using a spectral transmittance model, for varying atmospheric conditions on the site of Algiers. The effect of changes in total intensity and spectral distribution on the short circuit current and efficiency of different kinds of solar cells (amorphous, monocrystalline and multicrystalline) is examined. The results show a reduction in the short circuit current due to increasing turbidity. It is 4.41%, 4.79%, and 7.34% under global radiation and for mono-crystalline, multicrystalline and amorphous silicon cells respectively. However it increases under diffuse radiation. Increasing water vapor in the atmosphere leads to a reduction in the short circuit current of 4.57%, 4.4%, and 0.2% respectively for mono-crystalline, multicrystalline and amorphous silicon under global radiation and it is not influenced under diffuse radiation. The short circuit current decreases with increasing air mass for the different types of silicon solar cells. However, the efficiency increases with increasing air mass for monocrystalline and multicrystalline solar cells but it is the opposite for the amorphous silicon solar cell.

***Key Words*- silicon, solar cell, spectral radiation, diffuse, global.**

I. INTRODUCTION

The most important parameters that describe the operating condition of a solar cell are the total irradiance, the spectral distribution of the irradiance and the temperature [1]-[10]. Usually the solar cell designers assess their devices by evaluating the efficiency at standard reporting conditions (SRC: illumination= 1000W/m2, temperature=25°C and AM 1.5 reference spectrum). However, these conditions practically never occur during normal outdoor operation [1] as they do not take into consideration the actual geographical and meteorological conditions at the installation site.

The solar irradiance at ground level varies in intensity and spectrum due to varying atmospheric parameters such as the cloud cover, the turbidity, the water vapor content and the zenith angle [7-10].

The effect of the variations of the solar spectrum on the performance of the different photovoltaic devices is not yet quantified on a large scale because of the difficulty to obtain spectral measurements. Therefore, it is rather important to elaborate methods to estimate the influence of the varying atmospheric conditions on the solar cells performance.

The main purpose of the following sections is to know how silicon solar cells perform under global and diffuse solar irradiance variations due to the variation of the air mass, water vapor and turbidity using the spectral irradiance model (Spectral2) [11] for clear skies.

The value of the photocurrent density Jsc with respect to a spectral irradiance E(λ) can be computed from the measured spectral response SR(λ) using the following expression:

$$J_{sc} = \int E(\lambda)SR(\lambda)d\lambda \qquad (1)$$

Fig. 1 shows the spectral response of the different types of silicon solar cells considered in this work.

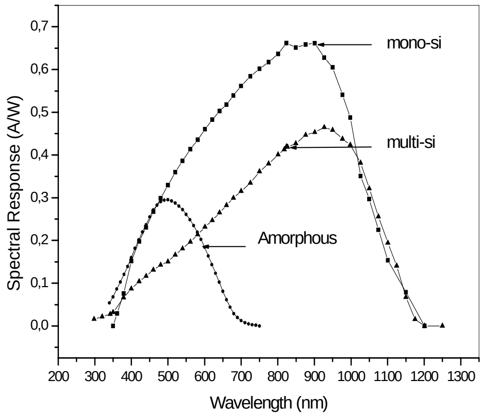
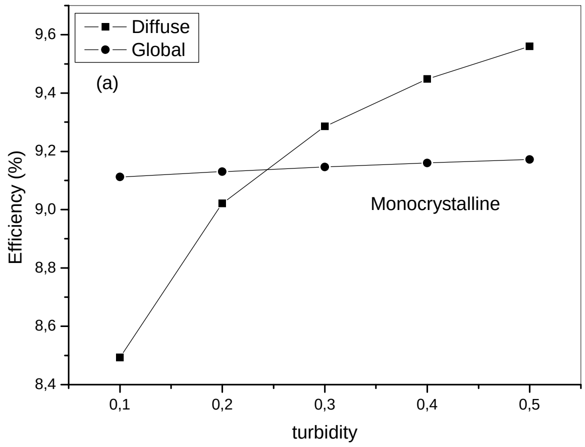
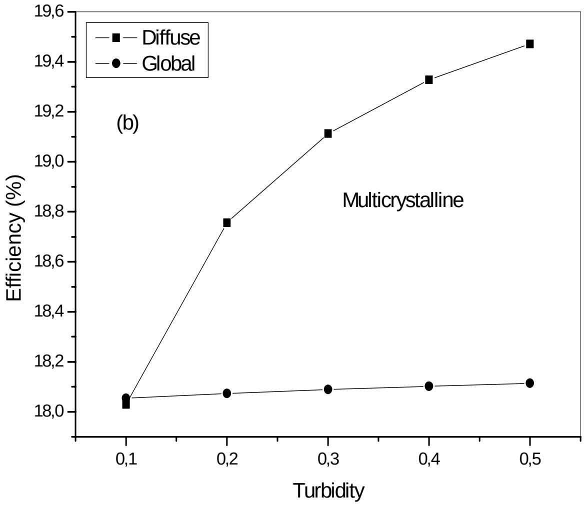


Fig. 1. Spectral response of different types of silicon solar cells

II-TURBIDITY EFFECT

Fig. 2 shows the influence of turbidity on the different considered solar cells. The output current is reduced but in different proportion for each type of cell according to the situation and shape of the spectral response. The reduction in the short circuit current due to increasing turbidity is 4.41%, 4.79%, and 7.34% respectively for mono-crystalline, multicrystalline and amorphous silicon cells. The current of the mono-crystalline silicon cell is subjected to a larger reduction than that of multicrystalline because the spectral response of mono-crystalline covers a larger area than does multicrystalline. However, the spectral response of the amorphous silicon cell is narrower than both of the mono-crystalline and the multicrystalline but the maximum of the spectral response is at the same wavelengths that are reduced by the turbidity, hence the percentage reduction in current is larger. A general summary of results is presented in Table 1.





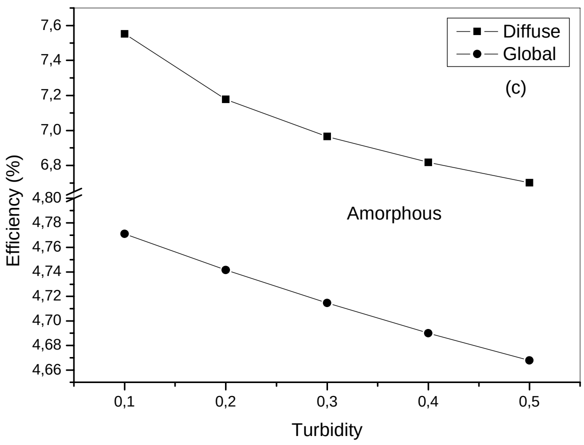


Fig. 2. Efficiency as function of turbidity on a horizontal surface under global and diffuse irradiance.
(a)- monocrystallline, (b)- multicrystalline, (c)- amorphous silicon solar cell

Table 1. Influence of turbidity on Jsc on the solstice summer on a horizontal surface under global and diffuse irradiance

Turbidity	Jsc (mA cm^{-2}) mono-Si		Jsc (mA cm^{-2}) multi-Si		Jsc (mA cm^{-2}) a-Si	
	Dif	Glb	Dif	Glb	Dif	Glb
0,1	2,97	32,63	3,68	37,76	1,48	9,6
0,2	4,65	32,25	5,65	37,29	2,08	9,41
0,3	6,19	31,89	7,45	36,84	2,61	9,24
0,4	7,61	31,55	9,1	36,42	3,09	9,07
0,5	8,92	31,22	10,61	36,01	3,51	8,93

I. WATER VAPOR EFFECT

The solar spectral irradiance is reduced by increasing water vapor in the atmosphere at larger wavelengths to which only mono-crystalline and multicrystalline silicon cells are sensitive. Fig. 3 shows the efficiency as function of water vapor on a horizontal surface for the different cells. The reduction is less than in the case of turbidity because water vapor affects only narrow spectral intervals and the spectral responses at those wavelengths are weaker than the ones affected by the turbidity. The reduction in the current (Table 2) is 4.57%, 4.4%, and 0.2% respectively for mono-crystalline, multicrystalline and amorphous silicon cells.

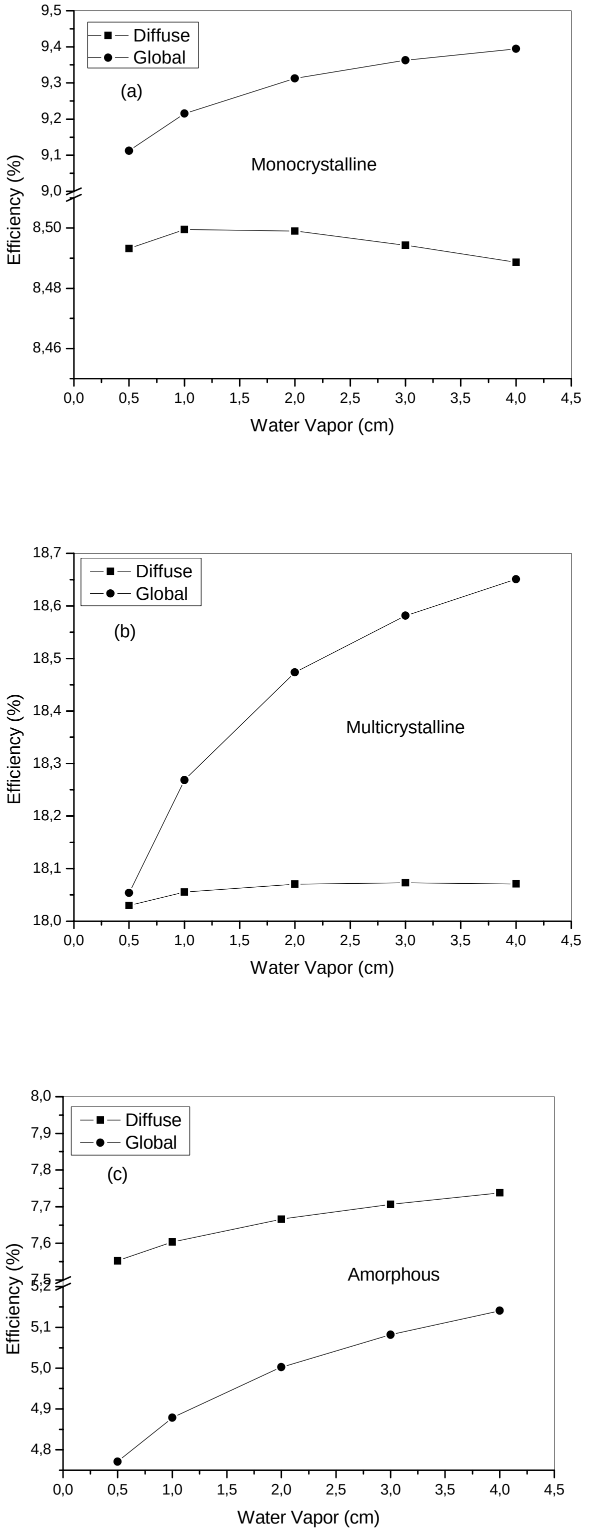


Fig. 3. Efficiency as function of water vapor on a horizontal surface under global and diffuse irradiance.
(a)- monocrystallline, (b)- multicrystalline, (c)- amorphous silicon solar cell

Table 2. Influence of water vapor on Jsc on the solstice summer on a horizontal surface under global and diffuse irradiance

Water Vapor	Jsc (mA cm^{-2}) mono-Si		Jsc (mA cm^{-2}) multi-Si		Jsc (mA cm^{-2}) a-Si	
	Dif	Glb	Dif	Glb	Dif	Glb
0,5	2,97	32,63	3,68	37,76	1,48	9,6
1	2,95	32,26	3,66	37,36	1,48	9,59
2	2,92	31,78	3,63	36,82	1,48	9,59
3	2,91	31,44	3,61	36,45	1,48	9,59
4	2,89	31,17	3,6	36,15	1,48	9,58

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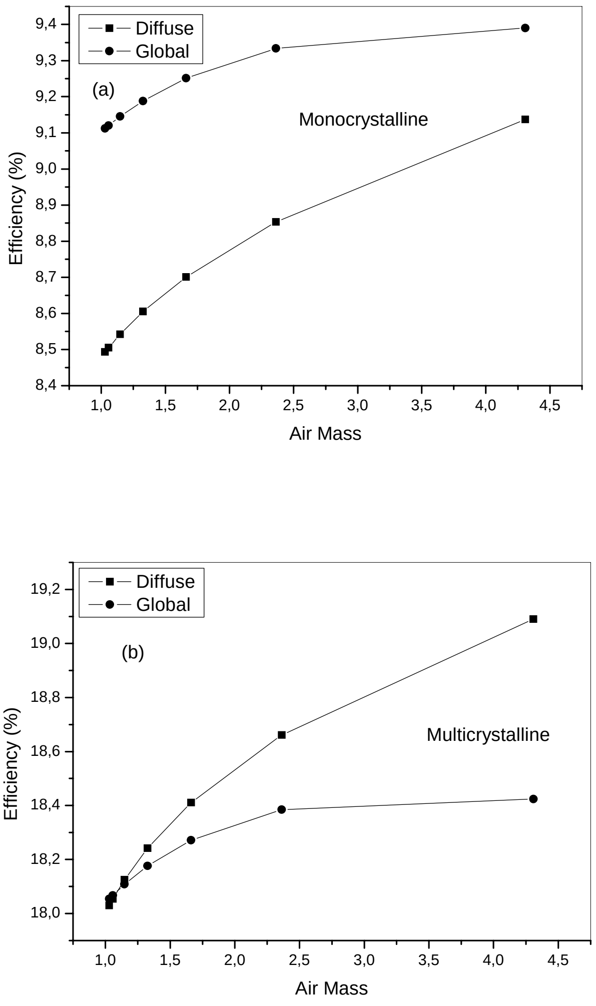
II. AIR MASS EFFECT

The variations of the short circuit current as a function of the air mass are illustrated in Table 3. The short circuit current decreases with increasing air mass for the different types of silicon solar cells. However, the efficiency increases with increasing air mass for monocrystalline and multicrystalline solar cells but it is the opposite for the amorphous silicon solar cell. This is illustrated in Fig. 4.



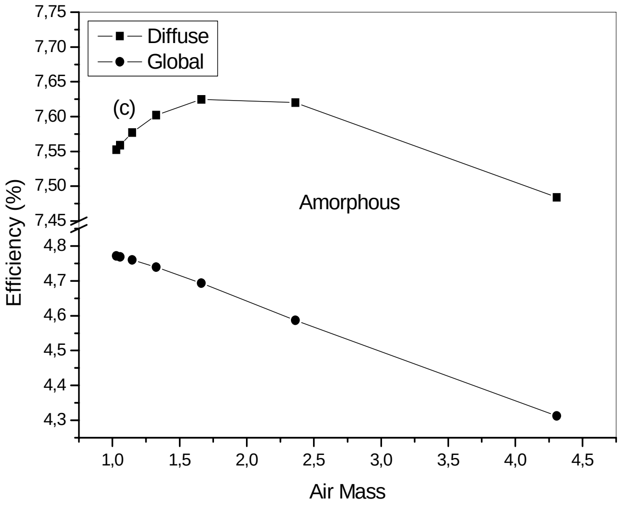


Fig. 4. Efficiency as function of air mass on a horizontal surface under global and diffuse irradiance.

(a)- monocrystallline, (b)- multicrystalline, (c)- amorphous silicon solar cell

Table 3. Influence of the Air Mass on Jsc on the solstice summer on a horizontal surface under global and diffuse irradiance

Air Mass	Jsc (mA cm^{-2}) mono-Si		Jsc (mA cm^{-2}) multi-Si		Jsc (mA cm^{-2}) a-Si	
	Dif	Glb	Dif	Glb	Dif	Glb
1.031	2,97	32,63	3,68	37,76	1,48	9,6
1.058	2,94	31,71	3,65	36,69	1,47	9,31
1.148	2,87	29,02	3,55	33,56	1,43	8,48
1.327	2,73	24,74	3,38	28,59	1,35	7,17
1.666	2,51	19,18	3,1	22,13	1,24	5,47
2.370	2,16	12,75	2,66	14,68	1,05	3,52
4.341	1,59	6,05	1,94	6,93	0,73	1,56

III. CONCLUSION

The global and diffuse solar irradiance incident on different types of silicon solar cells are simulated using the spectral transmittance model Spectral2 for varying atmospheric conditions on the site of Algiers. The analysis shows that the efficiency increases with increasing air mass and turbidity for monocrystalline and multicrystalline solar cells but it is the opposite for the amorphous silicon solar cell under global irradiance, the effect is greater under diffuse irradiance. The efficiency increases with increasing water vapor for the different types of silicon solar cells under global irradiance but it does not influence the cells parameters under diffuse irradiance.

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