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The Effect of Ground albedo on the Performance GaInP and (a-Si: H) of Solar Cells

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Abstract

Solar radiation incident on vertical and inclined surfaces consists of beam, sky diffuse and ground reflected components. The ground reflected component may be significant, particularly in the northern latitudes due to low elevations of the sun and, at times, due to the presence of highly reflecting snow cover. Accurate estimation of ground reflected radiation would require knowledge of the foreground type and geometry, its reflectivity and the condition of the sky. The electrical current generated by the solar cells is very sensitive to the incident spectral distribution and intensity. This distribution varies greatly during the day due to changes in the sun's position or weather conditions. This work investigates the feasibility of using a solar spectral radiation model SMARTS2 to estimate the global solar irradiance on two different sites in Algeria (Setif and Bejaia) and assess the influence of varying ground albedo on the conversion efficiency of GaInP and amorphous (a-Si: H) solar cells. The results show an augmentation in the short circuit current of amorphous (a-Si: H) solar cell due to increasing albedo. It is 6.25% and 9.84% under global radiation and for Setif and Bejaia sites respectively. However for GaInP solar cell, the augmentation of the short circuit current is 6.97% and 10.93% for Setif and Bejaia sites respectively. Nevertheless, the efficiency increases with increasing albedo for GaInP and amorphous (a-Si: H) solar cells.

Keywords : Ground Reflectance ; Albedo ; Solar Cells, (a-Si:H) ; GaInP; Irradiance.
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1. Introduction

Accurate knowledge of solar radiation at the Earth's surface is an important issue in many disciplines related to solar energy, environment, climate, architecture, and agriculture, illumination engineering and biophysical impacts of atmospheric pollution in large cities, atmospheric physics and remote sensing[1].

Atmospheric parameters play a very important role in the earth's radiation budget and, therefore, are very important in climate change [2-3]. Due to natural spectral sensitivity of solar cell devices, the solar spectrum is one of those environmental factors which may strongly influence module's performance.

Surface albedo, defined as the ratio of reflected to incoming radiation fluxes, is acknowledged to be one of the dominating factors of the Earth's radiation budget [4]. Snow and ice have the highest albedo of all surface types on the Earth. Variations in the surface albedo of the Arctic region have a large effect on the radiation budget of the earth atmosphere system and thereby on the global climate [5]. The ground albedo varies with a number of factors, such as the properties of ground surface material, solar position, sky clearness, ground vegetation, snow coverage, etc. An ideal white body has an albedo of 100% and an ideal black body, 0%. Visually we can estimate the albedo of an object's surface from its color. Albedo irradiation changes the spectral distribution of the incident irradiation on the surface of the PV device, which in turn affects system output [6].

In general, PV modules are optimized under Standard Testing Conditions (STC), which are defined as 1000 W/m^2 irradiance with an AM 1.5 spectrum at 25°C, In real operating conditions, the module output is strongly affected by various environmental conditions such as irradiance, temperature and spectral effects [7]. Furthermore the impact of each climatic factor on the energy production varies according to the module technology in use.

The main propose of this paper is to know how (a-Si: H) and GaInP solar cells, perform under possible solar spectrum variations and which albedo parameters produce more influence. For this reason, the variations short circuit, and efficiency of (a-Si: H) and GaInP solar cells due to the possible variations of the global solar spectral irradiance are obtained. The solar irradiance striking solar cells is estimated using the spectral irradiance model for clear skies SMARTS2 (Simple Model of Atmospheric Radiative Transfer of Sunshine) on different site of Algeria (Setif and Bejaia).

2. Calculation procedures

2.1. Spectral solar irradiance calculation

A large range of atmospheric radiation models has been elaborated by different authors for calculating the spectral solar irradiation [8]. Several of these models have been developed by various climate research centers and are highly complex numerical models utilizing the satellite observations as inputs. A physical spectral model is proposed by Gueymard [9-10] and called SMARTS2 (Simple Model of Atmospheric Radiative Transfer of Sunshine) is introduced here to examine the seasonal variation on the thin film solar cells output. It can be used in a variety of applications to predict full terrestrial spectra under any cloudless atmospheric condition. It gained acceptance in both the atmospheric and engineering fields due to its low number of inputs, ease of use, to its versatility, execution speed, and various refinements. It can calculate punctual estimations of spectral irradiances using as input parameters the local geographic coordinates, atmospheric water vapor content, atmospheric pressure, ground reflectance and aerosol optical thickness. SMARTS2 is used to generate the global component of the solar spectra for two sites in Algeria (Setif, Bejaia).

2.2. Cell Parameters Calculation

One of the key device parameters of a solar cell is the short circuit current density (*Jsc*). This parameter can be calculated by convoluting the spectral response of the device and the incident solar spectrum using the following equation:

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

Where SR (λ) is the spectral response of the device (A/W), E (λ) the global irradiance (W/m^2 nm) as a function of wavelength λ (nm)

The open-circuit voltage VOC and short-circuit current are related as follows:

$$V_{oc} = n \frac{kT}{q} \ln\left(\frac{I_{sc}}{I_s} + 1\right) \qquad (2)$$

After the calculation of V_{oc} the fill factor (*FF*) can be calculated using the normalized open circuit voltage *voc* [11]:

$$FF = \frac{v_{oc} - \ln(v_{oc} + 0.72)}{v_{oc} + 1} \qquad (3)$$

The ideality factor, n, and the saturation current, Is, are computed from the I-V characteristics using an approach that involves the use of an auxiliary function [12].

The fill factor and the conversion efficiency of the solar cell are linked through:

$$\eta = FF \frac{V_{oc} I_{sc}}{P_i S} \qquad (4)$$

Where: Isc is the short circuit current, S is the solar cell area, and Pi is the total irradiance in W/m2 and is given by:

$$P_i = \int_0^{\infty} E(\lambda)\, d\lambda \qquad (5)$$

With E (λ) is the spectral irradiance.

Figure 1 show the measured spectral response data of GaInP and amorphous (a-Si: H) solar cells [13-14].

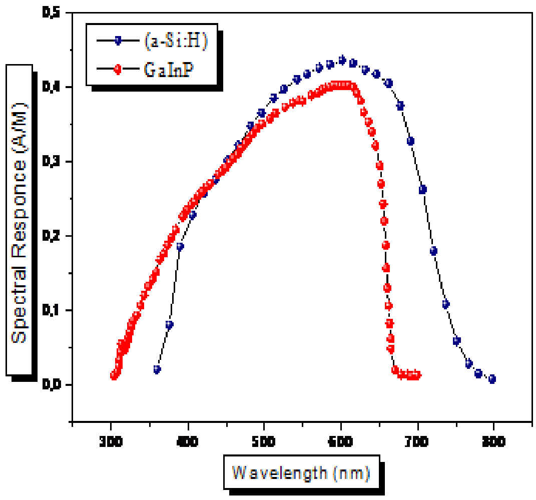

Figure.1 Spectral response of (a-Si: H) and GaInP solar cells [13-14].

3. Results and discussion

The global solar irradiance is calculated at Setif (36.11° N, 5.41°E and 1081m) and Bejaia (36.45° N, 5.04° E and 0.009 m) on a horizontal surface by varying the albedo parameter and maintaining the others fixed (water vapor, air mass and turbidity) using SMART2. Then for each value of the ground albedo, we calculated the short circuit current, and the conversion efficiency of solar cells.

The variations of the short circuit current as a function of the ground albedo are illustrated in Table 1. The short circuit current increases with increasing albedo for the different types of solar cells. Whereas, the efficiency increases also with increasing albedo on the site of Setif and Bejaia for (a-Si: H) and GaInP solar cells. This increase is greater in the site of Bejaia then Setif. The augmentation in the short circuit current due to increasing Albedo (Table 1) is 6.25% and 9.84% under global radiation and for Setif and Bejaia sites respectively. However for GaInP solar cell, the augmentation of the short circuit current is 6.97% and 10.93% for Setif and Bejaia sites respectively. This is illustrated in Figure 2 and 3.

Albedo	Jsc (mA/cm²) GaInP		Jsc (mA/cm²) (a-Si: H)	
	SETIF	BEJAIA	SETIF	BEJAIA
0.1	135.120	133.420	175.819	165.845
0.2	136.965	136.207	177.975	169.013
0.3	138.861	139.128	180.185	172.287
0.4	140.811	142.197	182.453	175.708
0.5	142.817	145.424	184.779	179.284
0.6	144.882	148.825	187.166	183.029

Table 1: Influence of ground Albedo on Jsc under global for GaInP and (a-Si: H) solar cells.

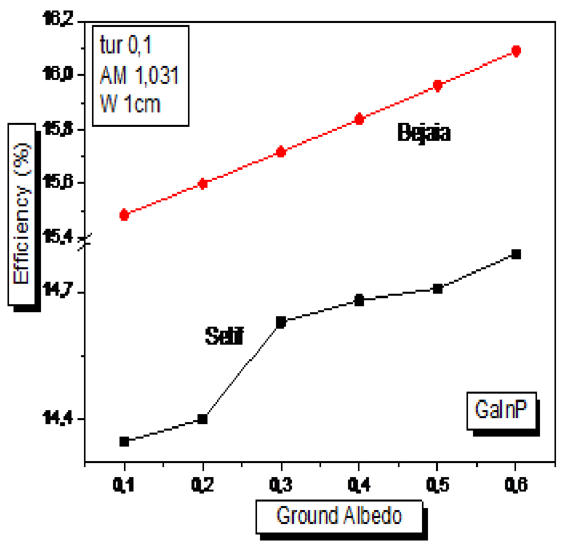

Figure.2 Efficiency as function of Albedo under global solar irradiance for GaInP solar cell

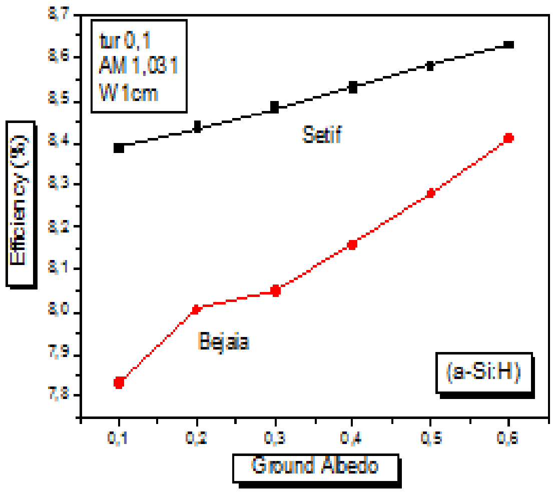

Figure.3 Efficiency as function of Albedo under global solar irradiance for amorphous (a-Si: H) solar cell.

4. Conclusion

The global solar irradiance incident irradiance incident on different types of solar cells on diverse site of Algeria is simulated using the spectral irradiance model SMARTS2 for varying atmospheric conditions. The analysis shows that the efficiency increases with increasing albedo for (a-Si: H) and GaInP solar cells. The effect is greater in the site of Bejaia then Setif and on the GaInP then (a-Si: H) solar cells.

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