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Comparative Study of the Effect of Shading Rate on the Electrical Parameters of CIGS and CdTe/CdS Solar Modules

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Abstract

In this paper, a comparative study of the maximum power on the shading rate on the maximum power of thin film PV modules. Thus two thin film PV modules of type Copper indium gallium selenide, CIGS, of 90W power and a CdTe (Cadmium telluride)/CdS (Cadmium sulfide) module, of maximum power 75 W. These modules, reference SN-CIGS90 and CX3 75 were tested under the conditions of the installation site to ensure their proper functioning and to determine the initial values of electrical parameters before shading. The results obtained are as follows: for the CIGS: Pm (80.717 W); Vco (23.06 V), Icc (3.5 A) and for the CdTe:Pm (54.914 W); Vco (35.52 V), Icc (1.546 A). After this characterization test, the modules are exposed to real operating conditions at the Center for Study and Research on the renewable energy (CERER), Cheikh Anta Diop University in Dakar. Four types of shading are performed on each module with the same mask: partial shading at 25%, 50%, 75% and complete shading at 100%. The comparison of the variation rates obtained on the experimental values of the 4 types of shading carried out on each module, shows that, the phenomenon of shading constitutes an environmental factor which influences negatively the maximum power of the thin film PV modules. But this reduction depends on the surface of the shaded module, the nature of the mask but also the technology used. Indeed, for a shading of 25% of the surface of the two modules, we note a reduction of 21.32% of power for the CIGS, against 40.53% for the CdTe/CdS, that is to say a difference which approaches 20%.

Keywords

CIGS, CdTe/CdS, Shading Rate, Maximum Power, Mask

1. Introduction

A PV module is characterized when new by the maximum power it delivers. This power decreases over time, when the module is exposed to sunlight under the real operating conditions of the installation site [1]. This variation can be due to several factors, among which we can mention the shading. Studies have shown that the power output of photovoltaic panels is sometimes lowered due to the appearance of shadows on them [2] [3]. In one of their studies, Quaschning & Hanitsch [4] showed that on only 2% of the module area shaded, the performance loss was 70%, Viitanen showed that if 5% - 10% of the module area is shaded, the power can be reduced by more than 80%. Shadows can be caused by trees, buildings, but also by the mounting structures of some modules on others, droppings that fall on the modules as well as leaves from trees and others... When a module is shaded in a series-connected module system, bypass diodes can prevent the shaded module from being reverse biased. If the bypass diodes open, the shaded module is effectively shorted. And if the shunt diodes fail or are ineffective, the shaded module can experience reverse bias stress, which is very dangerous to the module [5]. It has been observed that CIGS modules, subjected to reverse bias stresses develop white features similar to worms visible under glass that have been associated with hot spots [6]. The presence of hot spots in CIGS modules is a key factor in the failure of these modules induced by shading [7] [8]. The use of protective diodes to protect against power loss and reverse bias is difficult in thin film modules [9]. In our study, we have shown the impact of shading on the electrical parameters of CIGS photovoltaic modules installed in a Sahelian environment. The analysis of the variation rates obtained on the experimental values of 4 types of shading is the subject of this study.

2. Experimental Study

Description of the Experimental Material

To carry out this experimental study of the comparison of the effect of shading rate on the electrical parameters of thin film photovoltaic modules, we used two modules of types, (CIGS and CdTe/CdS, **Table 1**).

The work was carried out on the site of the Centre de Recherche sur les Energie

Table 1. Shows the construction data of each module.

Technology	Reference	Vco (V)	Icc (A)	Pmax (W)	Manufacturer
CIGS	SN-CIGS 90	25.600	4.890	90	S. SHINE SOLAR CO
CdTe/CdS	CX3 75	59.6	2.15	75	SHARP

Renouvela-bles de l'Université Cheikh Anta DIOP de Dakar (CERER), located on the Route du Service géographique (HB-87) x rue HB-478, Hann Bel-Air, Dakar Senegal. The center's mission is to contribute, in an efficient way, to the search for solutions to the development problems related to energy and environment that are acute in African countries and in particular in Senegal.

As shown in **Figure 1** below, the environment is surrounded by trees on both sides, which can create shade on the PV modules installed there.

The measurement platform is composed of:

- Solarimeter, to measure the illumination of the installation site during the experiment.

Thermocouple, to measure the temperature of the panels. Three rheostats, connected in series to increase the electrical resistance of the circuit. Two multimeters, one of which is used as an ammeter and the other as a voltmeter to measure current and voltage respectively connecting wires to connect the modules to the measuring devices (**Figure 2**).

Figure 1. Photovoltaic field at CERER.

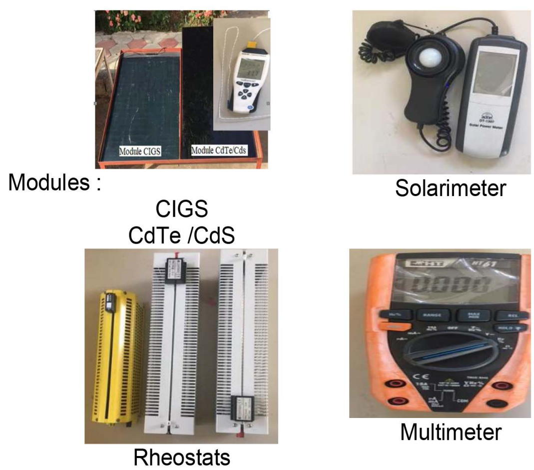

Figure 2. Shows the experimental equipment.

3. Experimental Study

After this test, the modules are exposed on the site of CERER have each undergone 4 types of shading:

- Partial shading at 25%, corresponding to a quarter of the module surface.
- Partial shading at 50%, corresponding to half of the module surface.
- Partial shading at 75%, corresponding to three quarters of the module surface.
- Total shading at 100%, corresponding to the total surface of the module.

Figure 3 below illustrates this.

4. Results and Discussions

With the help of the experimental device, we tried to determine the effect of the shading rate on the electrical performance parameters of each module (CIGS and CdTe). Then, we made a comparative study of this effect between these two technologies. The results obtained are presented in Table 2 below.

Shading CdTe at 25% | Shading CdTe at 50% | Shading CdTe at 75% | Shading ge CdTe at 100% | Shading CIGS at 25% | Shading CIGS at 50% | Shading CIGS at 75% | Shading CIGS at 100%

Figure 3. Different types of shading.

Table 2. Maximum power obtained on each module for the 4 types of shading.

Module	Experimental conditions		Measures position	rate
CIGS	- Illuminance (W/m²)	1076	First measurement	25%
	- Illuminance (W/m²)	1017	Second	50%
	- Illuminance (W/m²)	1036	Third	75%
	- Illuminance (W/m²)	1036	Fourth	100%
	- Temperature (˚C)	56.1	Initial measurement	0%
	- Temperature (˚C)	54.3	First measurement	25%
	- Temperature (˚C)	55.8	Second measurement	50%
	- Temperature (˚C)	48.3	Third measurement	75%
	- Temperature (˚C)	55.8	Fourth measurement	100%
CdTe/CdS	- Illuminance (W/m²)	1092	First measurement	25%
	- Illuminance (W/m²)	1048	Second measurement	50%
	- Illuminance (W/m²)	1113	Third measurement	75%
	- Illuminance (W/m²)	1046	Fourth measurement	100%

Continued

- Temperature (˚C)	57.2	Initial measurement	0%
- Temperature (˚C)	56.4	First measurement	25%
- Temperature (˚C)	57.9	Second measurement	50%
- Temperature (˚C)	57.9	Third measurement	75%
- Temperature (˚C)	58.3	Fourth measurement	100%

Modules	Maximum power [W]	
	CIGS	CdTe/CdS
Specifics values	80.71	55.06
Initials values	65.6	32.74
Values after 1 month with cleaning	46.41	21.22
Values after 2 month with cleaning	36.78	12.43
Values after 3 month with cleaning	27.21	8.076

Table 3. Results on the shaded module, (a) Shading at 25%, (b) Shading at 50%, (c) Shading at 75%, (d) Shading at 10.

	Shading rate	Shading rate		Relative rate of change	
		CIGS	CdTe/CdS	CIGS	CdTe/CdS
Maximum power according to The shading rate	25%	−15.11	−21.32	18.72%	40.53%
	50%	−34.3	−33.84	42.49%	61.46%
	75%	−43.93	−42.63	54.43%	77.42%
	100%	−53.5	−46.99	66.28%	85.34%

In our experimental studies below, we try to determine the absolute and relative rates of change between the initial and post-study parameters. For this purpose, we used the following equations [10] [11]:

$$\text{TVA} = V_F - V_I \tag{1}$$

$$\text{TVR} = \left(\frac{V_F - V_I}{V_I}\right) \times 100 \tag{2}$$

VAT, the absolute rate of change, TVR, the relative rate of change,

V-F, the final value of the parameter and V-I, the initial value of the parameter.

Table 3 shows the results obtained as a function of the shading rate.

It is found in this study that shading significantly reduces the maximum power (P_{max}) of thin film modules. But the (CIGS) module is less affected than the CdTe/CdS module.

Indeed, for only 25% of their surfaces shaded with the same mask, the CdTe/CdS module loses 40.53% of its maximum power against 18.72% for the CIGS module. That is to say twice less. Similarly, for a shading rate of 50%, the CdTe module loses 61.46% of its maximum power, against 42.49%. Here again, the difference in power variation obtained on the two modules is almost equal to

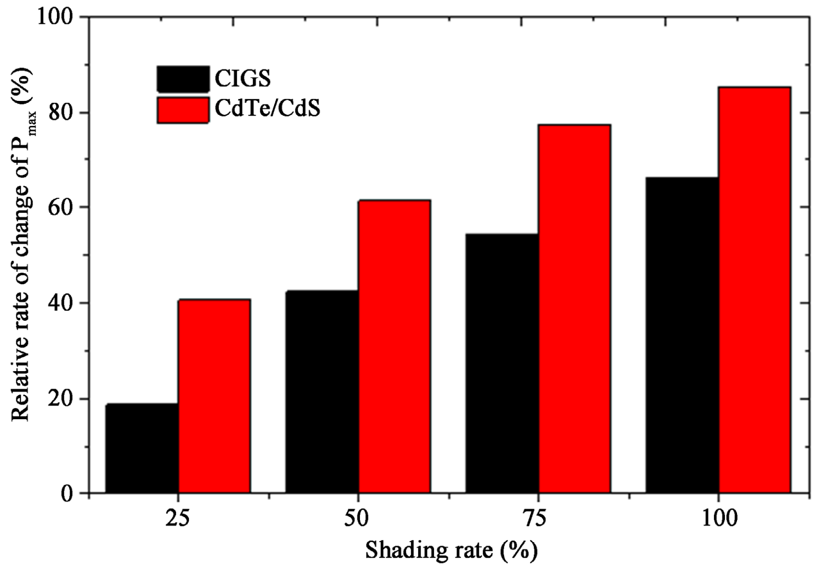

Figure 4. Comparison of the rates of change of the maximum power of the two modules as a function of the shading rate.

20%. For 75% and 100% also, we note almost the same differences on the variation of the power between the two modules. This is due to the fact that the CIGS module, due to its absorption coefficient of about 10^5 cm^{-1} is higher than that of CdTe which is about 10^3 cm^{-1}, resists better to the shading by showing much smaller rates of variation than that of CdTe/CdS. **Figure 4** shows the comparison between the different relative variations of the maximum power of the modules as a function of the shading rate.

5. Conclusions

The comparative study of the variation of the maximum power as a function of the shading rate on the surface of the PV modules based on CIGS and CdTe/CdS, give additional information which allows an optimization of the performance of the photovoltaic systems.

The results show that shading leads to a strong decrease in the maximum power of thin film modules. Indeed, with the same mask, and following the same time of sunshine, the CdTe technology loses twice as much power as the CIGS. This phenomenon could be explained by their absorption coefficient because that of CIGS (10^5 cm^{-1}) is 100 times higher than that of CdTe (10^5 cm^{-1}).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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