

Contribution to the study of the impact of relative humidity on the performance of amorphous PV panels: case of Saint-Louis (Senegal)

TEVI J.-P. G.¹, NDETIGMA K.¹, BEYE M.¹, EDJADESSAMAM A.¹, DIENG B.¹, FAYE M. E.¹, SENE M.¹, SEIDOU MAIGA A.¹

Corresponding author: tevi.gabriel-jean-philippe@ugb.edu.sn

INFOS SUR L'ARTICLE

Historique de l'article:

Reçu le : 31 juillet 2019

Reçu en format révisé le : 08 novembre 2019

Accepté le : le 11 novembre 2019

Keywords :

Amorphous PV Module, Climate, Output Power, Relative Humidity, Temperature

ABSTRACT

Climatic parameters such as irradiance, ambient temperature or wind speed, play an important role in the photovoltaic conversion process. These parameters have an impact on PV modules' output power in general, especially in the sahelo-saharan region. Indeed, this sahelo-saharan region is characterized by some harsh climatic conditions. Knowing that the variability of the weather conditions cannot be predicted, many studies are conducted on field, to assess and, at least bring to the light the impact of these conditions on PV modules. Thus, this paper focuses on the influence of the relative humidity RH on specific parameters of an amorphous PV module exposed at Gaston Berger University. The measurements results of intrinsic and extrinsic data allowed to evaluate and plot the variation of the efficiency. With an STC value around 4.9 %, the efficiency in operating conditions was less than 2.3% for RH=51%; and it dropped to 1.15% for RH close to 86%. Nevertheless, a lot more data, extended to a very long period of measurements are necessary to see permanent effects, to quantify proportions of the impact and to define a behavioral characterization of amorphous PV modules in real operating conditions in the Saharan environment.

RESUME

Les paramètres climatiques tels que l'éclairement, la température ambiante ou la vitesse du vent jouent un rôle important dans le processus de conversion photovoltaïque. Ces paramètres ont un impact sur la puissance de sortie des modules PV en général, en particulier dans la région sahélo-saharienne. En effet, cette région sahélo-saharienne est caractérisée par des conditions climatiques difficiles. Sachant qu'il est impossible de prévoir la variabilité des conditions météorologiques, de nombreuses études sont menées sur le terrain pour évaluer et, au moins mettre en lumière l'impact de ces conditions sur les modules PV. Ainsi, cet article se concentre sur l'influence de l'humidité relative HR sur les paramètres spécifiques d'un module PV amorphe exposé à l'Université Gaston Berger. Les résultats des mesures des données intrinsèques et extrinsèques ont permis d'évaluer et de tracer la variation de l'efficacité. Avec une valeur STC d'environ 4,9 %, l'efficacité en conditions réelles de fonctionnement était inférieure à 2,3 % pour une valeur de HR=51 % ; et il est tombé à 1,15 % pour une valeur de HR proche de 86 %. Néanmoins, beaucoup plus de données, étendues à une très longue période de mesures sont nécessaires pour voir les effets permanents, quantifier les proportions de l'impact et définir une caractérisation comportementale des modules PV amorphes en conditions réelles de fonctionnement dans l'environnement saharien.

¹LEITER, Applied Physics Department, UFR-SAT, Gaston Berger University of Saint-Louis, Senegal

I. INTRODUCTION

The development of Renewable Energies has stimulated a renewal of interests in the scientific community due to potentials and possibilities that could be accessed. The qualitative aspect of these energies thanks to reliable production devices is now a need. In this field, climatic parameters such as solar irradiance, ambient temperature, dust, rain, relative humidity, wind speed or even pollution, play an important role in the photovoltaic conversion process and have a great impact on the output power that is produced, particularly in the sahelo-saharan region. Many works have been done to assess this impact. For instance, Sadok *et al.*, 2012 focused on the degradation effect induced by the climate on PV generators. He concluded, after on-site measurements that up to 19% of power loss can occur after a period operation due to the hot climate and the dust in the region. The main role played by the local environment was emphasized by Darwish *et al.*, 2013. They showed in their work the different impacts that the region where a PV module is installed can have on its production. The different categories of factors they pointed out include geographical (latitude, longitude), environmental as mentioned before and technological (types of PV modules). Ndiaye *et al.*, 2013 investigated the impacts of atmospheric soiling deposits meaning here the dust. They measured on a one-year exposition panel covered with natural dust to accurately evaluate the performance degradation that resulted. They concluded that the maximum power output loss can be between 18 to 78 % for crystalline modules (polycrystalline and monocrystalline). A study approach for the working of PV generators by considering solar irradiation, ambient temperature, and wind speed has been proposed by Ndiaye *et al.*, 2015 with a focus on the polycrystalline technology. Most of the works afore mentioned, focused on the monocrystalline and the polycrystalline technologies. According to the Fraunhofer institute for Solar Energy Systems, ISE2019, the thin films technology production reached 4.5 Gwp in 2017 against almost nothing in the early 2000. Meaning that the interest in thin films is growing due to advantages they have. Even so, only few works have been devoted to the amorphous technology. An overview of studies focused on this technology has been recently presented by Elbaset *et al.*, 2016. However, in most cases, these studies do not consider the relative humidity.

Thus, the purpose of the present work is to investigate the impact of the “relative humidity” on the behavior of amorphous solar modules and to characterize the PV generator based on measurement in real operating conditions in the Sahelian environment.

II. EXPERIMENTAL SETUP

The location of our study is the Gaston Berger University of Saint-Louis. The Saint-Louis region is

covering 16°02'00'' latitude North and 16°30'00'' longitude West with a sea level around 20 meters. The experimental study environment is more precisely at 16°4'4.465'' North and 16°25'47.427'' West. The mean irradiance per-day is 5.97 kWh/m .

An amorphous module has been used with two multimeters to measure the current and the voltage, one pyranometer for the solar irradiance, another multimeter was used but connected with a thermo-sensor to take the back-side temperature of the module. A variable resistor (rheostat) was added to measure the I-V curves data of the module by varying the resistance at specific moments during the day. Those specific moments were linked to the position of the sun in the sky. The measurement system described above is shown in Figure 1. The technical data of the amorphous module is summarized in Table 1:

Table 1: Technical characteristics of the amorphous panel

Parameters	P	Isc	Voc	Impp	Vmpp
Values	20	1	30.5	0.872	23
Units	Watts	Amps	Volts	Amps	Volts

Where P is the nominal power, Isc is the short-circuit current, Voc is the open-circuit voltage, Impp is the maximum power point current and Vmpp is the maximum power point voltage.

The panel has a *length*×*width* equal to 1.256×0.325 m .

Based on the characteristics of the amorphous panel (see Table 1), the theoretical efficiency at the standard test conditions (STC) has been calculated with the following formula (Kazem *et al.*, 2011):

$$\text{Efficiency} = \frac{\text{power of PV panel}}{\text{area of PV panel} \times 1000 \text{ w/m}^2} \times 100 \quad (1)$$

The efficiency obtained is 4.9 % Usually, efficiencies of amorphous silicon a-Si:H modules are of only 4-6% (Radue *et al.*,2009) or even 7% (Kalogirou, 2018) for commercial panels but recent works attained in laboratory a stabilized efficiency value of 10.2% (Green *et al.*,v51-v52, 2018; Kalogirou, 2018) which is far better.

During a defined interval of time, the values of the voltage, the current, the temperature and the solar irradiance are measured. Ambient temperature, wind speed and relative humidity are collected separately from the experimental setup. The module is daily cleaned to make sure that the results will only show the effects of the relative humidity.

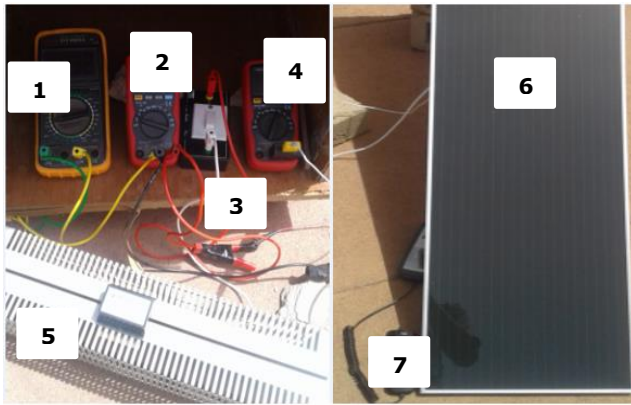


Fig.1. Measurement apparatus connected. (1) voltmeter, (2) amperemeter, (3) switch, (4) multimeter connected with the thermo-sensor, (5) rheostat (6) amorphous silicon panel, (7) pyranometer

As we want to investigate the impact of the relative humidity, the data was collected every 5 minutes to have as many values as possible. Then, the important parameters were plotted as function of the relative humidity (RH) only but considering values in an interval of 30 minutes. The values for I-V curves were also taken to determine the maximum power points of each day, and they will be used to investigate the correlation between the output power and the relative humidity as well as the maximum output power vs relative humidity.

III. RESULTS AND DISCUSSION

The aim of this study being to investigate the impact of the relative humidity on the output power of PV panels, one way is to correlate linearly the data. Thus, by calculating the determination coefficient R, and thanks to the efficiency values (Cf. Fig.9) one can make a conclusion. The determination coefficient R and the coefficient of correlation R have been evaluated on each plot and thanks to the “one-tailed test distribution”, the significance of the correlation was considered. The simplest way is by computing for each case a “t value” with the formula:

$$t = R \times \sqrt{\frac{N-2}{1-R^2}} \quad (2)$$

Where N is the number of values, R is the coefficient of correlation and R is the determination coefficient. Then these values obtained are checked in a distribution table and compared to a t_{critic} value.

3.1. Current vs Relative Humidity

Fig.2 shows the current produced by the panel as function of the relative humidity. A linear line is also added to visualize the trend of the values. Following this trend line plotted, there is a slight increase in values of current with the increase of the relative humidity. However, those values are not stable enough due to different reasons like the time interval between two successive values that might be too long. The slope of the

trend line is positive (0.0003) meaning that the current increased slightly with RH but still, the $R = 0.0427$ is not high thus a weak correlation. Though the values are too much diffuse around the trend line, this result is significative after verification with a one-tailed test distribution.

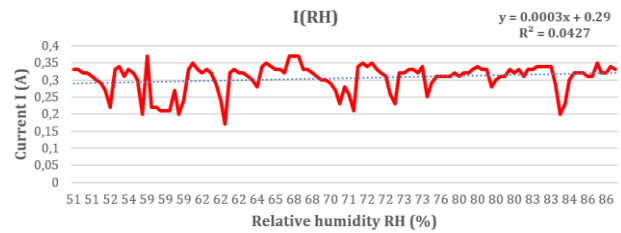


Fig.2. Current as function of relative humidity. The dot-line (blue) shows the tendency.

3.2. Voltage vs Relative Humidity

For the voltage in Fig.3, a slight decrease is noticeable. The slope of the regression line here is negative (-0.0108) meaning that the voltage and the relative humidity vary in an opposite way: if RH increases, the voltage decreases and vice versa. Kazem *et al.*, 2011 in their research paper, also noticed this impact. They assessed it to be more important for relative humidity between 93% and 96.5%. During the measurement period in Saint-Louis (Senegal), such values of relative humidity were not reached.

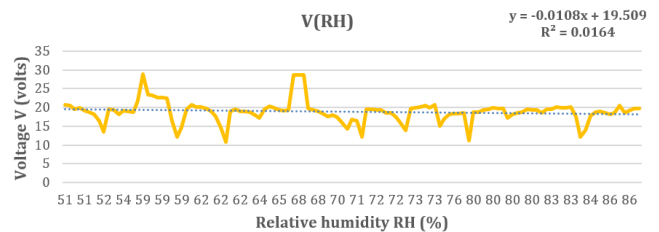


Fig.3. Voltage as function of relative humidity. The dot-line (blue) shows the tendency.

3.3. Output power vs Relative Humidity

The output power plot in Fig.4 confirmed the decrease of the voltage, with the reduction of the values while the relative humidity is increasing. The correlation coefficient is $R = -0.3217$ and it is significative.

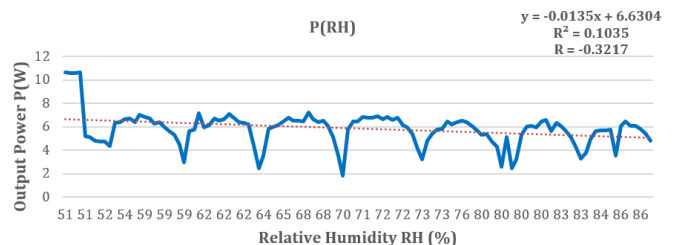


Fig.4. Output Power as function of relative humidity. The dot-line (red) is the tendency

3.4. Solar irradiance vs Relative Humidity - Module and Ambient temperatures vs Relative Humidity

The impact on the solar irradiance and the module temperature T_c (Fig.5 and Fig.6) is almost negligible; R values are very low (0.0023 and 0.00004 respectively). More data are needed to be accurate, but one can easily notice that the correlation between RH and the solar irradiance as well as the module temperature is weak and non-significant. As for the ambient temperature, $R = 0.5741$ shows a good correlation: while the relative humidity rises, the ambient temperature declines as it should be; and Fig.6 proved it.

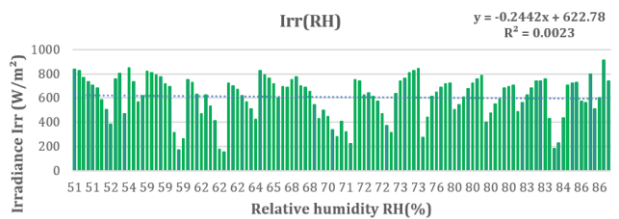


Fig.5. Solar irradiance as function of relative humidity. The dot-line (blue) is the tendency

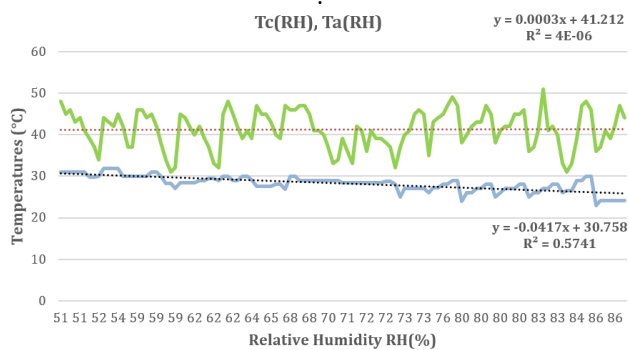


Fig.6. Module (green) and Ambient (blue) Temperatures as functions of relative humidity. The dot-lines show the tendencies.

3.5. Wind speed vs Relative Humidity

Fig.7 shows the wind speed of the area as function of the relative humidity. A linear line is also added to visualize the trend of the values. It can also be observed in Fig.7, that there is a straight reduction in the wind speed. Nevertheless, the value of the coefficient $R = 0.1185$ is significant and it means that too many values are diffused as we can see.

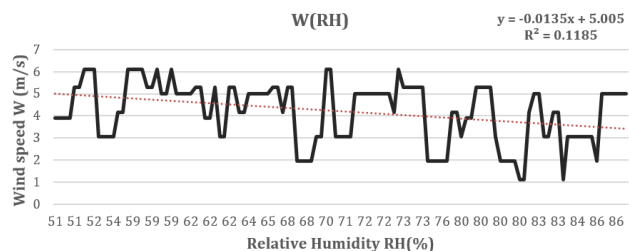


Fig.7. Wind speed as function of relative humidity. The dot-line shows the tendency.

3.6. Maximum power point values vs Relative Humidity

In Fig.8, the values of the maximum power point of the different I-V curves measured are represented. The coefficient R is negative (-0.4419) and but not significant.

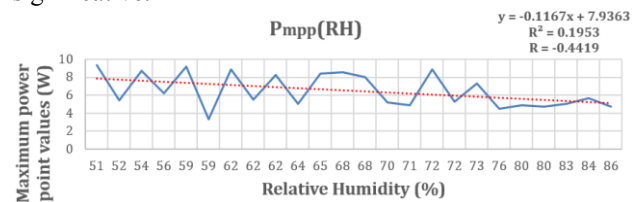


Fig.8. P_{mpp} as function of relative humidity. The dot-line shows the tendency.

3.7. Module efficiency vs Relative Humidity

The efficiency of the panel has been evaluated with the maximum power point values collected. Thus, Fig.9 displays efficiency data measurements versus the relative humidity. A linear correlation line is also added with the determination coefficient R whose value can explain the trend. Fig.9 which pictures the efficiency proved firstly that in real conditions less than of 2.3 % with RH=51% (STC efficiency equals 4.9%), can be reached. Secondly, due to the coefficient of correlation $R = 0.4403$ which is significant, the increase of the relative humidity directly involves the decrease of the efficiency of our amorphous silicon panel; it dropped to 1.15% for RH close to 86%.

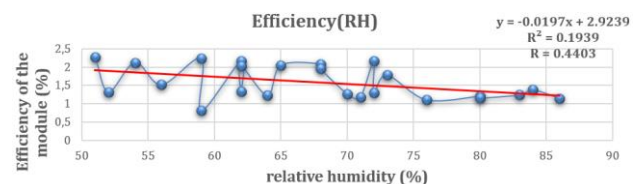


Fig.9. Efficiency as function of relative humidity. The dot-line shows the tendency.

IV CONCLUSION

In this paper, we have investigated the impact that the relative humidity (RH) can have on amorphous modules. The results obtained during this work showed that the relative humidity effectively causes some changes in the photovoltaic output production especially for the output power and the efficiency value, as shown by the correlation coefficient. The coefficients of correlation obtained for some parameters are significant. This is not the case for other parameters but at least the sign of these coefficients R is a factor that indicates how parameters will change with the increase of RH. However, a lot more data and a very long period of measurements are necessary to see permanent effects and to quantify proportions of the impact. Parameters such as the wind that can play a cooling role on the panel are also affected by the relative humidity as shown. Meaning that a certain

value of RH in the Sahelian region can cause serious production damages. Nevertheless, as we stated it, more data values are necessary to see and confirm such damages and to investigate also different aspects like the dust combined with the relative humidity and other environmental parameters.

ACKNOWLEDGEMENTS

The authors would like to thank the CEA-MITIC for funding this work which is part of a thesis project hosted by the LEITER laboratory.

REFERENCES

- Sadok, M., Benyoucef, B., and Mehdaoui, A., 2012. "Performances et Dégradation des modules PV en milieu saharien", *Revue des Énergies Renouvelables SIENR'12 Ghardaïa 203-2012*
- Darwish, Z.A., Kazem, H. A., Sopian, K., Alghoul, M. A., and Chaichan, M. T., 2013. "Impact of some environmental variables with dust on solar photovoltaic (PV) Performance: Reviews and Research status", *International Journal of Energy and Environment*, Issue 4, Vol.7, p 152
- Ndiaye, A., Kebe, C. M. F., Ndiaye, P. A., Charki, A., Kobi, A., and Sambou, V., 2013. "Impact of dust on the photovoltaic (PV) modules characteristics after an exposition year in Sahelian environment: the case of Senegal", *International Journal of Physical Sciences*, Vol.8(21), pp. 1166-1173
- Ndiaye, F., Sene, M., Beye, M., and Seidou, A. M., 2015. "Effects of climatic conditions on a polycrystalline photovoltaic module in Niger", *International Letters of Chemistry, Physics and Astronomy* Vol. 55 pp 60-66
- Fraunhofer Institute for Solar Energy Systems ISE, 2019. "Photovoltaic report", www.ise.fraunhofer.de
- Elbaset, A.A., Ali, H., and El Sattar, M., 2016. "New seven parameters models for amorphous silicon and thin film PV modules based on the solar irradiance", *Solar Energy*, Vol.138, pp. 26-35
- Kazem, H.A., Chaichan, M. T., Al-Shezawi, I. M., Al-Saidi, H. S., Al-Rubkhi, H. S., Al-Sinani, J. K., and Al-Waeli, A. H. A., 2011. "Effect of humidity on the PV performance in Oman", *Asian Transactions on Engineering*, Issue 04, Vol.2
- Radue, C., and Van Dyk, E. E., 2009. *Degradation analysis of thin film photovoltaic modules*, *Physica B* 4044449-4451
- Green, M.A., Hishikawa, Y., Dunlop, E. D., Levi, D H., Hohl-Ebinger, J., and Ho-Baillie, A. W. Y., 2018. *Solar cell efficiency tables (version 51)*, *Prog Photovolt Res Appl.*; 26:3-12
<https://doi.org/10.1002/pip.2978>
- Green, M.A., Hishikawa, Y., Dunlop, E. D., Levi, D H., Hohl-Ebinger, J., and Ho-Baillie, A. W. Y., 2018. *Solar cell efficiency tables (version 52)*, *Prog*
- Photovolt *Res Appl.*; 26:427-436
<https://doi.org/10.1002/pip.3040>
- Kalogirou, S., 2018. "McEvoy's handbook of Photovoltaics, Fundamentals and applications 3rd edition", Elsevier Academic Press, Cyprus University of Technology