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Study and comparison of the performance of PV modules installed in different areas

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ABSTRACT

The performance index is one of the most important values for evaluating the efficiency of a photovoltaic system. In concrete terms, the performance index designates the ratio between the actual energy yield and the theoretically possible energy yield. It is largely independent of the orientation of the photovoltaic installation and of the radiation on the photovoltaic installation. However, the performance index makes it possible to compare grid-connected photovoltaic installations at different locations around the world.

In this work, we have evaluated the performance ratio of PV modules of different technologies installed in West Africa in a Sahelian climate and in other climate zones. The modules tested at the Burkina Faso site were monitored for one year, from Au-gust 1, 2014, to July 31, 2015. A similar study was carried out using the PVGIS application which is an excellent simulation tool which makes it possible to calculate the pro-duction of photovoltaic systems connected to the grid in Europe and Africa (and also for isolated sites).

The results show, the micromorph modules present the highest values of the performance index whatever the irradiance or the temperature followed by the monocrystalline modules. Therefore, for the modules studied, the micromorph technologies are the most appropriate for the Sudano-Sahelian climate because they have the best performance ratio with an average of 95% and 91%. Both the monocrystalline and the polycrystalline 2 from manufacturer A have about the same average efficiency rates, about 87%. On the other hand, the comparative study of the different technologies in other areas shows that the crystalline technology is more adopted for the countries of Europe where the maximum temperatures can be around 25°C in STC conditions. On the other hand, in Africa, micromorph and thin-film technologies are the most appropriate with temperatures that can reach 40 to 50°C, which considerably reduces pro-duction and affects the lifespan and reliability of PV modules.

KEYWORDS: PV module, Performance, Performance ratio, Environmental parameters, PV Technologies

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INTRODUCTION

Analysis of data on degradation rates reported in previous literature shows its dependence on technology and climatic zones. The authors did an extensive literature search which yielded over 1100 data points on short circuit current degradation, open circuit voltage and maximum output power of modules in the field.

They mentioned that discoloration and delamination are common signs of degradation in modules, but failure of the interconnect will cause a greater decrease in maximum output power. It has been found that the greatest contributor to the output power drop in the case of crystalline silicon technology is the short circuit current reduction, to a lesser extent the Form Factor loss and that in a very low measures open circuit voltage.

One of the most important reports in the literature regarding the study of the electrical performance of PV modules is the article by Jordan et al. on "Technology and Climate Trends in PV Module Degradation" [1]

However, in the case of thin film technology, the degradation of the output power is mainly due to the strong degradation of the form factor. The reason for the high value of form factor (FF) degradation is induced by light in the case of micromorph silicon, and the increase in series resistance for CIGS.

All these studies mentioned above clearly show the difficulty when it comes to choosing the appropriate PV technology for a given site.

The performance of photovoltaic modules can be degraded due to several factors such as, [2, 3, 4, 5]:

- temperature,
- humidity,
- irradiation,
- dust,
- mechanical shocks

According to Phinikarides et al.[6], the common performance indicators used to rate the performance of photovoltaic technologies can be grouped into four categories:

electrical parameters from VEI curves recorded in indoor outdoor conditions or simulated and corrected at the STC,

regression models such as PVUSA (Photovoltaics for Utility scale Applications) and Sandia models [7],

(iii) standardized assessments such as PR (performance ratio) [8, 9,10],

(iv) Scaled ratings [11,12] of module performance with respect to seasonal variation.

Normalized and scaled ratings are shown for direct comparison between different PV technologies regarding geographic locations. The main advantage of the two metric ratings over the PVUSA method, is that they can be expressed for different time intervals such as daily, monthly or yearly, and can be calculated from the average of the generated energy values.

Among the normalized and scaled performance indicators, the most popular is the PR (performance ratio) [13,11]; it is recommended by the IEC 61724 standard for the evaluation of PV performance in a real environment. According to Carr et al.[14], the PR calculated using the maximum power values measured outdoors is a better indicator of the performance of the technology, when several PV modules are compared.

In this work, we will evaluate the performance ratio of PV modules of different technologies installed in West Africa in a Sahelian climate and in other climate zones and also study factors that may influence it.

THE PERFORMANCE RATIO:

The performance index is a dimensionless quantity normalized with respect to incident solar radiation. It provides important information about the overall effect of module losses.

The performance ratio is the ratio between the actual energy production (supplied to the grid) and the theoretical production that would be supplied by an ideal complete system (without loss) under standard sunlight (1 kW / m²) and temperature (25°C) conditions.

This indicator is internationally approved in IEC 61724.

$$PR = (Ea * Ir) / (Po * Gi) \qquad (1)$$

Where

PR: Performance ratio (in %)

Ea: Electrical energy actually produced (in kWh), as measured at the Delivery Station

P0: Installed power (in kWp)

Ir: Standard solar irradiance (reference value: 1000 W/m²)

Gi: Solar energy (in kWh/m²) measured by the pyranometers over the entire analyzed period.

PRESENTATION OF THE MEASUREMENT SITE:

The study covers fifteen modules of four different types,

3 sc-Si monocrystalline modules (VSPM50-12V),

6 polycrystalline modules, pc-Si_1 (Sw50 RMA/D),

3 polycrystalline modules, pc-Si_2 (VSP50P-12V),

3 micromorph modules (NA-F128GK).

The PV modules were characterized for a whole year

Figure 1: Bench Installed In Burkina

RESULTS AND DISCUSSIONS

On the Burkina Site

The modules tested at the Burkina Faso site were monitored for one year, from August 1, 2014 to July 31, 2015.

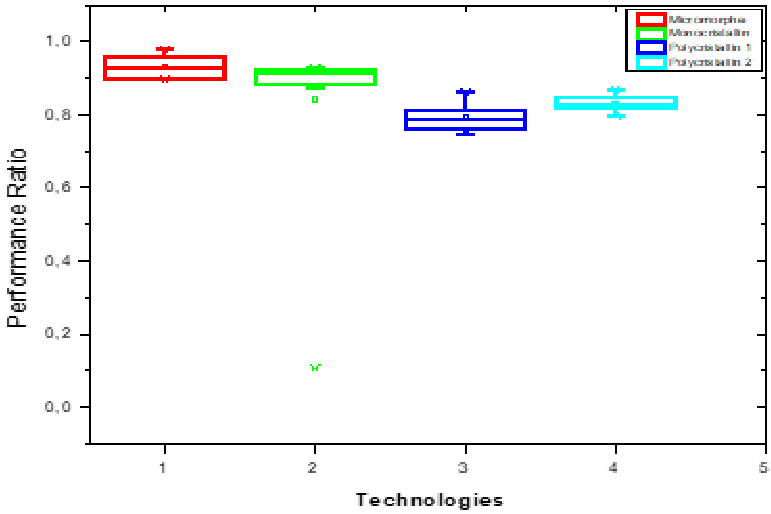

Figure 2: PR (Performance Ratio) For Different Technologies

From Figure 2, the micromorph has the best PR. The results show the PR (performance ratio) values for each module. All report performance values are less than 100%; this means that all the considered modules are running on the site under their STC performance. A similar study was done at LESEE where they did a simulation with these same technologies but in different West African countries to see their behavior (Figure 3)

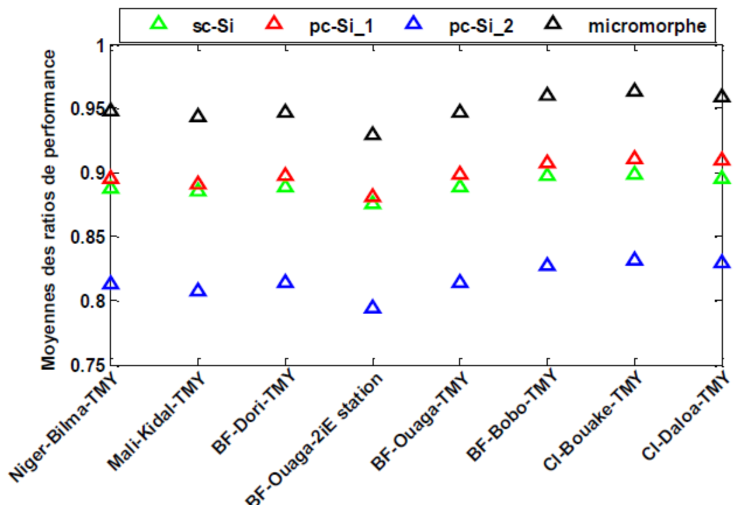

Figure 3: Annual Average Module Performance Ratios

On the whole, the micromorph modules present the highest values of the performance index whatever the irradiance or the temperature followed by the monocrystalline modules. Therefore, for the modules studied, the micromorph technologies are the most appropriate for the Sudano-Sahelian climate because they have the best performance ratio with an average of 95% and 91%. Both the single crystal and polycrystalline 2 from manufacturer A have roughly the same average efficiency ratio, around 87% while a second polycrystalline from another manufacturer B has the lowest performance ratio of around 75%. In addition, it thus comes close to the performance predicted by the manufacturer. Another study showed that tandem junction also called micromorph (Micro-Si) is the advantageous material for making solar cells because it is more stable compared to a-Si when exposed to sunlight. The study also reported that its structure produces devices that better exploit the solar spectrum and contribute to higher and more stable efficiencies. If the best performance of micro-morph is noticed regardless of the weather, the classification does not seem to be clear for the other modules Thus, this behavior should not be related to a manufacturing defect of a specific module of an account given the class or model. The decline of the

It can be seen that the ranking of the different technologies is the same in all the climatic zones studied. The module micromorph always comes first on all the sites studied.

A similar study was carried out using the PVGIS application which is an excellent simulation tool which makes it possible to calculate the production of photovoltaic systems connected to the grid in Europe and Africa (and also for isolated sites).

The PVGIS application (Photovoltaic Geographical Information System), using its integrated Google Maps interface, it is very easy to obtain the production data of a PV system from the site's precise insolation data (integrating in particular the distant masks linked to the relief, hills, mountains). In addition, PVGIS offers maps of sunshine (irradiation in kWh/m²) and precise high-definition temperature of all of Europe, Africa and the Near East.

Comparative study on other sites

In this section, the annual productions of various types of modules of different technologies and installed in certain climate zones are presented, in this case in West Africa, North Africa and Europe

West Africa

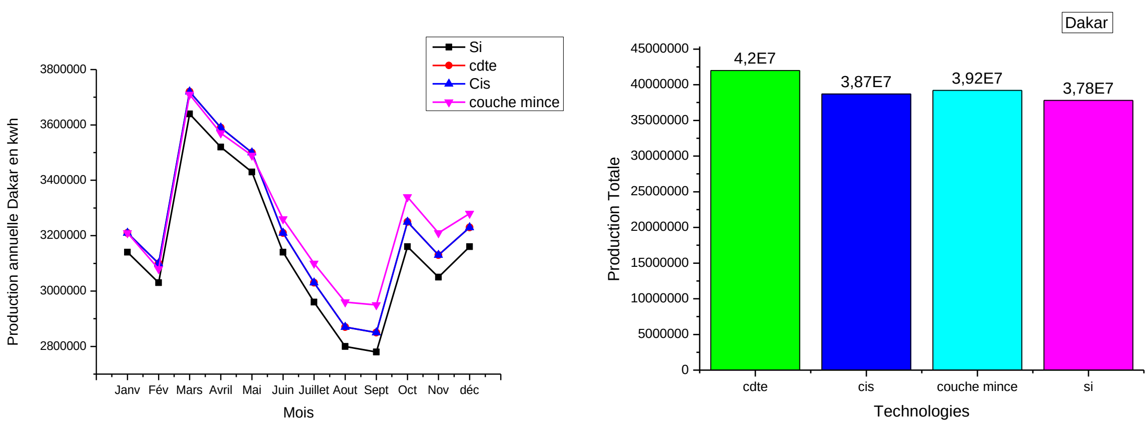

Figure 4: Assessment of Energy Production In West Africa With Different Technologies

(North Africa)

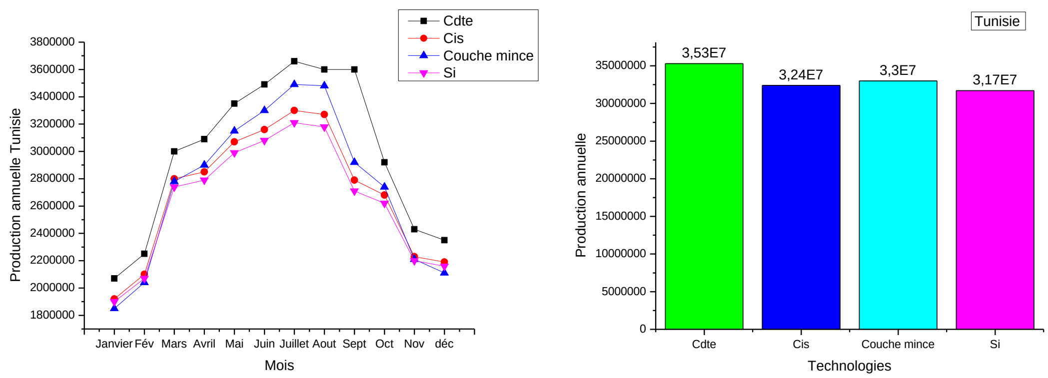

Figure 5: Assessment Of Energy Production In North Africa With Different Technologies (Europe)

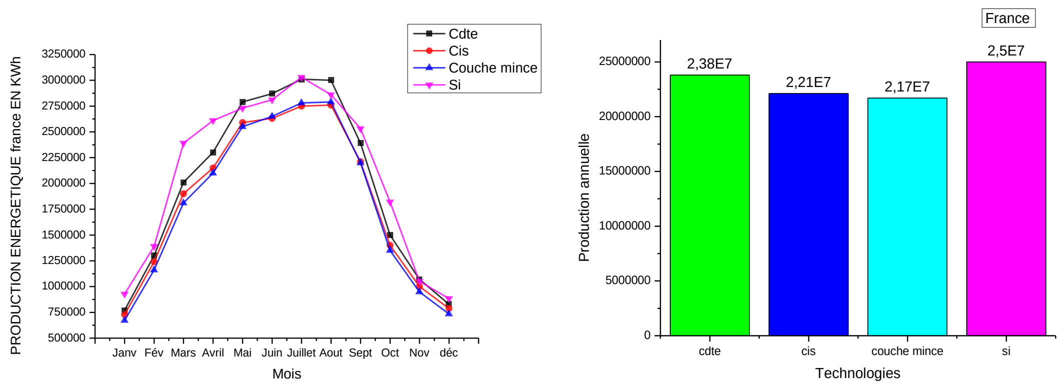

Figure 6: Evaluation Of Energy Production In Europe With Different Technologies

This comparative study shows that crystalline technology is more adopted for European countries where maximum temperatures can approach 25°C in STC conditions. On the other hand, in Africa, micromorph and thin film technologies are the most appropriate with temperatures that can reach 40 to 50°C, which have negative effects on production. It can be concluded that micromorph and thin film technologies are more resistant to temperature than crystalline modules.

Today, the performance of micromorph and thin film technologies is low (7 to 8%) and the lifespan of the panels is limited to around ten years, their performance decreasing significantly over time. For cadmium telluride compounds (CdTe), the main drawback lies in the toxicity of the products used to manufacture this type of solar panel.

However, with the monocrystalline technology, production of solar panels is optimal. Monocrystalline cells offer the best efficiency (up to 20%). Panels made using this technology have a good lifespan (up to 30 years). The cost of production is high and therefore the panels are expensive to sell. There is little performance with this technology in bad weather.

For photovoltaic cells polycrystalline silicon, the production cost is lower than that of monocrystalline cells. The panels also have a good lifespan (up to 30 years). Also, these solar panels are endowed with a good flexibility of irradiation which gives a correct performance, even in cloudy weather. Polycrystalline cells offer lower efficiency than monocrystalline technology (11 to 15%). These types of cells have the best quality/price ratio so far.

The challenges of photovoltaic cells remain as follows:

- Continue to lower the cost of solar energy,
- Finding ways to make solar cells more sustainable,
- Use abundant and non-toxic materials.
- Look for materials that will offer solar energy its full potential.

CONCLUSION

This work made it possible to compare and evaluate the performance of different PV technologies (monocrystalline, polycrystalline and micromorph) in several climatic zones of West and North Africa and Europe.

The comparison was made around two parameters, the temperature, and the performance ratio.

The study revealed better performance of micromorph modules in all climatic zones.

In European areas where the climate is close to STC conditions, crystalline modules have a better yield. Today, the performance of micromorph and thin film technologies is low (7 to 8%) and the lifespan of the panels is limited to around ten years. Their performance decreases significantly over time.

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