CONTRIBUTING TO THE QUALITY OF PV SOLAR MODULES IN WEST AFRICA

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ABSTRACT: In this work, we present the set up of a testing facility for photovoltaic (PV) modules and other PV system components in Dakar, Senegal. This creation is the result of a collaboration between the Polytechnic Schools of Dakar (ESP) and Lausanne (EPFL) aiming at improving the quality of PV systems by selecting components with sufficient quality. This testing center should also contribute to the education of all actors involved in the PV sector and contribute to research activities on the aging and failure mode analysis of PV modules exposed to sub-Saharian climates such as the hot semiarid climate of Dakar region but also those of the Economic Community of West African States (ECOWAS) region, including Senegal.

Keywords: PV modules, reliability, testing, emerging markets

1 INTRODUCTION

While the market for PV modules is growing worldwide, the deployment of PV in emerging countries is impeded by the poor quality of most of the components found in local markets. In Senegal and other ECOWAS countries, the low buying power, the lack of trained professionals and the absence of quality control laboratory are the major reasons for this situation. This poor quality of the components leads to unreliable and low system performance and a lack of confidence from the general public for PV renewable energy.

While the benefit of a high-quality standard is obvious for everyone, implementing and testing quality standards is not an easy task in low-income countries. The first necessary step is to be able to characterize components available on the local market to assess their performance and identify defects that could harm the long term reliability and performance. Such tests and quality assessments should be available as broadly as possible and be quick and inexpensive. In the case of PV modules, quality tests or module certifications as defined by the full test procedures of IEC 61215 norm [1] is obviously not applicable. The definition of a minimum quality standard that a PV module should pass is necessary and should be suited for the local context.

To address these shortcomings, the Polytechnic Schools of Dakar (ESP) and Lausanne (EPFL) are currently setting up an independent quality testing laboratory in Dakar (Senegal). A series of tests have been selected and implemented to provide fast and inexpensive assessment of the quality of modules to ensure reliable and long term performances. These tests consist of a subset of the IEC 61215 norm, including visual inspection, performance measurements, dry and wet insulation tests, as well as infrared and electroluminescence imaging. Given the sunny location of Senegal and to limit the infrastructure costs, module performances are measured outdoor. Besides the testing services, this center is also providing education to actors in the PV field as well as advice for PV installers. Field tests for PV systems will also be offered to examine faulty or poorly performing PV systems. The test center should also serve as a platform for the ESP and EPFL to conduct research projects on module reliability, module degradation, and PV deployment. These projects will greatly benefit from data collected by the center (indoor and in the field) [2].

Published data on the long term performance of PV modules in Africa are very scarce. While there is a significant number of PV systems installed in this continent, there is no systematic study, no traceability of the measurements and especially no initial characterization of the modules. Furthermore, the quality of the installed modules are in most cases questionable and renders any valuable study meaningless. Having access to a detail characterization of modules at various stages of their life using reliable characterization techniques would provide valuable scientific insight into the degradation and failure mode of modules in sub-Saharian climatic regions.

The implementation of an institution able to independently assess the quality of components and support system developers and installers in the design, commissioning and maintenance of PV projects is crucial to promote a “sustainable” diffusion of solar electricity in Africa.

This paper presents and briefly discuss the tests and methodology that have been set up. It also presents the results of some test analysis performed on new modules acquired on the Senegalese market that illustrate the quality deficit and the need for testing facilities.

2 METHODOLOGY

2.1 Approach

The development of PV installations in developing countries is often hindered by (1) a poor perception of the reliability of this technology, (2) the relatively high up-front capital and financing costs, (3) the lack of quality standard adapted to the local context, (4) the absence of laboratories being able to perform quality tests, and (5) the deficit in training of the professionals working in PV.

The setting up of the center here aim at offering fast, reliable, and affordable tests to assess the quality of PV modules. We are not aiming here at certifying modules but at verifying performance and compliance to minimal quality standards to ensure long-time performance in the

local environment. For that purpose, the selection of the tests (or test sequences) should correspond to the following criteria:

- Rapidity
- Simplicity
- Pertinence
- Suitability for the local context and needs
- Low-cost (equipment and operation)

2.2 Test selection and implementation

On this basis, the following tests were selected:

- Visual inspection
- Performance measurement at high and low irradiance (outdoor measurements under direct and diffuse sunlight)
- Dry and wet insulation
- Infrared (IR) imaging for hot-spot detection
- Electro-luminescence (EL) imaging with modified reflex camera for hidden defects (broken cells or connections)

All selected tests follow international standards/norms when applicable (such as IEC 61215 [1] or IEC 60904-1 [3]). As only c-Si modules are available on the local market and no provision has been so far taken to assess other technologies. Note here that the selection of the tests for the center is a subset of the IEC 61215 standards (see Fig. 1) with the addition of EL imaging.

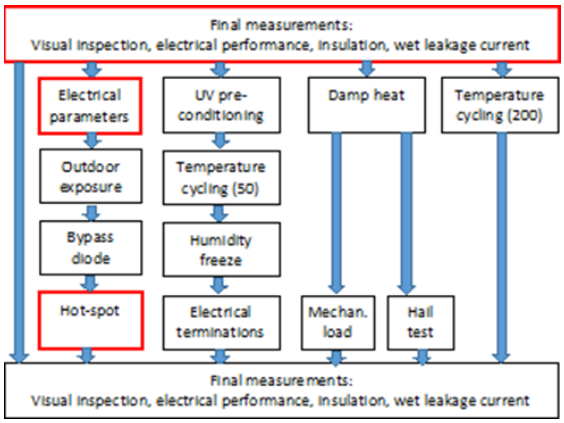

Figure 1: Test sequence for the IEC 61215 standard and selected test for the center in red.

Pass/fail criteria, and quality assessment are now been defined in accordance with the local context and needs. As observed during the analysis of new modules acquired on the local market (see section 3), such criteria should be adjusted to reject modules with severe defects or defects that will be detrimental for the lifetime while accepting ones with minor defects and reasonable performances.

The access to data from a large section of modules available on the local market from modules installed in PV systems, from feedback from installers or PV professionals active in the region, as well as from academic research projects conducted by ESP, we help refine minimal as well as recommended quality standards depending on the applications. Such quality standards will be reviewed regularly to push for the highest possible ones and guideline for the selection of modules will be provided. In the long term, data acquired by the center and related partners should also allow contributing to PV module reliability and lifetime assessment for climatic conditions specific to Sahelian or sub-Saharian regions.

2.3 Testing facility

The independent test center (Centre de test des systèmes solaires - CT2S) has been set up in Dakar with all equipment needed to perform the selected tests (see Section 2.2 and Figures 2 and 3). It was inaugurated on June 2019, and it is now ramping up its service offer. The creation and basic operation of the CT2S are financially supported by the Swiss REPIC platform [4]. Another project financed by the French investment firm Meridiam together with the CRDI (Canadian “Centre de Recherche et de Développement International”) is also financially supporting teaching and education of PV actors by ESP, research activities in PV (together with EPFL, ESP and CT2S) as well as the CT2S for its service offer.

The high insolation during most the year in Dakar permits to use outdoor conditions for the measurements of performance. Using calibrated reference cells and reliable modules temperature determination, operating condition performance measured with an IV tracer (Figure 2) can be converted to Standard Test Conditions (STC). This approach enables reliable performance assessment at an affordable cost.

IR imaging is performed using a commercial IR camera with a resolution of 640x480 pixels while EL imaging is carried out with a modified SLR consumer digital camera. Compared to industrial IR camera, this solution offers a much higher image resolution, unbeatable low-cost with a still acceptable (for lab testing) integration time. Images are acquired while modules are powered (in forward bias) with current values equal to short-circuit current. Figure 3 shows the IR and EL set-ups of CT2S.

Figure 2: Module performance measurements (outdoor) on the roof of the CT2S in Dakar.

Figure 3: EL and IR imaging systems.

Table 1 : STC performances of 3 PV modules as measured by CT2S, STC nominal values given by the manufacturers and observed differences.

Modules	STC performances	Pmax [W]	Voc [V]	Vmpp [V]	Impp [A]	Isc [A]	FF [%]
Module A: 72 cells, poly-Si	**Nominal**	**210**	**45.8**	**36.8**	**5.71**	**6.07**	**76**
	Measured	**154.8**	**42.6**	**32.2**	**4.80**	**5.52**	**66**
	Differences	**-29.3%**	**-7.0%**	**-2.2%**	**-15.9%**	**-0.3%**	**-13.2**
Module B: 60 cells, mono-Si	**Nominal**	**290**	**39.5**	**32.2**	**9.02**	**9.55**	**77**
	Measured	**268.9**	**37.3**	**30.4**	**8.85**	**8.73**	**75**
	Differences	**-7.3%**	**-5.5%**	**-5.7%**	**-1.9%**	**-8.6%**	**-2.6**
Module C: 60 cells, mono-Si	**Nominal**	**300**	**37.5**	**32.6**	**9.2**	**9.83**	**76**
	Measured	**275**	**37.4**	**30.3**	**9.08**	**9.71**	**76**
	Differences	**-8.3%**	**-6.3%**	**-7.1%**	**-1.3%**	**-1.2%**	**0**

3 RESULTS AND OBSERVATIONS

The CT2S just started to perform quality assessment for external customers. In this section, we present the analysis of 3 new Chinese modules acquired on the Senegalese market, which illustrate well the need for quality standards and quality testing. These modules comprise 2 mono-Si and 1 poly-Si modules with nominal performances between 200 and 300 W. The results presented in this contribution include measured STC performances and comparison with the nominal values given by the manufacturers (Table 1), EL images (Figure 4) for hidden defects and IR imaging (Figure 5) for hot-pot detection.

Visual inspection of all 3 modules did not reveal any particular defect that could affect performance or lifetime. STC power values are all below nominal ones and up to 30% lower for module A while being acceptable for

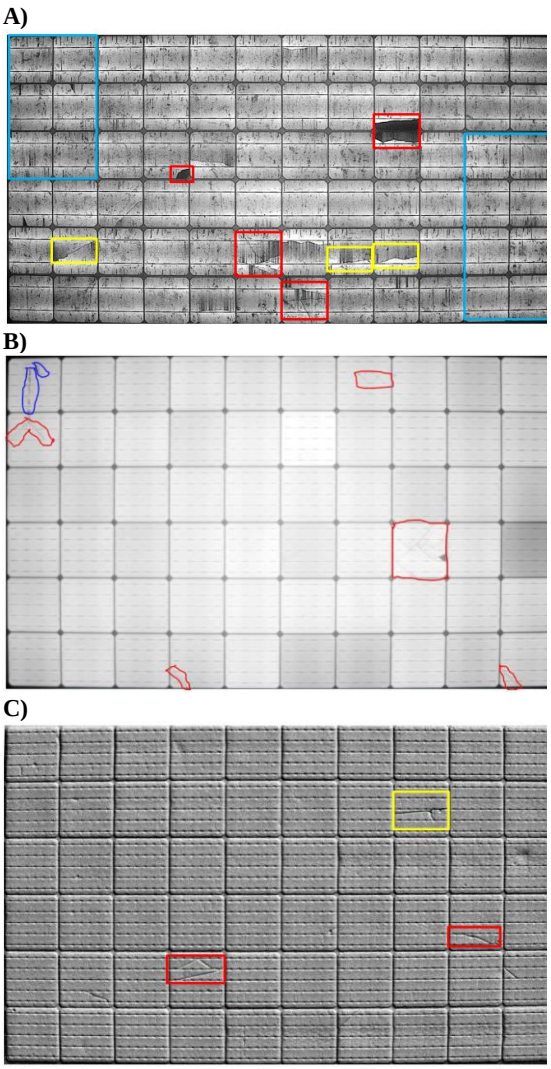

Figure 4: EL image of the 3 PV module. Manufacturing defects are indicated in blue, broken cells with detached pieces (or risks of detachment) in red and other broken cells in yellow.

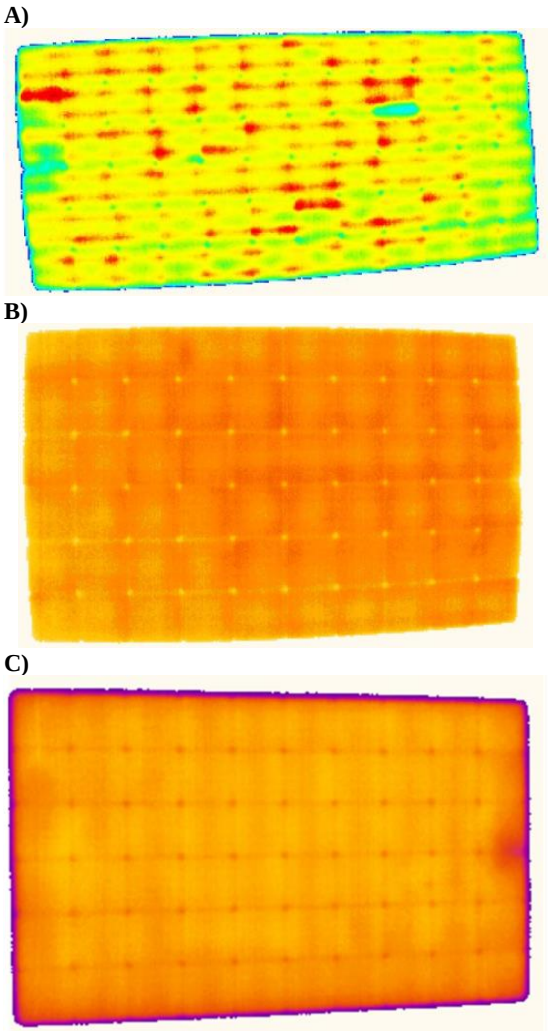

Figure 5: IR image of the 3 module. Module A (top) exhibit many hot spots while the others show none.

Module B and C (below 10%). All I(V) characteristics are found to be lower than the nominal ones.

EL images (see Figure 4) reveal defects in all modules, including broken cells and cell manufacturing defects. While we observe a large range of cell breakage severity (from fissures between the bus bars to fully detached and unconnected piece of cells), all modules exhibit breakage defects that could lead in the long term to a full detachment and a loss of power. Module A already includes such broken and unconnected pieces of cells, which explain the loss in performance compared to nominal values. It is not known if breakage occurs in the manufacturing phase, shipment of distribution of the modules. Module A and B also exhibit very irregular contact grid due probably due to poor control of the screen printing process of the fingers.

Because of the defects observed, module A also exhibits many hot spots while the other modules behave uniformly (no hot spots observed, see Figure 5).

4 CONCLUSIONS

In developing countries such as West African countries, promotion and sustainable diffusion of solar electricity cannot take place if adequate and adapted control mechanisms, and quality checks (at component and system level) are not set in place. It is observed that a significant number of new modules sold on these markets are already defective and do not perform as advertised. Furthermore, they contain several defects that could further reduce medium to long term performance and seriously affect system operation.

The center CT2S set up in Dakar can provide test services that can help select components with the highest level of quality to ensure the highest possible system lifetime and performance. With the opportunity to test a large and broad variety of products and to get field data and experiences from installed PV systems, the CT2S should also be able to contribute to research activities related to PV modules degradation and reliability and to be a valuable partner for the development of PV sector in Senegal and ECOWAS region.

Finally, the CT2S should act as a competence center for all actors in the PV chain, provide education to these actors and promote best practice for the design and installation of PV systems.

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