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Experimental evaluation of the discoloration effect on PV-modules performance drop.

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Abstract

The objective of this paper is to measure and evaluate the degradation impact on a photovoltaic (PV) module exposed for almost two years under Moroccan climate. This degradation is a discoloration spot observed above the module's junction box. For this purpose, the drop of the module's electrical performances has been firstly measured using the I-V tracer PVPM1000X and compared with the initial values given by the manufacturer. Afterwards, and in order to measure the direct effect of the detected discoloration on the power production, comparison between the outputs of the affected module and another one with the same characteristics (taken as reference) has been done. Results show that the module's degradation rate (from the initial state) is of 7.56 %/year. Moreover, the power difference between the affected modules and the one taken as reference was found to be of 13.2 watts in average. Generally, this difference is directly linked to the detected discoloration and it represents a power drop of 5.28% from the module's initial capacity.

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Keywords: photovoltaic; discoloration; performance; drop; crystalline silicon; outdoor exposition.

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Nomenclature

c-Si	Crystalline Silicon
m-Si	Monocrystalline Silicon
STC	Standard Test Conditions
A.M	Air Masse
GEP	Green Energy Park
Gd	Global degradation
Rd	Degradation rate
Pmax	Maximum output power
Imax	Maximum power point current
Vmax	Maximum power point voltage
Isc	Short-circuit current
Voc	Open-circuit voltage
FF	Fill Factor

1. Introduction

For a better integration and bankability of photovoltaic (PV) power plants, investors need clear warranties about the production as well as the lifetime of the plant components, mainly, the PV modules. Indeed, to be competitive in the electrical market, a PV power plant needs to operate with high performance for at least twenty-five years [21]. Even though arid regions -like Morocco- are known with their high solar irradiation records and capacity to host solar power plants [23-27], the presence of the harsh atmosphere affects not only the electrical output but the durability of the modules as well [1,2]. Accordingly, it's important to test the reliability and lifetime of any system before its installations in such conditions [3].

Degradation is the most important issue in long-term performance and reliability assessments for PV modules. It can be defined as a gradual deterioration of the electrical and thermal characteristics of the PV module; which affects its ability to operate within the limits of acceptability criteria and it's caused by the operating conditions [4]. From the early 1970s scientists start working on this issue and various researches linking the degradation to the financial risk have been published [5]. According to Vázquez [6], manufacturers take 20% of below the PV module initial power as threshold of degradation. This degradation is due to different mechanisms and factors. However, the most reported ones are temperature cycling, humidity, water ingress and the UV light. According to the National Renewable Energy Laboratory (NREL) [7], each one of those parameters is responsible for the generation of one or more degradation forms at the module components. In this respect, corrosion is mostly related to moisture ingress through the laminate edges, the front or the back side of the Encapsulant [8]. Delamination, which is one of the most prevalent field failure modes, appears at the encapsulating polymers level and it can be accompanied by corrosion at the cell's metallization or interconnect ribbons [9]. Discoloration is another degradation type usually reported as a colour change of the ethylene vinyl acetate (EVA) between the glass and the cells that turns to yellow and sometimes brown. This phenomenon causes a loss of the generated power due to reduction of the optical transmittance and sunlight reaching the cell, thus, the photo-generated current inside the module [10,11]. According to Oreski [12] the main reasons for the EVA's degradation are the UV rays the water penetration and the temperature values higher than 50 °C. Kuitche et al. [21] mentioned that solder bond failure and discoloration are the two dominant failure modes for hot and dry climates. Breakages and cracks of the modules during transportation and installation are also considered as a type of degradation [13,14]. Quintana [5] claims that broken modules are more susceptible to other degradation modes such as corrosion and delamination. Another famous degradation mechanisms for PV modules is the hot spots. A module hot spot is a very high temperature area that happens due to partial shadowing, cells mismatch or failures in the interconnection between cells [15].