Accelerated UV test for silicon photovoltaic modules

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Abstract

Humidity, heat and ultraviolet (UV) exposure are the main factors impacting the constitutive materials of photovoltaic modules inducing optical and electrical losses. An accelerated UV test was executed on commercial monocrystalline silicon (c-Si) and polycrystalline silicon (p-Si) mini-modules to analyze their functional properties and the involved aging mechanisms. The power conversion efficiency of c-Si solar cells of Module-1 (Mod-1) and Module-2 (Mod-2) in terms of fill factor (FF) calculated by comparing the maximum power to the theoretical power was reduced by 3.41% and 3.74% respectively from 0 to 400 kWh/m^2 UV dose due to photobleaching of encapsulant inducing a decrease in both the short-circuit current (I_{sc}) and the open-circuit voltage (V_{oc}), an increase in the series resistance (R_s) and a diminution in the parallel resistance (R_{sh}). Moreover, the FF of p-Si solar cells of Module-3 (Mod-3) and Module-4 (Mod-4) was reduced by 4.40% and 3.01% respectively from 0 to 400 kWh/m^2 of UV dose because of a decrease in I_{sc} and an increase in V_{oc} owing to a narrowing of the band gap of the semiconductor material and also to enhanced electron generation at the p-n junction at high temperature. On the basis of a UV dose equivalent to outdoor exposure, monocrystalline silicon Mod-1 and Mod-2 would exhibit an annual power degradation rate of 1.3% and 2.2% respectively whereas the polycrystalline silicon Mod-3 and Mod-4 would have power degradation rates inferior to 0.5% per year. These outcomes are in fair agreement with outer field degradation results acquired for different locations with hot temperate and desert climates. Therefore, the operating of polycrystalline solar modules in such environments would be expected to be more reliable with a lifetime of 20-25 years.

Keywords:
Crystalline-Si modules, UV illumination, Photobleaching, Degradation, Fill factor, Maximum power