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Technical note

Evaluation of performance parameters of PV modules deployed outdoors

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Abstract

This paper evaluates the performance parameters of five photovoltaic (PV) modules comprising crystalline silicon, multi-crystalline silicon and edge-defined film-fed growth (EFG) silicon technologies. This evaluation was accomplished by measuring and analysing the modules' performances during initial, intermediate and final stages of a 17-month test period. The effect of temperature and irradiance on the performance parameters was investigated. Results obtained indicate that some modules exhibited shunting behaviour and that the EFG silicon module experienced moisture ingress, which in part, resulted in 14% performance degradation. An analysis of the results revealed that the moisture ingress effectively reduced the active module area, resulting in reduced photon absorption, consequently reducing the electron-hole generation as indicated by the reduced short-circuit current. In addition, the EFG-Si module's shunt resistance appeared to decrease over the test period. The rest of the modules showed relatively stable performance, information that is crucial to the system designer and consumer.

Keywords: Photovoltaic modules; Current–voltage characteristics; Performance monitoring; *I–V* Monitoring system; Operational efficiency

1. Introduction

Photovoltaic (PV) modules have, over the years, come to be renowned for their reliability. However, some modules do degrade or even fail when deployed outdoors for

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extended periods of time, especially when the conditions are severe. The causes of degradation may be due to factors such as thermal cycling, ultra-violet absorption, loss of adhesion and moisture ingress [1]. In order to assess PV module performance, complete performance evaluation, both indoor and outdoor, is necessary.

In this study we evaluated the performance of seven silicon based PV modules that were deployed outdoors for over a year and were periodically characterised indoors using standardised techniques [2,3]. The modules used in this study had different field ages and had been used for various experiments in the past. In this paper we present an analysis of the power output characteristics of five of the modules measured during the baseline (initial), intermediate and final stages of outdoor exposure, and also discuss degradation that we observe.

2. Indoor assessment procedure

Prior to outdoor deployment at the Outdoor Research Facility at the University of Port Elizabeth, the modules were fully characterised in order to obtain a set of baseline data for future reference. These measurements were based on an assessment procedure that we use in our laboratories in Ref. [4]. The assessment procedure we used in this study is summarised in Table 1. The aim of these measurements was to determine any visual defects, and to characterise the modules with respect to power output and other performance parameters. This was conducted in conjunction with continuous monitoring [5] of the modules' performance while deployed outdoors. We also determined the temperature coefficients of the performance parameters and investigated the influence of irradiance on efficiency. The latter being an important measure of the presence of shunt paths, which are particularly detrimental to module performance under low irradiance [6]. The assessment procedure was carried out periodically in order to determine any change in module performance due to the outdoor exposure.

In this paper we evaluate the performance of five PV modules, comprising two crystalline silicon (c-Si) modules, two multi-crystalline (mc-Si) modules and one edge-defined film-fed growth silicon (EFG-Si) module. Table 2 lists the performance parameters of these modules.

3. Results and discussion

The initial STC parameters, short-circuit current (I_{sc}), open-circuit voltage (V_{oc}), maximum power (P_{max}), fill factor (FF), and aperture area efficiency (η) are shown in

Table 1
Indoor assessment procedures conducted on modules evaluated

Assessment	Objective
Visual inspection	Inspect module imperfections
STC *I–V* curves	Test electrical performance
Temperature dependence	Determine coefficients
Irradiance measurements	Evaluate cell shunting characteristics and performance at low irradiance