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Reliability of photovoltaic systems using seasonal mission profiles and the FIDES methodology☆

Susana de Leon, Hugo Calleja *, Jesus Mina

National center for research and development of technology, Electronics department, Interior Internado Palmira s/n, Cuernavaca, Morelos, C.P. 62490, Mexico

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ABSTRACT

In areas with hot weather, photovoltaic systems can be used to help relieve the peak demand caused by air conditioning equipment. Users, however, are reluctant to invest in solar technology, arguing that the equipment commercially available is unreliable because it was developed for others environments. In this paper, the reliability assessment of a DC/DC converter aimed at PV applications is presented. The reliability estimation was performed following the FIDES methodology, taking into account seasonal mission profiles developed for five specific sites for which there is meteorological data available. The goal was to identify the most failure prone components, and the dominant stress factors. It was found that the smallest contribution to the failure rate occurs during winter. The largest contribution occurs in spring or summer, depending on the site. In the converter, the most failure-prone components were the diodes, which contributed with about 70% of the overall failure rate.

1. Introduction

Currently, there are efforts under way aimed at fostering the widespread installation of photovoltaic (PV) systems in Mexico. The goal is to help relieve the power demand caused by air conditioning equipment. Many potential users, however, are reluctant to invest in solar technology because there is a perception that PV systems are unreliable, a common remark being that they were developed with other environments in mind.

One of the major requirements of probabilistic design for reliability is that "Design efforts should be specific for a product, and their most likely actual or anticipated applications" [1,2]. In the case of photovoltaic systems, this might be a difficult requirement to comply with because, at a daily basis, the power circuit operating point evolves from minimum load up to a maximum, and then back to minimum. Further, they are often installed outdoors, subject to daily and seasonal weather variations. As a result, efficiency, reliability, and other performance parameters of PV systems depend on the installation site [3–5].

The power electronics converter is usually the most failure-prone assembly [6–8]. It has been found that the dominant deterioration mechanism in semiconductor devices is usually linked to effects such as long-term exposure to high temperatures and thermal cycling, which produces thermo-mechanical stresses due to the difference in expansion coefficients [9–12]. These mechanisms depends both on environmental and operation conditions [13].

Design efforts should be oriented in such a way that the converter operational life is lengthened. These efforts usually require an assessment of the reliability taking into account, as much as possible, realistic information about the installation site. There are several options available for the assessment [14]. The procedure described in the Military Handbook 217F [15] has been widely used to predict the reliability of components in power electronics converters [16–18]. A drawback of this approach (and other that share the same philosophy), however, is that they rely on statistical data collected throughout the years. Therefore, reliability predictions are biased by data that applies to old components, often yielding over-pessimistic estimation [19]. A better approach that explicitly takes into account the mission profile is the FIDES methodology [20–23]. It has been found that this method yields results that match field data with an acceptable deviation [24].

It has already been shown that thermal stresses, and therefore contributions to the overall failure rate, are rather small at low irradiance levels [25]. The results reported, however, assumed a yearly mission profile, and did not take into account seasonal changes of irradiance, temperature and humidity. In this paper, the analysis is taken one step further, to include seasonal variations. The assessment of the reliability of a DC/DC converter aimed at a photovoltaic system, using seasonal mission profiles is described herein. Reliability is estimated following the FIDES methodology. Several sites were selected for the assessment. The results were compared to identify seasonal trends. The southernmost latitude considered is N 15.67°, and the northernmost is N 32.63°. The most failure-prone components within the converter were also identified. The ultimate goal is to provide manufacturers with reliability information that can be helpful in developing more robust systems.

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* Corresponding author.

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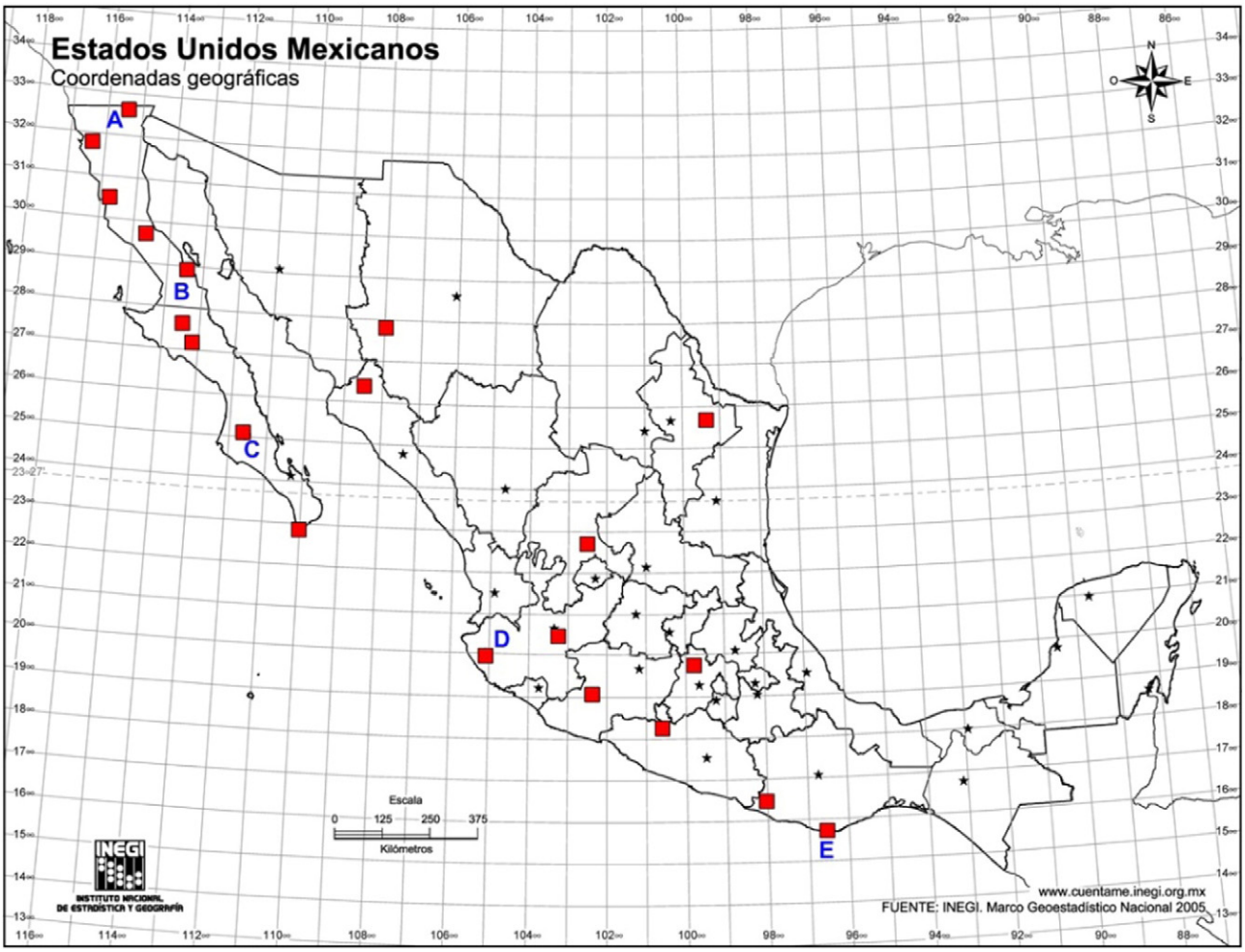

Fig. 1. Test sites.

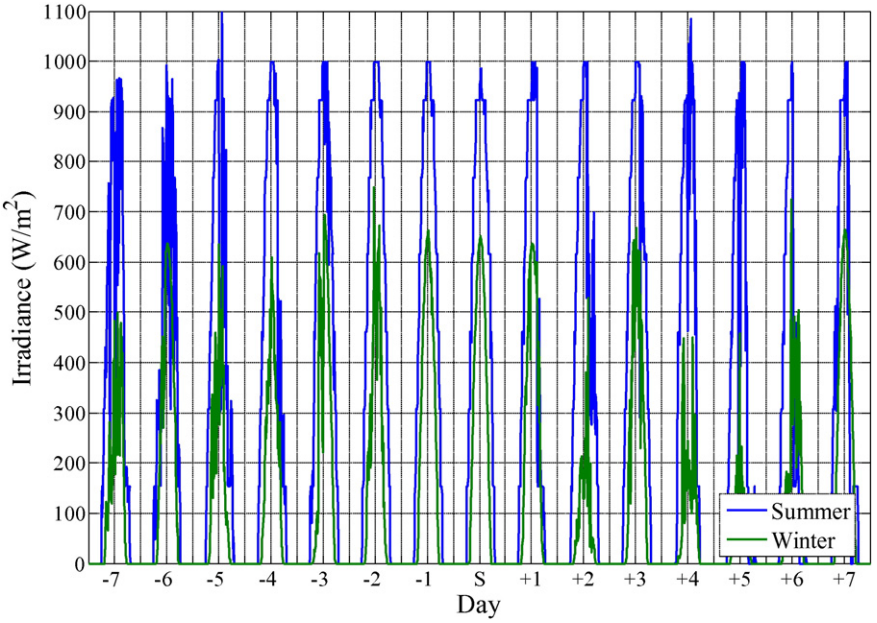

Fig. 2. Site E: daily irradiance around summer and winter solstices.