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# Amorphous silicon thin-film: Behaviour of light-induced degradation

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ABSTRACT

This paper aims to investigate and emphasize the importance of the grid-connected PV system regarding with the complex nature of thin-film PV technology behaviours. The investigation was critically reviewed the literature on the potential problems associated with the responses of metastable behaviour and developed a new technique in determining the stabilization period under outdoor exposure. According to the literature survey, the importance issues such as the performance and reliability of the thin-film PV technology using grid-connected systems have fairly good performance, although the amount rate as well as process of stabilization period of light-induced degradation (LID) generally depended on the type of thin-film PV technology chosen. This study will lead to the identification of light-induced degradation mechanisms by viewing and summarizing the potential impact on this behaviour, which makes it difficult to obtain reliable and robust for PV system applications.



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*Abbreviations:* LID, light-induced degradation; SWE, Staebler–Wronski effect; SUPSI-ISSAC, Scuola Universitaria Professionale della Svizzera Italiana—Istituto di Sostenibilità Applicata all'Ambiente Costruito; PVUSA, Test Facility Photovoltaics for Utility Scale Applications; MUERI, Murdoch University Energy Research and Innovation Group; ORF, Outdoor Research Facility; UFSC, Universidade Federal de Santa Catarina; ISE, Institute for Solar Energy Systems; FPC, Florida Power Corporation; FSEC, Florida Solar Energy Center; SNL, Sandia National Laboratories; ASU-PTL, Photovoltaic Testing Laboratory at Arizona State University; NREL, National Renewable Energy Laboratory; CIEMAT, Energetic, Environmental and Technologic Researches Centre; SMUD, Sacrament Municipal Utility District; RERC, Renewable Energy Research Centre; CREST, Centre for Renewable Energy Systems Technology; RAEEC, Rokko Advanced Energy Experiment Center; IEC, International Electrotechnical Commission; IEA, International Energy Agency; STC, Standard test conditions, 1000 W/m$^2$, 25 °C module temperature and AM 1.5 spectral distribution; a-Si, amorphous-Silicon; a-Si:H, hydrogenated amorphous-silicon

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## 1. Note

Thin-film photovoltaic (TFPV) technology has numerous advantages that make it very attractive for various applications based on the unique characteristics of low temperature coefficient, high energy producers, and the low quantity usage in silicon as raw material, low-cost manufacturing process, the diversity in terms of flexibility in product design and environmental friendly, which is non-toxic pollution.

However, several weaknesses and challenges in TFPV technology have been constantly discussed as in the material properties of the lowest in module conversion efficiency, the unique nature of the instability phenomenon called light-induced degradation and long-term technological risks in the field performance in terms of durability when compared with the crystalline technology, which has been proven in the historical reliability of the extended field performance.

However, two major technical challenges in solar PV technology have been constantly discussed are performance and reliability because of the potential that has not been fully utilized.

## 2. Introduction

Since the last 35 years and until today there is no general solution encountered by TFPV technology. The most challenging problems associated with one of the major drawbacks in hydrogenated amorphous silicon (a-Si:H). It has been shown by the nature of the disorder and the poor stability of its material in terms of electrical performance degradation, primarily due to the weak mechanism called light-induced degradation (LID). As reported in the first time, LID phenomenon changes in the a-Si's properties and could be referred to as Staebler–Wronski (S–W) effect after being spotted by D. L. Staebler and C. R. Wronski in 1977. The S–W effect was reported by them in [81,82]; it consists of "LID phenomenon" where it has undergone great changes in the dark conductivity and photoconductivity after a long light exposure and "thermal annealing phenomenon" occurs when an elevated temperature at or above 150 °C, where the reversible process occurs because of the hydrogen atoms will return to its original position.

Characteristically, this nature behavior usually tends to be gradually decreases until it stabilized at certain amount within their nameplate power rating by approximately 10–30% during the initial phase of outdoor exposure. For the first time of outdoor exposure, it have shown a fairly rapid decrease and followed by steady and consistent performances at the certain of period depend on the climatic conditions in a particular location, i.e. local geographic and climate history of exposure effects [3,4].

The majority of studies on TFPV technology in developed countries, notably under cold climates [1–3], claimed that the metastable behaviour behaves differently according to local geography and climatic conditions. In response to this, the metastable behaviour of LID phenomenon should be taken into account during sizing stage, in the purpose of preventing the dynamic behaviour from damaging the overall system. Additionally, it may be useful to allow the cooling process and minimum stress on the components of the inverter during operation, especially high ambient temperatures in the lower latitude areas. Although the manufacturers of DuPont Apollo, Sharp Electronics and BP Solarex suggested that the needs to pay extra attention in terms of system design considerations on their products [4–6], several studies still having the problem of power clipping on their designed system [7–9].

For TFPV technology, stability remains a primary issue, and most of the LID mechanisms have been discussed and still persists as a fundamental problem for use of TFPV technology in the PV outdoor applications. Surprisingly, the different climates have played an important influence on the intensity of LID phenomenon. This paper attempts to bridge this gap by empirically analyzing and summarizing associated with the LID phenomenon on TFPV technology in terms of the TFPV manufacturer datasheets and third-party publications. It contains framework related to TFPV technology with systematically reviewed by collecting and dividing third-party publication into five major different climates based on Köppen–Geiger climate classification around globe. The digital world map for Köppen–Geiger climate classification is available online for free at [10]. By dividing the different climatic zones based on the Köppen–Geiger climate classification, it can be assisted as an input in formulating the current issue of worldwide research regarding with TFPV technology's response. Hence, the multiple studies of light-induced degradation (LID) phenomenon consequences from a variety of geographical locations will be potential to be a great of interest in one of the solutions in understanding this unique phenomenon.

Surprisingly, many empirical studies have focused on the local real impact. In this study, it will focus on the impact of regional and worldwide comparative about LID phenomenon, and it could given the lack of study, especially at the local level has been absent.

### 2.1. Objective

The major objectives of this work are:

(1) Survey and summary on the TFPV manufacturer datasheet and empirical works related to LID phenomenon around the globe by dividing into a climatic zone region based on Köppen–Geiger climate classification.
(2) Propose a new technique to determine meta-stability behaviour of light-induced degradation process towards a stabilization period under field-work conditions in terms of data transition of power lines between the predicted DC power outputs based on the initial/stabilized data values as a benchmark.
(3) Validate the stabilization period in the outdoor exposure for amorphous-silicon single-junction thin-film PV technology under Malaysian climate and compare with the summarized results based on third-party publication.

## 3. Review of the literature

First, a brief context of the several situation of this complex nature of LID Phenomenon from different climates has been discussed in this section.