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Ageing and degradation in solar photovoltaic modules installed in northern Ghana

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ABSTRACT

Understanding field failure and degradation modes in solar photovoltaic (PV) modules is important for various actors along the value chain. This paper presents results from field studies on performance degradation in twenty-two mono-crystalline silicon modules exposed for 16 years in three communities in the northern part of Ghana, prior to electricity grid extension. The results show, that, maximum power of the modules (P_{max}) had declined by 18.2–38.8% (median – 24.6%) over the period, which translates to an annual linear degradation rate of 1.54%. The losses in module power output are dominated by losses in short-circuit current (I_{sc}) and fill factor (FF), which are 0.75%/year and 0.54%/year respectively (median values). Discolouration of the encapsulant and degradation of the junction-box adhesive were the most frequently occurring visually observable defects on the modules.

1. Introduction

Solar photovoltaic (PV) technology has become a mainstream technology, characterized by phenomenal and sustained growth for well over a decade, with cumulative global installed capacity reaching 402 GW by end of 2017 (REN21, 2018). In 2017, the annual installed capacity was almost 100 GW, which constitutes almost a quarter of this cumulative capacity (REN21, 2018; Schmela, 2017). The importance of the technology takes on added significance as the world pursues low-carbon development pathways through initiatives such as the sustainable energy for all (SEforALL) and the adoption of the sustainable development goals (SEforALL, 2018). In Africa, where access to electricity remains low, solar PV is once again widely acknowledged as one of the important technologies that can help in addressing the crucial problems of energy poverty, particularly with the deployment of solar home systems and mini-grids (Quansah et al., 2016). Peculiar features of solar PV, such as modularity and short deployment lead times, makes it a well-suited technology, as the challenges of energy access and climate goals have taken on renewed urgency.

Ghana currently has one of the highest rates of access to electricity in sub-Saharan Africa (80% (World Bank Group, 2016)) and seeks to attain universal electrification by 2020 - 10 years ahead of the SE4ALL target year of 2030. The medium-to-long-term plans of the country emphasize an important role for renewables in general and solar PV in particular. To give further push to its quest to harness the potential of solar energy, Ghana recently ratified its membership of the newly-formed International Solar Alliance, which was conceived at the COP21 Paris climate conference in 2015 (Government of Ghana, 2018).

Deployment of solar PV systems require investment and sound investment decisions in turn depend on the availability of reliable information regarding risk-return profiles. Understanding and minimizing technology risks associated with PV investments underpin the need for ongoing studies on operational performance and reliability of field-deployed systems. Indeed, such data is important to various actors along the solar PV value-chain; from institutions involved in basic research to those that are engaged in project development, system integration, field deployment and operations and maintenance (O&M) services (Quansah and Adaramola, 2018).

Globally, investments in solar PV have been rising, increasing from $11bn in 2004 to $160bn in 2017, with cumulative annual growth rate of 23% (Frankfurt School-UNEP Centre/BNEF, 2018). Along with this, is the increased interest in monitoring, acquisition and interpretation of operational data on fielded modules and from testbeds managed by many National Laboratories and other Research Institutes. For example, Osterwald et al. (2006) in 2005 conducted a review in which they identified only 10 studies that had researched the subject of

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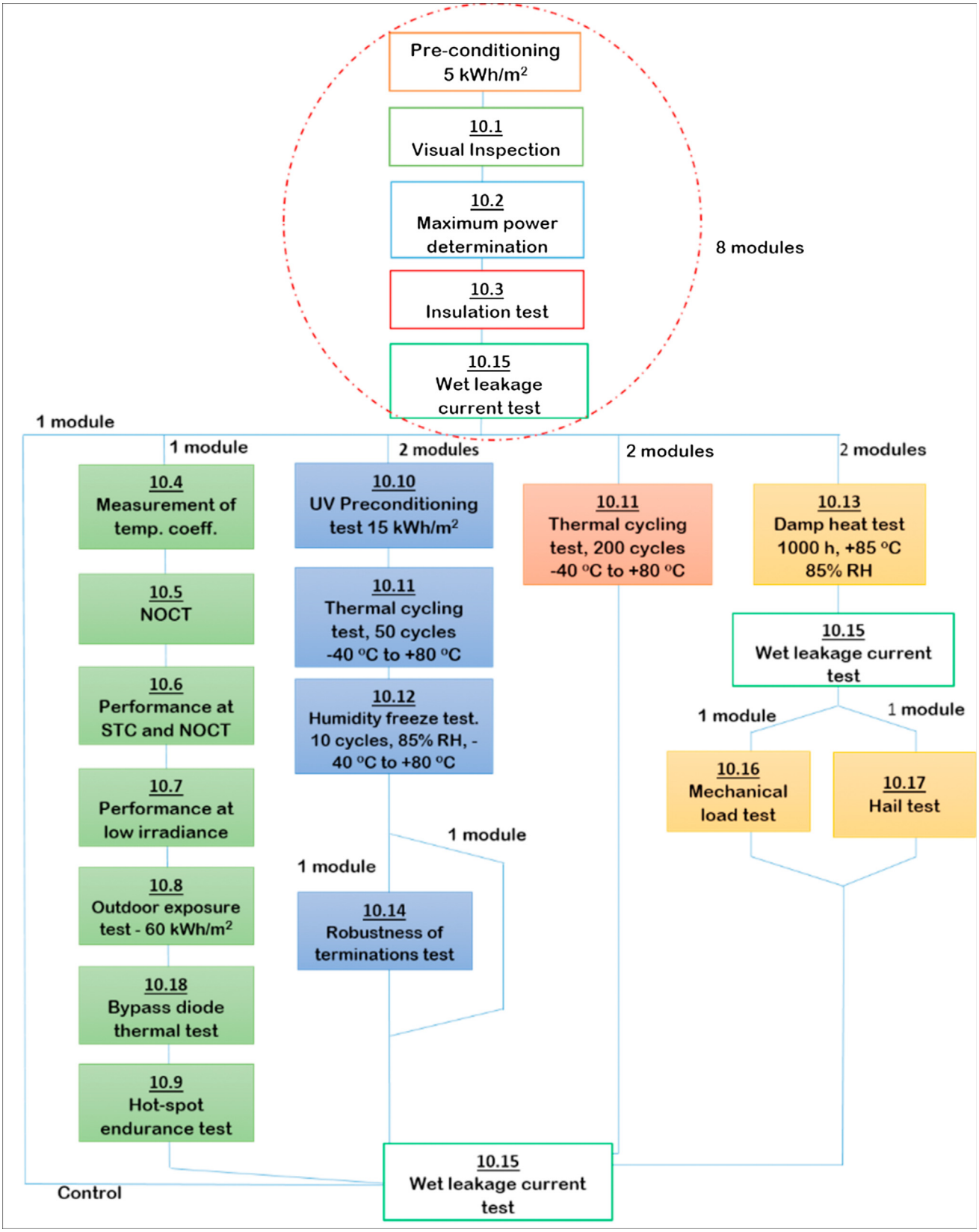

Fig. 1. IEC 61215 test series. Adapted from Arndt and Puto (2009).

photovoltaic performance degradation. By 2016 (after a decade), Jordan et al. (2016) reviewed almost 200 studies reporting more than 11,000 degradation rates from 40 countries. These meta-studies (Jordan et al., 2016; Jordan and Kurtz, 2013) have also highlighted the geographical imbalance of available data and made a case for an expanded representation of high-quality data on field performance and degradation of solar photovoltaic modules. Currently, the IEC 61215 qualification test series (Fig. 1) is widely accepted by market actors as a