Light and Elevated Temperature Induced Degradation (LeTID) Testing Method and Procedures for c-Si Photovoltaic (PV) Modules

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ABSTRACT –This work presents a testing method of light and elevated temperature induced degradation (LeTID) for crystalline silicon (c-Si) photovoltaic (PV) modules. The effect of different injected current to PV modules in the LeTID test was investigated. Dark voltage monitoring technology is applied in the test to record the degradation/regeneration trend during the LeTID, which can be used to accurately assess the LeTID state of PV modules. Based on the LeTID testing data and related simulation, the energy yield and degradation of the PV module regarding to the LeTID can be estimated with the environmental data.

Keywords – LeTID, PERC, Dark voltage, Degradation Simulation, Energy Yield.

1. INTRODUCTION

By the end of 2018, the market share of crystalline silicon (c-Si) technology in the photovoltaic (PV) market has reached more than 95% [1]. However, the outdoor performance and energy yield of c-Si PV modules, especially with multi-crystalline silicon (mc-Si) solar cells and passivated emitter and rear cells (PERC), are easily affected by light induced degradation (LID) and light and elevated temperature induced degradation (LeTID). LID is a well-known effect caused by the boron-oxygen (BO) defect, which would cause the degradation of the PV modules during the early operation. Different with LID, LeTID occurs at elevated temperatures > 50°C under illumination, whose mechanisms are not clear and probably caused by ionic hydrogen related defects. Both LID and LeTID have the degradation and regeneration (D&R) process, but the period of LeTID D&R process is much longer than that of LID, which would take hundreds to thousands of hours to be completed [2]. Thus, considering the test costs involved, testing of LeTID cannot be performed employing a light soaking method on a full module level, as it is the case for LID. An early version of the IEC 61215 draft described a method for LeTID testing which used current injection to PV modules in a dark environment at 75°C and periodic power measurements to detect the D&R phase and the LeTID degradation rate. Using the LeTID test method in IEC draft, significant degradation of up to 6% can be detected after 600 hours of laboratory testing. Due to the long testing period that is necessary following the procedure specified in the IEC draft, a method to accelerate the process for characterization the LeTID was deemed necessary. In this work, a new LeTID testing method was developed, which applies 2 times current injection of that in the IEC draft to the module to fasten the testing period down to less

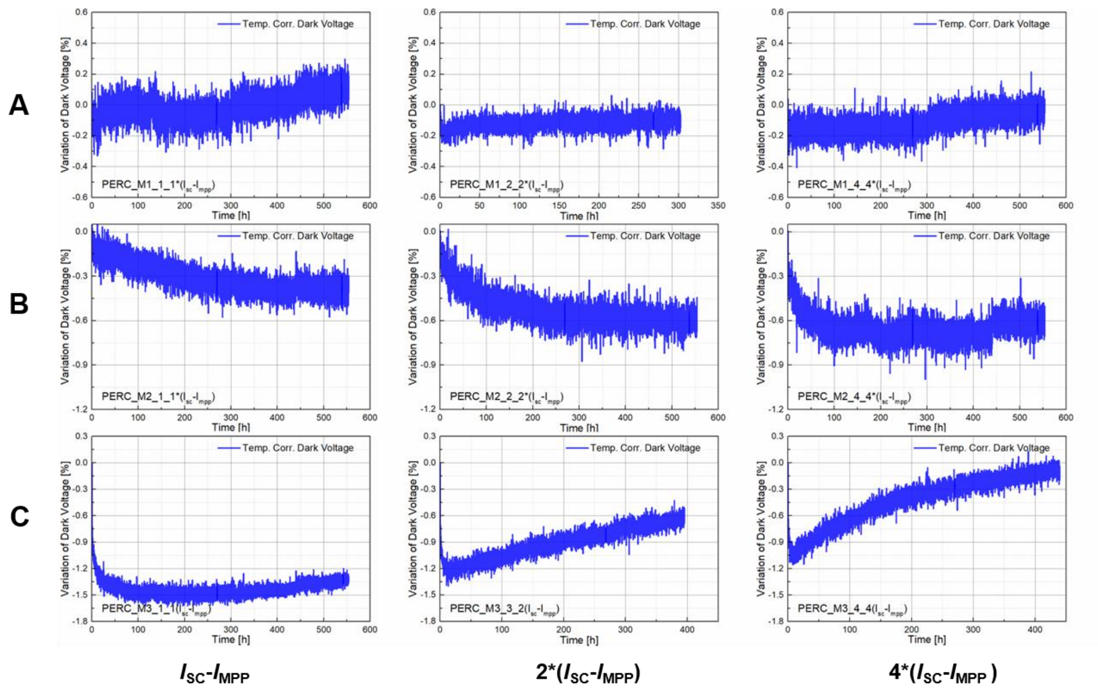

Fig.1. The variation of dark voltage of three types of PERC PV-modules (A, B and C) with three-level of injected current (I_{sc}-I_{mpp}, 2×(I_{sc}-I_{mpp}) and 4×(I_{sc}-I_{mpp})).

Table I. Comparison of LeTID test methods

	TÜV Rheinland method	IEC 61215 draft test method
Applied current	$2\times(I_{SC}-I_{MPP})$	$I_{SC}-I_{MPP}$
Temperature	75 ± 3 °C	
Duration	Max. of 300 hours or when the samples are in the fully degraded condition, whichever comes first	162 hours each cycle; Min. of 2 cycles x 162 until the difference in P_{MAX} between 2 cycles is less than 1%
Synchronized monitoring	Dark voltage monitoring during LeTID to avoid frequent taking in/out of samples, which might further affect LeTID testing	None
Power output measurement	Initial and final P_{MAX} measurement	Interim P_{MAX} measurement every cycle
Evaluation	$P_{\text{final n}} \geq 0{,}95 \times P_{\text{initial n}} \times \left(1-\frac{r[\%]}{100}\right)$ If the inequality is not satisfied, the PV modules are deemed LeTID-sensitive	

than 300 hours, and employs a dark voltage monitoring method to accurately assess when modules have entered the regeneration phase. The testing and simulation results show that recommended method can effectively assess the sensitivity to LeTID for different kinds of PV modules. Furthermore, the measurement results can provide useful input when predicting of the energy yield of PV-modules in the field due to LeTID.

2. EXPERIMENT AND TESTING METHOD

Different types of PERC and mc-Si PV modules from different PV manufactures were adopted in the test. Since LeTID has two phases of degradation and regeneration, it is challenging to assess in which phase the PV module is even with the periodic power testing. Thus, the in-site dark voltage monitoring technology is applied to monitor the degradation trend during LeTID testing. In Fig.1, the variation of monitored dark voltage of different types of PERC PV-modules with three-level injected current are shown. Although the PV modules in Fig.1 are all PERC modules, different production processes still lead to different LeTID behaviors; However, higher injected current would speed up the LeTID test for all modules. Using simultaneous power measurements it was shown that dark voltage monitoring can be used to accurately assess when PV-modules have entered the regeneration phase. With dark voltage monitoring, only power measurements before and after the test are required to calculate the LeTID degradation rate, which simplifies the testing process, but also helps avoid sample metastability caused by the interruption of tests for intermediate power measurements. The levels of injected current are crucial for this test. Too high currents can lead to fast regeneration that cancels out some of the degradation seen. According to our test results, a new LeTID method was developed. Key differences of the new method to the method described in the IEC 61215 draft are shown in Table I.

3. MODELLING APPROACH AND RESULTS

A simulation of LeTID was carried out using a four-state model [2,3] as shown in Fig.2. Based on the monitored dark voltage, the energy yield and degradation of the PV-module in the field due to LeTID can be modelled using environmental data. Fig. 4 shows the

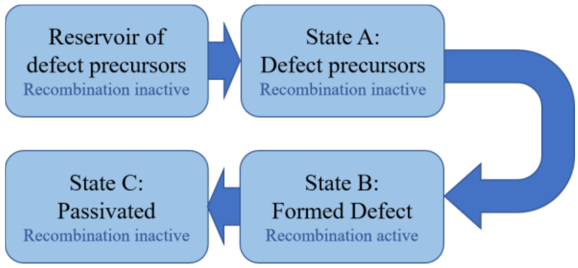

Fig.2. Proposed model for LeTID degradation and regeneration employed in simulations.

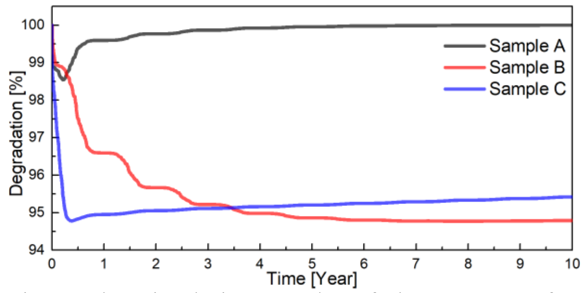

Fig.3. The simulation results of three types of PV modules based on the environment data of Beijing.

simulation results of three types of PV modules based on the environment data of Beijing. Results show that the field equivalent test time strongly depends on the sample technology and climate, which may vary between 2 months to 10 years in a field and would capture 60-110% of the degradation manifesting in a field.

4. CONCLUSION

This work proposes a new LeTID testing method. With dark voltage monitoring, only power measurements before and after the test are required to calculate the LeTID degradation rate, which simplifies the testing process, but also helps avoid sample metastability caused by the interruption of tests for intermediate power measurements. Furthermore, based on the monitored dark voltage, the energy yield and degradation of the PV-module in the field due to LeTID can be modelled using environmental data. Results show that the field equivalent test time strongly depends on the sample technology and climate, which may vary between 2 months to 10 years in a field and would capture 60-110% of the degradation manifesting in a field. This work provides a time-saving, lower-cost and more accurate LeTID testing method, which would help evaluate the impact of LeTID on the long-term performance of PV-modules.

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