Investigation of the Influence of the Dynamic Mechanical Loads on the Crystalline Structure of Photovoltaic Cells

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Abstract. *The efficiency of modern photovoltaic systems is strongly reduced when the crystalline structure of the solar cells is being damaged due to extensive mechanical stress caused by climatic factors such as heavy wind or snow. In this work the measurement and experimental setup has been applied to produce dynamic mechanical loads in order to simulate various weather conditions and investigate the reliability of the solar panels when they are subjected to stress. During experiments the solar panels have been treated up to 20 Hz vibrations with the maximum magnitude of the shift of the solar panel in the range of 0 - 0.3 mm. The acquired experimental data using electroluminescence setup showed appearance of micro fractures in the crystalline structure of the photovoltaic modules.*

Keywords: Solar Cells, Degradation, Measurement of Mechanical Stress, Reliability, Climatic Stress Simulation

1. Introduction

Reliability is a crucial parameter of photovoltaic systems and there are a number of standards covering the maximum allowed performance reductions influenced by heavy mechanical stress [1, 2]. During heavy mechanical loads the crystalline structure of the photovoltaic modules is damaged and the micro fractures appear, which negatively affect the conversion effectiveness of the energy of light into electricity and stimulates further degradation of the module [3]. In order to meet the standards and estimate the degradation ratio the measurement setup must be developed, which could allow accurate prediction and accumulation of statistical data of the solar cell performance in harsh weather conditions and under heavy dynamic mechanical loads. The area of research is new and still lacks accurate statistical and experimental data of mechanical stress influence on the appearance of micro cracks in the photovoltaic modules. In this work a computer controlled vibrational stand and an array of 3-axis mechanical stress evaluating sensors has been applied in order to investigate the influence of dynamic mechanical loads on the crystalline structure of a typical solar cell.

2. Subject and Methods

As it was mentioned above in order to simulate the mechanical stress the photovoltaic module might be experiencing in the real weather conditions a vibrational stand has been used. The alteration of the magnitude and the frequency of the vibrations allows to simulate dynamic mechanical stress due to burst of heavy wind the photovoltaic modules may be experiencing. In the experimental setup the solar panel has been attached to the shaker and the arrays of 3-axis mechanical stress sensors have been applied to the solar panel corners, the back plate, the middle point and the shaker itself. The block diagram of the resultant dynamic mechanical load generating facility is shown in Fig. 1. The position and the quantity of sensors that are shown in the block diagram do not scale with the prototype facility and are shown for schematic purposes. The simultaneous data acquisition, the control of the frequency and the magnitude of the vibrations have been performed and monitored using a computerized setup.

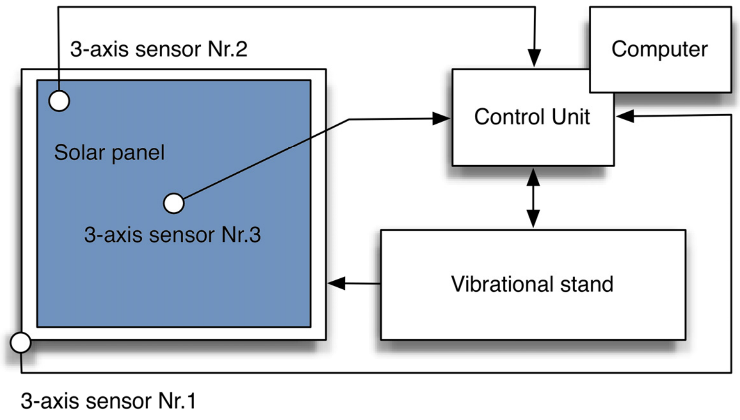

Fig. 1. The block diagram of the dynamic mechanical load generating facility

During experiments the magnitude and the frequency of the vibrations have been altered in the range of 0 – 0.3 mm and 0 – 20 Hz, respectively. The ranges have been selected in accordance to meet the goal of accurate simulation of real weather conditions when short bursts of heavy wind are possible. The maximal values of the parameters were limited by the maximum output characteristics of the shaker. The resultant displacement spectrum in the middle point of the solar panel is shown in the Fig. 2.

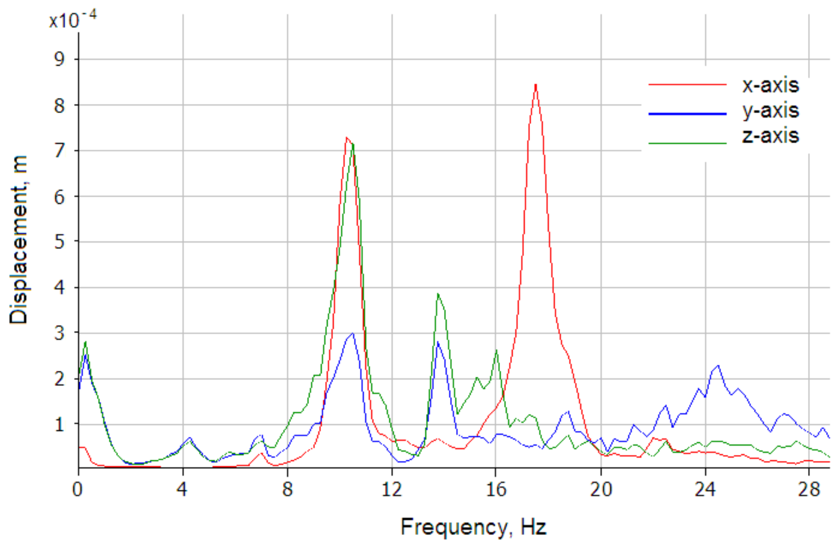

Fig. 2. The displacement spectrum in the middle point of the solar panel

During investigation it was determined that there were two resonance frequencies of 9.8 Hz (displacement amplitude 0.72 mm) and 17.5 Hz (displacement amplitude 0.85 mm). Based on the acquired data the experiment has been narrowed to the two frequencies mentioned above because it was presumed that there was the highest probability of micro fractures in the crystalline structure of photovoltaic cells to occur when the modules are subjected to dynamic mechanical load. The exposure time to the mechanical stress under these conditions has been varied in the range of 0.1 – 3 hours. Each time after exposure the photovoltaic modules have been checked using electroluminescence technique [4]. The modules have been connected to the 35 V DC power supply and a constant current have been maintained. The resultant luminescence of silicon has been observed using computerized CCD camera in dark room to remove any influence of light on the experiment. During each experiment the number of resultant micro cracks has been calculated and further exposure to mechanical stress has been carried out.

3. Results and Conclusions

A computerized vibrational stand simulating the real weather conditions causing dynamic mechanical stress on the photovoltaic cells has been applied to determine the influence of the mechanical stress on the appearance of micro fractures in solar panels. It was determined that there were two resonance frequencies of vibrations 9.8 Hz and 17.5 Hz, which resulted in the appearance of micro cracks. The appearance of micro cracks inside the crystalline structure of photovoltaic module due exposure to dynamic mechanical loads was analysed using electroluminescence technique. Electroluminescence image after exposure to 0.1 mm 20 Hz vibrations for 45 minutes is shown in Fig. 3.

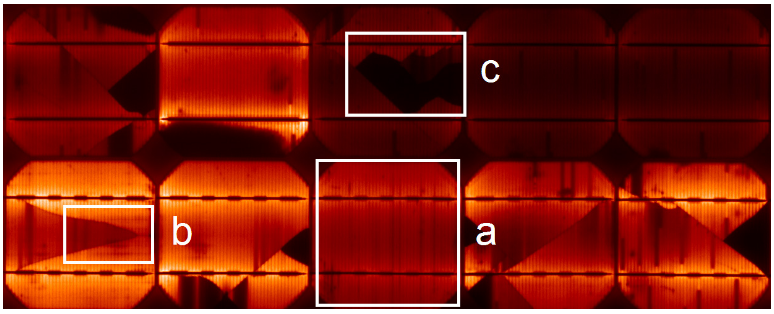

Fig. 3. Appearance of micro cracks inside the crystalline structure of solar cells after exposure to dynamic mechanical stress (a) damage of the reflective layer, (b) appearance of micro cracks, (c) microcracks resulting in appearance of inactive dark spots.

It was shown that low frequency mechanical loads simulating windy weather could cause considerable damage to the photovoltaic cell and therefore reduce the effectiveness of the module. Since the stated working cycle of a photovoltaic cell is assumed to be 15 – 20 years it is crucial to perform express mechanical load tests to ensure decent performance of the system. It assumed that the proposed measurement setup and the acquired data could help supply recommendations for the producers of the modern solar panels and improve the reliability.

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