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Research on hot spot risk for high-efficiency solar module

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Abstract

Based on the working principles of solar cells, the photovoltaic module mismatch model was constructed to simulate the heat dissipated by one single cell with different shading percentage ranging from 10% to 100%. ANSYS simulation was utilized in this paper to explore the relationship of hot spot temperature and type of solar cell defects (for example point defect and planar defect) with the module output power. The simulation results showed that the module hot spot temperature is inversely correlated with the solar cell defective area, and positively correlated with module output power. Solar cells with different type of defects and solar modules with different output power were picked to conduct the hot spot experiments, in which the leakage currents for the defected solar cells and the high-efficiency module cells (normal cells) were less than 1.5 A and 0.1 A, respectively, for an applied negative bias of 12 V. The results showed that the temperature of the module with point defected solar cell and the high-efficiency module reached up to 200 and 170°C, respectively, which could lead to encapsulation failure. The experimental data was consistent with the simulation, demonstrating the accuracy of the simulation model and providing directives for solving the hot spot problem of the high-efficiency module.

Keywords: PV modules; hot spot; solar module mismatch; defective solar cells; high-efficiency solar module

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1. Introduction

At present, crystalline silicon modules dominate the global PV market. As the output power of a single silicon solar cell is not enough to meet the actual needs, many silicon solar cells usually make up the PV module with the series and parallel connections. Hot spots may occur in a PV module when the solar cells are mismatched or have certain defects, or when one or more cells in the module are partially shaded. Zhen et al. [1]. investigated PV modules of about 200 MW_p that had been running in the United States for 1 to 3 years, tested and analyzed the performance of failure modules, and summed up the reasons for degradation and failure of these modules. As shown in Fig. 1 a total of 115 defective PV modules were observed, of which 22% were due to cell hot spots.

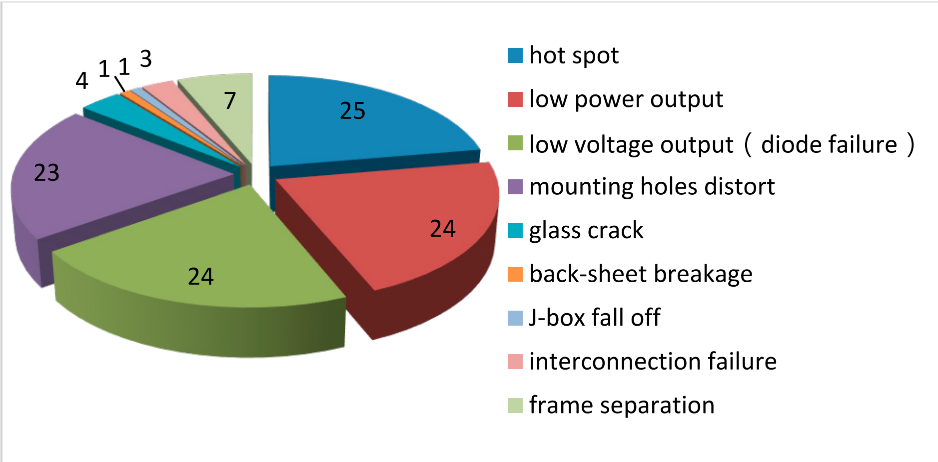

Fig. 1. The short-term failure distribution of solar modules in the US.

Several tests have been developed by Simon et al. to research the PV module hot spot failure mechanism [2]. This study investigated the influence of various string lengths with bypass diodes, shading ratio and cell leakage current on PV module temperature. Ramspeck et al. tested the temperature distribution of reverse-biased solar cells by the Infrared Thermal Imaging Technology, and observed the microscopic structure of partial hot spots by scanning electron microscopy to analyse the mechanism of hot spot caused by crystal defects [3]. Kim et al. showed that the risk of hot spot increases when the number of cells connected in series per bypass diode increases, based on MATLAB simulation [4].

In the present paper, the heating power of a single cell under different shading ratios is simulated. ANSYS is used to analyse the relationship between the PV module's hot spot temperature and the cell defect type as well as the output power of the module. We also research the hot spot risk for high-efficiency modules by experiment.

2. Solar cell model

A solar cell is basically a p-n junction fabricated in a thin wafer or layer of semiconductors. The electromagnetic radiation of solar energy can be directly converted to electricity through the photovoltaic effect. The typical equivalent circuit of a solar cell is shown in Fig. 2.