Energy Conversion and Management 103 (2015) 348–358

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Effects of various parameters on PV-module power and efficiency

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ARTICLE INFO

Article history:
Received 16 February 2015
Accepted 22 June 2015

Keywords:
Energy
Renewable energy
Photovoltaic
PV module
Cooling system

ABSTRACT

Photovoltaic (PV) modules are one of the most effective, sustainable, and ecofriendly systems. Only a small portion of solar irradiation incident to these modules is converted into electricity. The rest of the irradiation is converted into heat, which overheats the PV module and reduces its performance. In this experiment, various operating parameters such as irradiation intensity, cooling fluid mass flow rate, humidity, and dust have been varied to observe their effects on PV module performance. A heat exchanger was used on the back surface of the PV module to cool cell temperature. At 1000 W/m^2 irradiation level without cooling, cell temperature increased to 56 °C; the output power decreased to 20.47 W; and the electrical efficiency decreased to 3.13%. A decrease in output power of about 0.37 W and a decrease in electrical efficiency of 0.06% per 1 °C increase in solar cell temperature were observed. For every 100 W/m^2 increase in the irradiation intensity, the output power increased by 2.94 W, with a 4.93 °C increase in solar cell temperature. The reduction of the module temperature to 22.4 °C increased the output power by 8.04 W and increased the electrical efficiency by 1.23% by applying water cooling on the PV module. This value is 27.33% higher than the output power and efficiency produced without cooling. The output power decreased by about 3.16 W with a 20% increase in relative humidity, and the output power is reduced by 7.70 W because of dust falling on the surface of the solar module. In conclusion, the parameters of solar cell temperature, irradiation intensity, cooling fluid mass flow rate, humidity, and dust affect PV-module performance.

1. Introduction

Today, the application of renewable energy is broadly encouraged in many countries around the world. Limited non-renewable energy resources, environmental awareness, and abundant renewable resources are also discussed in policy making and the application of suitable technologies for renewable energy use [1,2]. Photovoltaic (PV) modules are one of the most effective, sustainable, and ecofriendly products in the field of renewable energy. PV cells directly convert solar irradiation into electrical energy [3,4]. In practice, only 15–20% of incident solar irradiation is converted into electricity, and the rest is transformed into heat [5,6]. PV module efficiency decreases as module temperature increases [7]. Radziemska [8] experimentally investigated the effect of temperature and found a decrease of about 0.65% output power and 0.08% conversion efficiency of the PV module for every 1 K increase in cell temperature. Ugwuoke and Okeke [9] experimentally investigated the electrical efficiencies of amorphous, poly-crystal, and mono-crystal PV modules and found that their values were 4.94%, 9.67%, and 12.97%, respectively, at 600 W/m^2 irradiation level. The efficiencies of amorphous, poly-crystal, and mono-crystal PV modules dropped to 3.62%, 7.65%, and 9.61%, respectively, as the irradiation level rose to 1000 W/m^2. Electrical efficiencies decreased by about 0.33%, 0.51%, and 0.84% for amorphous, polycrystalline, and monocrystalline PV cells, respectively, for every 100 W/m^2 increase in solar irradiation. The cooling of PV modules is important in improving output performance. Dubey et al. reported a 10.41% module efficiency of air-cooled PV modules; without cooling, the efficiency was 9.75% [10]. Hosseini et al. [11] reduced PV module surface temperature and reflection losses through a thin-film water-flow cooling system on the top surface; they found improved efficiency and output power. Valeh-e-Sheyda et al. [12] studied the performance of a microchannel cooling system that uses both air and water, and found that output power increased to 38%. Teo et al. [5] observed that the efficiency of polycrystalline photovoltaic modules decreased by 3.4% when cell temperature increased to 24 °C (54.54% higher than initial temperature), and they found that the performance was 28.33% less than the initial value. Uniform air flows through a parallel duct at the bottom surface of a PV module; efficiency was observed to

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http://dx.doi.org/10.1016/j.enconman.2015.06.067
0196-8904/