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The effects of nominal power of array and system head on the operation of photovoltaic water pumping set with array surface covered by a film of water

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ABSTRACT

The main problem in using photovoltaic (PV) systems is the low energy conversion efficiency of PV cells. The efficiency of PV cells will decrease significantly as the temperature of the cells exceed to a certain limit. In order to increase the efficiency, it is necessary to reduce the operating temperature of array. One of the ways for improving the system operation is cooling PV cells with a thin film of water. The aim of this research is to study the effects of nominal power of array and system head on the operation of system by using this method. For this purpose, a photovoltaic water pumping system is installed in Kerman city (Latitude: 30° 17′ and longitude: 57° 50′) and different methods examined to reduce PV cells temperature. The most effective way was chosen and used in set. This method is based on providing water for cooling cells by the pump itself. Experiments show that with decreasing of array nominal power and increasing in system head, the power generated by the array increases significantly. This increases the panel and total efficiency and therefore the pump flow rate. This method is ineffective as the array nominal power increases significantly.

1. Introduction

One of the most common applications of photovoltaic systems in developing countries is photovoltaic water pumping which has the potential to become a major force for social and economical development. In such a system, there is a direct relationship between the amount of water and the availability of solar energy received by the array surface [1]. By increasing in their usage, researchers are attracted to optimize the designation and utilization, in order to achieve the most economical reliable operation. In general, the major problem in using these systems is the low energy conversion efficiency of PV cells with respect to the high installation costs of array. The cost of PV array mainly depends on the array area. Therefore electrical power generated by the PV array, should be efficiently used to compensate the high costs [2].

It is obvious that by increasing the operating temperature, the open circuit voltage of cells drops and therefore the power generated by the cells and their efficiency decrease. Any changes in the system power, effects on its operation [3]. Thus the PV array manufacturer usually specifies a maximum operating temperature for the cells.

Photovoltaic panels (PVPS) are the main part of photovoltaic water pumping system. Increasing PVPS efficiency is the most important aim of cells designers. They use different methods for optimizing photovoltaic systems to improve their operation.

Roger [4], Metwally [5], Akbaba [6] suggested different components for matching DC motors and PV arrays and future development direction for a complete system matching with maximum power output.

Yeager [7] and Saied et al [8] concluded that controlling the insulation receive and rearranging the solar cells configuration of PV array with respect to changes in environmental conditions, overcome the main drawback of PV systems, i.e. high costs and low efficiency.

The main reason for low electrical efficiency of solar arrays is non linear variations of output voltage and current with solar radiation levels, operating temperature and load current. Hiyama et al [9,10] and Hua et al [11] stated that to overcome these problems, the maximum power operating point of the PV system (at a given condition) is tracked using online or offline algorithms and the system operating point is forced toward the optimal conditions.

Krauter, et al [12] studied the effects of cooling photovoltaic array surface with water on the power generated by the array. Amery, et al [13] improved the operation of a photovoltaic water pumping system by spraying water over the front of photovoltaic cells.

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Nomenclature

A	photovoltaic array area (m^2)
G	global irradiance on the tilted PV array (W/m^2)
h	total head (m)
I_a	photovoltaic cell current (A)
n	refractive index
P_{pv}	photovoltaic array power (W)
Q	flow rate (m^3/s)
V_a	photovoltaic cell voltage (V)
η_{pv}	photovoltaic cell efficiency (%)

The aim of this research is to study the effects of nominal power of array and system head on the operation of photovoltaic water pumping set with array surface covered by a thin and continuous film of water. A film of water improves the operation of system as a result of decreasing cells reflection and temperature.

2. The experimental procedure

The photovoltaic system used in this research, consists of a pump (model PS150 Boost Lorentz with 45 m maximum head and 1000 (L/h) maximum flow rate), a permanent magnet DC motor, Controller (model PS150 with 50 volt maximum input voltage), three panels (each one is crystalline type with 36 cells) and a filter.

The controller is a multi task system and each part of it has an important duty as follows:

- controlling and monitoring the motor
- acting as a maximum power point tracking (MPPT) system
- low voltage disconnecting (LVD) for battery protection (12 and 24 volt batteries)
- amplifying current of the array
- checking and displaying the operating states
- Adjusting maximum speed of motor (rpm) due to manual switch

The output power of the array passed through the controller. The power transmitted to the motor pump which pumps water from the tank. Several methods were examined to transport water on top of the array surface. The experiments showed that using the pump itself to provide water for cooling PV cells is the most effective way. By passing through a tube with tiny regular holes, water flew over the array surface and cooled PV cells (Figs. 1 and 2).

By considering to installation costs and least water waste, this design resulted in an effective reduction of cells temperature without expending energy for water transporting. Water was filtered and purified before entering the pump and the array surface pollution and dust was removed.

A sensor (model PT100) installed at the back of the array, measured the actual temperature as the temperature in front of the array surface was about 2 °C higher than the temperature at the back. Irradiance was measured by a pyranometer (model Kip&Zonen) installed parallel to the surface, at the same incident plane of the array (Fig. 3). The pump flow rate was measured by a digital flow meter.

Measurements have been performed over four month in 2008 in Kerman city and recorded every 15 min. In order to study the effects of the array nominal power and system head while cooling photovoltaic cells with a thin and continuous film of water, two similar arrays were used with 90 and 135 watt nominal power (two and three panel) and tested in three different head (10,12.5 and 16 m).

3. Results and discussions

The test location is a dry city placed in Asia continent with Latitude 30° 17′ and longitude 57° 50′. Variation of insolation received by the array surface during the test day, is shown in Fig. 4.

The experiments showed that continuous film of water on the surface of PV array has two important effects on the operation of system. First, it improves the optical properties of the array surface. Solar radiation hitting a laminated PV array reduces as a result of reflection loss. The amount of this reduction depends on different parameters such as the incident angle of solar radiation, array

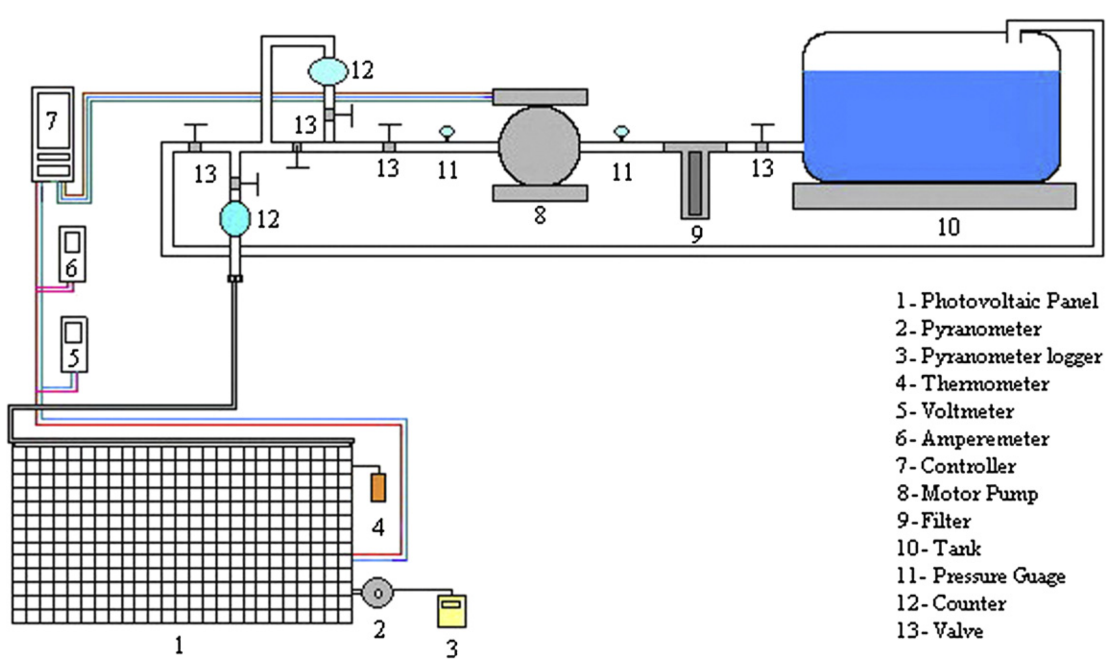

Fig. 1. The schematic of experimental photovoltaic water pumping system.