Optimal Design and Use of PV Water Pumping Systems in Armenia

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ABSTRACT

This paper presents the results of the experiment carried out in Armenia on a 420 Wp PV water pumping system, under two operational conditions: fixed and tracking modes of the PV modules. The overall performances of pumping system were analyzed and evaluated during the monitoring period. Results show that, for the climate of Yerevan city, the pumped water volume of the tracking PV modules is 1.2 - 1.3 times greater than the value obtained with the fixed PV modules. In September 2007, based on the results achieved in the territory of VS Technopark Co. (Yerevan), 3.1 kWp tracking PV water pumping demonstration system for micro irrigation of the VS Technopark garden (0.2 hectare) has been developed, constructed and setup. At present, with the help of specially developed Data Acquisition of program, seasonal testing of demonstration system for evaluating and analyzing performance of PV system, according to the overall effect of environment conditions on their operation characteristics, is in process.

Keywords: solar cells, photovoltaic, modules, tracking, radiation, water pumping.

1 INTRODUCTION

Solar photovoltaic (PV) systems find a large market in the developing countries in Asia, Middle East and Africa. Most of these areas are characterized by solar energy availability over a large part of the year. The continental type weather, having harsh winters, also delivers large amount of sunshine, thereby indicating about the possibility of the solar energy wide utilization. Solar energy can be directly converted into DC electricity by using PV technology, which in turn can be used for pumping water.

Main advantages of PV water pumping systems are as follows [1, 2]:

- Being fully automated, standalone systems that don't require fuel or much maintenance.
- Work best when you need water most – when the sun is shining in the summer.
- The ability to move the system as you move animals to different pastures.
- A range of pump types and power outputs means you can design a system for virtually any application.
- Little maintenance and simple to winterize.

There are four main markets for PV-powered water pumping systems with a growing variety of applications serving people around the world: Village Water Supply, Irrigation, Livestock Watering and Residential Needs.

The geographic location of Armenia pertains to the fourth zone of the solar radiation availability with more than 1700 kWh/m^2 of global horizontal and more than 1900 kWh/m^2 of direct normal components annually. The monthly average solar radiation data in Figure 1 shows that the period April to September gives excellent insolation over Yerevan city, Armenia, followed by reasonably good sunshine during Mart and October [3].

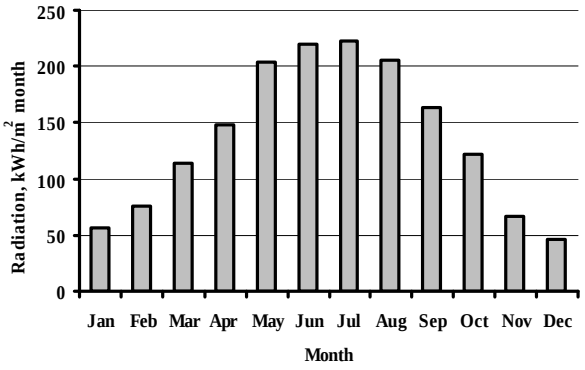

Figure 1: Monthly average solar radiation for Yerevan.

This paper presents the results of the experiment carried out in Armenia on a 420 Wp PV water pumping system. The given system and corresponding data acquisition system were installed in the yard of VS Technopark Co. in Yerevan city.

2 PV WATER PUMPING SYSTEM FACILITY

The schematic representation of experimental PV water pumping system is shown in Figure 2. The system consists of 420 Wp PV generator (modules), DC/AC three-phase pump inverter and multistage centrifugal submersible motor/pump [4].

The PV generator is composed of a PV array with six silicon modules connected in series, each module of 0.65

m^2 area and maximum power of 70 Wp (Figure 3). Two operational conditions (fixed and tracking modes of PV modules) were investigated. Experiments were performed with the PV modules tracking along its North–South axis, tilted at an angle of 42^0 (towards North).

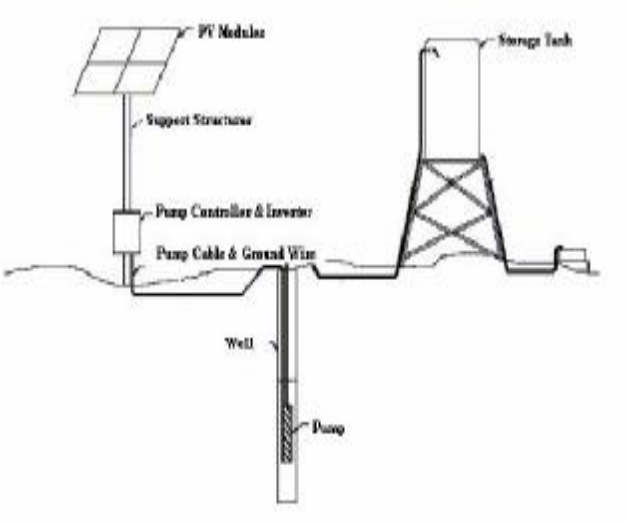

Figure. 2: Schematic representation of PV water pumping system.

The motor-pump is installed in an ideal well (cistern-like), pumping water to a tower. The pumping system operates with a water head of 12 m. The pump is made of high strength engineered plastics, stainless steel fasteners. A flow meter and a pressure gauge are incorporated with the setup to measure the water flow rate and pressure of the pumping fluid.

Meteorological variables, solar radiation in various planes; hydraulic variables (water flow rate and water volume), electrical variables (voltage and electric current) and temperature of the PV modules were measured.

Figure 3: General view of PV generator.

3 RESULTS AND DISCUSSIONS

The performance analysis of the PV water pumping system was studied for the different operating and performance parameters. The main idea of this work is to find out various performance of PV small-scale submersible water pumping in the prevailing climatic conditions in Yerevan, Armenia. The following findings give a clear picture about the prospect of the solar pumping even in a cloudy and rainy atmosphere during October in Yerevan. The curves shown in the Figure 4 and Figure 5 are variation of solar radiation and water flow rate in the daytime. Due to variation of solar radiation, the pump discontinue to pump water from time to time, and as a result, it has been found that flow rate becomes zero at that particular instant (Figure 5).

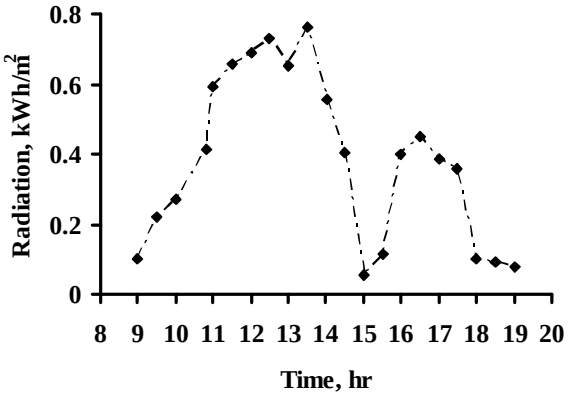

Figure 4: Variation of solar radiation in the daytime.

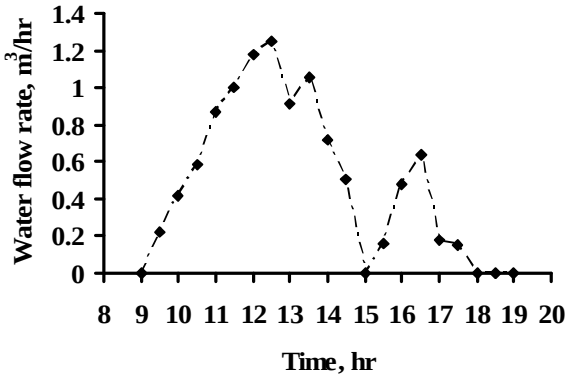

Figure 5: Variation of water flow rate in the daytime

Experiments for two operational conditions: fixed and tracking modes were run for several months. Monthly water volume pumped by the PV system for three-month period (September-November) is shown in Figure 6. Results show that, for Yerevan city climate, the pumped water volume of the tracking PV modules is 1.2 - 1.3 times greater than the value obtained with the fixed PV modules. The benefit of using tracking systems is derived from the fact that the

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incidence angle of the direct component of solar radiation is more favorable, i.e., lower than or equal to the angle that corresponds to fixed systems [5]. The behavior of the diffuse component for both systems is approximately the same. Therefore, the instantaneous solar radiation collected by the PV modules, assembled in a tracking system, is higher than the critical irradiance level for a longer number of hours in fixed systems.

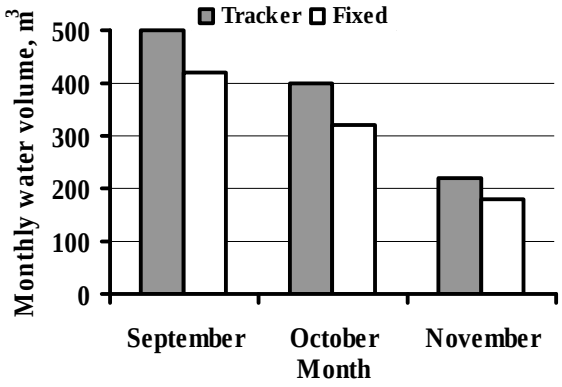

Figure 6: Monthly water volume pumped by the PV system operating in the fixed and tracker modes.

Preliminary results show that there is immense potential for PV submersible water pumping in the remote and rural areas of Armenia. In September 2007, based on the results achieved in the territory of VS Technopark (Yerevan), 3.1 kWp tracking PV water pumping demonstration system for micro irrigation of the VS Technopark garden (0.2 hectare) has been developed, constructed and setup (Figure 7). At present, with the help of specially developed Data Acquisition of program, seasonal testing of demonstration system for evaluating and analyzing performance of PV system, according to the overall effect of environment conditions on their operation characteristics, is in process.

4 CONCLUSION

420 Wp PV water pumping system and data acquisition system were installed in Yerevan city for evaluating and analyzing performance of water pumping system, according to the overall effect of environment conditions on their operation characteristics. The overall performances of PV system were analyzed and evaluated during several months. The overall conclusion of this study is that PV water pumping system with solar tracking can be practically and economically used in various operations in Armenia. Based on the above-mentioned results, new evaluation and analysis technologies will be developed for optimum design of grid connected PV system.

Figure. 7: General view of 3.1 kWp tracking PV water pumping demonstration system.

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