ISSN 0002-306X. Изв. НАН РА и ГИУА. Сер. ТН. 2011. Т. LXIV, ¹ 1.

UDC 621.383 BRIEF REPORTS

V.V. BUNIATYAN, A.A. VARDANYAN

# PERFORMANCES OF SOLAR WATER PUMPING STATION WITH SOLAR TRACKER

For the solar water pumping stations a solar tracking system with phototransistor is developed. On the basis of the experimental investigations the utility and efficiency of the PV water pumping station with solar tracker under different conditions of varying solar radiation in Armenia is shown.

***Keywords:*** solar water pumping station, tracking system, performances, radiation, phototransistor.

Solar photovoltaic (PV) stations 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, delivers a large amount of sunshine as well, thereby indicating the possibility of the wide utilization of solar energy. 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.

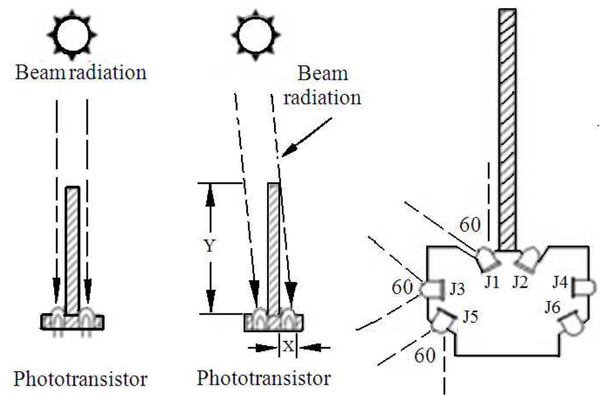
Solar energy can be directly converted into DC electricity by using PV technology, which in turn can be used for pumping water. There are four main markets for PV-powered water pumping stations with a growing variety of applications serving people around the world: Village Water Supply, Irrigation, Livestock Watering and Residential Needs [1].

Many scientists have studied Sun tracking systems with different applications to improve the efficiency of PV stations by adding the tracking systems to these stations [2]. A tracking mechanism must be reliable and able to follow the Sun with a high degree of accuracy, return the PV panel to its original position at the end of the day or during the night, and also track during periods of cloud cover.

This Research Note proposes a tracking method taking into consideration changes in solar radiation conditions using phototransistors. The validity of this tracking method has been proved through experimental investigations for a PV water pumping station under different conditions of varying solar radiation in Yerevan.

The experimental PV water pumping station consists of 420 $Wp$ PV panel (modules), DC/AC three-phase multistage inverter and permanent magnet synchronous motor- centrifugal submersible pump load [3]. The PV panel is composed of a PV array with six silicon modules connected in series, each module of 0.65 $m^2$ areas and maximum power being 70 $Wp$. 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 to measure the water flow rate and pressure of the pumping fluid.

For executing the tracking process a phototransistor as the solar detecting device is chosen. The semantic of solar detection is the solar position in this case. The altitude direction of the detection addresses the solar position by the shade of parabolic shape. As shown in Fig. 1a, when the semantic of solar position is parallel to the phototransistors, the parabolic shape phototransistors will receive solar energy in the “ON” condition. In addition, when the Sun orbits to its former position, the shades will form a shadow and the phototransistor status will be on the “OFF” condition. Note that the “OFF” condition denotes little to no current flow in the system. Consider the semantic “ON” status as “1” and “OFF” status as “0”. The phototransistor facing direction is 60°.




a) b)

Fig.1. Solar tracker; (a) light balance and unbalance; (b) a cross-sectional view of a tracker

Therefore, in order to detect solar energy all the way through the altitude, the device containing 6 phototransistors: J1, J2, J3, J4, J5 and J6 is designed. As shown in Fig. 1b, the characteristic of this design assures that the device is capable of detecting solar energy whenever it begins. The height of the shade $Y$ is

$$Y = \frac{X}{\tan\theta}, \tag{1}$$

where $X$ is the distance from the shade to the edge of the phototransistor and □ is the degree angle of the Sun which moves from its original position.

The outputs Q1 and Q2 of the solar detecting circuit which begins the motor in the altitude direction are given:

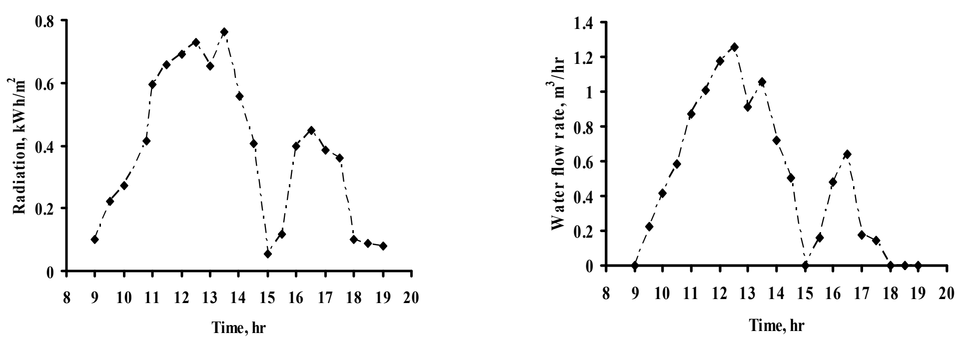
$$Q_1 = J_1\bar{J}_2 + \bar{J}_2\bar{J}_3 J_4, \tag{2}$$

$$Q_2 = J_{21}\bar{J}_1 + \bar{J}_1\bar{J}_4 J_1. \tag{3}$$

The digital circuit constructs truth table with an arithmetic Boolean logic as expressed in Eq. (2) and (3). From both equations, a logic gate circuit is obtained as well.

The experimental performance analysis of the PV water pumping system is studied for two operational conditions: fixed and tracking modes have been running for several months. 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 are measured.

The curves shown in Fig.2 are the variation of solar radiation and water flow rate versus the daytime. The following results give a clear picture about the prospect of the solar pumping system with the solar tracker even in a cloudy and rainy atmosphere conditions. Due to the variation of solar radiation, the pump discontinues to pump water from time to time, and as a result, it has been found that flow rate becomes zero at that particular instant (Fig.2b). The Sun tracking system is able to track the Sun under clear sky and partly cloudy sky. In worse case, this tracking system disables when there is no Sun under the overcast sky. The maximum Sun tracking error appears in daytime during low solar altitude angle which corresponds to morning and evening periods. However, the Sun tracking error decreases when the solar altitude angle increases. And the error is less than 1% when tracking angle approaches the zenith.




a) b)

Fig.2. Solar radiation (a) and water flow rate (b) as a function of the daytime

Monthly pumped water volume for three-month period (September-November) is shown in Fig. 3.

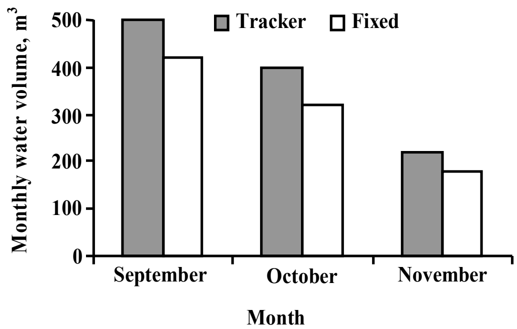



Fig.3. Monthly pumped water volume in case of fixed and tracking modes

The 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 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 [4]. 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.

The advantage of this research is to apply this type of solar trackers for PV submersible water pumping in the remote and rural areas of Armenia.

## REFERENCES

1. **Short T.D., Burton J.D.** The Benefits of Induced Flow Solar Powered Water Pumps// Solar Energy. - 2003. – 74. - P.77-80.
2. **Al-Mohamad A**. Efficiency Improvements of Photo-Voltaic Panels Using a Sun-Tracking System// Appl. Energy. - 2004.- 79. –P. 345-354.
3. **Ayvazyan G., Khachikyan K., Vardanyan A**. First Experience of Photovoltaic Water Pumping Systems in Armenia// Presented at the 20th Conference and Exhibition PV in Europe.- Spain, Barcelona, 2005. - P. 2964-2968.
4. **Vilela O.C., Fraidenraich N., Tiba C.** Photovoltaic Pumping Systems Driven by Tracking Collectors: Experiments and Simulation// Solar Energy.- 2003. – 74.- P.45-48.

SEUA. The material is received 10.01.2011.

Վ.Վ. ԲՈՒՆԻԱԹՅԱՆ, Ա.Ա. ՎԱՐԴԱՆՅԱՆ

## ԱՐԵՎԻՆ ՀԵՏԵՎՈՂ ՀԱՄԱԿԱՐԳՈՎ ԱՐԵՎԱՅԻՆ ՋՐՀԱՆ ԿԱՅԱՆԻ ԲՆՈՒԹԱԳՐԵՐԸ

Ֆոտոտրանզիստորների հիման վրա արևային ջրհան կայանի համար մշակվել է արևին հետևող համակարգ: Կատարված փորձնական հետազոտությունների հիման վրա ցույց է տրվել Հայաստանում արևի ճառագայթման փոփոխության տարբեր պայմանների դեպքում արևին հետևող համակարգով արևային ջրհան կայանի կիրառման նպատակահարմարությունը և արդյունավետությունը:

***Առանցքային բառեր.*** արևային ջրհան կայան, արևին հետևող համակարգ, բնութագրեր, ճառագայթում, ֆոտոտրանզիստոր:

В. В. БУНИАТЯН, А.А. ВАРДАНЯН

## ХАРАКТЕРИСТИКИ СОЛНЕЧНОЙ ВОДОНАСОСНОЙ СТАНЦИИ СО СЛЕДЯЩЕЙ СИСТЕМОЙ

На базе фототранзисторов разработана следящая система за Солнцем для солнечной водонасосной станции. Экспериментально показаны целесообразность и эффективность применения солнечной водонасосной станции со следящей системой при разных условиях изменения солнечного излучения в Армении.

***Ключевые слова:*** солнечная водонасосная станция, следящая система, характеристики, излучение, фототранзистор.