

EFFECT OF THE CRITICAL IRRADIANCE ON PHOTOVOLTAIC WATER PUMP DISCHARGE UNDER EGYPTIAN CONDITIONS

Mamdouh Abbas HELMY¹, E. M. KHALIFA², A. M. OKASHA², A. W. ELHADDAD³

¹Modern University for Technology and Information, Center of Training and continuing Education, Faculty of Agriculture, Cairo, Egypt. Phone: 002-01122357007, Fax: 002-02-27272148, Email: prof_mamdouh@hotmail.com

²Kafrelsheikh University, Faculty of Agriculture, Egypt

³Agricultural Engineering Research Institute, Giza, Egypt

Corresponding author: prof_mamdouh@hotmail.com

Abstract

The present investigation aimed to study the effect of critical irradiance due to changing tilt angle of PV panel and tracking sun on submersible pump discharge. The authors used solar tracker and suitable tilt angle for the panel to increase the time interval during which the water pump operates. For the same irradiance collected by the PV, all systems pump the same amount of water, although they occur at different periods of the day. The pump itself 'does not know whether the electric power comes from any processes, as long as it has the same intensity.

Key words: Egyptian conditions, critical irradiance, photovoltaic, water pump

INTRODUCTION

Some photovoltaic pumping systems, depending on their electric power and water head, require, to start operating, levels of collected irradiance higher than what is known as critical irradiance level (I_c). That feature limits the daily operational time and the volume of water pumped. To reduce its influence the following technical means can be considered: (a) to use solar trackers; (b) to use suitable tilt angle for the panel; (c) to use reflector. (a), (b) and (c) increase the time interval during which the water pump operates [1 and 2]. The present study used solar tracker and suitable tilt angle for the panel to increase the time interval during the water pump operates.

MATERIALS AND METHODS

Experiments were carried out at Meet Eldeeba Rice Mechanization Center, Kafrelsheikh Governorate, Egypt, which lies at latitude $31.07^{\circ}N$ and longitude $30.57^{\circ}E$ during Winter 2011.

The PV array has a capacity of 140 peak Watt (4modules, 16.6V., 2.11A., 35 peak Watt for each) and mounted on sun tracking

device surface (Fig. 1) with tilt angles of 0.349, 0.523 and 0.872 rad (0, 20, 30 and 50deg) from the horizontal plane.

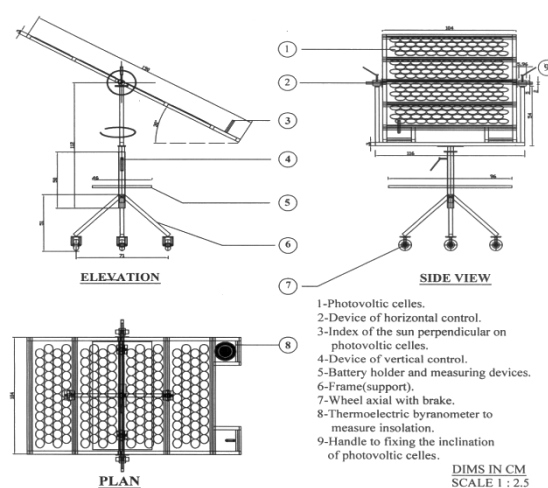


Fig. 1: Device of adjust the direction of the photovolatic cells horizontally and vertically with the direction of the sun

The PV array has got a tracking arrangement for orienting the panel towards East (from 9.00 a.m to 12.00 o'clock), South (from 12.00 to 15.00) and West (from 15.00 to 17.00) directions in Summer and Winter.

Submersible pump - model 02 made in Italy (Fig 2), delivery volume of 5679 l/h, high pumping capacity and reliability at a lower cost, delivery water head of 6 m, discharge

outlet diameter of 2 8.6 m m, 12 volts, 9 Amp, and DC motor driving a centrifugal pump type were connected to a PV array directly.



Fig. 2: Submersible pump

The experiments were divided to five processes as follows: 1) Panel tilted at suitable tilt angle [0.549 rad (20deg) in Summer and 0.872 rad (50deg) in Winter] and the panel tracking sun from East to West along day time. 2) Panel tilted at 0.523 rad (30deg) [latitude angle] and the panel tracking sun from East to West along day time. 3) Panel tilted at suitable tilt angle [0.349 rad (20deg) in Summer and 0.872 rad (50deg) in Winter] and panel was oriented toward south along day time. 4) Panel tilted at 0.523 rad (30deg) [latitude angle] and panel was oriented toward South along day time. 5) Panel positioned horizontally along day time.

RESULTS AND DISCUSSIONS

The effect of solar radiation on pump discharge at different heads in both Summer and Winter is presented in Fig. 3 and 4.

At the same value of radiation and the same water head, the discharge decreased by increasing in panel temperature because of the reduction in the panel output electric power. Some photovoltaic pumping systems, depending on their electric power and water head, require to start operating, levels of collected irradiance higher than what is known as critical irradiance level (I_c).

The minimum value of irradiance, is necessary to start the water pump operation (The critical irradiance levels). It is clear that the critical irradiance (I_c) increased by

increasing water head. In Summer, from Fig. 3, the critical irradiance at water heads of 2, 3 and 4m were 257.143, 328.571 and 628.571 W. In Winter from Fig. 4, critical irradiance has the same trend. It differed in magnitude due to panel temperature as it is discussed before. I_c increased by increasing water heads I_c values were 242.86 to 285.7 to 571.4 W at water heads of 2.3 and 4m, respectively.

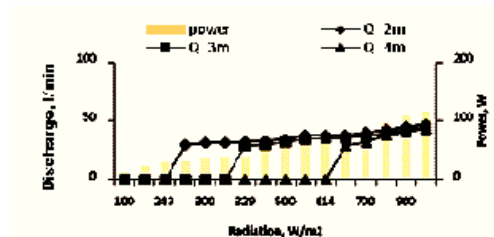


Fig.3: Discharge versus radiation and power at different water heads (Q) in summer

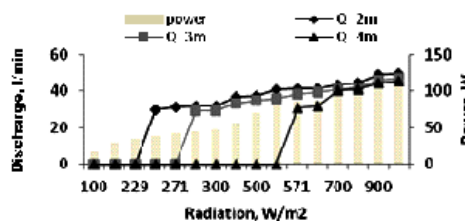


Fig.4: Discharge versus radiation and power at different water heads (Q) in winter

The discharge increased along day time from sunrise till noon when it reached its maximum value while it decreased with sunset. (Fig.5 and Fig. 6).

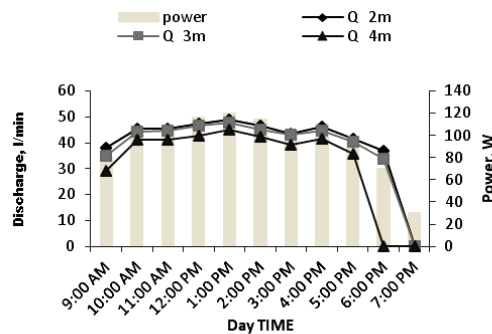


Fig.5: Discharge versus time and power at different water heads (Q) in summer, panel tilted at 0.349 rad (20deg) tracking sun from east to west

This naturally matched with solar radiation as usually water requirement increased during hot weather periods when the solar radiation intensity was high and the output of the solar array is at its maximum. On the other hand,

the water requirements decreased when the weather was cool and the sunlight was less intense.

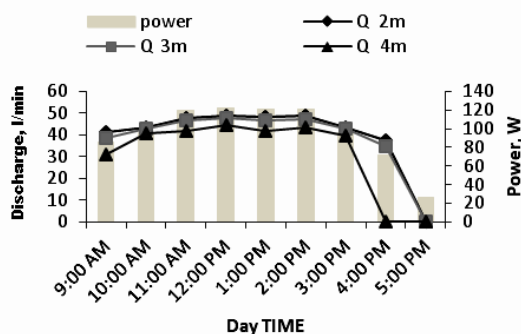


Fig.6: Discharge versus time and power at different water heads (Q) in winter, panel tilted at 0.0872 rad (50deg) tracking sun from east to west

The critical irradiance level limits the daily operational time and the volume of water pumped. For the same irradiance collected by the PV, all systems pump the same amount of water, although they occurred at different periods of the day.

The time interval during which the water pump operates at five different water heads in Summer and Winter for five processes is presented in Fig. 7 and 8.

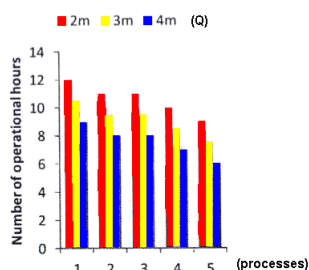


Fig.7.The relationship between five different processes and the time interval (n) during (z) the water pump operate at 2, 3 and 4m water head in summer.

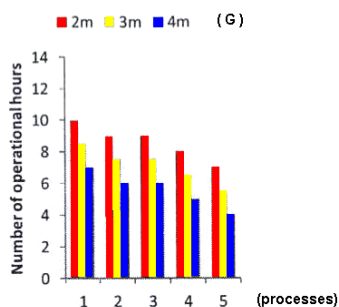


Fig.8. The relationship between five different processes and the time interval (n) during (z) the water pump operate at 2, 3 and 4m water head in winter.

From Figs. 7 and 8, it is clear that the interval time during the water pump operation decreased by increasing of water head. Also, it was longer in Summer than in Winter. The maximum time intervals were 12, 10.5 and 9 h in Summer and 10, 8.5 and 7 h in Winter for process one at 2, 3 and 4m head, respectively. The minimum time intervals were 9, 7.5 and 6 h in Summer and 7, 5.5 and 4 h in Winter for process No. five at 2, 3 and 4m water head, respectively.

CONCLUSIONS

The critical irradiance level limits the daily operational time and the volume of water pumped. To reduce its influence, solar trackers can be used with suitable tilt angle for the panel to increase the time interval during which the water pump operates. The best tilt angles were 0.349 rad (20 deg) Summer and 0.872 rad (50deg) in Winter. Its useful to track sun from East to West along daytime. The maximum time intervals were 12, 10.5 and 9 h in Summer and 10, 8.5 and 7 h in Winter for process one at 2, 3 and 4m water head, respectively.

ACKNOWLEDGEMENTS

The authors wish to express their thanks Mr.Gamal Abou El-Hadeed for his contribution in correcting the present investigation to be in proper form for publication.

REFERENCES

- [1]Anis, W. R., Metwally, H. M. B., 1994, Dynamic performance of a direct coupled PV pumping system. Solar Energy, 53(4):369-377.
- [2]Vilela, O. C., Fraidenraich, N., 2001, A methodology for the design of photovoltaic water supply systems. Progress in Photovoltaic : Research and Applications, 9: 349 – 361

