Central Power Research Institute

Vol. 16(2)/125-128, July-December 2020
ISSN (Print) : 0973-0338
DOI : 10.33686/pwj.v16i2.155503

Power Research

Development of a Novel Method for Maintaining Constant Total Head during Solar Surface Pump Testing

S. Jothibasu[*], R. Sudhir Kumar and V. S. Nandakumar

Energy Efficiency and Renewable Energy Division, CPRI, Bangalore – 560080, Karnataka, India; jothibasu@cpri.in

Abstract

Solar pumps (water pumps energized by solar photovoltaic power) are being installed in large numbers for irrigation and drinking water pumping applications in the country under various schemes. Automatic test facilities are necessary to ensure quality products are deployed in time. This paper describes a novel method developed for auto constant total head maintaining during solar surface pump testing.

Keywords: Constant Total Head, Novel Method, Solar Pump Testing, Surface Pump

1. Introduction

Solar powered pumps (pumps energized by solar photovoltaic power) have been deployed for irrigation and drinking water in the country for more than a decade. Government of India has been promoting the installation of several thousands of solar pumps in agriculture sector and community drinking water supply sector under various schemes. Deep well (implying high depth of water level) (submersible)/ shallow well (implying low water level) (surface) AC/DC powered pumps of capacity ranging from 0.25 HP (0.2 kW) to 10 HP (7.5 kW) are commonly being used. Surface pumps generally come with total hydraulic head of 10-30 m and submersible pumps with 30-100 m. Over the years, system cost has been brought down significantly through technological improvements in Solar Photovoltaic (SPV) modules, controller, and pumps. Surface pumps play vital role when large quantity of water being pumped in shallow head applications.

A simple low cost 1 HP (0.75 kW) solar water pumping system for irrigation with buck inverter has been designed and analyzed for use in Bangladesh[1]. The efficiency of a SPV operated solar pump is enhanced by effective design of VFD and tracking system[2]. Various components of a Variable Frequency Drive (VFD) are studied and analyzed. A normal DC bus conductor is modified into a foiled conductor and output voltage coming from VFD is regulated using a voltage regulator. Keeping the VFD very close to motor reduces the conductor length. Using better grade cables for solar PV panels wiring and using automatic sun tracking structures for holding the SPV panels instead of static structures, a prototype of 2 kWp (peak power rating) grid interactive SPV system integrated with 1.5 HP single phase pump installed in order to study the solar power plants. Sun oriented SPV cluster-based BLDC (brushless direct current) motor driven water pumping system utilizing a DC-DC help converter has been proposed[3]. The effect of pumping head on photovoltaic water pumping system using optimum SPV array configuration have been determined[4]. Four different heads (50, 60, 70 & 80 m head) have been tested with DC helical pump and concluded that best efficiency is at 80 m head.

2. Solar Pump Testing

Typical schematic of a solar pump test set up is given in Figure 1. Direct-solar SPV modules or SPV array simulators can be used for the testing. In case of direct method, adequate number of SPV modules in series /

*Author for correspondence

parallel combination are mounted and connected on the solar module mounting structure. In case of simulation, the tested parameters from standard test condition results of SPV modules (Table 1) are used as input for the simulator. The DC power from SPV modules/simulator drives the motor-pump through the controller. The piping is connected with foot valve, suction line, vacuum gauge, pump, discharge line, pressure gauge, motorized valve, flow meter and return pipeline. A Programmable Logic Controller (PLC) based computer system can operate, control and log all the data. The required test discharge pressure is set on the PLC. Once the motor-pump is energized, the water will start flowing; the motorized valve will open / close to maintain the set discharge pressure automatically.

Table 1. Typical SPV array parameters as simulator input

V_{oc} (V)	I_{sc} (A)	P_{max} (W)	V_{mp} (V)	I_{mp} (A)	Fill factor,-
721.2	8.7	4897.7	597.5	8.2	0.78

The solar radiation keeps changing from morning to evening. Typical solar radiation and SPV module temperature variation over a day is depicted in Figure 2. As the solar radiation increases, water flow increases, and the suction vacuum also keeps changing (even when discharge pressure is set constant). Figure 3 shows the variation of suction vacuum for a constant discharge pressure with time. Control of motorized valve is possible only through one of the variable, say discharge pressure or suction pressure. However if both suction vacuum and discharge pressure are varying continuously based on solar radiation, and then it was not possible to maintain constant total head automatically. Then constant total head has to be maintained by frequently changing the set discharge pressure manually based on the vacuum.

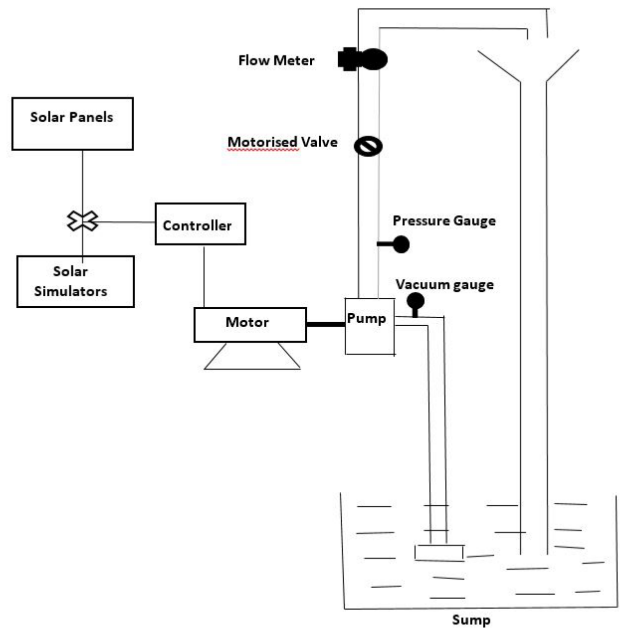

Figure 1. Schematic of solar photovoltaic powered pump test set up.

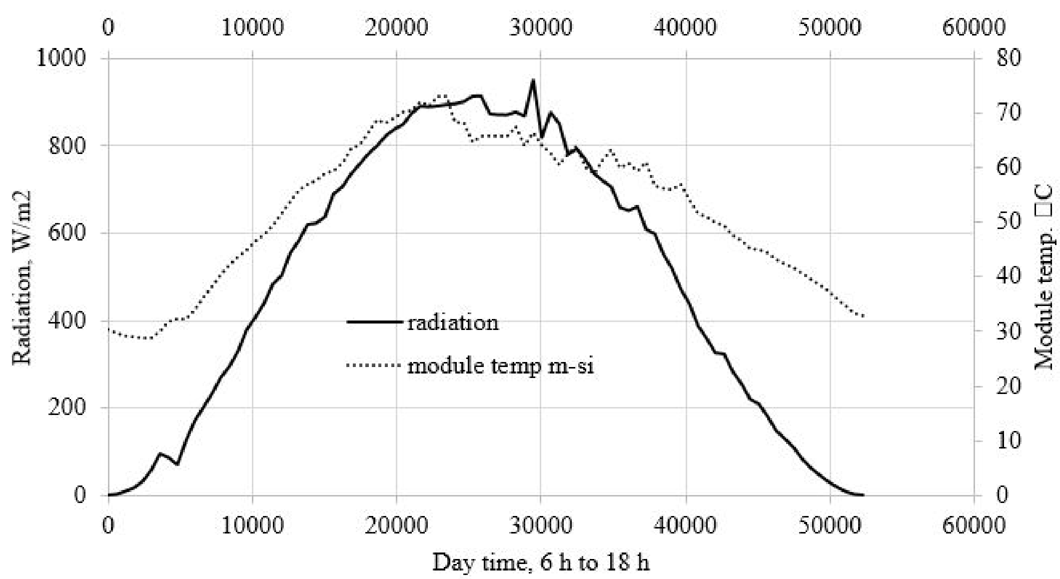

Figure 2. Variation of solar radiation and module temperature over a day.

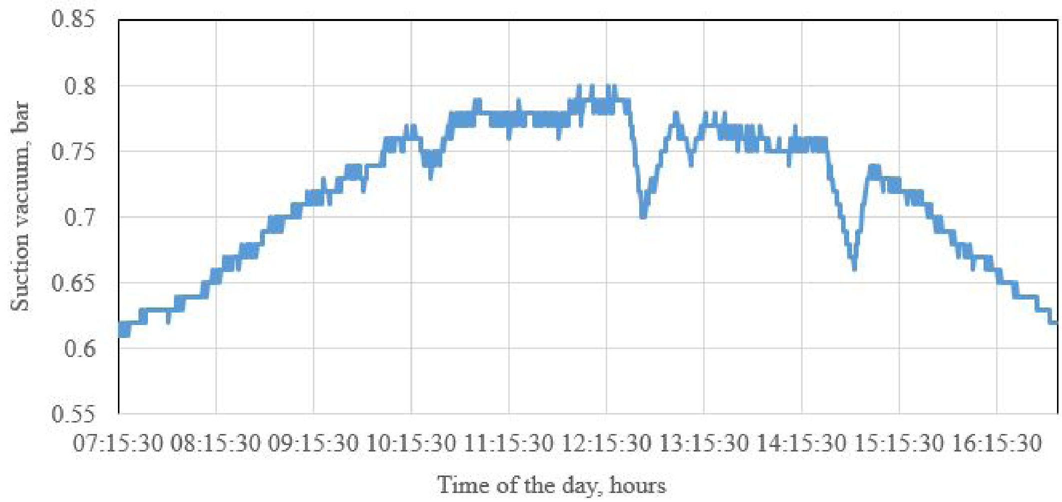

Figure 3. Variation of suction vacuum with time.

3. Results and Discussion

The problem of varying suction head was analyzed in detail and a novel method was evolved. Accordingly a minimum reference suction height (existing at lab say 5 m) is taken as reference vacuum and discharge head is fixed as 15 m (for a total head of 20 m testing). Pressure in bar unit is converted accordingly to set on the PLC system. Now a differential index is created between the 5 m reference suction and the actual suction in vacuum sensor at any given time. This differential value is subtracted from the discharge set head at each moment to maintain the total head constant always. Based on this varying discharge head, motorized valve is operated to maintain constant head automatically. For example, when the pump is started, if the suction head is say 8 m, then the differential index will be 5 (reference value) -8 (actual value) = -3 m and discharge set value is 15-3 = 12 m. The procedure is given in Table 2. Through this logic, the suction vacuum need not be controlled and only the discharge set pressure is varied every moment automatically to maintain the total head. The variation of water flow rate with time is plotted in Figure 4. The snapshot of various parameters on the PLC is shown in Figure 5.

Table 2. Typical calculation of differential index and discharge head

Sl. No.	Parameter	Unit	Head
1	Reference suction vacuum	m	5
2	Initial set discharge pressure	m	15
3	Total test head	m	5+15 = 20
4	Actual suction vacuum	m	8
5	Differential index	m	5-8 = -3
5	Revised set discharge head	m	15+(-3)=12

Total head = Suction vacuum + Discharge head

$$\textit{Water to wire efficiency of PV pump system} = \frac{\textit{Total head x Total flow}}{\textit{PV energy}}$$

4. Conclusion

This paper reports a novel method developed to maintain constant total head during SPV powered surface pump testing. This salient feature of this method is that the suction head can vary based on solar radiation and, but the discharge pressure is regulated automatically based on the differential variation in vacuum to maintain

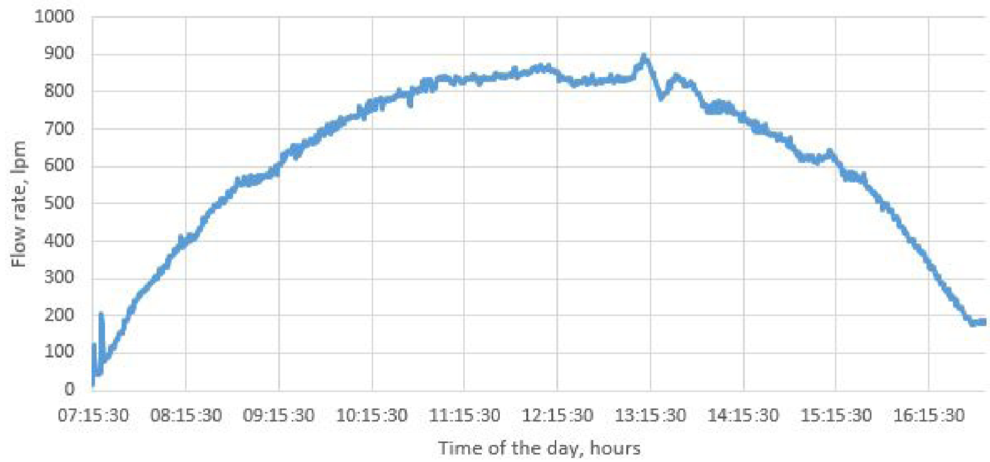

Figure 4. Variation of water flow rate @ 20 m total head.

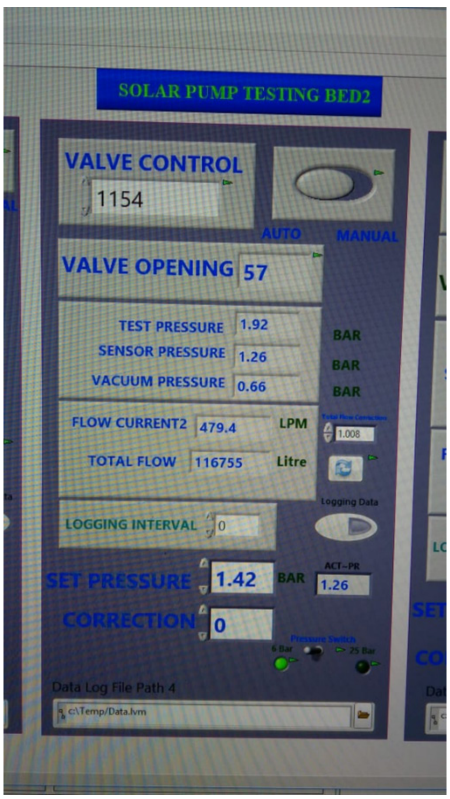

Figure 5. Snapshot of PLC monitoring system.

constant total head. This method has been practically implemented, experimented and several surface pumps are evaluated successfully.

5. Nomenclature

AC	Alternating current.
BLDC	Brushless DC motor.
DC	Direct current.
I_{mp}	Current at maxiumum power point (A).
I_{sc}	Short circuit current (A).
kW_p	Peak power.
PLC	Programmable logic controller.
P_{max}	Power at maximum power point (W).
SPV	Solar photovoltaic.
VFD	Variable frequency drive.
V_{mp}	Voltage at maximum power point (V).
V_{oc}	Open circuit voltage (V)

6. References

1. Khan SI, Md Mizanur R. Sarkar, Md. Quamrul Islam. Design and analysis of a low-cost solar water pump for irrigation in Bangladesh. Journal of Mechanical Engineering. 2013 Dec 2; ME43(2):98-102. https://doi.org/10.3329/jme.v43i2.17833
2. Shaik R, Beemkumar N, Adarsha, Hiriyannaiah, Dhass AD. Efficiency enhancement in a SPV operated solar pump by effective design of VFD and tracking system. Materials Today: Proceedings; 2020 Jun. https://doi.org/10.1016/j.matpr.2020.05.035
3. Harsh K, Rahul K, Pandey K, Jangir AK. BLDC motor driven water pump fed by solar photovoltaic array using boost converter. International Journal of Engineering Research and Technology. 2020 Jun; 9(6):635-9. https://doi.org/10.17577/IJERTV9IS060478
4. Benghanem M, Daffallah KO, Alamari SN, Joraid AA. Effect of pumping head on solar water pumping system. Energy Conservation and Management. 2014; 77(2014):334-9. https://doi.org/10.1016/j.enconman.2013.09.043