Performance Analysis of Solar Water Pumping System at Nawabshah

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Abstract

Performance of solar photovoltaic water pumping units relies on available solar radiations of the area, geographical conditions and system configurations. This study was conducted to analyze the influence of solar radiation, motor speed and water head on water discharge of a solar water pumping systems (SWPS). For that, a SWPS was installed, configured and its performance was examined at Sadiqabad Colony, Nawabshah for two consecutive months from 12:00 to 13:00 hours. Light meter, Model- HDS 2302.0, Delta OHM was used for measurement of global solar radiation, PROVA-RM 1000 tachometer for motor pump speed and stopwatch for time taken to fill the water tank. Results revealed that the average minimum solar radiations were 776 W/m^2 at 12:00 hours in the month of May and maximum 902 W/m^2 at 13:00 hours in the month of June during experimental work. The maximum average motor speed and flow rate were noted as 1447 rpm and 0.319 L/s at level-1 and minimum 1075.6 rpm and 0.207 L/s at level-4 respectively. The maximum time taken by the solar water pumping system was 144.4 sec for filling up of water tank at level-4 and minimum 94.00sec at level-1. The time taken to provide one liter of water was found inversely proportional with motor speed and directly with the water head.

Keywords—Flow rate, Motor speed, Solar water pumping, Solar radiations, Water head

1 Introduction

Solar energy is one of the key alternative, renewable and viable energy resources in the world [1]. It is green technology resource, nature-friendly, does not produce emissions that cause greenhouse effect or destroy the ecological balance. It is omnipresent, safe, abundant and freely available [2-4]. On average, Pakistan receives about 1kW/m2/day of global solar radiations for 6 to 7 hours. The number of sunshine hours per year in the country is nearly 3000 to 3300 [5]. There are two ways to use solar energy, namely indirectly through the use of thermal systems and directly via photovoltaic (PV) modules. The applications of solar energy include power generation, solar water pumping, water heating and cooling, street lighting and rural electrification [2, 4, 6].

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1.1 Solar Water Pumping

Clean water is vital for communal health, whether it is used for drinking purpose, cleaning, washing, bathing, food preparation or recreational determinations. Unfortunately, about 790 million people or 11% of global citizens have no approach to the paramount water supply [7]. Generally, water is withdrawn either from surface water sources or underground and then pumped to the homes and businesses [8]. The main function of water pump is to convey water from one point to the other one. Usually, water pumping depends on conventional electricity or diesel generated electricity. The application of fossil fuel or their derivative based need expensive fuel price and also creates noise and air pollution. Since, solar water pumping units decreases the reliance on fossil fuel based electricity [9].

The difference between a diesel and solar based systems only is the source of energy that is being utilized. Diesel pumping units use an electric generator and a solar PV system needs solar photovoltaic panels [10].

The other system components remain same, such as pump, controller or inverter, power cables, water withdraw pipes and fixtures. Solar water pumping systems (SWPS) can deliver water to the isolated locations which are far from the national power transmission lines. Thus, such places rely on anthropological or animal power or on diesel engines. Moreover, the price of solar photovoltaic based units has fallen extremely in recent years. The prices for the solar panels have fallen down up to 80% [11]. Moreover, the solar modules have a life time of about 25 years, which requires almost negligible maintenance [12,13].

SWPS working on the principle of photovoltaic (PV) technology that changes solar energy into electrical en0ergy to run a direct current (DC) or alternating current (AC) motor water pumps [14]. PV panels are linked to a motor, which changes electrical energy of PV panel into mechanical energy and later into hydraulic energy by the pump.

Solar powered water pumping systems are particularly ideal for remote locations where there is no electricity or national transmission lines [15]. It consists of photovoltaic modules, charge controller, battery, electric motor, pump and well or tank etc. [16].

1.2 Efficiency of Solar Water Pumping

The efficiency of SWPS mainly depends on the flow rate of water which is mainly influenced by solar insolation and temperature of the location. Other parameters which will be taken into account for design and sizing of water pumping systems include water demand, water dynamic head (m), required water quantity to be pumped (m^3), volume of storage tank (m^3), PV array energy output (kWh), available energy at the pump (kWh), pump efficiency and overall system efficiency (%). Total dynamic head (TDH) is sum of suction head, discharge head and frictional losses [17,18]. Hydraulic energy (Eh) is that part of potential energy, which is required to raise the water to discharge level [17, 18]. Eh (kWh/d) required per day to supply a volume, V of water (m^3) at TDH is given by [3, 19]:

$$E_h = \rho \times g \times V \times TDH \tag{1}$$

where ρ is the water density and g is the acceleration due to gravity. Solar photovoltaic array power (P_{PV}) required is given by:

$$P_{PV} = (\frac{E_h}{I_T \times \eta_{mp} \times F}) \tag{2}$$

where; I_T is the average daily solar radiation (kWh/m^2 day) incident on the plane of array, F is the array mismatch factor, ηmp is the efficiency of motor pump. The amount of water pumped, $V(m^3)$ is given by:

$$V = (\frac{P_{PV} \times I_T \times_{mp \times F}}{\rho \times g \times TDH}) \tag{3}$$

The efficiency of motor-pump system (ρ_{mp}) is hydraulic energy output (E_h) divided by input energy, whereas the efficiency of PV array, ρ_{pv} (%) is given by:

$$\eta_{PV} = \frac{P_{PV(W)}}{I_T(W/m^2) \times A_c(m^2)} \times 100 \tag{4}$$

The overall water pump efficiency is obtained as:

$$\eta_{total} = \eta_{PV} \times \eta_{mp} \tag{5}$$

Different analysis of solar water pumping system has been performed by different researchers, like system performance, size optimization, techniques of efficiency improvements and economic and environmental aspects. Solar water pumping systems relies on different parameters including climatic variables, location and configurations [9]. A few study has been found in literature that contains information about quantitative data that influence solar water pumping systems, but no study was found for Nawabshah region. Thus, this study was conducted to analyze the influence of weather parameters, pump speed and water head on water flow rates of a solar photovoltaic water pumping systems in Nawabshah.

2 Materials & Methods

A typical solar powered pumping system was installed which consists of photovoltaic modules, direct current (DC) motor (Khilji), water pump, battery, charge controller, and discharge tank. In this study, the two monocrystalline PV modules, model AEP 36 (M) were purchased from local market in order to supply solar electric power to the battery and directly pump the water during sunny weather. A DC motor (Khilji Company) was purchased and used in this study so as to rotate the water pump and moves the water under pressure. The rated current and voltages of DC motor was 7A and 12V respectively. A super diamond company water pump was used to pump the water. A lead acid battery of OSAKA Company with a rated current of 100A and 12V and A SOGO Company solar charge controller was used in this study.

2.1 Instruments

The instruments used for analysis of solar water pumping efficiency were lightmeter, tachometer and stopwatch. The amount of solar radiation was measured with the help of a light meter, Model- HDS 2302.0,

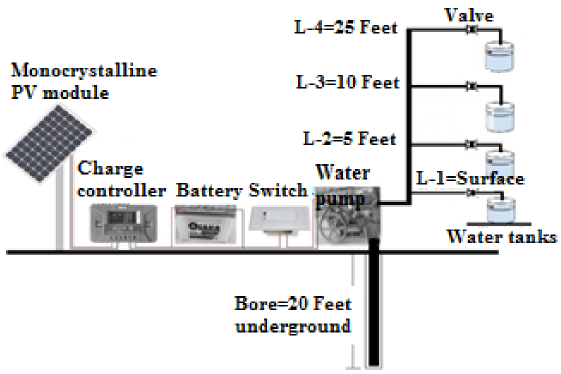

Fig. 1: Schematic diagram of installed water pumping system

Delta OHM on horizontal surface. A PROVA-RM 1000 tachometer was used to record the speed (revolution) of running motor pump and stopwatch for recording of elapsed time to fill the 30 liters capacity can. Besides that an electric switch button was used to turn ON and OFF the electric supply.

2.2 Experimental Setup

Solar water pumping system was made after drilling of bore hole, placing of piping system and interconnection of different components. Water borehole drilling involved drilling and casing a hole to access groundwater. Hence, a bore was drilled in the ground to reach water table. A manual hand auger drilling process was chosen to drill a bore in the selected area. A service of an experienced and skilled borehole driller was acquired for proper drilling of bore and installation of solar water pumping system. A shallow bore (up to about 20 feet depth) was drilled by hand and put a 1 inch diameter of polyvinyl chloride (PVC) pipe in the drilled bore. The outlet of PVC pipe was connected with the positive displacement reciprocating water pump. Monocrystalline PV module was used to generate electricity and supply it to electric motor so as to run the pump. Four different levels were selected as the water head. Level-1 (L1), Level-2 (L2), Level-3 (L3) and Level-4 (L4) were taken as surface level, 5 feet, 10 feet and 25 feet height (water head) respectively. At each selected level, the intensity of global solar radiation, motor pump speed (rpm), discharge time (s), and water flow rate (L/s) were measured during study period. Experimental work was conducted persistently for two months from May to June. The readings were taken from 12:00 to 13:00 hours at an interval of 20 minutes. During study period, the weather was found partially cloudy, sunny and hazy. The schematic diagram of the conducted work is shown in Figure 1.

3 Results & Discussion

The study results include solar radiation and performance parameters, like motor speed, time taken by the SWPS to fill up the 30 liters capacity can at different levels (water head) and water flow rate.

3.1 Solar Radiations

Average measured global solar radiations of both months from 12:00 hours to 13:00 levels are illustrated in Figure 2. The average values of global solar radiation in the month of May were found 823 W/m2 and for June 855 W/m2 with mean value of 839 W/m^2. In both months, the minimum value of solar radiations was noted as 776 W/m^2 at 12:00 hours in the month of May and maximum 902 W/m^2 at 13:00 hours in the month of June. Since, the weather was found partially cloudy, sunny and hazy throughout analysis period.

3.2 Performance of Solar Water Pumping System

Performance of solar water pumping unit was examined by measuring motor speed (rpm), discharge time (sec) and flow rate (L/s) for two months as given in Figures 3 to 5.

Figure 3 displays the average values of motor speed. The overall maximum values of motor speed were noted as 1447 rpm at L1 and minimum 1075.6 rpm at L4. It was observed that the speed of motor was lowest due to the position of water tank at maximum height from the ground level. Figure 4 displays the overall average values of time taken for filling up of 30 liters can with waster by the pumping system. The overall maximum and minimum time was recorded as 144.4 sec at L4 and minimum 94.00 sec at L1. It was noted that the maximum average time taken for the discharge of one liter water was 4.81 sec at L4 and minimum 3.12 sec at L1. The overall maximum, minimum values and percentage difference are given in Table 1. It was found that the maximum time required for filling up of 30 liters capacity can at L4 as it was placed at the maximum height and minimum time was noted at L1 due to water tank placement at surface level with no height of water tank. Figure 5 shows the average values of flow rate of water. The maximum flow rate of water was observed as 0.319 L/s at L1 and minimum 0.207 L/s at L4.

The maximum and minimum water flow rates were found at L1 and L4 due to the L1 is surface level and L4. The overall average results of motor speed (rpm) and flow rate (lit/sec) of water were noted as 1270 rpm and 0.268 lit/sec respectively. It was found that the maximum time was consumed at L4 due to low flow rate of water. Thus, the time taken to provide

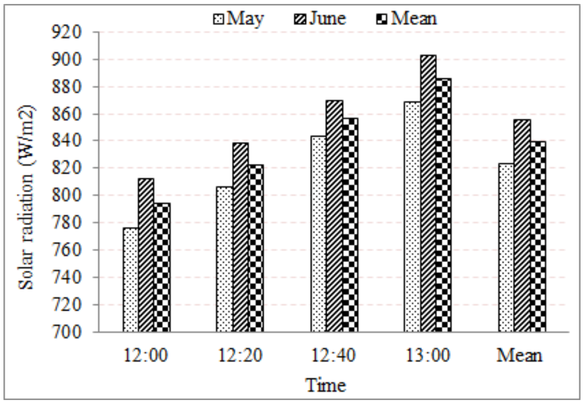

Fig. 2: Global solar radiations during experimental work

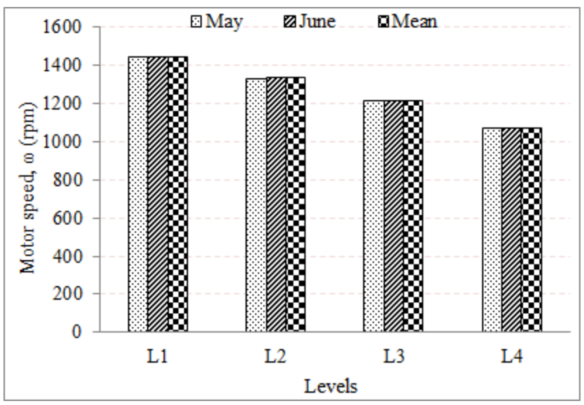

Fig. 3: Motor speed at selected levels analysis

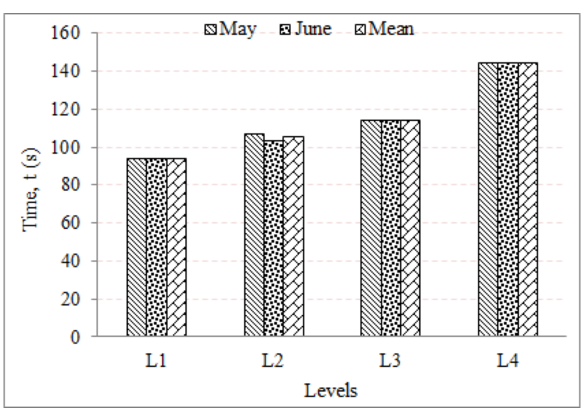

Fig. 4: Time elapsed for filling up of water tank at selected levels

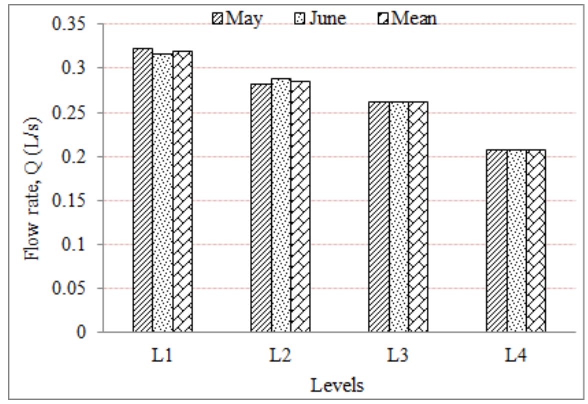

Fig. 5: Flow rate at selected levels

one liter of water was found inversely proportional with motor speed and directly with the water head. It is established from the analysis that the maximum average motor speed and flow rate were at L1 and minimum at L4, whereas, the maximum time taken by the SPVWPS for filling up of water tank with a capacity of 30 liters at L4 and minimum at L1.

It was found that the maximum time was consumed at L4 due to low flow rate of water. Thus, the time taken to provide one liter of water was found inversely proportional with motor speed and directly with the water head. It is established from the analysis that the maximum average motor speed and flow rate were at L1 and minimum at L4, whereas, the maximum time taken by the SPVWPS for filling up of water tank with a capacity of 30 liters at L4 and minimum at L1.

4 Conclusion

The average values of global solar radiation were noted as 839 W/m2 during study period. Minimum solar radiations were noted as 776 W/m2 at 12:00 hours in the month of May and maximum as 902 W/m2 at 13:00 hours in the month of June. However, due to monsoon period, the weather was partially cloudy throughout experimental analysis. Maximum average motor speed and flow rate were noted at L1 and minimum at L4. Likewise, the maximum time taken by the solar water pumping system for filling up of 30 liters water tank at L4 and minimum at L1. The time taken to provide one liter of water was found inversely proportional with motor speed and directly with the water head.

In future, work can be extended by using centrifugal pump or rotor for the same well under the identical outdoor conditions of Nawabshah.

Summary of Findings	Values
Maximum motor speed (rpm)	1447
Minimum motor speed (rpm)	1076
Difference in motor speed (%)	26
Maximum water flow (L/s)	0.32
Minimum water flow (L/s)	0.21
Difference in water flow (%)	35
Maximum time taken for filling of water tank (sec)	144
Minimu time taken for filling of water tank (sec)	94
Difference in time taken for filling of water tank (%)	35

TABLE 1: Overall maximum, minimum and difference values of motor speed, water flow and time

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