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Evaluation study of solar-powered irrigation pump

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ABSTRACT

Solar photovoltaic (SPV) water pumping systems have the potential to provide clean drinking water to millions of unserved people around the world. The performance of 3, 5 and 7 hp solar operated AC-submersible pumps was evaluated. The experimental data on head discharge, input power, solar insolation etc were recorded in order to access the overall efficiency of the system. The overall efficiency of 3, 5 and 7 hp pumps was found to be in the range of 5-10 per cent. The discharge was found to be directly proportional to solar intensity.

Keywords: Solar insolation; overall efficiency; array efficiency; discharge

INTRODUCTION

Renewable energy technologies can play a significant role in increasing access to clean water without increasing the fuel bill. There is tremendous global interest in using solar photovoltaic (SPV) technology for water pumping. Solar energy provides a dependable energy source. In such locations additional advantages would be the availability of energy exactly when water is in short supply, few moving parts required in a photovoltaic system and long-term efficiency of solar panels (Meah et al 2008a). The solar energy is the rich energy source present in the world. The solar power is not only helpful in dealing with the energy crisis but it is also an environmental friendly energy. The PV or photovoltaic creation is a competent method for using the solar energy. The solar panels are now being utilized for powering the heaters, for the street lights and fulfilling the domestic loads. The solar panels' cost has been decreasing that increases its use in different sectors (Meah et al 2008b). This technology is also used in the irrigation systems for farming. The solar powered irrigation system is a suitable substitute for farmers in the recent condition. It is a method of energy production that gives free energy after making the initial investments.

The generation these days is heading towards ultratechnology. The pumping of water has a huge history and there are several methods that have been developed to pump water. There are several resources that are being used by people including animal power, solar, wind, hydro-power and the fuels for various generators. Some of the common pumps that are utilized in the remote communities are hand pumps, solar submersible pumps, direct drive diesel and the borehole pumps (Khatib 2010).

MATERIAL and METHODS

Solar photovoltaic AC pump

A solar-powered pumping system used for the experimentation consisted of following components:

PV array: The SPV water pumping system operated using PV array consisted of combination of solar panels each having capacity of about 285 watt.

3 hp SPV AC pump: For operating 3 hp AC pump 10 panels were used having total capacity of about 2850 watt. All the ten modules were distributed and connected in series so that these could be used to obtain the required PV array power output.

5 hp SPV AC pump: For operating 5 hp AC pump 16 panels were used having total capacity of about 4560 watt. All of sixteen modules were distributed and connected in series so that these could be used to obtain the required PV array power output of PV modules with higher power output.

7 hp SPV AC pumps: For operating 7.5 hp AC pump 24 panels were used having total capacity of about 6840 watt. Out of twenty four modules 12 were distributed and connected in series and group of 24 panels connected in parallel so that these could be used to obtain the required PV array power output of PV modules with higher power output.

Pump

Pumps were designed specifically for solar power that utilize alternate current (AC). The size of the pump depends on several factors including available water supply, available power, available storage, total dynamic head (TDH) and water need. The pump was designed to operate during peak sunlight hours.

Solar pump controller (Table1, Plate 1)

Solar pump controller used for AC pump was designed to convert DC supply of PV array to AC supply required for AC pumps. The pump controller was electronic with no moving or wearing parts. A technical term for a pump controller was a linear current booster. The purpose of the pump controller was to regulate and match the flow of DC electricity to the needs of the AC pump (Kumar and Singh 2014).

Table 1. Specifications of solar pump controller

Particular	Specification
Maximum power voltage	Vmp >800VDC
Open circuit voltage	VOC max 230-415 VDC
Company	ABB
Model	ACS355-03E-12A5-4
Output	30-130 VEC PWM, 3-phase

Plate 1. Solar pump controller

Tracking: Panels were tracked manually three times in a day period (10:00 am, 01:00 pm and 03:00 pm).

Solar photovoltaic pumping system

The performance of solar photovoltaic pump was evaluated for measuring discharge corresponding to voltage and current generated by solar photovoltaic panels. There are two types of solar water pumping systems available viz battery-coupled solar water pump and direct-coupled solar water pump. During experimentation direct-coupled solar water pump was used in which electricity from the PV modules was sent directly to the AC pump which in turn pumped water through a pipe to where it was needed. This system was designed to pump water only during the day time. The amount of water pumped was totally dependent on the amount of sunlight falling on the PV panels and the type of pump. The intensity of the sun and the angle at which it striked the PV panel changed throughout the day; the amount of water pumped by this system also changed throughout the day. Direct-coupled pumping system was sized to store extra water on sunny days so that it was available on cloudy days and for the night. Water could be stored in a larger than needed watering tank or in a separate storage tank and then gravity-fed to smaller watering tanks.

Performance evaluation of solar photovoltaic pumping system

Performance of solar photovoltaic pump was evaluated by determining hydraulic power output, array efficiency, system efficiency and overall efficiency (Mansaray 2014). Table 2 gives the list of

Table 2. List of instruments used with specifications

Instruments used	Specification	Measurement
Solar power meter	Maker: Tenmars, Measurement: W/m^2 Range: 0 to 1750 W/m^2 Permissible error: 2%	Solar radiation (W/m^2)
Digital anemometer	Make: LUTRON Measurement: m/s, km/h, ft/min Operating temperature: 0 to 50ºC	Air flow rate (m/s)
Multimeter	Make: Beemet Range: 300 V Make: Meco Maximum: 20A COM- maximum 750VAC, 1000 VDC	Voltage (DC) Current (DC)
Infrared thermometer	Make: Mextech Range: 5 to 200ºC	Temperature
Water meter	Measurement (m^3)	Water discharge

instruments used during experimentation to evaluate the performance of the system.

RESULTS and DISCUSSION

Fig 1 reveals that the maximum discharge of 10000 l/h was obtained at 11:30-15:30 hrs with corresponding power output of 2300-2250 W. It was observed that the discharge was directly proportional to the power output of PV array. Same study was carried out by Kolhe et al (2004).

From Fig 2 it can be observed that overall efficiency varied from 3-4.5 per cent with corresponding solar radiation of 700-900 W/m^2. It was also observed that maximum overall efficiency was recorded to be 4.50 per cent corresponding to maximum solar radiation of 900 W/m^2 during11:30-14:00hrs.

From Fig 3 it is observed that maximum discharge of 15000 l/h was recorded at maximum power obtained from panel of 3500-4000 W during 12:00-13:30 hrs.

Fig 4 reveals that overall efficiency varied from 6 to 8 per cent with corresponding solar radiation observed to be 600-900 W/m^2. It was also observed that maximum overall efficiency of 8 per cent was determined to maximum solar radiation of 900 W/m^2 during the time interval between 13:30 and 14:00 hrs.

Fig 5 gives the comparative performance of power output and discharge for 7 hp solar operated AC pump. It was observed that maximum discharge was recorded to be 16000 l/h; maximum power obtained from panel varied from 3500 to 4800 W during 12:00-13:30 hrs. It was found that maximum discharge was

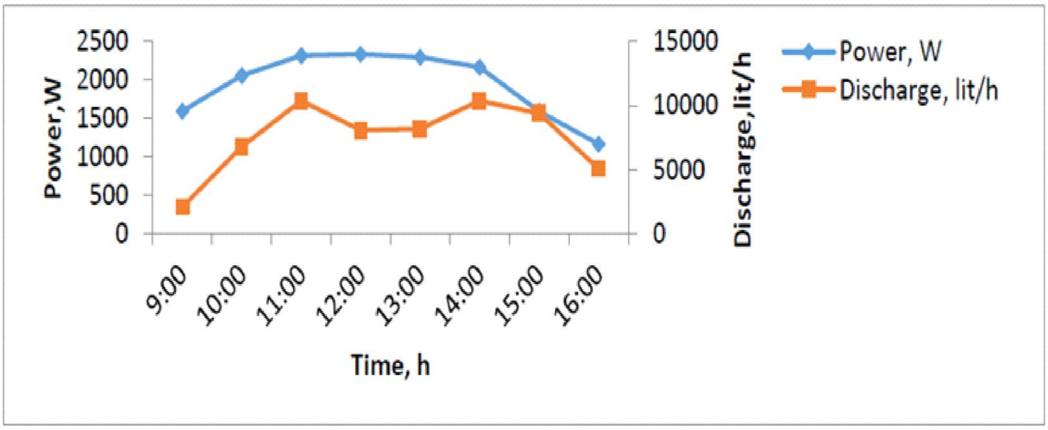

Fig 1. Comparison of power output and discharge with respect to time for 3 hp AC pump

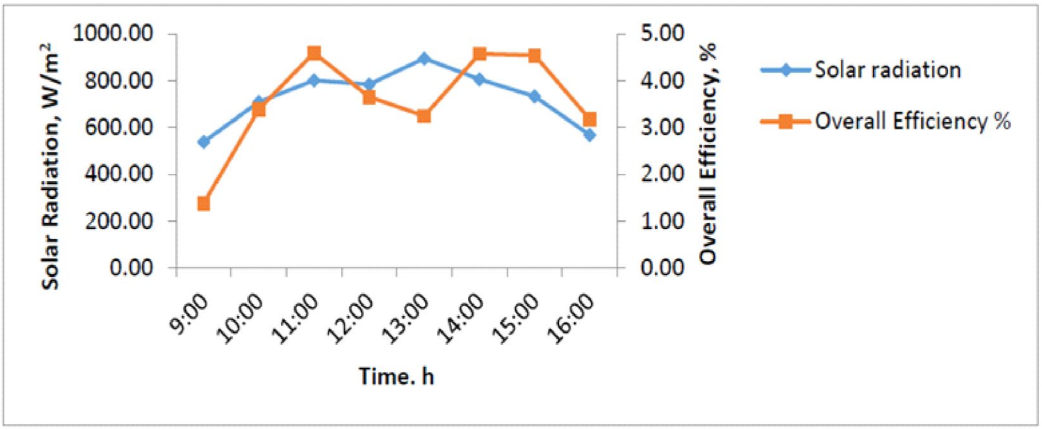

Fig 2. Variation of solar radiation and overall efficiency with respect to time for 3 hp AC pump

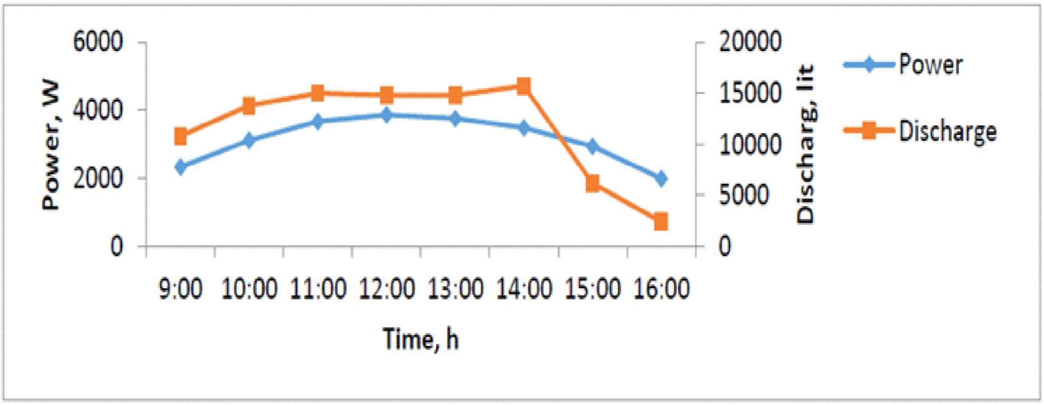

Fig 3. Comparison of power output and discharge with respect to time for 5 hp AC pump

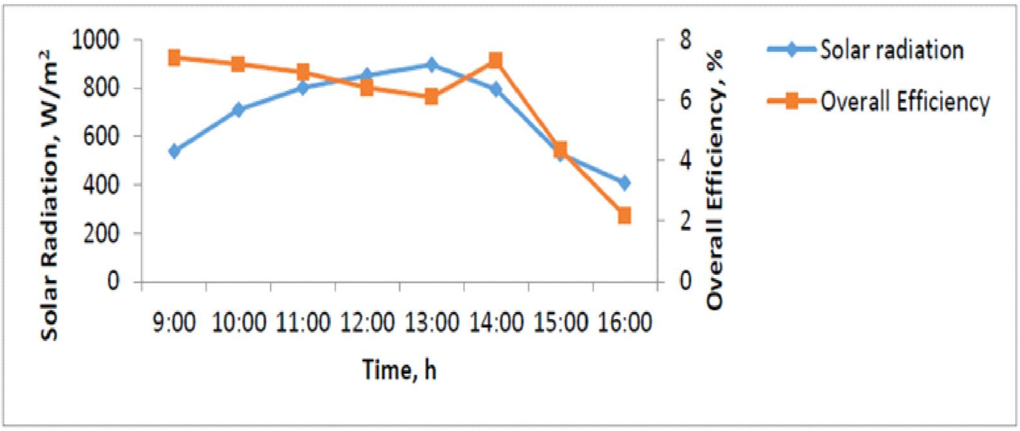

Fig 4. Variation of solar radiation and overall efficiency with respect to time for 5 hp AC pump

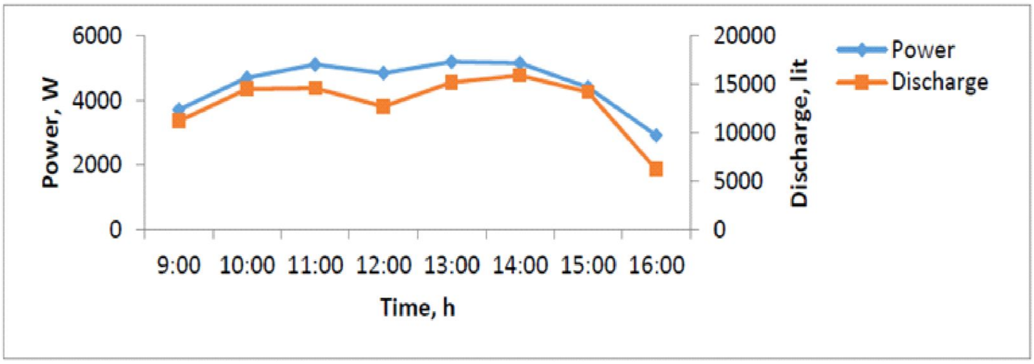

Fig 5. Comparison of power output and discharge with respect to time for 7 hp AC pump

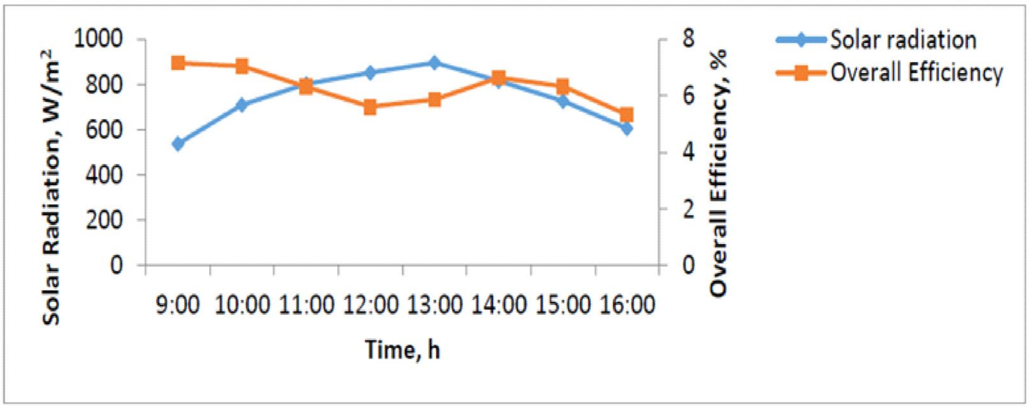

Fig 6. Variation of solar radiation and overall efficiency with respect to time for 7 hp AC pump

recorded at maximum power of 3500 W obtained at 13:00-14:30 hrs. The study was carried out in accordance with Narale et al (2013) and Pande et al (2003)

From Fig 6 it is observed that overall efficiency varied from 6 to 7 per cent and solar radiation varied from 500 to 850 W/m². It was also observed that maximum overall efficiency observed was 7 per cent corresponding to maximum solar radiation of 900 W/m² during 13:00-14:30 hrs.

CONCLUSION

Daily trial revealed that the pump discharge varied from 8000 to 10000 l/h with corresponding power output of 1700-2300 W during 12:00-14:00 hrs for 3 hp. For 5 hp pump discharge varied from 10000 to 16000 l/h with corresponding power of 2700-4000 W during 9:00-13:30 hrs. The pump discharge varied from 12000 to 15000 l/h with corresponding power of 3500-4500 W at 9:00-13:30 hrs for 7 hp on the single day of testing and the pump delivered maximum discharge during 9:00-13:30 hrs and it was then decreased. It clearly indicates that pump discharge increased with the increase in solar radiation. The overall efficiency of 3, 5 and 7 hp SPV AC pump increased during 10.00 to 13.00 hrs with corresponding solar intensity of 600-800 W/m² on the single day of testing.

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