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Utilization of Solar Power for Operating Micro Irrigation Systems

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A B S T R A C T

Photovoltaic based electricity generation saves a major portion of renewable energy generation in India. Ever increasing fuel cost and doubtful availability of electricity hampers the irrigated crop production. Use of solar pump is an alternate to electric or diesel pumps for irrigation of crops. This paper presents the utilization of solar power for operating micro irrigation systems for irrigating field crops. An open well submersible pump of 5hp capacity was operated by 4960Wp solar panel installed at ICAR-CIAE, Bhopal for irrigation. The discharge rate of pump has been observed as 11400 to 24120 l/h at a dynamic head of 2.5 m corresponding to solar irradiation range of 164 to 808 W/m^2 during time period from 8 am to 4 pm. The total power generation from the panel during this period has been observed as 3013.5 W. The total excess power availability during different irrigation treatments such as drip (T_1), portable sprinkler (T_2), rain hose (T_3) and flood irrigation (T_4) has been estimated for other uses of solar photovoltaic system. In different irrigation systems the excess power availability range per year per ha has been varies from 235 to 1160 kWh, 246 to 1213 kWh, 246 to 1213 kWh and 220 to 1084 kWh respectively. The maximum area irrigated by T_1 of 2000 to 3500 m^2, T_2 800 to 2500 m^2, T_3 500 to 1500 m^2, T_4 100 to 450 m^2.

Introduction

Indian economy is 6th largest developing economies of the world and over 60% of population depends on agriculture or allied activities. Ever increasing fuel prices and unreliable availability of electricity in villages hampers the irrigated crop production in India. In order to reap a good harvest, providing appropriate moisture to the plant is a necessary requirement. Over last two decades the demand for electricity in irrigation is growing up as the cost of an electric powered pump is lower as compared to a diesel engine driven pump. Though the demand for electricity is increasing on supply side, the availability of electricity is of limited duration and during odd hours. It is therefore, solar pump may be an alternate to address these problems faced by farmers. The ranges of solar radiation in India are between 4.0 and 7 kWh/m^2 day with an annual radiation ranging from 1200–2300 kWh per square meter and the bright sunshine hours vary from 6 to 9 h/day (Yadav *et al.*, 2015). Abu-Aligah (2011) reported that in locations where electricity is not available photovoltaic pumping system is a good option for irrigating crops and supplying drinking water.

Namibia Renewable Energy Programme (NAMREP) conducted a study on feasibility of solar pumps in Namibia (Anon, 2006). The report concluded that for small to medium sized wells, a solar photovoltaic pump was much cheaper (on a life cycle cost basis) than a diesel-powered pump. When looking beyond the original purchase price, solar pumping systems costed from 22%-56% of diesel pumps cost and could achieve a payback over diesel engine operated pump in two years. Hahn (2000) reported that in regions with high insolation levels, photovoltaic pumping systems were technically suitable for use, beneficial for the environment and were cheaper over the diesel engine driven pumps. The use of solar powered irrigation systems (SPIS) offers a chance to lower the energy and water consumption under irrigation systems. This is achieved through the use of solar energy and the increased efficiency in water application (Williamson, 2006). The transportation of SPIS is simple compared to other types of renewable energy systems because the system can be transported in parts and put together on site (Khatib, 2010). Biswas and Hossain (2013) reported that though the initial cost of a solar pump is higher than a conventional diesel engine operated pump, solar pump has lower maintenance cost which makes it cost effective over the years at the same time and a solar pump is a pollution free and environment friendly water pumping system. In many rural areas, especially in developing and emerging countries, the access to the electricity grid and electricity availability is not always guaranteed. Therefore, a study was undertaken to utilize solar pump for operating micro irrigation systems such as drip irrigation, portable sprinkler irrigation and rain hose irrigation systems.

Materials and Methods

A open well submersible pump of 5 hp capacity operated by 4960 Wp solar panel with two arrays (each consist of 8 panels) was installed at Precision Farming Development Center of ICAR- Central Institute of Agricultural Engineering, Bhopal for irrigating field crops by different irrigation treatments. The delivery lift of the pump is 2.5m. The performance of the pump was tested by collecting the information on solar radiation, generated voltage, current, lift, discharge and other relevant data were recorded for the pump. The daily flow rate of the pump to deliver water for different irrigation system over a period of time was maintained by water meter. The solar irradiation has been measured by using pyranometer. The maximum area irrigated by each irrigation system which is operated by solar photovoltaic system has been measured by operating micro irrigation systems individually at a peak solar irradiation of 808 W/m^2. The layout of solar power micro irrigation system is presented in Figure 1.

The specializations of different micro irrigation systems and solar pumping system components uses are presented in table 1.

Results and Discussion

Performance of solar panel

The array of solar photovoltaic panels (SPV) is capable of generating 4960 Wp under an ideal condition. The actual range of power generated by the SPV array is observed as 211-3563 W in a sunny day having solar radiation of 58-975 W/m^2. The total generation efficiency of the system was observed as 71.8% in the field condition. The effective field efficiency of the system is found to be 14.25%. The solar radiation from April 2017 to March 2018 has been measured using pyranometer and analyzed. The data on the basis of time has been observed (8 am to 6 pm) and presented month wise in the Figure 2. Maximum solar radiation has been observed in the month of April 2017 is 902 W/m^2 at 12 pm whereas minimum 365 W/m^2 has been observed in the month of Aug 2017 corresponding to same time.

Performance of pump

Variation of discharge of solar pump with solar radiation at different times of a day was tested in the project location and presented in Figure 3. It is observed from the figure that solar pump could not lift water below 60 W/m^2 solar radiations. Discharge increased with the increase of solar radiation and it reached peak in the noon (12:00 am) and then decreased gradually as solar radiation decreased. During the testing period the maximum discharge was found 7.35 l/s at 11.30 pm and average discharge was 3.67 l/s.

The discharge rate of pump has been observed as 3.16 to 6.7 l/s at a dynamic head of 2.5 m corresponding to solar insolation range of 164 to 808 W/m^2 during time period from 8 am to 4 pm (Fig. 4). The total power generation from the panel during this period has been observed as 3013.5 W. The ambient temperatures have been observed to be in the range of 30-31° C.

The maximum area covered under different micro irrigation systems with solar power was compared with solar powered conventional (flood) irrigated area by operating each irrigation system in a day corresponding to solar radiation during 8 am to 4 pm. The same is presented in Figure 5.

It can be seen from Figure 5 that the maximum area irrigated by T_1 is 2000 to 3500 m^2, T_2 800 to 2500 m^2, T_3 500 to 1500 m^2 and T_4 100 to 450 m^2 corresponding to solar irradiation range of 164 to 808 W/m^2 during time period from 8 am to 4 pm.

Table.1 The specializations of different micro irrigation systems and solar pumping system components uses

S.No	Unit	Specification
1	Water Source	Water Tank, 20,000 liter
2	Pump	5 hp, Open well Submersible pump (AC supply)
3	Drip irrigation	16 mm inline (0.40 m X 2 lph)
4	Portable sprinkler	Lateral connected, mini sprinkler 70 lph
5	Rain hose irrigation	40 mm, 1 liter / minute / meter
6	Solar panel capacity	4960 Wp
7	Total number of panels	16
8	Number of array	2
9	Max. output voltage	600-725 V
10	Max. power current	8.28 A
11	Input voltage	400-750 VDC
12	Working current	1-20 A
13	Output voltage	250-440 VAC, 3 Phase
14	Frequency	0-60 Hz

Figure.1 Layout of the solar power micro irrigation system, which indicates the different parameters required for sizing the solar PV array and the pump

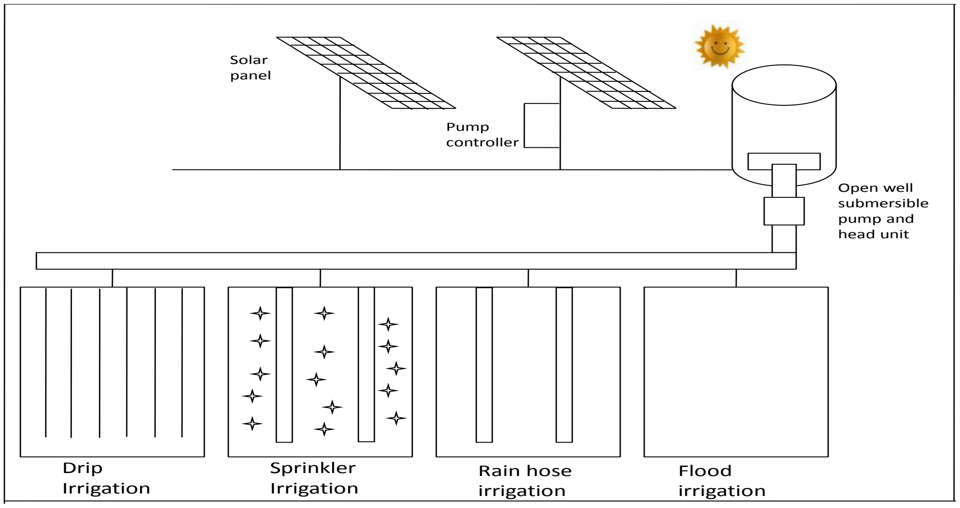


Figure.2 Monthly average solar radiation

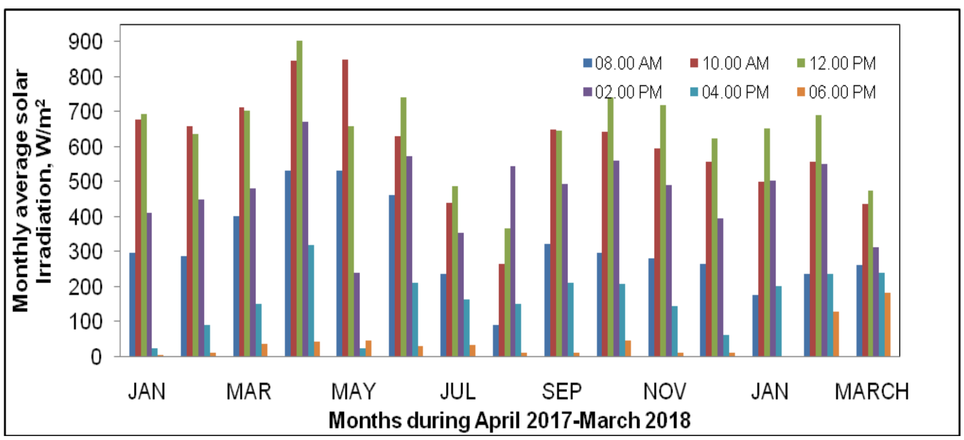


Figure.3 Variation of discharge of solar pump with solar radiation at different times of a day

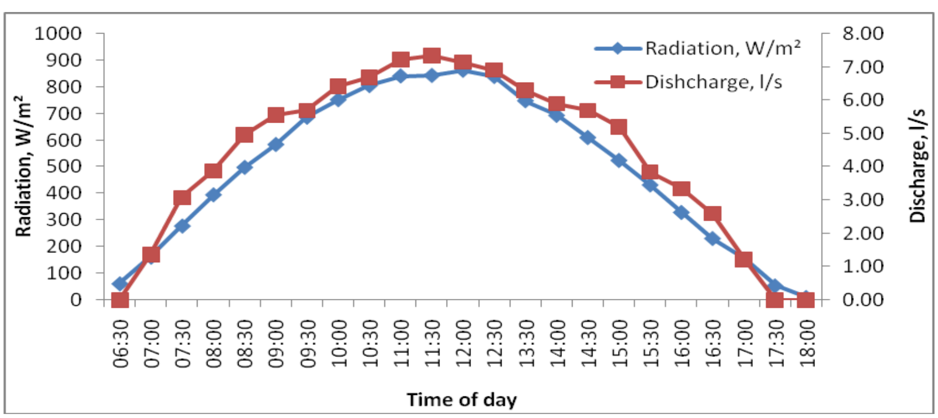


Figure.4 Power generated from SPV panel and discharge of pump

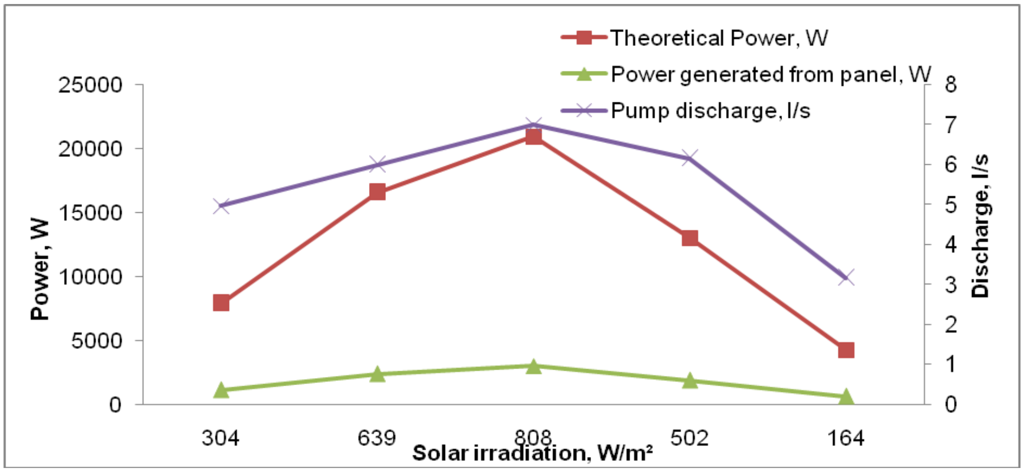
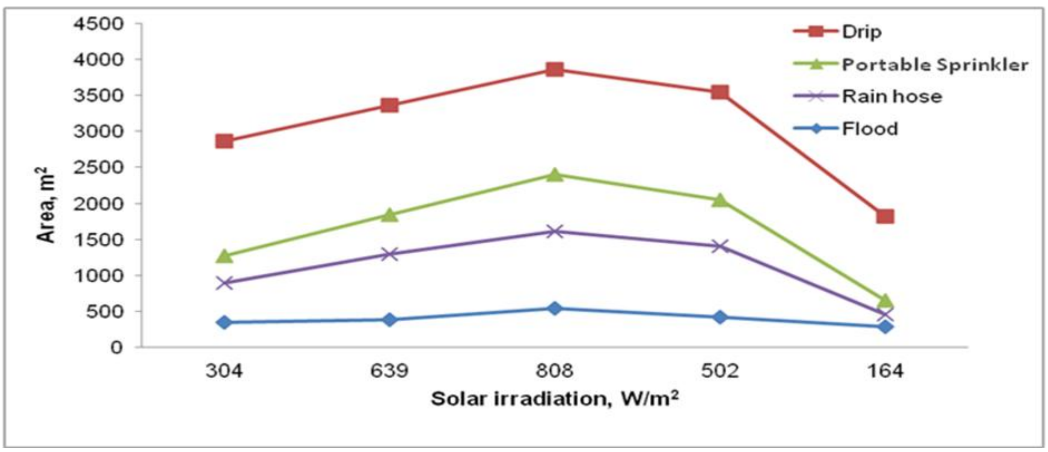


Figure.5 Area covers by irrigation system under different solar radiation respectively discharges



In conclusions, a solar powered irrigation system is an alternate to conventional powered (electricity/diesel) irrigation systems. The study carried out at ICAR-CIAE, Bhopal indicates that the solar power can be effectively utilized in irrigating field crops using micro irrigation systems such as drip, portable sprinkler and perforated pipes. Use of solar power facilitated to cover maximum area with drip irrigation followed by portable sprinkler, where as conventional flood irrigation resulted in covering lesser area as compared to micro irrigation systems. For the study area, the solar radiation required to operate solar pump shall be more than 60 W/m^2. The study also concludes that if the installed solar panels exclusively used for water pumping the effective field efficiency is 14.25% though the power generation efficiency of the system is 71.80%. It is therefore, recommended to plan for alternate use of trapped solar energy for other purposes during non pumping hours for enhancing the field efficiency of solar power.

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