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Performance of Low Capacity Solar Pump under Tracked and Fixed Mechanism of Solar Array in Eastern Region of India

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ABSTRACT

Under the policy frameworks and financing schemes for solar energy use in agriculture many Indian states are providing subsidies on small capacity solar pumps even upto 90% for the use of smallholders' irrigation. One of most the popular and subsidised solar pump is of 3.0 HP solar submersible pump, operated by 3.0 kWp solar array. This paper presents the performance of 3.0 HP solar pump with tracking and fixed array evaluated under the prevailing solar global radiation of 3.4-6.4 kWh/m^2/day, solar irradiance of 0-930 W/m^2 and the groundwater depth regime 10 ±4m of Eastern region of India. The results showed that the 3 times manually tracked array yielded 19-23 percent more water compared to fixed array. The mean monthly daily groundwater yield with 3 times manually tracked array was found in range of 80-155 m^3/day.

Keywords: Irrigation, tracked array, fixed array, solar radiation, groundwater

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INTRODUCTION

Eastern region of India is dominated by smallholders who shares major portion of operational land. Despite the fact that the small holdings are better in efficiency with good inputs resource, these stallholders are still susceptible to poverty and hunger (NCEUS, 2008; Sen, 1964; Mazumdar, 1965; Berry, 1972; Bardhan, 1973). The reasons lie in the facts that, in general, these smallholders grow staple crops of relatively low commercial value and their production systems are often been risky and relatively of low yield due to erratic rainfall and lack of supplementary irrigation infrastructure. However, if they had the access of key inputs of crop production then under current global market integration these smallholders could be playing a major role in food production and food security of the world (Lipton, 2006). Lack of water supply infrastructure has been the major constraint, as assured water supply provides ample opportunities for investing in high yielding seeds and ensures crop diversification.

In Eastern region water abstraction structures are mostly diesel operated. Further, the ensuring of energy security to smallholders in the form of fossil fuels and electricity at affordable cost is almost unlikely (Shah, 2009). Under such circumstances subsidised solar photovoltaic water pumping system can be a good option in mitigating energy crisis at farm level (Rahman and Sundaram, 2020). Solar system coupled with pressurised irrigation technology will have additional benefits in reducing over-exploitation of groundwater and enhancing input use efficiency (Qureshi *et al.*, 2001; Sivanappan, 2002; Namara *et al.*, 2005, Narayanamoorthy, 1997, Dhawan, 2000) (Table 1). Despite numerous benefits, adoption and diffusion of pressurised irrigation system is still far below the potential level though many Indian states are providing good subsidy on pressurised irrigation technologies (Table 2).

Eastern region of India receives high solar irradiance with on an average 250 -300 bright days in a year (Sharma *et al.*, 2012; Jaswal, 2009). Typically, mean monthly averaged solar irradiance in this region is ranging from few W/m^2 to about 930 W/m^2 and mean monthly averaged solar global radiation is ranging from 3.6- 6.4 kWh/m^2/day (Fig. 1a &1b) (Rahman and Bhatt. 2017). The highest solar global radiation is received in the month of April while the lowest is found in the month of December. This enormous energy can be harnessed for electrical energy.

Under new policy frameworks and financing schemes, the central as well as states governments are pushing investments into solar energy infrastructure and promoting installation of off-grid stand-alone solar powered water pumping system either on community basis or on individual basis with sponsored schemes by providing subsidies even upto 90 percent on some specific small capacity solar pump. In Eastern region states, such as Bihar, Madhya Pradesh. Chhattisgarhi, Jharkhand, Eastern Uttar Pradesh and West Bengal, the most popular subsidised solar pump is of 3 HP solar submersible pump.

Further, the groundwater depth regime is an important attribute which greatly affects the performance of solar pump in groundwater abstraction. The prevailing ground water depth regime in this region, in general, is ranged from 2 - 10 m with annual fluctuations of ±2 to ±4m (GWB, 2019). This paper presents the impact of manual tracked solar array structure over fixed array structure in terms power generation and discharge of 3.0 HP subsidised solar pump to enable the farmers to select appropriate time band for operation and to fulfil the irrigation needs efficiently

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and performing allied activities under the prevailing solar radiation condition and groundwater depth regime of Eastern region.

Table 1: Irrigation and Application efficiencies of various Irrigation Systems

Sl. No.	System	Irrigation Efficiency (%)	Application Efficiency (%)
1.	Surface methods of irrigation	70-90	50 -95
2.	Sprinkler Irrigation Systems	70-90	60 - 95
3.	Micro Irrigation Systems	80-90	70-95

Source : *Rogers et al* (1997)

Table 2: Subsidy provided on micro irrigation system

Sl. No.	State	Agency	Subsidy
1.	Bihar	State Horticultural Mission	90%
2.	Chhattisgarh	Department of Agriculture	70%
3.	Jharkhand	Department of Agriculture	50%
4.	Odessa	Horticultural Development Society (OHDS)	70%
5.	Uttar Pradesh	Special Agricultural Department Scheme for *Bundlekhand*	100%
6.	West Bengal	Department of FPI and horticulture	50%

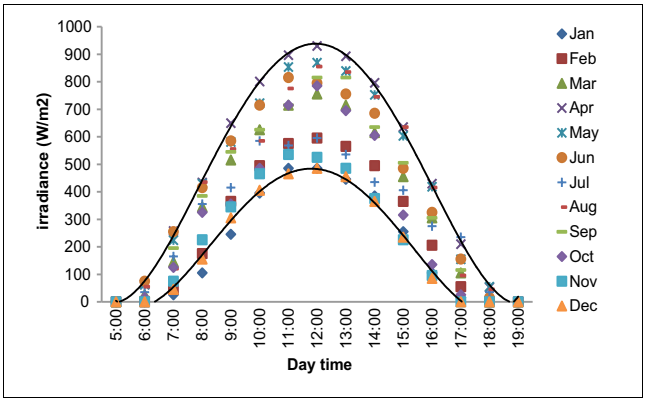

Fig 1a: Mean monthly averaged solar irradiance on cloud free day in Eastern region of India

MATERIAL AND METHODS

For Eastern region of India, in general, 3.0 kWp solar array is used for operating 3 HP solar pump. This size array is developed by using solar modules with specific combinations. The electrical characteristics of solar modules used in developing required size array are reported in Table 3. The array involved 10 modules, connected in series and paralleled combination to get desired voltage-ampere (V-I) characteristics as required in solar pump specification.

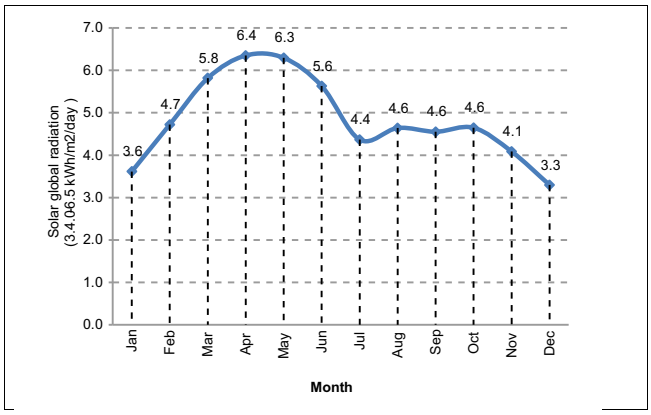

Fig 1b: Mean monthly averaged global solar radiation on a cloud free in Eastern region of India

Table 3: Attributes of solar panels, used for submersible and centrifugal pumps

SN	Attributes	Description
1	Pump type	Solar submersible with shut off head 35m
2	Array size	3.0 kWp±3%
3	No. of modules	10
4	Material of cells	C-Si
5	Module size	0.3 kWp
6	Efficiency	15.4%
7	Open circuit voltage (V_{oc})	44.64V
8	short circuit current (I_{sc})	8.75A
9	Voltage at maximum power (V_{mp})	35.93V
10	Current at maximum power (I_{mp})	8.35A
11	Temperature coefficient W/ ^{0}C	± 0.4% / °C

In order to maximise the power generation, solar modules should be perpendicular to the incident sun rays. This is done by mounting solar array on dual-axis tracking structure to align array in E-W and N-S directions. However, some users prefer fixed structure over tracked to avoid additional cost and labour in manual rotation. The instantaneous power generation from 3.0 kWp solar array on a cloud free day with 3 times manual tracking with tracking alignment options: in the morning hours 45° E from vertical; during middle of the day 0° and in afternoon hours 45°W. To include seasonal variation the array was kept inclined permanently at 32° S from vertical during mid-November to mid-February and E-W tracking were performed as usual over the day.

In case of fixed structure, the array was fixed on a structure with permanent inclined angle of 32° south from the vertical and no rotation was performed. With these two options a 3.0 HP solar pump was operated at research farm of ICAR Research Complex for Eastern Region, Patna. For two different array tracking configurations, the power output and the corresponding system discharge were evaluated for different months. The power output from operating solar array under two different configurations is reported in Fig. 2 and pump discharges with two different configurations over a day during the month of April is shown in Fig. 3.

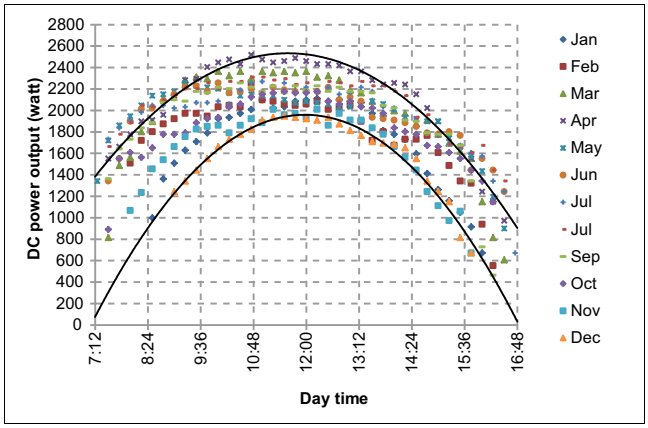

Fig 2: Power output from 3.0 kWp operating solar array in Eastern region of India

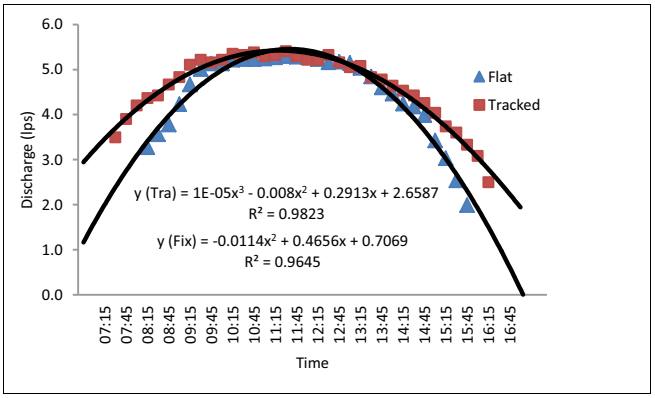

Fig 3: Discharges under tracked and fixed array from 3 Hp-3.0kWp solar pumping system over a day during month of April

RESULTS AND DISCUSSION

The interpolation of Fig. 2 showed that the power availability to the pump is depending upon the months and ranged from 1.5 -2.4 kW between 9.0 AM -2.30 PM. Hence, with 3.0 kWp solar operating array the 3.0 HP pump, having rating 2.2 kW, runs at its rated power only during some months and over a certain time band over a day, otherwise it run below its rated value. The operational threshold irradiance for 3.0 HP solar pumps was found to be 0.2 kW/m^2. From Fig. 2 it has been observed that during low insolation months the operational time band was ranged between 8.0 AM to 3.30 PM; whereas, in remaining months it was from 7.30 AM to 4.30 PM.

From Fig. 3 it is observed that during 9.30 AM- 2.00 tracked and fixed solar array generated almost equal power. However, a tracked solar array in comparison to fixed array was found more effective before 9.00 AM and after 2.00 PM. Therefore, the tracked solar array was found more effective in maintaining standing water depth in fish pond. During this time band pump discharge was very good and therefore very good irrigation efficiency was noticed under flood methods.

Coupling of pressurised irrigation equipment, such as drip and micro-sprinklers, with this solar pumping system over the time band 9.00 AM- 2.00 PM was found most appropriate and effective. Therefore, if solar system is to be used for solely irrigation purposes fixed array configuration found at par with tracked structure over said time band of the day.

The mean monthly averaged daily water output on cloud free day with 3 times manually tracked as well as for fixed array configurations during the month of highest radiation month (April) is given in Fig. 4. The difference in abstracted groundwater volume under two different array configurations was found 19 percent whereas for reaming month it ranged from 21-23 percent higher. Thus, overall difference was found to be 19-23 percent less water with fixed array compared to 3 times manually tracked array. The excess water abstraction with tracked array was due to the more operational hours over a day contributed by early morning and late afternoon hours to the total operational hours. The mean monthly daily water yield from this solar water pumping system, for different months under manual tracking array on a cloud free day under 10 ±4m suction head, is reported in **Table 4**.

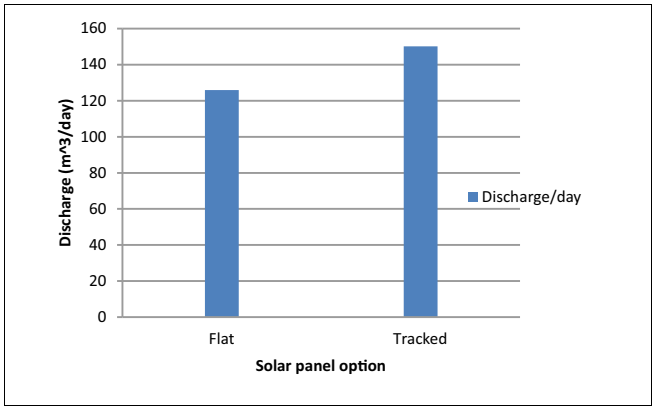

Fig 4: The mean monthly averaged daily water output on cloud free day with 3 times manually tracked and fixed array for the month of April

Table 4: Performance of 3 HP solar pumping system in different months under manual tracking of solar array on a cloud free day

1. Months	Sep-Nov	Dec-Jan	Feb	Mar-June
2. Water yield per day (m^3/day) from a solar pump on a cloud free day	135-120	85-80	90-115	160-135

CONCLUSION

Farmers using subsidised pump of this capacity should choose the option of tracking array and fixed array based on their requirements. For exclusively irrigation purpose user can opt fixed structure, however, for allied purposes such as maintain water level in fish pond a tracked structure is better option as more water can be abstracted on daily basis. Further, operation of a solar pump is limited to day time and good discharge is available only over a certain time band therefore a limited area can be irrigated per day with good irrigation efficiency. Therefore, under solar pump crops must be grown in diversified mode with pre planned irrigation scheduling.

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