Journal of Natural Resource Conservation and Management
Vol. 1, No. 1, pp 48-53, 2020
doi: 10.51396/ANRCM.1.1.2020.48-53

Solar photovoltaic technology options for smallholders

Atiqur Rahman*, B. Sarkar, Ajay Kumar, K. Sarma, A. Dey and A. Upadhyaya

ICAR Research Complex for Eastern Region, Division of Land and Water Management, Patna-800 014, Bihar, India
**Corresponding author E-mail: rahman_patna@yahoo.co.in*

Received : February 20, 2020
Revised : April 8, 2020
Accepted : May 2, 2020
Published : June 30, 2020

ABSTRACT

Solar energy technology is having many added advantages in terms of its divisibility, sustainability and environmental friendliness, therefore, offers many scopes and opportunities for its use in agriculture and allied fields. However, despite of these many benefits, applications of solar energy is still limited and confined to only few wealthy and large farmers. The foremost reason behind this limitation is the high initial investment cost and lack of awareness among the smallholders about the solar system's benefits. This paper presents a solar photovoltaic technology model for smallholders which can perform many operations such as groundwater abstraction, operating pressurized irrigation system, improving dissolved oxygen concentration in fish ponds and maintaining microclimate and hygiene in animalsheds by use of a small capacity solar pump of 1.0 horsepower energized by 1.2 kWp solar array.

Keywords: Solar energy, Dissolved oxygen, Integrated farming, Smallholders

INTRODUCTION

In India more than 80 percent farmers are of small category with operational land holding size less than 2.0 ha. These smallholders are facing a series of challenges in terms of rising cost of farm inputs and the climate change. The production and productivity of these smallholders are low, though from the efficiency point of view small farms are equal or better than the large farms. The major reason behind this limitation is their direct dependence on ecosystem services and has less capacity to adapt the changing contexts (IFAD, 2013). To overcome these limitations a series of efforts are being made by the scientist and researchers to increase the productivity of small farms. One of the most preferred solutions is the integration of crops, horticulture, animal husbandry and fishery. There are many success stories of such integration in terms of improved production and productivity of smallholders (Nageswaran *et al*., 2009). This type of integration is intensive, symbiotic and synergistic but the water supply is to be assured for successful implementation of this concept, as water is an indispensable ingredient for all the components (Behera *et al*., 2012).

The integration of fishery component is done by culturing fishes in an earthen pond with high stocking density. The water in this pond is turbid and high stocking density leads thermal stratification and dissolved oxygen deficiency (Nnaji *et al*., 2003). Therefore, for better-quality and productivity it is vital to maintain optimum concentration of dissolved oxygen in such pond, as low oxygen concentration reduces feed intake of the fishes, increases feed conversion ratio and even slowdowns growth and increases susceptibility to the diseases (Oakes 2011). The aeration, i.e. an artificial surface agitation is treated to be a good option to add atmospheric oxygen into the water column for desired level of dissolved oxygen concentration. An aerator can be a sprinkler, paddle wheel or an air diffusion system. Since, an artificial aeration is a continuous process over a long duration and therefore requires much energy in terms of electricity or fossil fuels. Keeping these facts in view the use of solar energy for this purpose can be a good option, as electricity is still a deficit commodity for the farm applications and increase in prices of fossil fuels is unstoppable.

For good profitability, in general, high milk producing dairy cattle are integrated in the system.

These high dairy cattle require plenty of water every day, as the total water content of body of adult dairy cattle is ranged from 56 - 81 percent of its body weight and loss of even 20 percent of total body water could be fatal (Woodford *et al.*, 1985). The increased environmental temperature due to the climate change has further enhanced the water requirement and therefore continuous and assured water supply is essential for high milk producing dairy cattle.

Again, the thermal environment, i.e., the ambient temperature and the humidity negatively affects the milk production, hormone management and fertility dairy cattle, as high temperature and low humidity dehydrates the mucous membrane and increases the vulnerability to viruses and bacteria (JóŸwik *et al.*, 2012). The temperature more than 27°C is a critical maximum temperature for cows; therefore, the most challenging task in dairy management is to maintain appropriate microclimate. There are some management practices of microclimate in cattle shed which includes humidifier (Broucek, 2009).

Further, the lack of assured supply of supplementary irrigation water is restricting the farmers in raising high value crops and in adoption of precision farming. In most part of India, the main source of supplementary irrigation is the groundwater which needs to be abstracted judiciously and needs to be applied to the crops at high efficiency. Therefore, this is imperative upon the farmers to increase irrigation efficiency by the use of low energy water application devices such as LEWA (Rahman, 2015).

Fortunately, India's geographical area receives good amount of solar radiation solar radiation. The average incident solar radiation is ranging between 3.5-7.0 kWh/m^2/day with 250-300 bright sunshine days per year. This paper suggests how a low cost solar system can be used to perform multiple functions such as, for groundwater pumping, operating pressurized irrigation system, humidifying animal sheds and to increasing dissolved oxygen concentration in a fishpond under integrated system.

Solar groundwater pumping and pressurized irrigation

The main components of a solar photovoltaic groundwater pumping system are the solar pump, solar array and the array support structure. If groundwater source is deep, a submersible pump is to be preferred while for shallow water depth, i.e., up to 7.5 m or less the centrifugal can be a better option. But, under the current scenario of climate change submersible pump is to be preferred over the surface pump, as groundwater level is highly fluctuating due to erratic rainfalls.

Further, in general the most preferred method of irrigation water is the flood method. It is performed either through open channel or through flexible pipes. However, due to high initial investment cost and limited affordability, small holders prefer low capacity pumps. But, a low capacity solar pump offer low delivery head and therefore direct feeding through pipe network or operating pressurized irrigation is almost impractical due to non-availability of desired delivery head. This further restricts the farmers in using pressurized irrigation technology and also forcing them to irrigate crops through open channels. Further, the increased capacity of solar pump will make the solar photovoltaic array size larger and this makes the system costlier and unaffordable to smallholders. Therefore, the practical approach should be to devise a low cost solar system which can perform groundwater pumping and offer sufficient pressure head to perform pressurized irrigation. Since, a solar system does not provide constant output due to variation in incident solar radiation (Fig. 1) and therefore discharge of the solar pump vary over day time. Under these facts is it better to adopt an alternative approach to have a pumping unit, a storage unit and a delivery unit of the type shown in Fig. 2. Here, the pumping unit consists of a low capacity pump which can independently extract water into the storage pond and this pond can serve as a water reservoir for fish farming.

The delivery unit consists of a low capacity solar submersible or surface pump and operated by same

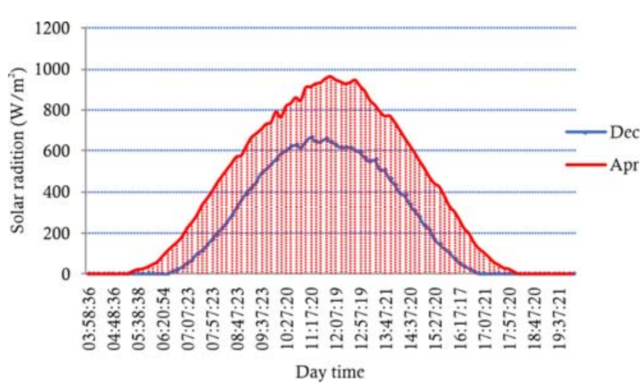

Figure 1. Instantaneous Solar radiation over a day in Eastern region of India

a) Pumping unit for groundwater abstraction into an storage tank

b) Delivery unit lifting water out of storage tank for irrigation at high head

Figure 2. Solar system model with pumping unit, storage tank and delivery unit at ICAR Research Complex for Eastern region, Patna

Table 1. Electrical parameters of 0.3 kWp module

Parameter	Value	Parameter	Value
Isc (A) (0 ± 3.0%)	8.80	Module Efficiency (%)	15.48%
Pmax (W) (0 + 3.0%)	300 Wp	Maximum System Voltage (VDC)	1000
Voc (V) (0 ± 3.0%)	44.20 V	Nominal Operating Cell Temp. (NOCT) (°C)	43 ± 2
Vmax (V)	36.15	Temp. Coefficient of Pmax (%/°C)	-0.39
Imax (A)	8.30	Temp. Coefficient of Voc (%/°C)	-0.31
Fill Factor (%)	77.13%	Temp. Coefficient of Isc (%/°C)	0.06

solar array alternatively. As delivery unit encounters very low suction head; therefore, it offers a very high delivery head. This high delivery head availability facilitates pressurized irrigation system. Further, it is to be noted that if the two units, i.e, the pumping unit and the delivery unit if differs in types and configuration then they cannot be operated with the same solar panel until the configuration of combination of the solar modules are changed. This is a tedious process and cannot be performed every time. Hence, it is better to have the two pumps of same type and same configuration with same electrical parameters.

In order to reduce the overall cost of the system a low capacity pump of 1.0 horsepower solar submersible pump energized by 1.2 kWp solar array was taken and tested with manual tracking option and the number of tracking per day was three. Under testing the condition the solar array was cleaned to avoid the dust effect on power production by solar modules. The electrical characteristics of solar modules used in developing 1.2 kWp solar arrays are given in Table 1. This solar array was developed by the combination of 4 modules, each of size 0.30 kWp, under series and parallel combinations to match the pump's rating. The discharge of the pump at different operating head and at different radiation conditions is reported in Table 2 and the corresponding performance curve is given in Fig 3. The ambient temperature ranged from 30-45°C. The water output was with tracking, as without tracking water output was reduced by 10-25% depending on angle of incidence. Further, the actual output was reduced if solar array was not properly cleaned. The radiation was measured by a pyranometer. It was

Table 2. Discharge of 1.0 hp-1.2 Wp solar submersible pump at different operating head and incident solar radiation.

Incident radiation kWh/m^2/day	Operating Head (m) 10 m	20 m	30 m
	Discharge (m^2/day)		
1.0	-	-	-
2.0	9	2	-
3.0	20	10	-
4.0	40	21	10
5.0	55	25	15
6.0	61	36	18
6.5	65	41	22
7.0	-	-	-

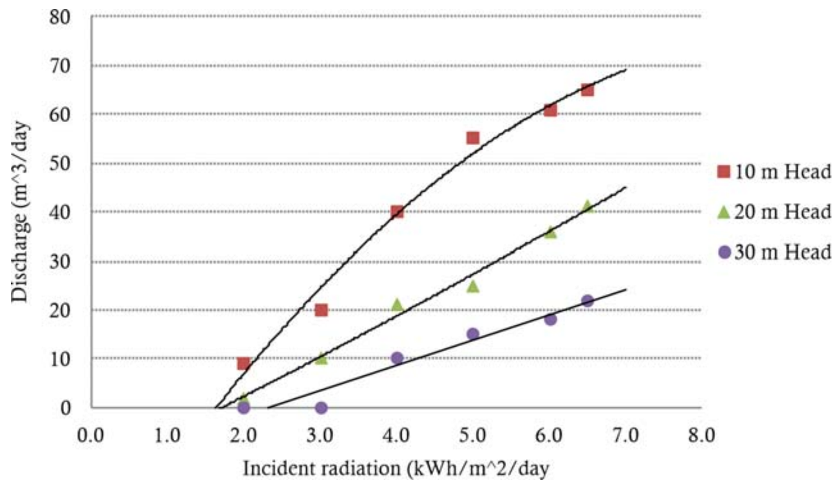

Fig 3. Performance curve of 1.0 hp-1.2 kWp solar submersible pump at different operating head and incident solar radiation.

observed that, with standard operating procedure and manual tracking a good amount of water can be pumped out per day if groundwater depth is shallow, as in case of Eastern region of India, where in most of area, the groundwater depth in pre monsoon and post monsoon is ranged between 5-10 m with annual fluctuation of ± 2 to ± 4 m. Under the prevailing solar radiation condition of 3.5-6.5 kWh/m^2/day, as prevails in Eastern region of India, the discharge of pumping unit was ranged between 20-65 m^3/ day under the operating head of 10 m, while for 20 m and 30 m operating heads, the discharges were in the range of 10-41 m^3/ day and 10-22 m^3/ day, respectively.

Further, if one more pump of same capacity is installed in the water storage pond and use it to deliver water to the field, then due to low suction head it will deliver water at very high pressure and pressurized irrigation system could be operated successfully. With low suction head of 3.0-4.0 m, a 1.0hp-1.2 kWp delivery unit offers a pressure head, ranged between 0.8-1.5 kg/cm^2 if incident radiation flux ranged between 600-900 W/m^2. This much radiation always prevails round the year between 10.00 am - to 2.00 pm of IST in the Eastern region of India. Therefore, by selecting suitable time band of a day the same solar panel can be used for irrigating crops by use of pressurized irrigation system.

Oxygen management in fish ponds

In an aquaculture pond total biomass in the form of fish, plants, microbes and organic matter are much higher and therefore dissolved oxygen exhausts faster. The demands of oxygen further increases with the increase in temperature due to accelerated respiration rate. If an aerator is used it influence the rate of oxygen transfer from air to water by increasing turbulence and surface area of water in contact with air (Boyd, 1998). Circulation of pond water also facilitates mixing of column pond water by breaking thermal stratification and chemical substances (Boyd and Martinson, 1984).

In general, aerators work mainly on the principles of water splashing into the air, air diffusion into water or creating agitation for wave in water. Keeping these many facts in view an experiment was conducted at ICAR research complex for eastern region using 1.0 horsepower solar surface pump operated by 0.9 kWp solar array to splash water in to the air to improve dissolved water concentration (Fig. 4). The pump was operated over day time for improving dissolved oxygen concentration in a fishpond of area of 800 m^2 with standing water depth 1.30 m. The dissolved oxygen concentration and temperature was measured using multi-parameter analyzer at different layers of water column viz. surface water at 0.1 m depth , middle water layer at 0.5 m and bottom layer at 1.0m. The distances from the aerator at 0.0m 10.0 m, 15.0 m and 20.0 m were selected for horizontal spatial change in oxygen concentration. Observations showed that in early hours there was 110 percent increase in dissolved oxygen concentration in treatment while there was only 94.5 percent increase in control. Similarly, in temperature there was increase of only 4.7 percent while in control it was

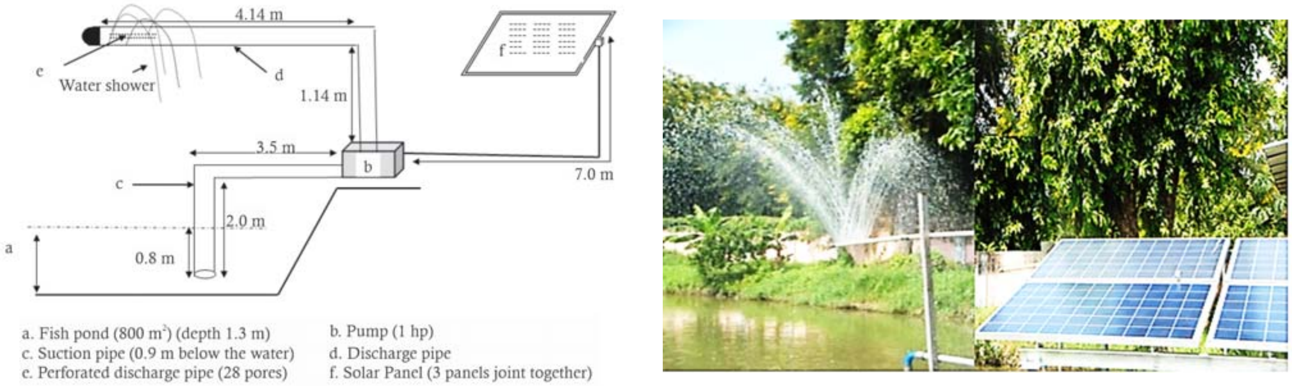

Figure 4. The schematic diagram and operational view of solar aerator at ICAR-RCER, Patna

6.3 percent during same period. This indicated that use of solar aerator increases dissolved oxygen concentration while it reduces the water temperature. Same trend was also observed in middle layer of water column. The increase in dissolved oxygen concentration in treatment was 125.4 percent while in control was only 87.8 percent. The corresponding in temperature was 4.4 percent and 5.0 percent, respectively. In bottom layer of water column the impact was significantly higher and the corresponding increase was 60.4 percent and 33.6 respectively, while in temperature, the change was 1.9 percent and 2.49 percent. This indicates that almost 26.8 percent higher dissolved oxygen concentration was seen over the control in case of bottom layer while the change in temperature was almost same. This indicated that overall dissolved oxygen concentration in pond water with such splashing type solar aerator was higher compared to control pond. The spatial and diurnal variations of dissolved oxygen level and water temperature across the pond were measured and found substantial increase in dissolved oxygen concentration up to 20 m from the aerator position.

Further the data pertaining survival of fishes in aerated pond compared to the control was found to be 84 percent and 73 percent, respectively. Similarly the weight gain in fishes was 211.4 percent and 119.8 percent and the corresponding specific growth percentage was 1.51 percent and 1.04 percent in treatment and control pond over given period of time. This shows that aerator had a significant impact on the overall pond environment and productivity of the fishes. Thus, if we set a system of water splashing then the productivity of fishes can be increased.

Keeping above facts in view, if delivery pump is allowed to operate to splash same pond water in which it is installed into the air when it was not in use for irrigation and the operating solar array was not in use with groundwater lifting pump, then it acts as aerator for the pond for improving dissolved oxygen concentration, as above experiment showed that the pond water splashing improve dissolved oxygen concentration.

Solar energy in dairy management

In the summer season India's landscape temperatures averaged around 32 - 40 °C and peaks about at 45-48°C. Such high temperature and the reduced humidity conditions substantially increases the Temperature Humidity Index (THI) of cattle shed. This unfavorable microclimate can be modified by injecting some humidity in the animal shed by use of use of humidifier. This humidification increases humidity of the shed and reduces the temperature. Since, delivery pump offers a good pressure and therefore can be used to operate water sprinkling devices inside the animal sheds to maintain good humidity in shed during high temperature conditions. If it is operated for small duration at certain intervals over a day, as developed and tested at ICAR Research Complex for Eastern region (Fig. 5), then microclimate of the animal shed could be maintained favorably.

Further, maintaining of good hygiene in an animal shed is of decisive importance, as it makes impacts on overall performance of dairy animals. However, this requires pressured water for regular cleaning of sheds as well body of dairy animals. As delivery pump provides water at good pressures water; therefore, these two objectives can be fulfilled by use of this system.

Figure 5. Solar humidifier operation and watering system for animal shed

CONCLUSIONS AND RECOMMENDATIONS

The proposed solar system is a good model for integrated farming. As crop irrigation schedules once or twice in a week, washing of cattle shed is required generally once in a day while humidification is done twice or three for short duration during mid-day hours; therefore, for remaining period, system can be used for abstracting groundwater or for aerating fish pond. Thus, with a thoughtful and judicious time management various operations can be performed with two small capacity solar pumps operated by single solar array in turn. This reduces the effective cost and could be affordable by smallholders.

Conflict of Interest

The authors declare that they have no competing interests.

REFERENCES

Behera, U. K., Panigrahi, P. and Sarangi, A. (2012). Multiple water use protocols in integrated farming system for enhancing productivity. *Water Resour. Manage.*, 26, 2605–2623.

Boyd, C. E. (1998). Pond water aeration systems. *Aquacultural Engineering*, 18, 9–40.

Boyd, C. E. and Martinson, D. J. (1984). Evaluation of propeller-aspirator-pump aerators. *Aquaculture,* 36(3), 283–292.

Brouèek, J., Novák, P., Vokøálová, J., Šoch, M., Kišac, P. and Uhrinèa, M. (2009). Effect of high temperature on milk production of cows from free-stall housing with natural ventilation. *Slovak J. of Cattles Sci.,* 42(4), 167-173.

IFAD (2013). Smallholders, Food Security, and the Environment, United Nations Environment Programme, International Fund for Agricultural Development, Rome.

Jóźwik, A., Krzyżewski, J., Strzalkowska, N., Polawska, E., Bagnicka, E., Wierzbicka. A., Niemc zuk, K., Lipi ń ska, P., Horba ń czuk J.O. (2012). Relations between the oxidative status, *mastitis*, milk quality and disorders in cattle reproductive functions – a review. *Cattles Sci. Papers and Reports,* 30(4), 297-307.

Nageswaran, M., Selvaganapathy, E., Subbiah, V. R. and Nair, S. (2009). Demonstration and replication of integrated farming systems at Chidambaram, Report of M.S. Swaminathan Research Foundation (MSSRF), Chennai, pp.16 -53.

Nnaji, C. J., Okoye, F. C. and Ogunseye, J. O. (2003). Integrated fish farming practices with special reference to combination rates production figures and economic evaluation In: Eyo AA, Ayanda JO (eds) Conference proceedings of fisheries society of Nigerian (FISON), pp. 173–178.

Oakes, P. L. (2011). Aeration of ponds used in aquaculture, Agric. Eng. Tech. Note, No. AEN-3, Natural Resources Conservation Service, United States Department of Agriculture, USA.

Rahman, A. (2015). Low energy rotary nozzle: An energy and water saving device for field crop irrigation. *J. Agr. Sci. Tech.,* 17, 1071-1082.