A Sustainable Design Solution for Providing Drinking Water by Harnessing Floating Solar PV-Based Generation in Rural India

Abhijit Sen and Sougata Karmakar

Abstract Globally, about 2 billion people lack access to safe drinking water. In India, this is a major challenge for rural communities on account of falling levels of water table in two-thirds of the districts, lack of piped water facilities, and presence of harmful chemicals in groundwater. Sustainable Goal 6 of the UN targets the "availability and sustainable management of water and sanitation for all" by 2030. Therefore, there is an urgent need for sustainable decentralized drinking water systems that can be operated and maintained by rural communities. In recent years, floating solar PV (FSPV) projects have been installed in large numbers because of their varied advantages such as land neutrality, reduced evaporation, carbon savings, negligible effect on water quality, and feasibility on various water bodies. India has a water surface area of 18,000 km^2 and rural areas have a huge potential for installation of floating solar plants. This paper proposes a sustainable design solution for providing drinking water by harnessing the power generated from FSPV projects. A literature review with the search terms "floating solar" and "drinking water" was carried out using the bibliographic databases of Scopus, Web of Science & Science Direct wherein similar concepts or designs were not reported. The benefits include the 24 × 7 availability of safe drinking water, water conservation, monetization (battery swapping, charging of e-devices, etc.), and employment generation for local people. This study will be useful for policy makers, planners, designers, financial institutions, and local self-governments. The future scope includes the implementation of the proposed design solution through a pilot study.

Keywords Drinking water · Floating solar photovoltaics · Design · Sustainability

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S. Karmakar et al. (eds.), *Innovative Design for Societal Needs*,
https://doi.org/10.1007/978-981-99-6468-0_2

1 Introduction

Sustainable Development Goal 6 of the UN targets the “availability and sustainable management of water and sanitation for all” by 2030. On demand availability of contamination free drinking water is a key indicator of Sustainable Goal 6.1 of the UN. Close to two billion people across the globe lack access to safe water for drinking purposes [1]. Collecting and transporting drinking water from distant sources results in a loss of productivity, may lead to musculoskeletal disorders, and compromises with personal safety [2]. These constraints have economic, social, and implications for health for communities across the globe. The availability of clean and safe drinking water is a major challenge in many parts of India, especially among rural communities. Moreover, the percentages of arsenic and fluoride in the water are above acceptable levels [3]. In addition, there is a depletion of groundwater level in two-thirds of the districts across the country [3] with about 43% of rural households [4] depending on hand pumps, compounding the problem further. A study has shown that groundwater is fast depleting in the basins of Indus-Ganga-Brahmaputra affecting the northern and eastern states [5]. At the same time, the rise in population and climate change is resulting in an increased demand for water. Recognizing these challenging issues, the Ministry of Jal Shakti, Government of India has launched the “Swajal” initiative, a self-sustaining drinking water supply project aimed at 117 districts. Considering these issues, rural community managed drinking water projects have assumed importance. In recent years, floating solar PV projects have been installed in large numbers because of their varied advantages such as land neutrality, reduced evaporation, higher efficiency than ground-mounted solar photovoltaic installations, carbon savings, negligible effect on water quality and feasibility on various water bodies [6–8]. However, most of these projects are of utility-scale for replacing fossil-based generation. Rural India is endowed with a large number of natural lakes and ponds. India has 345968 water bodies with sizes less than 0.5 ha [9]. In the North Eastern States, such water bodies are about 11000 in number [9]. These water storage structures are the lifeline for the rural communities and often the only source of water for daily sustenance. This study proposes an opportunity for the installation of decentralized FSPV-based microgrid units on these water bodies for supplying drinking water on a 24/7 basis. The intervention will be in pursuance of UN Sustainable Development Goals 3 (Good Health and Well-being), 6 (Clean Water & Sanitation), 7 (Affordable and Clean Energy), 11 (Sustainable cities and human settlements), and 13 (Climate Action). The aims and objectives of the present paper are (a) To explore existing FSPV-based drinking water systems if any, (b) To develop a sustainable design solution of a FSPV-powered drinking water system for rural communities, and (c) To estimate the cost economics of the proposed design.

2 Methodology

A literature review was carried out using the search terms “floating solar” and “drinking water” using the online bibliographic databases of Scopus, Web of Science & Science Direct. The period of search was selected between 1950 and 2022. Only papers in the English language were considered. The objective of the review was to determine whether existing FSPV-based designs existed. The PV * SOL software was used to develop a model and circuit diagram for the proposed design. Babuisol village (23.49°N, 87.57°E) located in the Andal block in the district of Paschim Bardhaman in West Bengal State of India (Fig. 1) was selected for implementation of the proposed design. Technical requirements and cost economics were computed after a discussion with FSPV developers.

Fig. 1 Location of the proposed project. (Image source: Google Earth)

3 Results

3.1 Literature Review Findings

The search of online databases resulted in 30 papers from Web of Science, 29 papers from Scopus & 2193 papers from Science Direct. Literature outcomes indicate that solar water pumps have been successfully adopted for providing water for irrigation and drinking in rural communities. A study reports that these pumps are of three types namely surface, floating, and submersible [10], and are an economically viable solution to address local and social needs. These pumps are an alternative to polluting diesel pumps and can be maintained by local people using local resources. The technology for PV-powered pumping was first introduced through a World Bank Program-supported project in 1978. The project was found to be successful in countries where there was sufficient sunshine, fuel cost was high, and water was needed throughout the year [11]. Aimed at agricultural uses, solar pumps were first introduced in India in the year 1992. PV-powered solar pump systems have a life of 25 years and a payback period of four to six years [11]. The provision of drinking water in rural areas with the use of PV-powered pumps was found to be both economically and technically viable [12]. The solar panels powering the pumps are ground mounted. Land holdings in rural areas of India are important assets and judicious use of land and water is important [13]. Therefore, alternative land neutral locations to install solar PV panels like on stationery water bodies can be a more sustainable solution. The review did not elicit any study on floating solar PV-based drinking water system. This establishes a knowledge gap that this paper aims to address. Other papers report the design and development of solar stills which aim at desalination of sea or brackish water which is beyond the scope of this paper.

3.2 Existing Drinking Water System at the Proposed Location

A total of 788 people reside in 183 households in the Babuisol village as per census data of 2011. Considering a daily need for three liters of water per person, a total of about 2400 L of drinking water is required for daily consumption. Presently, a solar powered drinking water system is installed which uses a submersible pump to transfer groundwater into an overhead storage reservoir for providing drinking water. Handpumps supplement the drinking water needs apart from the solar powered system. The existing system is shown in Fig. 2. Limitations of the existing system are the fast depletion of groundwater and lack of filtration. Contaminated water leads to waterborne diseases and compromises with the health and well-being.

Fig. 2 Existing drinking water system at the proposed location. (Image source: Damodar Valley Corporation, India)

3.3 Proposed Design

The FSPV-powered drinking water system consists of solar PV modules floating on a stationary water body (Fig. 3). The renewable energy generated from the system is stored in a battery unit and can power the solar pump and the filtration system which is based on Reverse Osmosis (RO) technology. RO systems have been found to be very effective in producing clean and safe drinking water [14]. The excess water from the RO system is returned back to the water body for recirculation. The incremental power generated can be used for charging electrical devices and battery swapping for running e-rickshaws. Figure 4 shows the circuit diagram.

The components of the system are enumerated in Table 1.

To determine the cost economics of the proposed system, the design was shared with FSPV developers. Inputs were received on the materials required and the installation cost of the different components in India. Under a scheme subsidized by the government, solar pumps are provided at a reduced cost [15]. Utilization of these pumps can bring down the overall cost of the project significantly. The estimated cost is presented in Table 2.

The FSPV system has a life of about 25 years. The cost of maintenance primarily includes cleaning of solar panels, pump maintenance, and replacement of RO filters. In order to recover the running cost, a funding and monetization model is proposed. The system is to be operated and maintained by the local self-government. The proposed design can be financially supported by a subsidized scheme of the Government or by Corporate Social Responsibility (CSR) programs undertaken by various companies/organizations. An important pre-requisite is the selection of a relatively

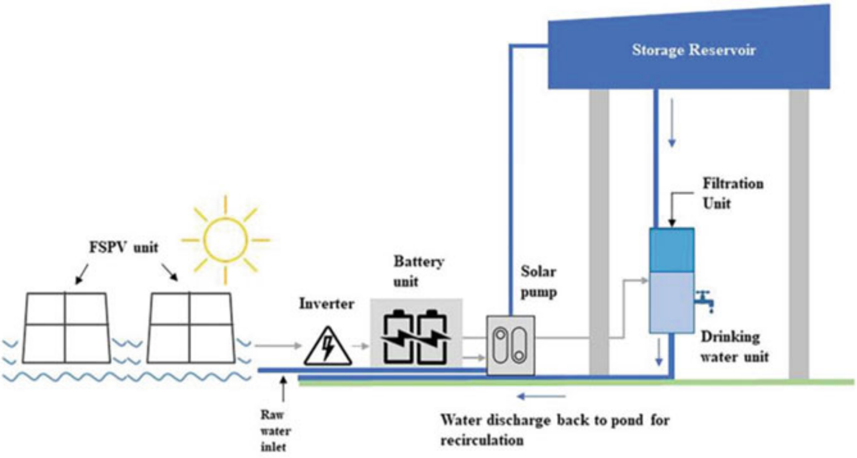

Fig. 3 Proposed design of the FSPV-based drinking water system. (Image: Authors)

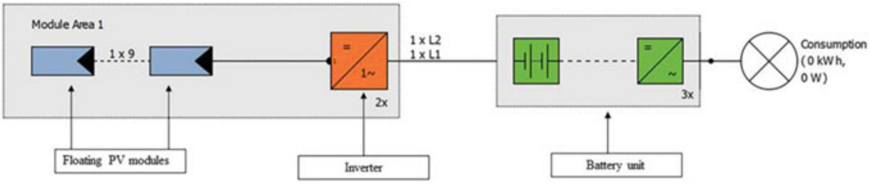

Fig. 4 Circuit diagram of the proposed system. Source: PV * SOL software

large water body so that 2400 L of drinking water can be supplied on a daily basis. Alternatively, two smaller systems of size 2.5 kWp can be installed in two water bodies in the village.

Following the battery swapping system, the additional batteries (refer to S.No. 3 of Table 2) can be used for running small e-vehicles such as e-rickshaws, charging e-devices, and powering small businesses such as food vendors. In addition, it is also proposed for charging a nominal fee for the use of the drinking water so as to prevent wastage and sharing of cost among the consumers. These measures will ensure monetization and faster payback of the investment as well as fund the maintenance costs.

Training of locals in the operation and maintenance of the FSPV system will further empower the rural communities and provide employment. This approach will not only make the proposed design sustainable from an ecological perspective but also financially viable.

Table 1 Overview of the FSPV-based drinking water system

S. No	Component	Particulars
1	Location	Pond
2	Type of system	Stand-alone floating PV system
3	Annual sum of global radiation	1573 kWh/m^3
4	Annual average temperature	26.5 °C
5	AC mains	230 V
6	Number of PV modules	10
7	Efficiency	15%
8	Peak power	500 Wp
9	PV generator output	5 kWp
10	Inclination	15°
11	Primary floats (for supporting the modules)	10
12	Secondary floats (for walkways)	20
13	Inverter	3.4 kW
14	Total battery power	15–20 kWh
15	Solar pump	2 HP
16	Storage reservoir	1000 L
17	Reverse osmosis purification system	100 L
18	Pipes, distribution box, wires, and electrical accessories	As per requirement
19	Civil structure for storage reservoir and RO system	As per requirement

kWh: kilowatt hour; Wp: Watt peak; kW: kilowatt; HP: Horse Power; RO: Reverse Osmosis; L: Liters

4 Discussion and Conclusion

India has a large number of water bodies in the rural areas. Many of these water bodies serve as community ponds for providing water for drinking, sanitation, domestic uses, and miscellaneous purposes. To fulfill the basic societal needs, community managed drinking water system is being considered as the most viable and sustainable solution for rural communities. This study proposes an FSPV microgrid that can be set up on a water body for providing drinking water on a 24 × 7 basis. The electricity generated from the floating solar panels would power the solar pump and the RO system during the day. The batteries would provide the power to operate the pump and RO system at night. The self-sustaining system will lead to the following benefits:

- Availability of 24/7 safe drinking water for rural communities.
- Reduced evaporation from the water bodies on which the FSPV system is installed.
- Utilization of part surface area of water bodies without the need for land acquisition.

Table 2 Estimated cost of installation

S. No	Component	Estimated cost
1	FSPV System	INR 350000
2	Battery unit	INR 24000 (4 × INR 6000)
3	Batteries for swapping	INR 24000 (4 × INR 6000)
4	Solar pump	INR 80000 (after considering a 60% subsidy under the government scheme)
5	Storage reservoir	INR 8000
6	RO system	INR 25000
7	Civil structure	INR 40000
8	Accessories	INR 10000
9	Manpower cost	INR 20000
10	Miscellaneous expenses	INR 5000
	Total cost	INR 586000

- Alternative solution to indiscriminate use of depleting groundwater.
- Minimum water loss after treatment/filtration through recirculation (discharge back to the water body).
- Battery storage allows the running of the RO filtration system at night.
- Conservation and sustainable water use.
- Requires less investment compared to piped water schemes.
- Incremental power can be used for other purposes such as for battery swapping, street lights, small vendors, etc.
- Creation of employment for locals.

The contribution of this study is that it proposes a self-sustainable community managed drinking water scheme harnessing the power of FSPV which is not yet explored. With 11000 water bodies in the North Eastern States of India [9], adoption of this model is likely to have multiplier effects apart from empowering rural communities. This approach can also be adopted across the country since according to a study, India has a water surface area of 18,000 km^2 for installation of FSPV projects [16].

The study is also aligned to five of the seventeen Sustainable Development Goals of the UN. This study will be useful for policymakers, planners, designers, financial institutions, and local self-governments.

5 Limitations of the Study

A limitation of this study is that the design is a conceptual model which has not been tested in field trials. Another limitation is that only articles in English were considered in the literature review.

Acknowledgements The authors are grateful to Dinesh Singh, Chief Engineer, Renewable Energy, Sanjoy Nath, Senior Divisional Engineer, and Shamim Ahmad, Manager, Corporate Social Responsibility from Damodar Valley Corporation, India for providing inputs for the study. The authors also acknowledge the library facilities provided by the Indian Institute of Technology (IIT) in Guwahati, Assam, India.

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