



Leveraging Of Floatovoltaics For Green Energy And Water Sustainability At Pune Area

K Kranthi Kiran¹, Dr P R Dongarwar(Prof)², Lt Col Jitendra Kumar Verma³,

1,2,Department of mechanical engineering, Collage of Military Engineering, Pune India.

1Assistant Engineer, Student Officer. ² Project Guide, Professor Mechanical Engineering Department of Mechanical Engineering, ³Project Guide, SCRI, Collage of Military Engineering, Pune, India

1.0 ABSTRACT

The growing demand for renewable energy sources has led to increased interest in the utilization of solar power. Solar photovoltaic (PV) systems have proven to be a viable and sustainable solution. While ground mounted solar installations have gained popularity, the concept of floating solar panels has emerged as a promising alternative. This abstract explores the implementation of floating solar panels on the dam located around Pune, Maharashtra, India. The dam presents an ideal location for deploying floating solar panels due to its expansive water surface area and proximity to populated areas. By utilizing this vast space, floating solar panels can generate clean electricity while minimizing land usage. Additionally, the cooling effect of the water beneath the panels can enhance the overall efficiency of the PV system, leading to increased power output.

2.0 OBJECTIVES

Pune city is surrounded by various rivers. Four dams have been constructed on these rivers to store water for irrigation and domestic purposes for Pune city. These dams not only provide water to Pune city but also cover a large area around it.

- a) Identify the area covered by water surface.
- b) Potential for installation of flotovoltaics over that area.
- c) Feasibility study.
- d) Materials require for installation of flotovoltaics.
- e) Identifying the meterological parameters of Pune city.
- f) Analysing the evaporation rate from the surface of water.
- g) Exploring the benefits of flotovoltaics.
- h) Exploring the stages of flotovolatics installation.

3.0 ABBREVIATION :

kWp	:	Kilowatt power.
MLD	:	Million liters per day.
Km	:	Kilometer.
FSPV	:	Floating solar photovoltaics.
m/s	:	Meter per second.
PV	:	Photovoltaic.
MSETCL's	:	Maharashtra State Electricity transmission Company Limited
NTPC's	:	National Thermal Power Corporation Limited

S No	Name of Dam	River	Gross storage capacity (x10 ³ m ³)	Length (in mtrs)	Reservoir Area (in m ²)
1	Khadakwasla dam	Mutha	86000	1539	1,48,00,000

4 INTRODUCTION

The dams is located near Pune, Maharashtra, India. The dam is constructed on river of Pune city. The details of the dam are shown in table. Khadakwasla dam: Khadakwasla dam is a dam on the Mutha River 21 km from the centre of the city of Pune in Maharashtra, India [1][2]. The dam created a reservoir known as Khadakwasla Lake which is the main source of water for Pune and its suburbs.

Table 1: Details of dams and their gross capacity and reservoir area around Pune city

The Khadakwasla dam is supplying the water to the pune areas. Pune most of the population is receiving the portable water through this dam. The water surface of the dam can also be used for power generation by installing the floating solar power plant makes efficient use of available space and reduces the need for large amounts of land. Installation of solar panel on the water surface also provides additional benefits such as cooling the panels, which helps them work better and last longer. It also reduces water evaporation from the dam, which is good for conserving water. The floating solar power plant is an eco-friendly solution that contributes to the use of renewable energy and reduces harmful carbon emissions. It adds to the existing hydroelectric power generated by the dam, creating a more diverse energy mix. Overall, the project is a smart and sustainable way to generate clean electricity and move towards a greener future. It not only reduces our reliance on fossil fuels but also contributes to the fight against climate change by reducing greenhouse gas emissions. The floating solar power plant on Khadakwasla dam is a shining example of how we can harness renewable energy sources to meet our power needs while preserving our natural resources.

5. INDIAN SCENARIO

The FSPV as a technology is still in the nascent stages of development in India. The journey started with a 10 kW FSPV plant on a pond in Rajarhat, Kolkata in 2015. The project was part of a research activity sponsored by the Ministry of New and Renewable Energy (MNRE). In 2016, NTPC installed country's largest 100 kW plant on a reservoir of its combined cycle power plant situated in Kerala's Kayamkulam district. Later in December same year, Kerala State Electricity Board started its operation of 500 kW plant

at Banasura Sagar reservoir in Wayanad district replacing NTPC's 100 kW as a largest FSPV-based plant. The plant is actually a scaled-up version of the 10 kW plant commissioned in January 2016 at the same location. The plant was able to bring some confidence to FSPV promoters by successfully surviving the recent flood ravage in the state. The recently commissioned 2 MW project at Visakhapatnam, Andhra Pradesh has now the largest FSPV-based plant commissioned in the country till date and with this the total installed capacity of FSPV has becomes 2.7 MW. The FSPV sector is now getting a lot of attention in the country, which can be seen via an increase in the numbers of tenders that are released in the past 2 years by 2019. At the moment there is more than 1700 MW worth of projects, which are in various stages of development and more are in pipeline making the outlook very positive for this new segment.

Indian Scenario

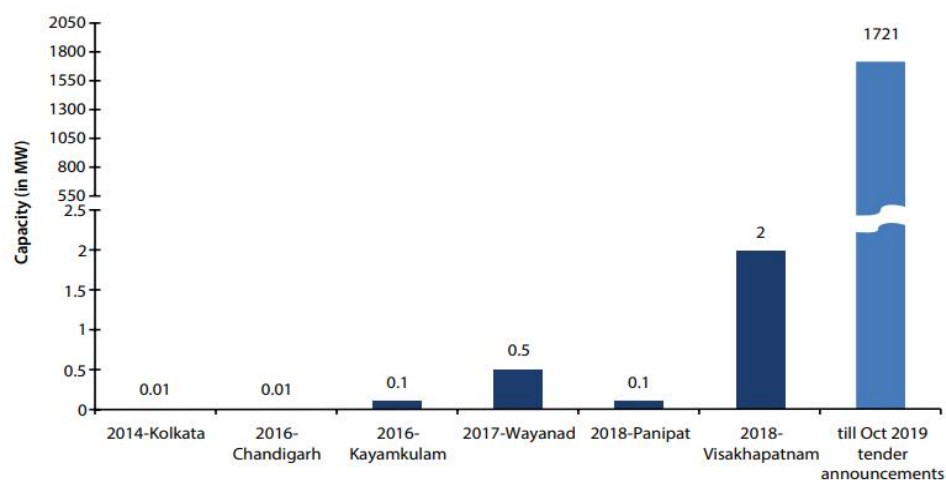


Fig 1: Floating solar PV installation in India

India's largest floating solar power project 101.6 MWp – Kayamkulam, Kerala



Fig 2: One of the indias largest fsp installed by tata power solar

This 101.6 MWp capacity solar plant's large-scale installation and commissioning were the fastest in the FSPV category and secured a Commercial Operation Date (CoD) certification on 24th June'22. It boasts a floating inverter platform having a 5 Megawatt (MW) capacity for the first time at Tata Power

6. CLIMATE CONDITION OF PUNE

The average wind speed in Pune is 2.9 m/s with the maximum wind speed of around 10 m/s (Approx). The average ambient temperature remains 24.5°C, varies from 11°C to 37.2°C. The average relative humidity remains around 69.3%, varies from 19.9% to 99.3%. The selected coordinates i.e. lat 18°31'0"N, lon: 73°55'0"E is found within the limit of Pune district, in the state Maharashtra, India.

Month	Avg Wind speed (in m/s)	Avg Temp (°C)	Avg RH (in %)
Jan	3.00	23.46	66.64
Feb	1.80	21.13	64.94
Mar	2.31	25.64	67.24
Apr	3.30	29.04	63.76
May	4.02	28.57	72.10
Jun	5.02	27.39	93.96
Jul	7.62	23.92	97.12
Aug	6.41	22.72	96.27
Sep	4.25	22.86	91.32
Oct	2.66	24.59	72.22
Nov	3.23	23.25	66.41
Dec	3.44	18.75	55.59

Table 2: Meteorological data of Pune

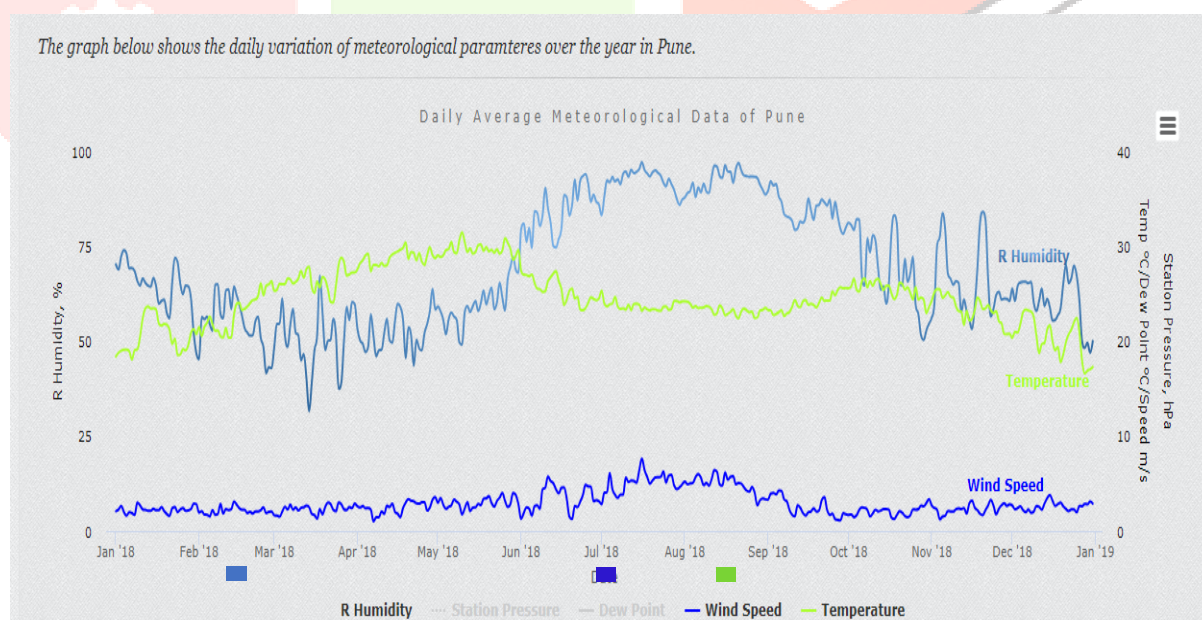


Fig 3 : Meteorological data of Pune city (13)

The rainfall details of the pune city is shown in the graph. From the Graph it is observe that from January to Mar there is no rain fall and in Apr and May the rains are started, the water level in the dams are start to increase. That is from Jan to May we are unable to run the hydro power plant and produce electricity.

By using the solar flotovolatis we can produce the electricity from Jan to Dec (sunny days) efficiently even when there the water level is reducing in the reservior.

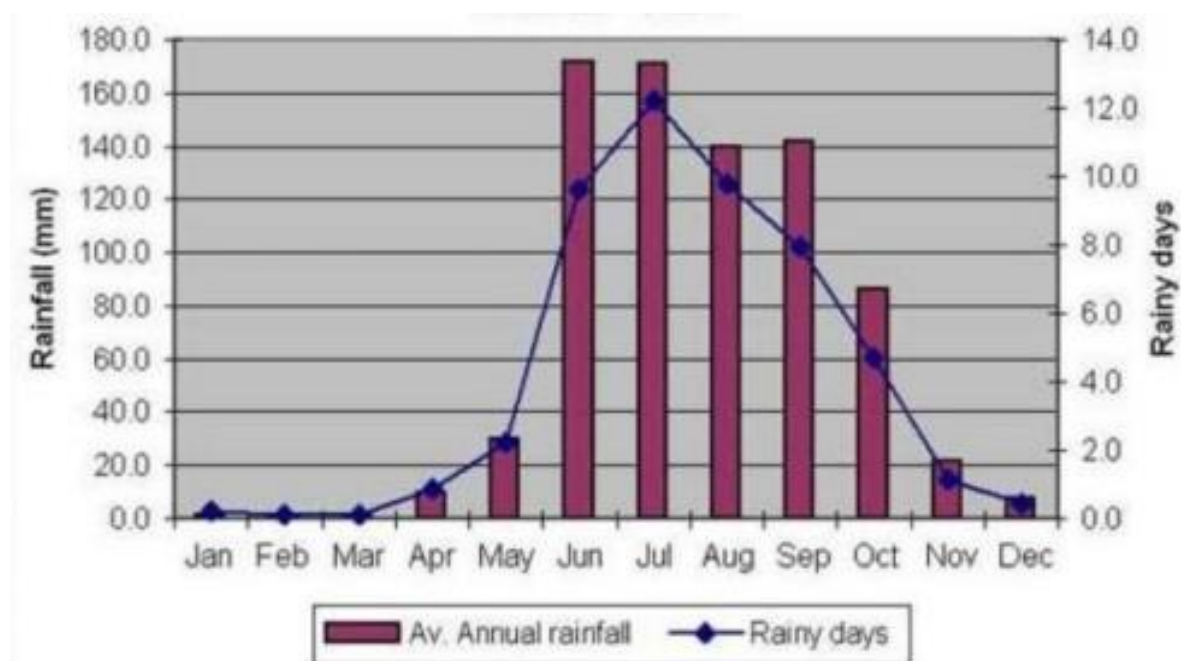


Fig 4: Annual Rainfall of Pune

7. LITERATURE REVIEW

7.1) **Nguyen et al. (2019):** Conducted a comprehensive study on the technical design aspects of floating solar panels. They examined different floating platform materials, anchoring systems, and solar panel configurations. The study highlighted the importance of efficient design for maximizing energy generation and ensuring system stability. [2]

7.2) **Kazmerski et al. (2020):** In this paper discussed the performance characteristics of floating solar panels. They analyzed various factors such as panel tilt angle, water surface conditions, and shading effects. The research emphasized the need for optimizing panel orientation and mitigating the impact of shading to enhance overall system performance.[2]

7.3) **Ondraczek et al. (2018) :** Investigated the environmental impacts of floating solar panels. They examined potential effects on water quality, aquatic ecosystems, and biodiversity. The study concluded that appropriate site selection, monitoring, and mitigation measures are essential for minimizing any adverse ecological effects. [2]

7.4) **Tidball et al. (2021):** Assessed the impact of floating solar panels on water bodies' evaporation rates. The research found that these systems can reduce water evaporation, offering potential water conservation benefits in arid regions. The study emphasized the importance of further research to understand the longterm effects on hydrological cycles. [2]

7.5) **Farid et al. (2020):** Conducted an economic analysis of floating solar panels compared to conventional solar installations. They found that floating solar systems can be more cost-effective, especially in regions with limited land availability. The study highlighted the potential for market growth and investment opportunities in the floating solar industry.[2]

8.0 MATERIALS

8.1) **Floating Platforms:** - We use primary component of a floating solar power plant is the floating platform. These platforms are typically made of materials such as high-density polyethylene (HDPE), high-density polyethylene with UV stabilizers (HDPE-UV), or ethylene-vinyl acetate (EVA). These materials are lightweight, buoyant, and resistant to corrosion and degradation in water.[2]

8.2) **Solar Panels:** - We use solar panels used in floating solar power plants are usually similar to those used in traditional ground-mounted or rooftop solar installations. They are made of photovoltaic cells that convert sunlight into electricity. The panels are typically made of silicon-based materials, such as monocrystalline or polycrystalline silicon, or thin-film solar cells.[2]

8.3) **Mounting Systems:** - We use this system to secure the solar panels to the floating platforms are crucial for stability and panel orientation. Common mounting materials include aluminum or stainless steel. These materials provide strength, resistance to corrosion, and durability in water environments. [2]

8.4) **Anchoring Systems:** We are using Anchoring systems for secure the floating platforms in place and prevent them from drifting. These systems may include concrete blocks, steel cables, or mooring systems. The choice of anchoring materials depends on factors such as water depth, wave conditions, and the size of the floating solar power plant. [2]

8.5) **Electrical Components:** Floating solar power plants require electrical components for the collection, transmission, and conversion of electricity. These components include wiring, connectors, inverters, and transformers. The materials used for these components are typically copper or aluminum for conductors. [2]

8.6) **Anti-Fouling Coatings:** To prevent the accumulation of algae, marine organisms, and debris on the floating platforms, anti-fouling coatings may be applied. These coatings are typically made of non-toxic materials that deter biofouling, such as special paints or polymer coatings. [2]

9. METHODOLOGY

9.1 **Feasibility Study:-** The first step is to conduct a feasibility study to assess the suitability of the dam reservoir for a floating solar power plant. The dams near to the Pune are studied and the details of dams like gross storage capacity, reservoir storage capacity, length of dams etc to absorb the catchment area. From the Indian climate web site the details of annual weather condition of the Pune city is collected. In this report we found the details of annual rain fall, wind speed, relative humidity and average temperature of the month is obtained from the graph. These details were used to calculate the evaporation capacity of water with respect to the storage surface area. The evaporation rate calculator is used to estimate the evaporation rate of water from the surface under various climate data collected from the Indian climate web site. By evaluating the details the minimum gross available catchment area is 2960000 m² considered for calculation of floatovoltaics feasibility study.

9.2 Collection of environmental data

Month	Avg Wind speed (in m/s)	Avg Temp	Avg RH	water in Reservoir Area (in m ²)	Evaporation rate of water (in ltrs)
Jan	3.00	(°C)	(in %)	4,04,49,650	47,94,98,768
Jan	3	23.46	66.64	74,00,000	8,77,21,176
Feb	2.8	21.13	64.94	59,20,000	6,07,97,991
Mar	2.31	25.64	67.24	44,40,000	4,96,66,696
Apr	3.3	29.04	63.76	37,00,000	7,15,49,953
May	4.02	30.5	72.1	29,60,000	5,55,24,459
Jun	5.02	27.39	93.96	1,48,00,000	5,93,17,505
Jul	7.62	23.92	97..12	1,48,00,000	3,22,67,104
Aug	6.41	22.72	96.27	1,33,20,000	3,01,81,359
Sep	4.25	22.86	91.32	1,33,20,000	5,10,41,707
Oct	2.66	24.59	72.22	1,18,40,000	11,54,65,431
Nov	3.23	23.25	66.41	1,03,60,000	12,85,57,785

Table 3: Evaporation rate of water from the surface of the Khadakwasla dam

9.3 Design Of Floatovoltaics

FSPV design is similar to a conventional solar PV system except it requires a special arrangement to float on the water surface. The typical floating structure supports the PV arrays, inverters, combiner boxes, lightning arresters, etc. on a floating bed, which is made of fiber-reinforced plastic (FRP) or high-density poly ethylene (HDPE) or metal structures. The whole floating bed is buoyed with the help of anchoring and mooring systems.

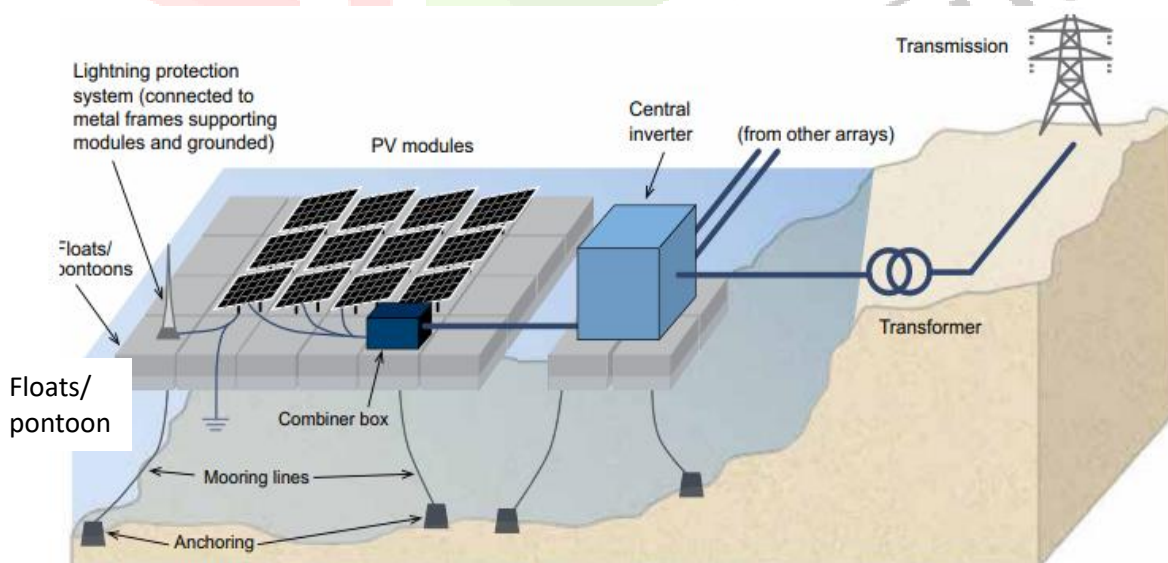


Figure 5 : Schematic representation of typical large scale FPV system with its key components [1].

The area required for 10 kW electricity is 64 m^2 and 40 nos solar panel can generate 10 kW energy, Each solar panel can produce 250 watt energy. area of solar panel is 1.6 m^2 In this case , for a 10 kW system, assuming we are using solar panels with a power rating of 250 watts/panel, the calculation would be as follows: Formula: Number of panels = $10\text{kW}/0.25\text{kW}=40$ nos. Therefore, require approximately 40 nos solar panels to achieve a 10 kW system [2]. overall size including floating system for 10 kWp is 96 m^2 .

- Each monocrystalline solar PV panel can produce say 250 watt energy.
- Area of one solar panel is 1.6 m^2
- Area requires for FSPV panels for generating 10 kW
$$= (1.6 \times 10 \times 1000) / 250$$
$$= 64 \text{ m}^2$$
- Number of panels require to achieve a 10 kWp
$$= (10 \times 1000) / 250$$
$$= 40 \text{ panels}$$
- Overall size of floating system require for 10 kWp is 96 m^2 .
- In this study the available minimum reservoir area left for floatovoltaics is $29,60,000 \text{ m}^2$ therefore:
- The available catchment area is
$$= 29,60,000 \text{ m}^2$$
- For 10 kW the required area is
$$= 96 \text{ m}^2$$
- The total power generated is
$$= (2960000 / 96) \times 10$$
$$= 308333.33 \text{ kWp}$$
- The efficiency of the plant is 13 %
$$= 13\%$$
- Net capacity to be installed
$$= 308333.33 \times 13\%$$
$$= 40083 \text{ kWp}$$
$$\text{say } 40 \text{ MWp}$$

The potential of power generation capacity of total Pune reservoir area is 40 MWp for the available reservoir area 1198190 m^2 . That is the land area for installation of the solar power plant of $29,60,000 \text{ m}^2$ is saved by installation of the flotovoltaics system

Pune needs around 1,600 MLD (Million Litres per Day) of water. Estimating the city population to be more than 5.5 million [10]

Details of evaporation of water:

The evaporation rate of water from $29,60,000 \text{ m}^2$ is 5,55,24,459 Ltrs that is 55.52 MLD

For 12 months = $55.52 \text{ ML} \times 12 \text{ months}$ = 666.24 ML per year

The water saving by preventing the evaporation is 666.24 ML, If we consider 60% of the total capacity of evaporation is prevented from evaporation from the reservior surface, then, we can supply water for approx one and half day for entire city with the water saved from evaporation.

10. BENEFITS OF INSTALLATION OF FLOATOVOLTAICS

10.1 Reduction of water evaporation : Pune city people is facing water crisis during the summer every year. The study had explained that by the installation of floatovoltaics on the reservoir surface can reduce the evaporation of water from the surface of water. Loss of water resources due to evaporation is a well-known phenomenon, reported as high as 40% (8) worldwide, and its effect is more significant particularly in dry and aired regions. As per an estimate by Central Water Commission (CWC) India, the evaporation loss in the country varies from 150-300[9]cm per km² per annum. Since FSPV plants are deployed on the water surfaces, they provide shade to the water surfaces, thus reducing the amount of solar radiation reaching the water surface and also limiting the interaction of wind on the water surfaces. The combined benefit of these may results in reduction in the water evaporation losses (14,15). However, it is extremely difficult to exactly quantify the net effect on water evaporation loss due to deployment of FSPV plants since in general FSPV plants are installed on some fraction of a total water surface. By the calculation we can reduce the evaporation of 4518 million litres every year which can be very useful to meet the summer crisis in Pune areas.

10.2 Higher gains in energy production: Correlations between the solar PV array yield, solar PV array temperature, and local weather conditions such as ambient temperature, wind speed, solar irradiance, etc. are well known(8,9). These correlations indicate that reduction in ambient temperature and higher wind speed reduces the solar PV array temperature which in turn results in higher energy yield. As the ambient temperature at the vicinity of a waterbody is generally lower than the ambient temperature at land and wind speed tends to be higher over open water surfaces as compared to on land, it resulting in an evaporative cooling effect. This effect results in lower operating temperatures of the PV cell, which in turn improves the energy yield. The improvement as much as by 10% Higher gains in energy production: Correlations between the solar PV array yield, solar PV array temperature, and local weather conditions such as ambient temperature, wind speed, solar irradiance, etc. are well known(8,9). These correlations indicate that reduction in ambient temperature and

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10.3 Land neutral: Since FSPV plants are installed on water surfaces, the land requirement is none or greatly reduced as compared to ground-mounted solar PV plants and hence FSPV is termed as land neutral. This is particularly of importance for developing countries like India, where land is scarce and land acquisition creates hurdles for deployment of solar PV projects

10.4 Possibility of sharing existing electrical infrastructure: Many inland waterbodies especially reservoirs used for various purposes like irrigation, water supply, reservoirs of hydroelectric plants, etc. have grid connections that are already available. Hence deploying FSPV plants in such cases may save investment cost by utilizing the already existing infrastructure.

10.5 Complementary operation with hydroelectric power plants: As of August 2019, India has 45 GW[12] of installed capacity of hydroelectric power plants. Since most of these plants are seasonal, their output decreases particularly during dry seasons when water flow is less and solar radiations are high. Thus, deploying FSPV plants in combination with already existing hydroelectric power plants would not only improve power production in lean seasons but also acts as energy storage, using solar power during the day and hydropower during the night. Since the response time of the hydro turbine is fast, the combination of hydroelectric–FSPV plant can be used for supplying power during peak demand. However, in some cases, hydroelectric plants having large variations in water level, pose difficulties in designing of anchoring and mooring for supporting the floating platform. Hence it is suggested to conduct a detailed study considering the effect of water level variation on the viability of deploying the FSPV plants at any particular hydroelectric plant.

10.6 Reduction in algae growth: Among several other factors the growth in algae mainly depends upon light intensity and temperature of the water. Since FSPV plant provide shade to the water surface, they reduce the amount of sunlight reaching the water surface, which may cause a reduction in algae growth [12]. However, the effect of deploying the FSPV plants on the local water environment is still not well understood and would require further studies to understand the related issues.

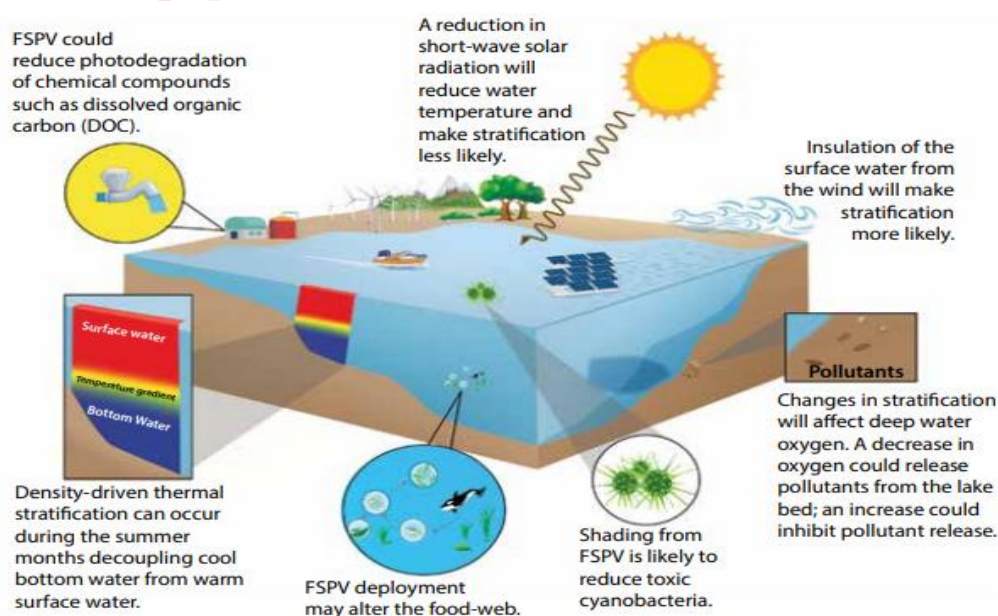


Fig 6: Potential impact of deploying large-scale floating solar PV (11)

10.7 FSPV as a new source of revenue: Deploying FSPV plants can provide an additional source of revenue to a waterbody owner by—either utilizing the electricity generated via self-consuming, thereby reducing their own consumption or via selling the electricity generated to the grid. In either way, FSPV creates an economic value of a waterbody. For example, Jinko has installed 120-MW FSPV-based plant on a fishing farm at Poyang Lake in China, spread over 2000 acres of water surface and generating 137.70 GWh of electricity. Till now there are very few studies that provide some information on the potential impact of deploying FSPV on local ecology, hence it is suggested to conduct a detailed study before deploying largescale FSPV plants.

10.8 Less soiling loss: Since wind blowing over water surfaces contains less dust as compared to wind blow over land, FSPV plants are subjected to less dust as compared to land-mounted solar PV installations.

10.9 Ease of cleaning: In case of FSPV plants deployed on inland waterbodies, water is readily available for cleaning purposes. However, the quality of the water needs to be checked and should be under the permissible limit as described by PV manufacturers.

10.10 Easy installation and deployment: In general, installation of a typical FSPV plant is simpler and easy as compared to land-mounted solar PV plants. This is because of –

- (a) No civil work is required to prepare the site;
- (b) Floating platform used to float solar PV arrays on a water surface are made in form of a modular individual floats which are prefabricated and are interconnected to form a large section,
- (c) Floating platforms are assembled on land by adding rows of these modular interconnecting floats. Each of these rows is pushed into water as the next row being added to form a large platform. Once completed, the entire platform is towed to the exact location on the waterbody with the help of boats. As per discussions with India-based FSPV developer, the typical rate of FSPV plant installation, provided other supply chain is in place, varies from 2.5 kWp/person/h to 3.0 kWp/ person/h.

11. STAGES IN FSPV INSTALLATION

Stage of project	Name of stages	Main activities
1	Site identification/ concept	Identification of potentials sites
2	Prefeasibility Study	Assessment of technical options
		Estimate of costs/benefits
		Assessment of permitting needs
3	Feasibility study	Technical and financial evaluation of preferred option
		Assessment of financing options
		Initiation of permitting process

		Development of fine-tuned technical concept
4	Financing /contracts	Permitting
		Funding of project development
		Development of contracting strategy
		Selection of suppliers and negotiation of contracts
		Financing of project
5	Detailed Design	Preparation of detailed for all relevant lots
		Preparation of project implementation schedule
		Finalization of permitting process
6	Construction	Supervision of construction
7	Commissioning	Performance testing
		Preparation of as-built design (if required)

Source : adapted from IFC 2015

Table 4: Stages of development and main activities for a utility -scale FPV project [4].

12 CONCLUSION:

The Khadakwasla Dam is located near Pune, Maharashtra, India. The dam is constructed on river of Pune city. The research had illustrated that minimum available reservoir area is approximately identified and it can be efficiently be used for installing the floatovoltaics to harness solar energy on the water surfaces of dams. By utilising the area, we can harness the power of 308.33 MWp and considering the solar efficiency 13 % we can generate the power of 40 MWp. By installing the floatovoltaics to harness solar energy on the water surfaces of dams we can save the water from evaporation of capacity 666.24 Million liters per year.

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