Floating Solar PV Potential in Large Reservoirs in India

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Abstract

The 100GW Solar Power (by year 2022) target set by Govt. of India needs optimum utilisation of available area for deployment of Solar PV panels. Though land & roof tops are considered as focus areas, Floating Solar PV (FSPV) on large reservoirs & other water bodies also offers significant potential. This paper aims to analyse the FSPV potential in large reservoirs in India. This paper also touches upon the types of FSPV & benefits of deployment of FSPV.
Keywords: PV, FSPV, HDPE

I. INTRODUCTION

Floating Solar PV (also called Floatovoltaics , Liquid Solar Array & various other names) is not a new concept & a number of installations already exist or planned e.g. following -

- Far Niente winery in California's Napa County, a combined 477 kilowatt land and floating solar system has been running successfully for the last three plus years on a retention pond.(20)
- Water giant United Utilities is to install Europe's biggest floating solar power system on a reservoir near Manchester, as it seeks to capitalise on the novel technology to cut its energy costs. The 12,000 panel, £3.5m development will be only the second of its kind in Britain, dwarfing an 800-panel pilot in Berkshire, and will be the second biggest in the world after a scheme in Japan. (21)
- In Brazil, a 350 MW pilot FSPV project is being planned at the Balbina hydroelectric plant in the Amazon. In Japan, Kyocera is building a 13.5 MW floating solar PV plant on a reservoir behind the Yamakura Dam, east of Tokyo, (16)
- In Kerala, India state utility KSEB has commissioned a 10-kilowatt-capacity plant, spread over 1,200 sq ft has been installed on concrete floaters with hollow insides. The platform can carry 45 tonnes and the power generated will be fed to the KSEB grid through cables drawn through the reservoir bed. KSEB officials said that it is the first floating solar plant to be set up inside a reservoir in the country. The KSEB also has plans to convert the largest earthen dam in the country to a hub of solar power generation with the launch of construction works for two other solar projects at the site. The projects include a proposed 500-kW floating solar plant at the reservoir and a 400kW 'dam- top' solar power generation project.(4)
- India's National Hydro Power Corporation (NHPC) is planning to set up a 50 MW solar photovoltaic project over the water bodies in the southern state of Kerala(6)
- A floating solar power plant is commissioned at Rajarhat near Kolkata. The pilot project has 10 KW capacity. (7)
- A 2.3MW installation was constructed in Hyogo Prefecture, Japan. (3)
- Sheeplands farm, Berkshire, United Kingdom, 200KWp installation comprising of 800 Trina panels. (5)
- Yasugi City, Shimane Prefecture, Japan 4 480 panels installed (245W Kyocera) on water regulation pond Water surface - 5.64 ha Island surface - 1.23 ha, Coverage ratio ~22% Grid connection in November 2014(3)
- Maeno-ike, Hyogo Prefecture, Japan Type on Irrigation pond for rice agriculture 3 392 panels (250Wp Yingli modules)Water surface: 2.43 ha ,Island surface: 0.91 ha Coverage ratio: 37% World's first floating PV plant built on a pond dedicated to agriculture (12)
- Kawagoe, Saitama Prefecture, Japan , 2 786 panels (255Wp Yingli modules) Water regulation pond Water surface: 1.90 ha Island surface: 0.81 ha ,Coverage ratio: 43% (3)
- Okegawa, Saitama Prefecture, Japan PV modules: 4 536 panels (260w JA solar modules)Rainwater control pond Water surface: 3.07 ha Island surface: 1.22 ha Coverage ratio: 40% Grid connection in July 2013(3)
- Piolenc, France on Reservoir formed from gravel extraction quarry 64 panels (235 GESolar modules) Grid connected in February 2011(3)
- Ochang Dam, South Korea PV modules: 2000 panels (250Wp Hanwha modules) First floating solar plant installed on a dam(3)
- Yothathikan, Samutsongkham province, Thailand Aquaculture pond 22 panels – 250w Kyocera modules Grid connection in October 2014(3)
- Yoshiwara, Zentsuji City, Kagawa prefecture, Japan Irrigation pond for agriculture 24 panels – 245w Kyocera modules Grid connection in November 2014(3)

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- The government of Singapore is undertaking the largest side-by-side comparison study of floating pv systems, which is managed by the Solar Energy Research Institute of Singapore (SERIS). "This SGD11 million project will be held in two phases over a period of 4 years, and in phase one, starting in 2015, will deploy eight floating PV systems, each with a capacity of around 100 kWp. Phase Two will see an expansion by another 2-3 MWp in size. (14)

This paper aims to analyse the FSPV potential in large reservoirs of in India as well as its relation to hydroelectric power generation. This paper also touches upon the benefits & challenges of deployment of FSPV in these large reservoirs.

II. TYPES OF FSPV

- LSA, Liquid Solar Array by Sunengy is a PV concentrator using relatively lightweight plastic concentrators that float on water, mounted on anchored rafts. A thin plastic focusing concentrator lens rotates slowly to track the sun both daily and seasonally. A minimal amount of silicon (or other types of) photovoltaic cells are housed in a PV container that sits in the water where the cells are kept cool and efficient, through convective heat flow to the surrounding water. In bad weather the lens is protected by rotating it under the water to avoid damage in high winds, so the water becomes the vital structural component, cooler and protector.(1)
- Ciel & Terre offers HDPE floating platform for mounting solar modules. Easy to install, dismantle & recycle, Easy to adapt to any electrical configuration, scalable from low to high power generation, no tools/no heavy equipment needed.(3)
- Solaris Synergy offers individually floating modules contained within a light-weight tension based, floating grid , provides self-regulation of panel angle under varying wind loads, allowing the installation of the system in regions of very high wind speed, even up to hurricane levels .The system is agnostic as to water depth and unaffected by changes in water level. The structure has a very low physical profile providing a minimal visual impact. The open structure of the system ensures adequate aeration of the water as well as natural light penetration and presents no hazard to underwater life.(22)
- Novation's 'Solar-Islands' are floating platforms (12 – 100 meters in diameter) designed to be compatible with both photovoltaic panels as well as concentrating solar thermal (CST) technologies. They have not yet been put into operation, but three are in the process of being built in Switzerland. The island consists of an outer torus and a membrane, on which the solar receivers are placed with longitudinal cables to hold them aligned in position. Below the membrane, a small overpressure of typically less than 1% of the atmospheric pressure is applied (still representing 100 kg/m2), carrying the load of the solar receivers and allowing the solar island to rotate and align its receivers to the sun, via azimuth tracking. This element is crucial for concentrated solar or CPV receivers, which have to be constantly and precisely aligned with the sun's perpetual movement. (2)
- Smart Floating Farm by Forward Thinking Architecture is a solar energy & Polyculture based solution, a highly productive floating ecosystem. It is a flexible one able to adapt its dimensions to the local food production needs and can be located close to many mega-cities or dense populated areas with a physical water access (sea-lakes-rivers)(17)
- Tracking Type FSPV - where the azimuth and altitude of the sun is tracked to receive the sunlight perpendicular to the module surface. The tracking type PV is a high efficiency generation system that produces a greater amount of electricity by adding real-time sun-tracking function to the PV module. In general, it is known that on the ground, the power generation of a dual-axis tracking-type is 30% greater than a fixed-type.(10) In the passive-tilting type, PV panels are connected on rotating steel bar and placed on SMC members with angle changeable parts. Considering the location of the sun in each month of the year, the angle of the passive-tilting type is changed manually in every month or season. The automatic-tilting type is designed to find and track solar altitude and azimuth automatically according to pre-programmed algorithm. Since this type makes PV panels orthogonally receive the sun rays automatically based on the information from solar sensors, this type has higher efficiency.(13)

III. BASIS OF ESTIMATES (15,18,19)

Based on the experience in above installations & indication by various installers, a conservative estimate of 40 MWp capacity FSPV can be taken per sq. km of reservoir surface area covered.

The coverage of minimum 20 % of total reservoir surface area can be considered with negligible impact on environment. The coverage in the sites listed above is 22 to 43% of reservoir surface area.

The saving in water due to reduction in evaporation losses is taken as 1250 million litres per year per sq. km.(4 million gallons per acre per year) based on above examples.

IV. FSPV POWER PLANT RATING & WATER SAVING ESTIMATES

Example –
Nagarjun Sagar Dam
Total reservoir surface area = 284.90 km^2
Present hydroelectric generation capacity = 815.6 MW
Proposed area coverage for FSPV = 284.90X 0.20 = 56.98 km^2
Proposed FSPV rating = 56.98X40 = 2279.2 MW

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Water Saving per year = 56.98X1250 = 71,225 million litres

Table – 1

Similarly for other major reservoirs of India the figures are as follows:

Reservoir	*State*	*Reservoir Area Sq. Km*	*Floating Solar PV GWp potential*	*Water Saving million litres per year*
Nagarjun Sagar	*Andhra Pradesh*	*284.9*	*19.943*	*356125*
Sriramasagar	*Andhra Pradesh*	*450.82*	*31.5574*	*563525*
Srisailam	*Andhra Pradesh*	*616.42*	*43.1494*	*770525*
Somasila	*Andhra Pradesh*	*212.28*	*14.8596*	*265350*
Manimata Hasdeo	*Chhattisgarh*	*188.47*	*13.1929*	*235587.5*
Pong	*Himachal Pradesh*	*260*	*18.2*	*325000*
Salal	*J&K*	*93.56*	*6.5492*	*116950*
Maithon	*Jharkhand*	*106.19*	*7.4333*	*132737.5*
Panchet	*Jharkhand*	*153*	*10.71*	*191250*
Tenughat	*Jharkhand*	*64.8*	*4.536*	*81000*
Krishnarajasagar	*Karnataka*	*129*	*9.03*	*161250*
Tungabhadra	*Karnataka*	*378.13*	*26.4691*	*472662.5*
Bhadra	*Karnataka*	*117.25*	*8.2075*	*146562.5*
Linganamakki	*Karnataka*	*316.65*	*22.1655*	*395812.5*
Malaprabha	*Karnataka*	*129.5*	*9.065*	*161875*
Hidkal	*Karnataka*	*78.04*	*5.4628*	*97550*
Hemavathy	*Karnataka*	*91.62*	*6.4134*	*114525*
Supa	*Karnataka*	*123*	*8.61*	*153750*
Almatty	*Karnataka*	*754.25*	*52.7975*	*942812.5*
Cheruthoni	*Kerala*	*59.83*	*4.1881*	*74787.5*
Gandhisagar	*Madhya Pradesh*	*660*	*46.2*	*825000*
Tawa	*Madhya Pradesh*	*200.55*	*14.0385*	*250687.5*
Bargi	*Madhya Pradesh*	*267.97*	*18.7579*	*334962.5*
Indira Sagar	*Madhya Pradesh*	*913.48*	*63.9436*	*1141850*
Koyna	*Maharashtra*	*115*	*8.05*	*143750*
Paithan	*Maharashtra*	*398*	*27.86*	*497500*
Ujjani	*Maharashtra*	*336.5*	*23.555*	*420625*
Totladoh	*Maharashtra*	*77.71*	*5.4397*	*97137.5*
Hirakud	*Odisha*	*743*	*52.01*	*928750*
Rengali	*Odisha*	*378*	*26.46*	*472500*
Upper Kolab	*Odisha*	*122*	*8.54*	*152500*
Indravati	*Odisha*	*110*	*7.7*	*137500*
Ranapratap Sagar	*Rajasthan*	*198.29*	*13.8803*	*247862.5*
Mahi Bajaj	*Rajasthan*	*134*	*9.38*	*167500*
Bisalpur	*Rajasthan*	*218.36*	*15.2852*	*272950*
Mettur	*Tamil Nadu*	*153.46*	*10.7422*	*191825*
Rihand	*Uttar Pradesh*	*468*	*32.76*	*585000*
Matatila	*Uttar Pradesh*	*138.85*	*9.7195*	*173562.5*
Rajghat	*Uttar Pradesh*	*2453*	*171.71*	*3066250*
Kangsabati	*West Bengal*	*124.32*	*8.7024*	*155400*
Total			*909.05*	*16233187.5*
			GIGAWATT	*MILLION LTRS.*

Thus a potential of 909.05 Gigawatt power generation & saving of 16233 billion litres of water per year exists if large reservoirs are used in India for Floating Solar PV Power Plants.

V. ADVANTAGES OF FSPV (3, 8, 9, 24, 25, 26, 27)

The following facts illustrate the need & benefits of FSPV -

- By installing solar panels over a pond, the panels are naturally cooled, resulting in improved power production performance. The cooler environment also reduces stress on the system, extending the system's lifespan.
- Floating solar is cost competitive with, roof and ground-based single-axis tracking solar systems and uses the same commercially available solar panels..
- Aside from generating power, the systems also provide other environmental benefits. As an example, the system shades the water and can reduce evaporation by up to 70%. A 3-acre storage pond covered with solar panels could save over 4 million gallons of water each year.

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- The systems can also improve water quality. As water bodies are exposed to the sun, photosynthesis promotes growth of organic matter, including algae. By shading the water, algae growth is reduced, minimizing the associated treatment and labour costs.
- Typically areas with high solar energy potential tend to be dusty and arid, so in comparison to their ground mounted counterparts, floating PV system not only have to perform in a low dust environment, they can always use a sprinkler to bathe themselves clean.
- Availability of land is a big problem. This is one of the primary reasons why Japan has been interested in the floating PV technology. If one is planning to put floating PV in dam reservoirs, it can make better use of the reservoir surface, which is anyway lying idle.
- In dam reservoir-based hydro power plants, solar power can substitute hydro based generation during day time when sun is available. In such a case, the stored water in the reservoir will serve as an effective energy storage systems.
- All materials can be recycled
- Low environmental impact: no excavation work, no impact on water quality
- Reduced erosion of reservoir embankments by reducing waves
- Easy to adapt to any electrical configuration
- Scalable from low to high power generation
- In terms of installation speed per kW, it's seven times faster than a rooftop installation.
- No tools or heavy equipment needed
- Return on investment boosted from the low lease price and installation costs
- Standardised equipment to ensure low production cost and competitive system prices
- FSPV can support distributed generation & micro-grids , using local water bodies.

VI. FSPV – ISSUES TO BE CONSIDERED (11, 3, 24, 25, 26, 27)

The additional issues to be considered for FSPV Power Plants are -

- Will water birds be attracted to the project by virtue of its being on water? Could they nest, leave droppings or otherwise cause problems?
- What concerns are relevant in the case of freshwater as opposed to saltwater/seawater?
- What is the risk of power loss in PV modules due to micro cracks caused by vibrations due to wind, waves and external forces?
- Factors that directly affect generation (efficiency): Solar radiation, fog, occurrence of shade, etc.
- Factors that affect installation and maintenance: depth of water (water level fluctuation), frozen region, inflow of floating matters, accessibility, interference by dam facilities (water intake tower, waste-way), etc.
- Connection with power system, distribution line, distance to distribution line, distance to load
- Legal restrictions: water source protection area
- Environment Preservation Act, Protection of Wild Fauna and Flora Act, fishing prohibition area, marine leisure activity prohibition area, civil complaints, excessive compensation expense, inducement of environmental problems, etc.

VII. CONCLUSION

The Floating Solar Photovoltaic offers an economical, eco-friendly alternative to Land or rooftop solar PV. The savings in water & land/roof area requirement are important additional benefits. The estimates by various renewable energy organisations do not include the potential for Floating Solar PV in their estimates. This needs to be rectified.

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