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A Comprehensive Overview and Assesment of Floating Solar Photovoltaic Power Plants

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Abstract: The limited fossil fuel resources and increased demand for energy make solar energy the major area of concentration, as this is free and unlimited source of energy, also environment-friendly and sustainable to the environment. But while executing the projects, problems face the government and the partners in the execution of the plan, such as land availability, land development and acquisition, substation capacity, and evacuation, also timely clearances for the execution of the plan on land, which are the major problems in completing the project. Most of the locations identified by the government, considering the solar radiation data in the country, are hot
And dry places. Even though the radiation is high at these places, the energy yield is low at these places due to the heating effect of the solar panel and the high temperature of the surface of the solar cells. In order to avoid all these issues, an innovative idea has come in front to install the solar power plant on water, i.e., on the top of canals, water bodies, lakes, dam backwaters, and reservoirs, which are under the government.
Keywords: Energy, Solar Power Plant, Solar Cell, Radiation, Sustainable

1. INTRODUCTION

India has proposed that there will be generation of solar energy from renewable energy sources up to 1.75 GW and 1 GW of Solar PV power in the next 10 years. India is progressing as per the policies that have been declared. As on date, 5000 MW has been commissioned in different parts of the country as per the Indian National Solar Mission [1]. The increase in consumption of energy, absence of habitable land, and environmental concerns has led to the increased use of renewable energy sources in these areas [2]. The major forms of marine renewable energy have been researched extensively, which has led to the development of technologies for offshore energy. These are the energy sources from wind, waves, and tides [3]. In addition, solar energy is considered an alternative form of energy that is rarely exploited in the marine environment [4]. To explore alternative forms of energy, solar floating photovoltaic (FPV) systems on seas and oceans have been considered as a new way of generating alternative forms of energy without utilizing water and land resources[5]. There are many benefits of installing an FPV system over water bodies, and these benefits include land savings, water cooling due to improved efficiency of the PV system, fewer obstacles for shadow loss, and less dust. In addition, 50% of the total world population is estimated to live within 100 km of the coast, and it is considered a good opportunity for providing electricity [6,7]. The energy produced in the solar PV system is renewable, eco-friendly, and sustainable with a long life of the system. There are various advantages of the floating solar PV power plant compared to the roof top and ground-mounted solar PV systems, which include the efficiency of the solar panels due to the cooling of the panels with the air above the water bodies, as it reduces water evaporation and due to the shading of water, algae do not grow [8]. The renewable energy sources such as hydropower, wind power, and solar PV have covered 46.5%, 23.9%, and 23.8% of the total installed power sources as of 2020. The most perceptible observation is that FPVT installation is rising significantly and rapidly and is able to accumulate wind power in less than 10 years. The PV technology with FPVT systems is expected to rise by 7.38%, up to 485.4 GW, compared to today's installed power and installation of hydropower, which is expected to reduce by 9.28% of today's installed power worldwide [9]. Apart from the production of energy, the systems have other environmental benefits. For instance, the solar system will shade the water and reduce evaporation up to 70%. In addition, the systems can be used to purify water. For instance, as the water body is exposed to the sun, photosynthesis will lead to the formation of algae. The system will shade the water, thus preventing the formation of algae. This will reduce costs associated with algae treatment. The first countries to establish FPV systems in offshore areas are China and the Netherlands [10]. There are many researches and reports and reviews on FPV in offshore areas, which is one of the renewable energy resources that will be very common and potential to be a target of a green and clean energy solution, such as the environmental impacts of marine floating solar [11,12].

2. FLOATING SOLAR PV SYSTEM

Solar arrays floating on the surface of drinking water reservoirs, quarry lakes, irrigation canals, and remediation and tailing ponds are floating solar PV systems. There are a small number of floating solar PV systems in France, India, Japan, Korea, the UK, Singapore, and the USA [3, 4]. The systems are said to have some advantages compared to photovoltaic systems on land. The cost of land is higher, and there are fewer regulations and laws regarding structures erected on water not meant for recreation. The floating systems are said to be less conspicuous as they are not exposed to public view. The systems are also efficient compared to photovoltaic panels on land as water acts as a cooling agent. The panels are coated with a special layer that prevents rust and corrosion.

Components of Floating Solar PV System

1. Pontoon/Floating Structure - A pontoon is a floating structure with buoyancy that can float on water and support a heavy load. It is designed in a way that it can support a number of panels.
2. Mooring System - Any permanent structure to which a floating structure can be secured is called a mooring. A floating structure can be secured to a mooring to prevent the free movement of the floating structure on the surface of the water. An anchor mooring secures the position of a floating structure relative to a point on the bottom of a waterway without attaching the floating structure to land [13].
3. Solar Module - The solar module is able to generate only a limited amount of power, and generally multiple solar modules are connected together in a solar photovoltaic system. The photovoltaic system consists of a solar panel or solar module array, solar inverter, and sometimes battery and solar tracker. Mostly crystalline solar PV modules are being used for floating solar systems.
4. Cabling - As these cables are used outside, they are specially designed to withstand high temperatures and are not affected by the weather conditions in outdoor environments. They are also resistant to high UV exposure.

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3. OVERVIEW OF DIFFERENT FLOATING SOLAR FLOTAVOLTAIC POWER PLANT

305 kWp FPV system, Goias, Brazil

Source: ©Ciel & Terre International Note: kWp = kilowatt-peak

FPV system in Alto Rabagao, Portugal

Source: ©Pixbee/EDP S.A

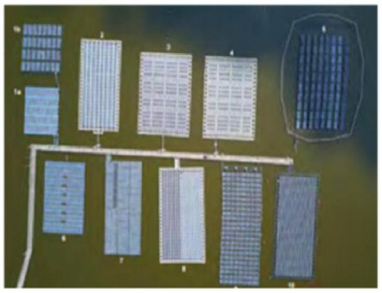
3 MWp FPV system, Lake, Chungju Dam, Korea

Source: ©LSIS

FPV system in Taiwan, China

Source: ©Sungrow

1 MWp SERIS FPV, Reservoir, Singapore

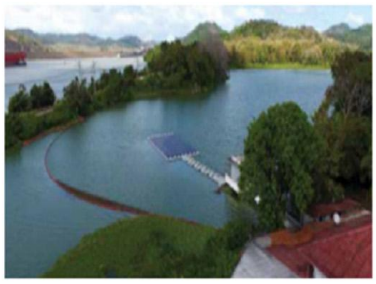


Source: ©SERIS
Note: MWp = megawatt-peak

13.7 MWp FPV installation, Yamakura, Japan

Source: ©Kyocera TCL Solar LLC.
Note: MWp = megawatt-peak

24 kWp FPV system at Miraflores, Panama



Source: ©Ciel & Terre International.
Note: MWp = Kilowatt-peak

1.85 MW FPV system, Azelealaan, Netherlands

Source: ©Ciel & Terre International.
Note: MWp = Megawatt-peak

FPV project, Reservoir, United Kingdom

Source: ©Lightsource BP Floating Solar Array, London

FPV project in Orlando, Florida, United States

Source: ©Ciel & Terre International.

4. NUMEROUS SOLAR FLOATING INSTALLATIONS

The global world has been in race for installation of solar floating power plants ever since its advent came into existence. The various plants globally are discussed below:

4.1Projects in 2007-2010

The first solar project known to have been built on water was the Aichi project. It was made possible by a team of researchers from the National Institute of Advanced Science and Technology in Japan [14]. It was sponsored by the Ministry of Environment in Japan. The objective of this research was to present the concept of floating solar systems as

well as the effect of module temperatures on the performance of the solar plant [15]. One of the biggest projects realized up to now is the one designed and realized by Bubano in Imola, Italy. This is a 500kWp rated system, and it is installed in a lake, realizing this ambitious work in collaboration between two local enterprises. The system, named "Flotovoltaico®", is grid-connected and is realized using 'floating islands' constituted by polyethylene cubes placed at the two sides of the system, connected by struts where the panels are placed. The next project in floating solar was set up in Solarolo, Italy in 2009, and this was to be called the 'Lotus Project.' This was a 20kWp array that was set up on top of an irrigation pond and was designed by D.A.E.I.T. s.r.l. There were ducts installed below the panels to provide air cooling to the panels. It was installed at an angle of 8 degrees to achieve maximum power density by using more panels in the same area. It was designed to be accessible to individuals, and in fact, the floats extend directly to land to make it accessible. The only one known to be installed as of 2010 is one at a Winery Located in Suvereto, Italy. What differentiates it from any of the above-discussed systems is that it is installed with a tracking mechanism, which rotates according to the movement of the sun, and a reflector is installed in front of the panel to maximize the amount of sun radiation it is able to receive.The safety and tracking feature were analyzed by a researchgroup at Scienza Industria Technologia (SCINTEC), whereas the design and construction were carried out by Terra Moretti Holdings. This concept is known as Floating Tracking Cooling Concentrating Systems (FTCC). A major percentage of its structure is made of metal struts, which keep the crystalline panels at an optimal angle of 40 degrees and have a reflector installed in front of it, tracking the movement of the sun.

4.2 Projects in 2011-13

The same research team who carried out the research on the tracking feature at Petra's Winery above (Section 3.1) also came up with the following installation at Lake in Pisa, Italy. In this case, the solar panels are placed horizontally, and at the edges, there are reflectors forming a V-shape, ensuring maximum radiation. This, in turn, means that the temperatures are high. However, in this case, the solar panels are closer to the lake, and thus the cooling effect was greater than in the Suvereto project above. It should be noted that the tracking feature was used in this installation. It is evident that the results showed that this installation was able to produce higher results than the Suvereto project above and thus made it a favoured concept. It was noted that this installation was able to increase output by 60-70% compared to conventional land-based solar systems [16, 17]. Another new entrant into this landscape is Ciel et Terre whose first floating solar plant was the design and installation of a floating solar plant in an abandoned and flooded quarry site in Piolenc, France. Metal struts are used not only to hold the solar plant together but also to ensure that the solar plant is at an angle, pointing towards the sun. Floats are placed at the bottom of each row of solar panels in the solar array. These floats are made of High density polyethylene (HDPE), which offers special resistance to corrosion, thus providing a durable solution as opposed to using metal. A research project has been set up in Singapore. The research project is located in Bishan Park. The research project was set up by Phoenix Solar as a pilot project. The 5kWp system is angled at 10°. The system has its modules placed on floats that are connected to each other. The structure is then moored to the lake bed at the 4 points [18]. The largest floating solar project so far has indeed been installed this year on a water reservoir in Okegawa, Japan, with a capacity of 1,157 kWp.The developer of this major project is Ciel et Terre, who had earlier gained success with their Hydrelio © floating solar system in Piolenc, France, and now have gone on to install this larger project in Japan. Submerged solar panels have also been a point of thought for a few

Specialized groups. So far, the only means of obtaining power underwater is by the use of batteries. The US Naval Research is researching solar cells that can absorb the small spectrum of wavelengths that can be obtained at certain points underwater. A few semiconductors (GalnP cells) have been used for this purpose as they have shown better results in the absorption of wavelengths in the blue and green spectrum as compared to silicon cells. This concept still needs to be analysed to present results for its long-term deployment [26]. Silicon cells have been analysed for their use underwater. Results show that they are not as effective once they are submerged even a few centimetres underwater [19].

4.3 Projects in 2014 and onwards

Hydrelio is an innovative solution for water-based solar power generation, and it was invented in France. The high technology in design has enabled the construction of water-based solar photovoltaic facilities using anchors. Hydrelio is a float module solution designed by Shell Tail for the construction of water-based solar photovoltaic (solar power). The module consists of two floats, which are made from high-density polyethylene (HDPE). The first float can carry solar panels with 60 cells, and the second float connects the floats and is used as a foothold for the purpose of maintenance. Connect the floats using a connecting pin and create solar islands. Hydrelio System is a small and area that allows the

implementation of solar power generation projects without deforestation, soil pollution, and water pollution through the effective use of irrigation ponds, reservoirs, and dams that are dispersed in Japan.

It is a particularly innovative water-installed solar system that is particularly suitable for. In addition, as the natural cooling effect is obtained by installing on the water, it is expected to have higher power generation efficiency compared to the ground installation type, which can achieve excellent cost effectiveness in terms of the shortening of the construction period with its simple structure. Young-Kwan Choi et al has compared and analysed the generation efficiency of floating and land photovoltaic systems. The generation efficiency of floating photovoltaic systems is higher by more than 10% compared to the general photovoltaic systems that are installed on land. This paper compares and analyzes the empirical data of floating photovoltaic systems that are installed by K-water and existing photovoltaic systems on land and verifies that the generating efficiency of floating photovoltaic systems is higher by 11% and more [20]. Jinyoung Song and Yosoon have examined the potential of the floating PV system on the mine pit lake in Korea to remove the misconceptions associated with the topic [21]. According to the study, however, the creation of a pit lake in an open-pit mine and the utilization of the pit lake for the construction of a large-scale floating PV system is not only beneficial to the economy but can also reduce the emission of greenhouse gases. Therefore, the floating PV system on the pit lake of the abandoned mine site is considered an efficient method of using the abandoned mine site.

5. CONCLUSION

The review in this paper will show the timeline of concepts and floating solar PV systems that have been established to date. The systems were either erected for research or commercial purposes. All the grid-connected systems are kept afloat using pontoons or floats with the panels being rigidly attached to the floats. FPV systems in the offshore region have been developed and matured due to the increase in energy production, based on the results obtained for the FPV sector in the onshore region, where the FPV systems are installed in water bodies such as lakes, reservoirs, and dams. However, up to now, the FPV in the offshore region is still a novel sector in the world. Therefore, there are some studies in progress, adapting the FPV systems in the offshore marine environment in a mature way, such as PV modules and the influence of the environment on the FPV systems. Some examples of the application of the FPV systems in the offshore region in the world are presented, particularly in the developed countries, such as Japan, South Korea, the UK, and China. There are many successful projects of FPV, which have been implemented and functioning in various countries of the world, and FITs are offered by governments as an opportunity for developing FPV offshore. Additionally, it is an excellent opportunity for providing power to those islands where there is a severe deficiency of power. This review provides an overview of the opportunities for applying FPV offshore globally.

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