Floating solar photovoltaic system

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Abstract
India has done a remarkable job in terms of deployment of renewable energy-based installations, growing almost 3.5 folds in the last 5–6 years, with most of the capacity coming from onshore wind and solar photovoltaic (PV) based installations. At present India's grid-connected solar PV sector is majorly dominated by the ground-based installations (93%1) while the balance is contributed by rooftop the based solar PV installations. The installation cost of utility-scale solar PV in the country has declined by 84%2 between 2010-2018, making India world's topmost country in achieving the lowest installation cost for utility- scale solar PV. It is well know that solar PV deployment is quite land intensive and scaling up the project sizes requires large chunk of contiguous land parcels, which becomes challenging in many situations. In order to keep pace of development commensurate with the national targets for solar capacity additions, alternatives are required to be explored and established. Floating solar PV (FSPV) or floatovoltaics is one such alternative, which has started getting traction worldwide and is expected to grow strongly over the coming years.
It is estimated that the annual capacity addition may rise from the current installed of 1.314 GWp in 2018 to 4.6 GWp by 2022. Presently, China is the leading international market followed by Japan and South Korea. India also has very bright prospects to develop FSPV projects due to availability of large water bodies.
As a technology, FSPV is in a very early stage of development in India. Till now, only a few projects with cumulative capacity of 2.7 MW have been installed. However, over 1.7 GW capacity projects are reported to be in various stages of development. FSPV market appears to inch forward to make its presence felt in India and the tariffs discovered through bids have already shown rapid reductions. So far large-to-medium size man-made inland waterbodies seems to have attracted initial interest to install FSPV based power plants, but all these waterbodies were created to serve various purposes like – irrigation, water supply, fishing, hydroelectric, navigation, etc., and this warrants great deal of diligence to balance out various usages of these waterbodies on the basis of accurate information.

Keywords: Floating Solar PV

1. Introduction

Solar energy is a clean and renewable form of energy as compared to fossil fuels. With the strong commitments of the national governments around the world toward greenhouse gases (GHG) reduction, solar Photovoltaics (PV) is a clean technology solution to reduce the Greenhouse Gas emissions in the power sector.
In many countries, land recourses are limited for giant scale ground-mounted solar PV systems. Moreover, rooftop areas in housing, commercial and industrial buildings may not be important for rooftop solar solution. In this context, floating solar PV systems are the suitable ecological alternative solutions. Floating solar photovoltaics is coined as "floatovoltaics".

As per the International Energy Agency, the deployment of solar photovoltaic were globally at peak in 2020 in the focus of 90% grow in demand of renewable electricity. Photovoltaic (PV) are able to directly convert sunlight to electricity. From photovoltaic point of view, there are four main factors influencing the output PV energy yield. First comes the source of energy which is the sunlight, then is the converter which is the PV cell, moreover the amount of time for which the Photovoltaic unit can function, and finally the size of area that this technology is auxiliary on. We do not have much control on sunlight. In addition to that, PV converter efficiency is touching its maximum theoretical efficiency. And that is why researchers have now put more effort into investigating approaches to boost the lifetime of PV and also looking into possibilities to add PV on or integrated it into any possible surface. Since the efficiency of PV modules is low, they take large amount of area, which can be utilized for other essential necessities of human kind, such as food and accommodation. The demand for food, accommodation, and green energy is increasing with increase in world population therefore, there is a possibility that food and energy sectors might compete or already are competing over area. This inevitably draws the attention to another largely available surface area, the water. Simply placing any type of PV system on top of water bodies, such as lakes, reservoirs, hydroelectric dams, industrial and irrigation ponds, and coastal lagoons, is called floating PV (FPV) or floatovoltaics [1].

2. India's Scenario

The Floating Solar PV as a technology is still in the earlier process of development in India. This started with a 10kW FSPV plant on a pond in Rajarhat, Kolkata in 2015 when the project was supplementary of a research activity sponsored by the Ministry of New and Renewable Energy (MNRE). In 2016, NTPC commissioned India's largest 100kW 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 500kW plant at Banasura Sagar reservoir in Wayanad district replacing NTPC's 100kW as a largest FSPV-based plant. The plant is in-fact a scaled version of the 10kW plant commissioned in January 2016 at the very 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 2MW 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 Floating Solar PV sector is drawing a lot of attention in the country, which is visible from an increase in the numbers of tenders that are released in the past 2 years. At present there are more than 1700 MW worth of projects, which are in various stages of development and more are in pipeline making the outlook very promising for this new segment.

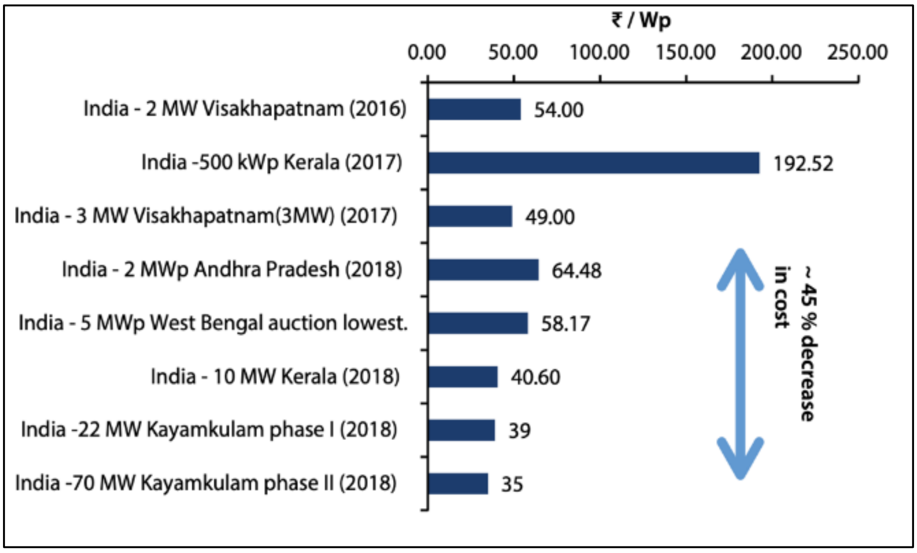

Fig 1

2.1 India's Potential

It is known that India has a huge number of artificial reservoirs and other water bodies, which are and can be used for a variety of uses like water supply, navigation, irrigation, etc. The prevalent high temperatures and arid conditions, however, result in substantial evaporation losses from these reservoirs. CWC estimates that average annual evaporation from reservoirs/ waterbodies in India varies from 1.5 m to 3.0 m per km^2. Thus, FSPV creates a possibility to produce clean energy from a technology that is has the potential to conserve water by reducing the losses due to evaporation.

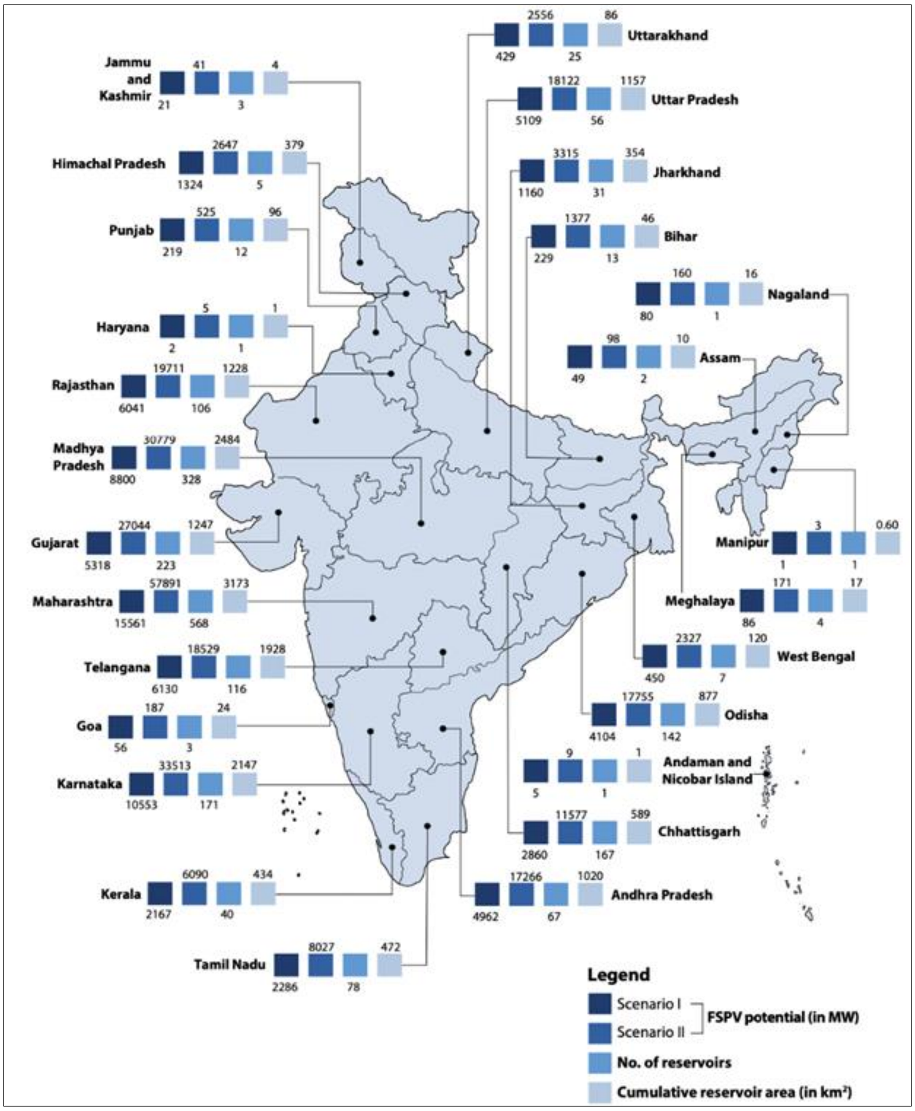

Fig 2

Even though numbers showcase huge potential of FSPV in the country there is a very limited amount of data available at the moment, raising speculations on the long-term viability of this new technology. Hence in order to reap the benefit of this technology, it is essential to create local knowhow via concentrating more on the long-term impact of technology through proper monitoring of projects. Learning through these initial projects would then be utilized in setting standards and guidelines for further developing such projects. Based on the data gathered, the study tries to identify the difficulty levels in setting up the FSPV-based projects for all the locations and rank them in form of priority, that is, Priority I, Priority II, and Priority III. Locations involved under Priority I are the ones that are considered as 'low-hanging fruit'. These require minimum level of knowledge available presently and thus easy to install [2].

3. Technology Analysis

3.1 Components of PV System

3.1.1 Solar Module / PV System

The fundamental part of the floating solar photovoltaic system is solar PV modules and similar to conventional solar projects generally, poly or monocrystalline or thin film solar panels are used for the installation of the project. A single solar module can produce only a limited amount of power; most installations contain more than one modules. A photovoltaic system typically includes a panel or an array of solar modules, a solar inverter, and sometimes a battery and a solar tracker and inter-connection wiring.

3.1.2 Floating Structure

A pontoon is flotation structure and has buoyancy enough to float on water and support a heavy load. The structure is designed such as it can hold number of panels. It allows the installation of the photovoltaic module. This is the most crucial component of floating solar photovoltaic system which supports all the necessary components. Therefore, it is very important to select the appropriate materials for the floating structure. High Density Polyethylene (HDPE) is the most widely used in a majority of the FSPV power plants across the globe [3].

3.1.3 Mooring system

A mooring refers to a permanent structure to which a floating structure can be secured. A floating structure is secured to a mooring to forestall free movement of the floating structure on the water. An anchor mooring fixes a floating structure's position relative to a point on the bottom of a waterway without connecting the floating structure to shore. Since FSPV plants are installed on water bodies, any variations in water levels induced by monsoon, wind velocity or increase/decrease in water quantity could be problematic for the plants. To avoid this situation, FSPV plants are anchored through mooring systems.

3.1.4 Underwater cable
It is responsible for the transfer of the generated energy therefore, cable routing and its management requires cautious planning. Due to their outdoor usage, solar cables are designed uniquely to be resistant against UV radiation and extremely high temperature fluctuations and are generally unaffected by the weather. The cables are routed by two different ways - either via floating on water surfaces or via submarine cables. Cable trays, cable conduits, and cable clip holders are used to keep cables on the water surface. Cables used must be UV-resistant, and uses of wiring trunks are recommended to protect them from direct sunlight. To avoid DC cables/ conduits coming into contact with water, using proper cable ties or clamps is recommended [4].

3.1.5 Inverters
Similar to a conventional solar plant, DC power generated from solar PV modules is taken to the inverter through a series of combiner boxes and finally converted into AC power. A developer may select multiple string inverters or central inverters. Depending upon scale and distance from shore, inverters can be placed either on a separate floating platform or on land. Generally, for smaller capacity FSPV inverter may be located on land near to PV arrays, otherwise for large capacity plants it is suggested to position inverter on a floating platform to avoid excessive resistive losses.

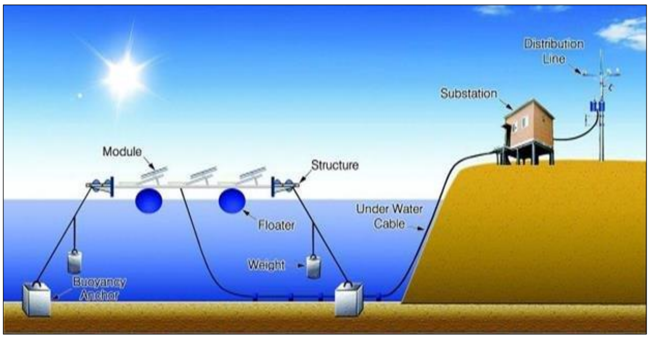

Fig 3

3.2 Technological Advantages
The most important parameter considered for the performance evaluation of the floating solar PV is the module effective conversion efficiency in operative conditions, which affects the electricity generation, therefore, the most valuable product of the component. The conversion efficiency of a PV module is given by the ratio between the generated electrical power and the incident solar radiation intensity. The expression is as follows:

$$\eta_{el} = \frac{P_{max}}{S \times A_{PV}} \times 100$$

Where,
η_{el} is the efficiency of electricity produce (%),
P_{max} is the maximum power produce by PV system (W),
S is the solar radiation strength fall on the PV module (W/m2)
A_{pv} is the area of PV module on that solar radiance fall on the surface (m2)

3.3 Technological Disadvantages
Few of the several disadvantages of the floating photovoltaic system that need to be taken into consideration include the following:

- The floating PV system is more exposure to hydraulic and weather conditions, then may result in unstable power output.
- Fishing and transportation activities may be affected by the floating system.
- Located within the water environment could lead to the corrosion of modules and structures, thus could reduce the system lifetime.

Yamakura dam case study
The company Kyocera TCL Solar LLC began construction in December on a new floating solar power plant located on the Yamakura Dam reservoir in Japan's Chiba Prefecture (Goode, 2016). Floating solar arrays are gaining popularity worldwide, with installations also in the United States and Australia. 'Floatovoltaics' have several advantages over land-based solar arrays. Buying or renting land is more expensive than renting space on a reservoir or body of water, and there are fewer regulations for floating farms on non-recreational bodies of water [5].

Specifications
Location-Yamakura Dam (Ichihara City, Chiba Prefecture, Japan).
Operation-Kyocera TCL Solar LLC
Nameplate Capacity-13.7 MW
Solar Modules-50,904 270-watt modules
Expected Annual Power Generation-16,170 MWh/year
Size-180,000 square meters, or 44.5 acres

Impact
The floating solar array will produce around 16,170 MW hours per year, which is adequate electricity for approximately 4,970 typical Japanese households. This clean energy will shadow 8,170 tons of CO2 emissions on an annual basis, which is equivalent to 19,000 barrels of oil. Obviously, this solar farm will be a massive step in the forward direction in terms of creating carbon-free renewable energy. If this project is economically profitable, then Kyocera will probably pursue dozens more projects on reservoirs in the coming years.

Conclusion
Compared to land mounted photovoltaic systems, the advantages of FPV power plants are greater efficiency, less evaporation of water and a reduction the emissions of CO2 greenhouse gas, which leads to the expanding of these systems in many countries. In countries with arid and semi-arid locations, the water crisis is a serious issue and the utilization of FPV modules to minimize the evaporation rate of water is the correct choice. In general, the sun in these countries is cheaper. FPV plant design covers all aspects, including electrical and mechanical functions. The mechanical configuration of the FPV has been studied by many researchers, but the wiring diagram needs to be applied. In this case, this work describes the different possible configurations of the FPV grid connections and the use of multi-level DC-DC converters when connecting the FPV panels to the grid network. By moving towards FSPV integration into the city, FSPV systems encourage a faster

and more economic development of solar projects, as it reduces the burden of land acquisition on the governments and encourages projects to be finished on time (due to the less probability of prolonged legal disputes regarding acquisition) by contractors.
The consultation of related articles shows that most of the work focuses on the study of energy efficiency and production and on the evaluation of the mechanical structure of these systems. In the conclusion, the review show that 40% of the water in open reservoirs is lost through evaporation. By covering only 30% of the water surface by PV system, evaporation can be reduced by 49%. In 2018, the world's total photovoltaic capacity reached 512 GW, an increase of 27% compared to the total capacity and about 55% of the renewable resources newly created that come from photovoltaic systems. It has been also foreseen by this report that in 2025 the solar technology including the FPVT system will jump by 7.38% that is 485.4 GW more of present day installed power worldwide.

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