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A REVIEW ON FLOATING PHOTOVOLTAIC SOLAR FARM

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ABSTRACT

The day by day rising electricity demand, fast depleting fossil fuels, along with concerns of environmental degradation the world is leading towards commissioning solar photo voltaic (PV) plants in large scale. Solar plants installation requires intensive use of land which is a premium commodity. To conserve the land, installation of Solar PV plants on water bodies like lakes, ocean, lagoons, irrigation pond, reservoirs, waste water treatment plant, fish farm, wineries and dams can be an option. There are numerous advantages of floating type solar plants as compared to overland installations which includes, no obstacles to sunlight, convenient, effective cooling underneath leading to high power generation efficiency, energy efficiency. In addition to this, the aquatic ecosystem is profited as the shading by the PV plant prevents excessive evaporation of water, prevents algae growth which improves water quality. This paper provides details about floating PV technology, its present status & various design options.

Key words: Photovoltaic, Rectifier, Bouncy

I. INTRODUCTION

In recent years, renewable energy sources are growing rapidly all over the world. Solar energy is considered to be one of the most promising energy alter natives due to its ubiquity and sustainability. The solar energy is freely and enormously available throughout the world. The most common application for the use of solar energy is all through the photovoltaic (PV) systems. Photovoltaic (PV) modules are one of the most effective, sustainable, and eco-friendly products in the field of renewable energy. The installation of solar PV has the burden of intense land requirement which will always be a premium commodity. There are large water bodies available in various parts of the country which can reduce the saving cost of land and operating cost for power generation expenses. So the solar PV systems can become a very logical alternative for harnessing solar energy by utilizing obtainable water bodies and help to increase the economic viability of solar projects. Energy from photovoltaic's though a renewable source, maintains a low efficiency of less than 15% in its long life use. Floating solar generate more electricity than ground mount and roof top (solar)systems because of the cooling effect of water. It also reduces reservoir vaporation and algae growth by shading the water. The floating platforms are 100% recyclable, utilizing high density polyethylene which can withstand ultraviolet rays and corrosion.

II. TYPES OF SOLAR PV INSTALLATIONS

The classification of various solar PV Installations is shown in Fig. 1.

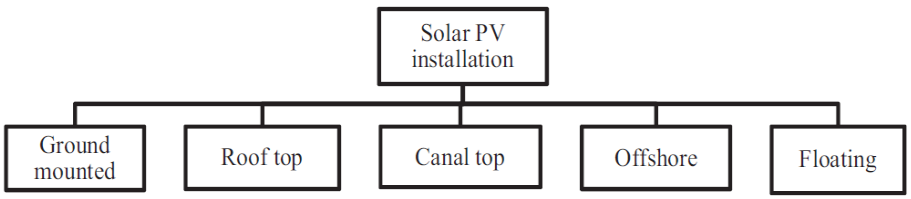

Fig.1

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Ground mounted/conventional and based solar project

Ground mounted photovoltaic systems are generally large, utility scale solar power plants. Their solar modules are held in place by racks or frames that are attached to ground based mounting supports. Ground based mountings up ports include (Fig. 2):

1) Pole mounts, which are single-minded directly into the ground or fixed in concrete.
2) Foundation mounts, such as concrete slabs or poured footings.
3) Ballasted footing mounts, such as steel bases or concrete that use weight to secure the solar module system in position and do not have need of ground penetration. This type of mounting system is well suited for sites where dig is not possible such as capped landfills and its implifies decommissioning or relocation of solar module systems.

Fig. 2. Ground mounted solar PV

Roof top solar project

A roof top photovoltaic power station, or roof top PV system (Fig. 3), is a photovoltaic system that has its electricity generating solar panels mounted on the roof top of a residential or commercial building or structure [10]. The various components of such a sys- tem include photovoltaic modules, mounting systems, cables, solar inverters and other electrical accessories. A roof top photovoltaic power station(either on-grid or off-grid) can be used in con- junction with other power sources like diesel generators, wind turbine etc. This system is capable of providing a continuous source of power. Roof top mounted systems are small compared to ground-mounted photovoltaic power stations with capacities in the mega watt range. Roof top PV systems on residential buildings typically feature a capacity of about 5–20 kW, while those mounted on commercial buildings often reach 100k W or more.

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Fig. 3. Roof top solar power PV plant

Canal top solar system

Conventionally Solar Plants are setup on ground requiring massive amount of land area. To avoid acquisition of large area of land, the new concept of setting Solar PV plant on Canal was conceived. By eliminating the use of land, not only deforestation is avoided but reforestation is encouraged through landscaping (Fig. 4).

Fig. 4. Canal top solar systems.

Off shore solar PV system

Oceans cover more than 70% of the earth's surface; they receive a great amount of solar energy. The available solar resource could be exploited to counter act the current generation of electricity using solar PV technology. Due to the land scarcity on shore, the off shore environment which takes full advantage of sun rays during the day is an ideal option for setting up PV plants(Fig. 5).

Since one of the key components in PV panels is Cadmium Chloride, which is extremely toxic and expensive, it affects both the manufacturing process and the price of solar panels. The sea water contains Magnesium Chloride, which could replace the highly toxic and expensive Cadmium Chloride.

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Fig. 5. Off shore solar systems.

Reservoir/Lake based floating solar system

The Floating PV is a new concept, with no commercial deployments being under taken and only few demonstrator projects being deployed worldwide [11]. There are many places around the world that do not have enough land for PV installations, mainly islands such as Japan, Singapore, Korea, Philippines and many others. There is already a demand for Floating PV in Japan, USA, Korea, Australia, Brazil, India and others. This demand is likely to increase and will spread all over the world. Floating solar systems can be installed in water bodies like oceans, lakes, lagoons, reservoir, irrigation ponds, waste water treatment plants, wineries, fish farms, dams and canals etc. A typical PV module converts 18% of the incident solar energy in to electricity, depending upon the type of solar cells and climatic conditions. The rest of the incident solar radiation is converted into heat, which significantly increases the temperature of the PV [12,13]. The power output of solar cells varies according to change in temperature. Due to this efficiency of the PV module depend on the temperature so if we installed solar PV systems on the water surface benefit from a significant lower ambient temperature in virtue to the cooling effect of water [7,14–16]. If aluminium frames are used for supporting the floating solar PV module, it carries out the cooler temperature from water as well, bringing down the overall temperature of the modules(Fig. 6). On an average efficiency of floating type solar panels are 11% higher compare to ground installed solar panels [17].

Fig. 6. Floating solar power plants

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III. CONCEPT OF FLOATING PV SYSTEM

It is a new idea to install solar photovoltaic system over water bodies by using floating technology. The power generation results from the combination of PV plant technology and floating technology [8]. This technology replaces the installation of photovoltaic power plants over valuable land. The floating PV plant consists of a Pontoon or separate floats, mooring system, solar panels and cables (Fig. 7). According to a research, having this effective cover up from the pontoon and the PV panels on the reservoirs resulted in reduction of water evaporation from the reservoir . Research in Australia suggests that upto 40% of open reservoir's water could be lost during evaporation [18]. The most important parameter considered for the performance evaluation of the FPV is the PV effective conversion efficiency in operative conditions, which affects the electricity generation and thus 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, according to the following expression,

$$\eta el = \frac{Pmax}{SXA_{Pv}} x100\%$$

where ηel is the electrical efficiency (%), P max is the power generated by PV module(W), S is the solar radiation intensity incident on the PV module(W/m2) and Apv is the front PV module surface exposed to the solar radiation intensity(m2).

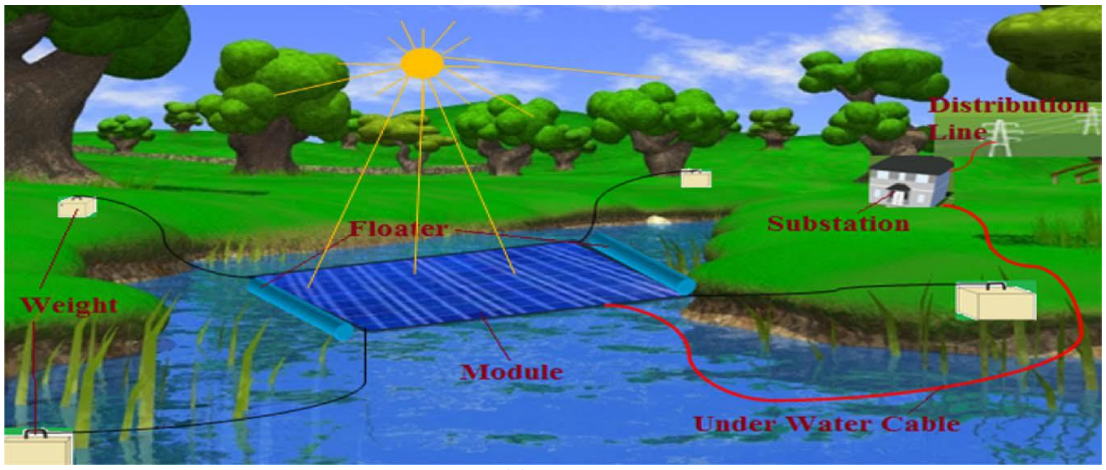

Fig. 7. Layoutof floating solarpowerplant

Components of floating PV system

- Pontoon: A pontoon is flotation device with buoyancy enough to float by itself as well as with a heavy load. The platform is design to hold suitable number of modules in series parallel combination according to the requirement and space availability [19,20]. The Fig. 8 shows the floats and the pontoon structure.

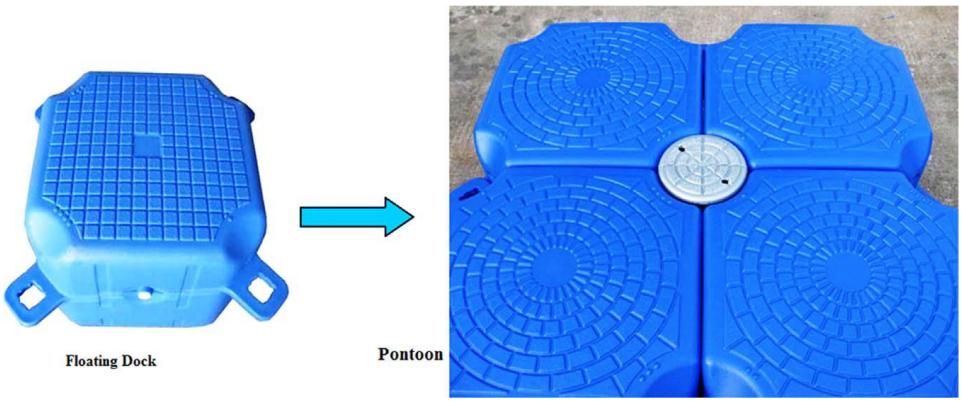

Fig. 8. Pontoon Structure.

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- Floats: Multiple plastic hollow floats with effective buoyancy to self weight ratio are combined over and over again, forming a giant pontoon. The floats are typically made of HDPE (high density poly-ethylene),known for its tensile strength, maintenance free, UV and corrosion resistance. Glass fibre reinforced plastic (GRP) canal to be used for construction of floating platform. HDPE is commonly used for the fabrication of fuel tanks, milk bottles, water pipes, and can be recycled as well.
- Mooring system: A mooring system usually refers to any permanent structure to which a container may be secured. Example includes equays, wharfs, jetties, piers, anchor buoys, and mooring buoys. In the case of a floating solar system, the mooring system keeps the panels in the same position and prevents them from turning or floating away [21]. The installation of a mooring system can be a challenge and expensive in deep water. Mooring system for floating platform can be done with nylon wire ropes lings which can be tied to bollards on bank and lashed at each corner. The Fig. 9 shows the mooring system which is used in floating power plant.

Fig. 9. Floating active cooling and concentrating design, SIT – Italy.

- Solar PV module: Till now standard crystalline solar PV modules have been used for the floating solar systems. However as more projects are installed on salty water surfaces, specifically fabricated modules will be required to resist the long term salt mist exposure. Nearly any metal will corrode over time and therefore alternatives to standard aluminium frames and mounts, such as polymer made frame is needed.
- Cables and connectors: Electricity is drawn from the solar array and transported to the land. Therefore, the power can be fed to the grid or stored in batteries. The projects commissioned so far, did not have cables pulled under water, but kept wiring above water. Even though no electrical components are under water,proper lyrated cables and waterproof IP67 junction boxes are important with floating solar projects. Other electrical components such as inverters and batteries remain 'nice and dry' on the land. High temperature resistance, water proof and robust cables are to be used to provide a long service.

Key design factors

Layout of pond/lake/reservoir

Floating cover systems require site specific planning and design to be successful. In addition, both the reservoir's walls and the different design layouts for the internal 3D geometry of the reservoir are highly incompatible. As a result, the geometry of the floating module has to be adaptable enough to suitably get used to different internal geometries of the water reservoir.

Floating structure/geometry

The floating module's geometry was designed taking into account two main issues. First, the dimensions of the module must be modified to commercial photovoltaic panels. Second, the modules must cover the maximum possible water surface to avert water evaporation [22]. The solar issues under analysis were: photovoltaic panel dimensions and tilt angle, number of units to be installed, distance between panel rows to prevent shade effects and access ways to ease operational maintenance. 3.2.3. Orientation of floating PV panel India is lying in northern hemisphere with latitude of 22° north and longitude of 77° east. The main longitudinal axes of the reservoir are to be aligned with the cardinal directions and the solar panels should face south [22]. In some cases the panels could be designed not to be oriented and so not having any particular orientation.

IV. ECONOMICAL ANALYSIS OF FLOATING SOLAR POWER PLANT

The economics of 1MW Floating solar Power plant has been worked out and the payback period is calculated. The payback period of the plant is only 5years based on calculation and plant life will be minimum 25–30 years.

$$\text{Payback period} = \frac{\text{Total cost of PV system with all auxilliary equipment}}{\text{Total annual cost saving after installation of PV system}}$$

Calculation of payback period
Total No of Module Nos.4000.
Capacity of each Module Watt 250.
Total Capacity of the Plant MW1.
Installation Cost for 1MW Unit crore 8.
Total Installation Cost crore 8.
Selling Cost per Unit Rs/kWh9.
Total Generation Hrs 1920.
Total Generation (MU) MU/per Day 0.008.
Total Generation (MU) MU/perYear1.92.
Earning Per Year Crore 1.728.
Savings after 5 years Crore 0.64.
Savings after 10 years Crore 9.28. Pay Back Period is 5 year (approx.).

V. COMMERCIAL DESIGNS OF FLOATING SOLAR SYSTEM

Photovoltaic floating rotating active cooling and concentrating solar system
The floating solar plant is constructed to float on a raft casing that is free to track the sun and takes benefit of the cooling properties of the water body. This systems installed on the water surface benefit from a significant lower ambient temperature due to the evaporative cooling effect of water. The aluminium frames certainly conduct the cooler temperature from the water as well, bringing down the over all temperature of the modules. The system can operate under all weather conditions and also withstand seismic loads. In this design, it also includes floating solar unit combined with cooling, tracking and concentrators to gain maximum solar energy. System allows exploiting basins, natural and artificial lakes to install PV plants. This system consists of a series connected floating rafts with PV panels supported by tubular frame buoyant base. The power of a single PV module ranges from 1W to 300W, depending on the type of system configuration and panel used. The modular structure allows different plant sizes and configurations: fixed installation (in order to maximize the coverage of the available area) or tracking installation (in order to maximize the energy collection).

VI. ENVIRONMENTAL IMPACTS OF FLOATING SOLAR PV PLANT

- May create an impact on ecologically protected and susceptible areas.
- Potential reduction in algae growth due to reduced sunlight diffusion and reduced photo synthesis.
- The silicon modules and High-Density Polyethylene (HDPE) thermoplastic floats; may affect the quality of water.
- Possibilities of electrical accidents owing to under water cables and have impact on existing ecosystems.
- Fishing and other transport activities in water bodies may get affected. Bio diversity of aquatic system may likely to get affected.

VII. FLOATING SOLAR DEVELOPMENT FORECAST TO 2020

Asia pacific is the largest and fastest growing market of floating solar panel followed by Europe, Japan, China and India. A new market opportunity lies in the expansion of floating panel type solar power system in densely populated countries such as China, India, Japan , USA, Korea, Australia, Brazil and others where there is shortage of land that can be used for the installation of overland solar panels. As the cost of water surface is much lower than the cost of land the demand for Floating PV is expected to increase and will spread all over the world. In addition arability of the water resources, demand and supply gap of electricity in India and china are also high in comparison to the developed countries which in turn expected to boost the market of floating solar

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technology. India has taken a challenge of installing of 100GW capacities of solar power installation and generation by the year 2022. In India, such technology can contribute to the share of the RE based generation targets and save the limited water sources availability.

VIII. CONCLUDING REMARKS

This paper highlights the concept of floating PV system installed on still water bodies such as ponds ,lakes, dams and reservoirs. It also compares the installed capacity of floating PV plants across the world. The following conclusions are drawn from the study.

1. A floating solar technology would prove to be an innovative step as it could solve the perennial problem of land.
2. As these solar panels would be floating on water, they are expected to stay cool and hence generate more power than those set up on land.
3. In India large water bodies are available in Eastern, Southern and South-eastern part of the country in states such as West Bengal, Assam, Orissa and Andhra Pradesh, Tamil Nadu and Kerala. This technology can be adopted in these states leading to considerable savings on land prices and bring down power generation expenses, thus reducing the gap between thermal and solar power.
4. Continued research on designing anchoring system for floating PV system is needed to completely fix the buoyancy system.
5. The effect of salt water on the PV structure and the module performance has to be researched.
6. Development of solar tracking system that can change the tilt and azimuth angle of floating PV system is required.
7. Most of the projects in existence in corporate rigid crystalline PV modules which are incapable of withstanding harsh water environment therefore research on flexible thin film technology for such harsh condition have to be explored.
8. Developments of large mega watt scale floating solar farms in near future may pay way for the off shore solar technology development.
9. Maximum speed of wind, water current, temperature limit, snow load, cyclone and typhoon has to be considered while designing the solar panel.
10. The efficiency of floating solar plant is 11% higher and reduces the water evaporation by 70%, however the investment of such power plant is 1.2% times higher than the conventional solar power plant.
11. Remote sensing and GIS based techniques can be used to determine the potential of floating solar PV projects.
12. Appropriate safety measures to transport the power from the water bodies to the land have to be carried out.

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