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FLOATING SOLAR PHOTOVOLTAIC SYSTEM

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ABSTRACT

India has done a notable job in terms of deployment of renewable energy-based installations, increasing to 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. India's grid-connected solar PV sector currently is majorly dominated by the ground-based installations (93%1) while the balance is contributed by rooftop based solar PV installations. The cost of installation of utility-scale solar PV in the country has declined by 84% between 2010-2018, making India world's topmost country to achieve the lowest installation cost for utility- scale solar PV. It is well known that solar PV deployment is very land intensive and scaling up the project sizes requires large portion of contiguous land parcels, which becomes challenging in many situations. In order to keep pace of development commensurate with the country's targets for solar capacity additions, alternatives are required to be established and explored. Floating solar PV (FSPV) or floatovoltaics is one such substitute, which has started getting attention globally and is expected to grow strongly over the coming years.

It is assessed that the yearly capacity addition may rise from the current installed of 1.314 GWp in 2018 to 4.6 GWp by 2022. At present, China is the leading international market followed by Japan and South Korea. India also has very bright outlooks to develop FSPV projects due to availability of large water bodies.

As a technology, Floating Solar PV is in a very nascent stage of development in India. Until 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 processes of development. FSPV market appears to crawl forward to make its presence felt in India and the taxes and 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: FSPV, Floating Solar PV, Solar Panel, Floatovoltaics.

I. INTRODUCTION

Solar power is a smooth and renewable shape of power compared to fossil fuels. With the sturdy commitments of the country wide governments round the arena closer to greenhouse gases (GHG) reduction, sun Photovoltaics (PV) is a smooth generation technique to lessen the Greenhouse Gas emissions withinside the electricity quarter. In many nations, land recourses are constrained for large scale ground-set up sun PV structures. Moreover, rooftop regions in housing, business and commercial homes won't be vital for rooftop sun solution. In this context, floating sun PV structures are the correct ecological opportunity solutions. Floating sun photovoltaics is coined as "floatovoltaics".

As in step with the International Energy Agency, the deployment of sun photovoltaic had been globally at top in 2020 withinside the attention of 90% develop in call for of renewable electricity. Photovoltaic (PV) are capable of at once convert daylight to electricity. From photovoltaic factor of view, there are 4 predominant elements influencing the output PV power yield. First comes the supply of power that is the daylight, then is the converter that is the PV cell, furthermore the quantity of time for which the Photovoltaic unit can function, and eventually the dimensions of place that this generation is auxiliary on. We do now no longer have plenty manage on daylight. In addition to that, PV converter performance is touching its most theoretical performance. And this is why researchers have now placed greater attempt into investigating tactics to reinforce the lifetime of PV and additionally searching into opportunities to add PV on or included it into any feasible floor. Since the

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performance of PV modules is low, they take big quantity of place, which may be applied for different vital requirements of human kind, consisting of meals and accommodation. The call for for meals, accommodation, and inexperienced power is growing with growth in international populace therefore, there may be a opportunity that meals and power sectors may compete or already are competing over place. This necessarily attracts the eye to some other in large part to be had floor place, the water. Simply putting any kind of PV device on pinnacle of water bodies, consisting of lakes, reservoirs, hydroelectric dams, commercial and irrigation ponds, and coastal lagoons, is referred to as floating PV (FPV) or floatovoltaics.

1.1 WORLD ENERGY SCENARIO

1.1.1 UNITED STATES OF AMERICA

The Solar Photovoltaics Supply Chain Review explores the worldwide sun photovoltaics (PV) deliver chain and possibilities for growing U.S. production ability. The evaluation concludes that, with tremendous economic help and incentives from the U.S. authorities in addition to strategic moves centered on workforce, production, human rights, and trade, America should re-set up a sturdy home sun production deliver chain and grow to be a aggressive chief in a worldwide sun industry. This should result in remarkable blessings for the weather in addition to for U.S. workers, employers, and the economy. Produced via way of means of the U.S. Department of Energy (DOE) Solar Energy Technologies Office (SETO) with help from the National Renewable Energy Laboratory (NREL) and launched on February 24, 2022, that is one in all a sequence of power quarter commercial reviews directed thru President Biden's Executive Order 14017 "America's Supply Chains." The Executive Order will assist the U.S. federal authorities to construct greater steady and various U.S. power deliver chains – facilitating more home production, an acceleration in smooth power, a variety of deliver, integrated redundancies, ok stockpiles, secure and steady virtual networks, and a international-magnificence American production base and workforce.

1.1.2 CHINA

China is a leading country in terms of highest installation capacity accounting for more than 960 MWp out of global total of 1314 MWp. The country is also home to the world's largest FSPV plant of 150 MW capacity installed at Huainan, south Anhui province. Most of the FSPV plants in China are installed at unused mining ponds.

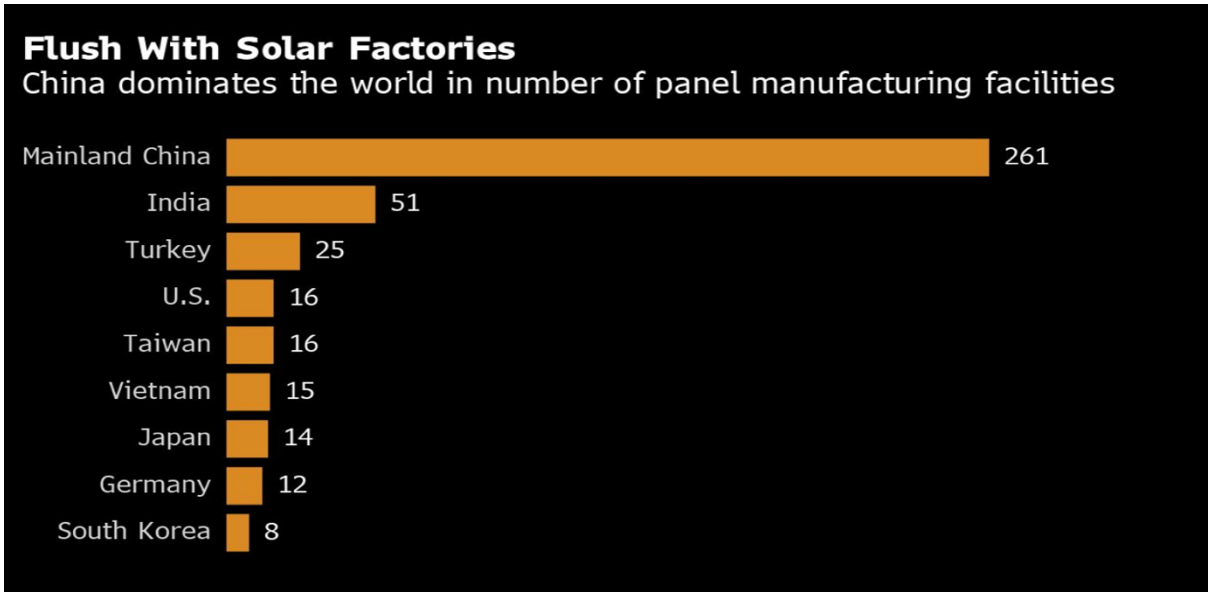

Figure 1: Solar Panel manufacturing facilities

1.1.3 INTERNATIONAL SOLAR ALLIANCE (ISA)

The release of the International Solar Alliance (ISA) became introduced via way of means of H.E. Mr. Narendra Modi, the Hon'ble Prime Minister of India and H.E. Mr. Francois Hollande, former Hon'ble President of France on thirtieth November 2015, on the twenty first consultation of United Nations Climate Change Conference of the Parties (COP-21) in Paris, France. Former UN Secretary-General Ban Ki-moon attended the release, along

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the Heads of approximately a hundred and twenty countries who affirmed their participation withinside the Alliance to commit efforts for advertising of sun power. The ISA became conceived as a joint attempt via way of means of India and France to mobilize efforts towards weather alternate thru deployment of sun power solutions. It became conceptualized at the sidelines of the twenty first Conference of Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Paris in the year 2015. With the change of its Framework Agreement in 2020, all member states of the United Nations are actually eligible to enroll in the ISA. At present, a hundred and one nations are signatories to the ISA Framework Agreement, of which eighty nations have submitted the vital contraptions of ratification to grow to be complete individuals of the ISA.

1.2 INDIAN SCENARIO

The FSPV as a technology is still in the nascent stages of development in India. The journey started with a 10kW 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 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 actually a scaled-up version of the 10kW 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 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 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. 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.

II. REVIEW OF LITERATURE

2.1 Analytical Framework and Related Literature

Integrated Renewable energy systems and renewable energy systems are used to take benefit of available renewable supply (Vishnupriyan & Manoharan, 2018). Renewable energy sources play a crucial role in the production of electrical energy (García et al., 2014), because they function to overpower dependence on non-renewable resources (Sahu & Raheman, 2020). Renewable energy sources (RE) are the best alternative available to fulfil the demand for electricity. The main sources of Renewable Energy based systems are solar Photovoltaic systems, wind power generation systems, fuel cells (FC), micro-turbines etc. Renewable Energy sources are gaining more and more attention for industrial as well as domestic applications due to their advantageous features such as reliability, availability and environmental friendliness. Solar energy is deliberated as a promising, profitable and reliable energy source. It has countless advantages such as pollution free, long life, low maintenance etc. (Gupta et al., 2016). Solar energy is the most abundant source of energy that can fulfil community requirements that come from sustainable economic development (Husain et al., 2018). The vogue of growing rapid PV energy use is associated with increased efficiency of solar cells as well as improvements in manufacturing of solar panel technology (Dondi et al., 2008). In most scenarios, desalination plants powered by non-renewable energy sources count on fossil fuel energy to power solar generators, resulting in greenhouse gas emissions and environmental pollution (Elmaadawy et al., 2020). Therefore, real power control is also an efficient way to synchorize voltage interactions in a network distribution (Safayet et al., 2017) (Rottondi et al., 2016). Also management strategies (Merei et al., 2016), for electricity efficiency (Monjezi et al., 2020), the price of installing a solar tracking system, various moving parts, motorization and maintenance costs must all accounted while considering an increase in production of power (Hasan & Dincer, 2020).

2.2 Relevance with Production Engineering

Being energy self-sufficient is a crucial national objective. In case of solar energy, this can be achieved sans sacrificing on competitiveness through appropriate strategic policies and global vision to assist smart production and creation of effective supply chain. With growing attention on green and cleaner sources of

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energy in the country, solar photovoltaic (PV) manufacturing in India is getting a stimulus with laid-back acceptance across potential users and these further leverages specific integral advantages including low cost of HR capital and prevalent penetration of smart production programs throughout industry which relaxes capital investment. Solar Energy will have a vital role to play in fulfilling India's energy security needs in the coming years. The increasing energy demands of India and the focus on clean energy has generated unique opportunities for the solar energy sector in India. India presents a massive marketplace for the growth and penetration of solar energy; Eliminates risk associated with installations which have a high operating life since the main suppliers being indigenous enforcement of obligations contractually and legally becomes more efficient and effective vis-a-vis global suppliers and specially from project lenders and investing entities point of view prevents undermining of highly potential sunshine sector in India.

III. TECHNOLOGY ANALYSIS

3.1 COMPONENTS OF FLOATING SOLAR PV SYSTEM

3.1.1 Solar Module / PV System

The essential part of the floating sun photovoltaic device is sun PV modules and much like traditional sun tasks generally, poly or monocrystalline or skinny movie sun panels are used for the set-up of the project. A single module can produce best a restrained quantity of energy; maximum installations include a couple of modules. A photovoltaic device normally consists of a panel or an array of sun modules, a sun inverter, and now and again a battery and a sun tracker and inter-connection wiring.

3.1.2 Pontoon / Floating Structure

A pontoon is defined as a flotation structure which has enough buoyancy to float on water and support a heavy load. The structure is designed such that it can hold a 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.

3.1.3 Mooring system:

A mooring refers to an everlasting shape to which a floating shape may be secured. A floating shape is secured to a mooring to stop unfastened motion of the floating shape at the water. An anchor mooring fixes a floating shape's role relative to some extent on the lowest of a waterway, without connecting the floating shape to shore. Since FSPV flowers are established on water bodies, any versions in water degrees caused with the aid of using monsoon, wind pace or increase/lower in water amount can be intricate for the flowers. To keep away from this situation, FSPV flowers are anchored via mooring systems. It has the cap potential to modify to water stage fluctuations whilst retaining its role with inside the southward direction. The placement of a mooring device ought to do not forget the location, bathymetric, soil conditions, and water-stage versions.

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.

3.1.5 INVERTERS

Similar to a traditional 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.

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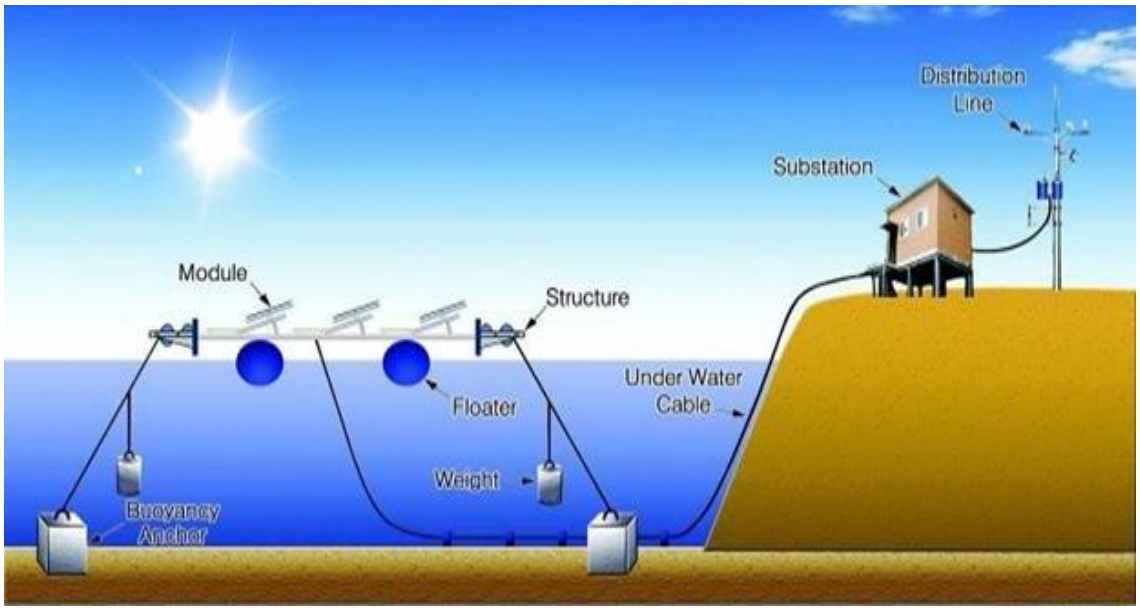

Figure 2: Layout of a typical floating PV system

3.2 TECHNOLOGY 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/m^2)

A_{pv} is the area of PV module on that solar radiance fall on the surface (m^2)

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.

3.4 Technical Design Parameters

- **Energy demand**

First, calculate the total energy demand per day (kWh/day). This calculation is done by multiplying each electrical equipment power by time required to operate and number of items.

$$\mathbf{E = P \times n \times t\ (kWh/day)}$$

Where,

E is energy demand,

P is power in watt (W) of each electrical device,

n is No. of items,

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t is time required to operate in hours (h).

- **Weather forecasting**

After energy calculation, the weather data like monthly and daily average insulation, minimum and maximum daily average temperature, monthly or daily average wind speed, has been observed from the NASA website or other solar simulation software by implanting the latitude and longitude of the installation site of about 10 to 20 years' span.

- **Cell temperature of Floating PV system from weather data**

The sea temperature, sea wind speed, PV cell temperature on land, PV cell temperature in the sea were determined by the following equations.

$$T_w = 5.0 + 0.75T_a$$

Where T_w = sea temperature (°C) and Ta = air temperature (°C).

$$V_{wsea} = 1.62 + 1.17 \times V_{wland}$$

Where V_{wsea} is sea wind speed, V_{wland} is land wind speed m/s.

$$T_c = 0.943 \times T_a + 0.0195 \times G - 1.528 \times V_{wland} + 0.3529$$

Where T_c is PV cell temperature on land G is global solar radiation at STP which 1000 W/m2.

$$T_{cw} = 0.943 \times T_w + 0.0195 * G - 1.528 \times V_{wsea} + 0.3529$$

Where T_{cw} is PV cell temperature in the sea.

- **De-rated Daily Output Energy of Offshore Floating PV Array**

$$E_{PV} = W_p\,(f_{dc/ac})(G/G_{STC})[1 + \beta(T_c - T_{STC})]$$

Where,

E_{PV} is energy output from PV,

W_p is power output at STP,

$f_{dc/ac}$ is DC to AC de-rating factor,

G is incident solar radiation,

G_{STC} is solar radiation at STP,

β is power temperature coefficient %/°C.

- **Size of PV Array**

$$W_p = \frac{E_L}{\left(\frac{G}{G_{STC}}\right)(f_{dc/ac})(f_{temp})}$$

Where, $f_{temp} = 1+\beta(T_C - T_{STC}) = 1+\beta(T_{Cw} - T_{STC})$.

No. of modules in parallel N_{mp}

$$N_{mp} = \frac{W_p}{\text{peak power of each module}}$$

No. of modules in series N_{ms}

$$N_{ms} = \frac{\text{System DC voltage}}{\text{module voltage}}$$

- **Size of Inverter**

In the first step the size of the Inverter is determine by the real power drawn from all appliance run at a same time. In second to start the heavy motors must consider the inrush current and compensate the power by multiplying the power by a factor by 3 otherwise we use 1.25 standard safety factor.

$$P_{inv} = P_a \times 1.25$$

Where P_{inv} is rated power of inverter, Pa is running power of the appliance.

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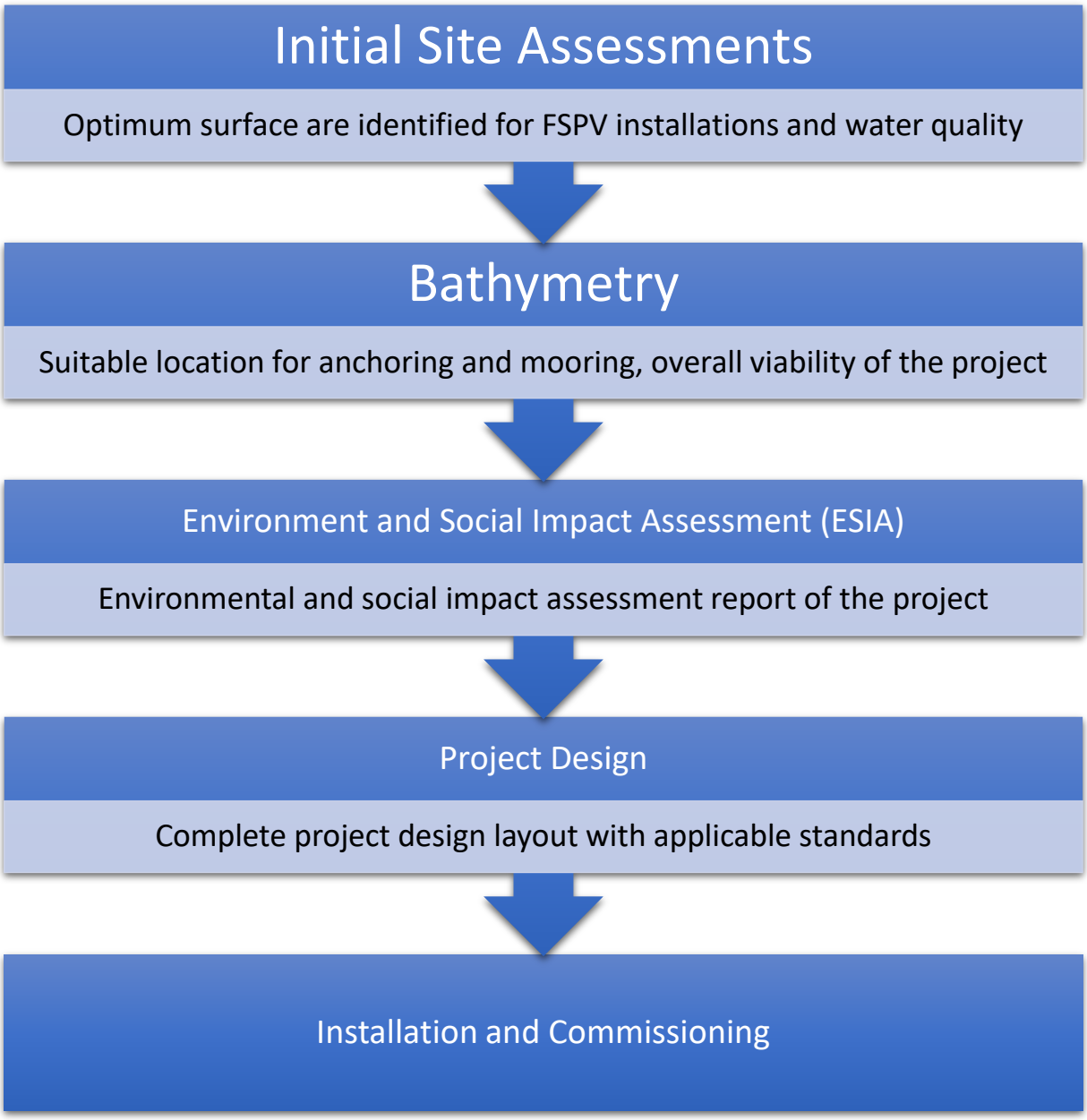
IV. PROJECT GUIDELINES

Floating Solar Photovoltaic system as a technology is still in the evolving phase and involves several crucial elements including phases for establishing SPV plants that are not available publicly. Therefore, coming up with the most suitable practice guidelines and methods for the FSPC sector would undoubtedly be a great help to the project developers, investors and the policymakers in getting the idea and understanding the steps involved in the FSPV project development. In addition to this, FSPV plants are deployed in waterbodies and often subjected to harsh environments. Hence it is important to consider relevant standards to ensure the quality of the FSPV plant components while being attentive of not depreciate the quality of water as well as local bio-diversity. In a nutshell, major steps in developing an FSPV project can be understood through the flow chart of floating solar PV design as shown below:



V. CASE STUDIES

5.1 Banasurasagr Reservoir, Wayanadu, Kerala.

The floating solar power plant, was commissioned and inaugurated on 4th December 2017. The project will generate about 700,000 kWh per year which will be fed directly to the grid. Previous studies have proved that

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floating solar panels generate higher output due to lower ambient temperature existing on the surface of the waterbody. Apart from this evaporation of water from the reservoir will be minimal as the surface is covered by solar panels.

- Location : Wayanad
- Latitude : 11.67° N
- Longitude : 75.96° E
- Altitude : 2423

Figure 3: Satellite view of Banasurasagr Reservoir

System Details

The 500 kWp Grid Interactive Floating Solar Power Plant in the Banasura Sagar dam, Wayanad is the first of its kind in India. The project is designed for Kerala State Electricity Board (KSEB) and the solar photovoltaic array is installed on 18 floating platforms made of Ferro cement floaters with hollow insides which are able to adapt to varying reservoir water levels by means of an innovative anchoring system. Floating solar farm floats on 6,000 square metres of water surface of the reservoir.

Upkeep and Maintenance

Dust and bird droppings were noticed in approximately all parts of the PV array. Frequent cleaning provisions are required to ensure that the array is clean and thereby ensuring maximum energy yield.

Earthing

Water Earthing: Supports are provided around the floating platforms to which the earthing plate is attached. The earthing plate is placed in that portion of the floating platforms which is submerged in water.

Armor Earthing: During occurrence of earth faults, the metallic sheaths are expected to carry a substantial proportion of the total fault current. For safety and reliable operation, the shields and metallic sheaths of power cables must be grounded. Armour earthing is done at the site which is good for the system safety.

VI. CONCLUSION

Solar energy is the most abundant source of clean energy over most parts of India. Utilizing FSPV systems, this energy can be harnessed on areas that have no competitive purpose and is often closer to areas of consumption compared to traditional power plants. In contrast to land mounted photovoltaic systems, the advantages of FPV power plants are less evaporation of water, greater efficiency and a reduction the emissions of CO2 greenhouse gas, which leads to the expanding of these systems in many countries. In countries with semi-arid and arid locations, water crisis is a huge problem and the use of FPV modules to reduce the evaporation rate of water is the right choice. In general, the sun in these countries is less expensive. Floating PV plant design includes all

aspects, even mechanical and electrical functions. In this case, this work describes the various possible configurations of the Floating PV 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. Given the spatial spread of the lakes, PV-EV-based charging stations can be established, reducing the payback period of the plants, enhancing accessibility for electric vehicle users in urban areas and encouraging start-ups, including addressing mobility issues using micro-mobility vehicles.

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