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A Comprehensive Review of Floating Photovoltaic Technology (FPVT) and Its Applications to Improved Efficiency.

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Abstract— The development of floating solar technology (FPV) is driven by decarbonization ambitions, the shortage of usable land, efficiency loss at high working cell temperatures, and the need for energy security. In 2024, the growth rate of this technology is expected to surpass 31% because of a combination of government efforts and scientific developments. Global energy consumption is increasing due to population growth and technological progress. Because of the abundance of sunshine, there is an unparalleled need for solar energy to power electrical systems.

Land use limitations and growing land costs are obstacles in the way of solar energy's progress towards net-zero emissions. A solution to this problem is floating photovoltaics (FPV), which are becoming more and more popular around the globe. Numerous approaches to solar energy harvesting have been developed by researchers; however, a major disadvantage of these approaches is their poor efficiency, which may be affected by types of cells, orientation, panel temperature, and intensity of irradiance.

The current state of floating photovoltaic technology (FPVT) and its various designs are examined in this paper. It looks at research that has been published and cutting-edge developments, offering insights into the possible advantages and challenges of incorporating FPVT into renewable energy portfolios. It also makes recommendations for future research paths that might further improve FPVT's integration into the global renewable energy market.

Index Terms— Floating photovoltaic technology (FPVT), Types of Solar PV Systems, Components of FPV Systems, FPV Design Factors, Future aspects of FPVT

1 INTRODUCTION

Energy transition, which arose to transform the energy industry, has made it possible for power plants to migrate significantly from carbon-based to renewable sources in the upcoming decades. The primary objective of this pathway is to reduce carbon emissions, which will be accomplished by significant changes in the energy sector's research, policies, market, and technology. The need for energy around the world is always growing. Between 2015 and 2040, an estimated 28% growth is expected [1]. These days, the main source of this increase is fossil fuels, such as coal, gas, and oil, all of which are finite and have well-known detrimental effects on the environment. It is therefore necessary to develop more sustainable and alternate sources of electricity production. The obvious answer is renewable energy.

Globally, the use of renewable energy sources has increased dramatically in recent years. Because it is so widely available and sustainable, solar energy is one of the most promising energy sources. All around the world, solar energy is abundant and easily accessible. Photovoltaic (PV) systems are the most widely used application of solar energy.

In the world of renewable energy, photovoltaic (PV) modules are among the most efficient, long-lasting, and environmentally benign goods. The floating photovoltaic (FPV) system, which has better efficiency and can also lessen the evaporation of water reservoirs, is one of the promising uses of PV modules. In response to its enormous potential for producing electricity, adopting renewable energy technologies in floating and offshore environments is expanding quickly. These systems, including floating photovoltaic, floating solar chimney, and wind offshore, have garnered much interest.

Considering the circumstances, FPV is a viable alternative to lessen the difficulties because it will make use of vacant spaces, preventing conflicts with activities such as tourism or agriculture. For nations with high population densities, where land scarcity will drive up land acquisition costs and hurt the profitability of ground-mounted solar projects, fixed-point solar (FPV) offers an alluring alternative. Therefore, we will be able to transform underutilized surfaces into lucrative and valuable commercial solar projects because of FPV. Furthermore, the addition of FPV will boost the plant's efficiency because of the natural cooling impact that comes from being near water and the fact that water reflectivity raises the PV array's irradiance. all working together to boost production (versus land-based plants). It is predicted in the literature that the efficiency gain over land-based solar PV modules will be greater than 10% [2].

To evaluate the performance of the FPV, the most important parameter considered is the PV effective conversion efficiency under operational conditions. This factor affects energy generation and, in turn, the component's most valued product. The relationship between the amount of electrical power generated and the intensity of incident solar radiation gives the conversion efficiency of a photovoltaic module. The following expression:

$$\boldsymbol{\eta = \frac{Pmax}{SXApv} X100}\%$$

2 Types of solar PV installations

The categories of various solar photovoltaic setups are illustrated in the figure below, which is based on the location and use of the system:

Figure 1. shows the classification of solar photovoltaic setup installations.

The technological and environmental advantages of floating photovoltaic (FPV) plants over ground-mounted PVs are considerable. They use less water, are more efficient, and may be used in deteriorated conditions. Notwithstanding, the absence of governmental rules and apprehensions about enduring dependability may impede their sustainable development and curtail their proliferation in varied energy sources.

Ground-mounted, rooftop, canal, floating, and offshore solar photovoltaic (PV) systems all provide different benefits and difficulties. Ground-mounted systems provide challenges related to land use and regulations, but they also provide room for large-scale installations and simple maintenance access. Although they reduce the amount of land used, rooftop installations have space, orientation, and structural constraints. Canal systems are the most efficient way to utilize land water, but they need precise engineering and permission from the government. Though they present technical difficulties and environmental issues, floating photovoltaic plants capture underutilized water bodies. Although offshore PV projects offer large-scale deployment, they also come with greater prices, more difficult maintenance, and more complicated regulations. Solving these issues is critical for sustainable energy development as solar energy is a key component of the worldwide shift to renewable energy sources. Unlocking the full potential of solar energy requires combining legislative support, technology improvements, and stakeholder participation [3].

3 Floating PV system concept

Strong mounting solutions are typically used to install solar PV modules on roofs and above ground. The use of solar panels on water bodies such as canals, lakes, reservoirs, and seas has attracted interest owing to considerations such as limited land availability, high population density, and the significant risk presented by deforestation.

FPV plants, also known as floating photovoltaic plants, utilize suitable technology to support photovoltaic panels over water bodies. The power generation capacity of PV panels primarily relies on two factors: the temperature of the panels and the intensity of solar radiation they receive. Water may effectively lower the temperature of panels placed above it; however, the impact of shadows on FPV systems is negligible or nonexistent. FPV panels have about 11.0% higher efficiency compared to ground- and roof-mounted PV panels [4].

It is a novel concept to construct photovoltaic solar systems on bodies of water using aquatic technology. This concept combines floating photovoltaic technology with several other PV system technologies to generate electricity. On valuable sites, photovoltaic plants have been supplanted by this technology. The floating photovoltaic system is made up of an independent float structure, also known as an oath, a morning structure, solar PV modules, and wires.

One novel solution to the problem of limited land is the floating photovoltaic (FPV) solar power plant. The components of FPVA include cables, inverters, transmitters, floating structures, mooring, anchoring, and solar panels, also known as PV modules. The figure below illustrates that an average FPV module consists of a PV module, a supporting system, and a floating system. Strong winds and uneven surfaces are two important elements that pose a risk to stiff PV panels in this type of installation.

The ability of photovoltaics to effectively convert into operating circumstances is the most crucial characteristic for measuring FPV performance. This ability affects energy output and is, therefore, the most valued device of this module. The link between the photovoltaic module's power conversion and total solar radiation is determined by the intensity of energy generation.

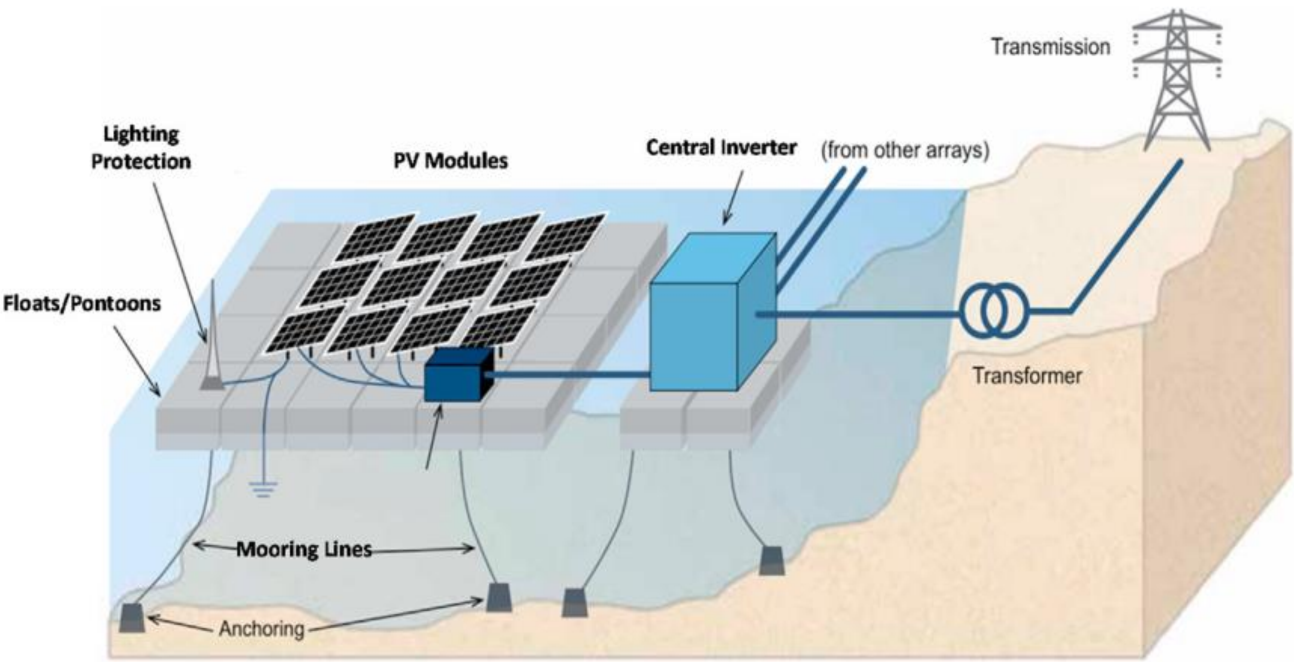

Figure 2. Schematic view of a typical FPV system and its main components (Sahu et al., 2016).

An example of a solar energy system that is installed using water bodies is the floating photovoltaic (FPV) system. The components of this system include solar panels installed on floating platforms composed of HDPE, anchor systems to keep the platforms stable, electrical components such as combiner boxes and inverters, and cables and cabling to carry the power. Personnel and watercraft safety is guaranteed by safety measures like buoys and fences, and remote monitoring and control systems allow for the observation of system operation. Land preservation, less water evaporation, and possible cooperation with hydroelectric plants are some of the advantages of this approach. [5].

4 Factors Influencing Floating Pv Technology Performance

Many factors can affect the performance of floating photovoltaic (FPV) technology, including:

Environmental factors: These comprise temperature, humidity, dust, shade, and intensity of solar radiation.

Module temperature: The efficiency, power output, and performance of FPV modules can all be adversely affected by high temperatures.

Module orientation: The module's tilt angle may have an impact on how well it functions. For instance, FPV works best at tilt angles less than 45°, yet NOCT PV's solar PV cell temperature is lower than FPV's at tilt angles more than 55°.

Wind speed: The efficiency of photovoltaic systems can be impacted by wind speed.

PV panel spacing: The performance of FPV plants can be greatly impacted by the mutual shading of PV panels.

The performance of FPV technology can also be impacted by other aspects including location, plant layout, system design, equipment quality, and operations and maintenance.

the caption.

5 Benefits and Challenges of FPVT

The major factors for the development and explosive expansion of floating solar are the high demands on rooftop space and land resources, the incompatibility of floating solar with other industries like tourism and agriculture, and the efficiency loss at high operating cell temperatures. More benefits for the traditional uses of PV systems have been discovered as research on floating solar grows, which makes the use more appealing. Numerous benefits of technology have been highlighted:

- ✓ When comparing floating type solar photovoltaic panels to conservative solar panels, there are several advantages, such as accessibility and increased energy productivity. The reason behind the better power generation efficiency of floating type solar photovoltaic panels over overland installed solar panels is that the temperature beneath the panels is lower.
- ✓ Lower water temperatures have a favorable impact on the performance of floating solar PV due to the following reasons: reduced sunlight penetration, natural reflectivity of the water surface, reduced algae growth, and a shading effect.
- ✓ Lower water evaporation and preserve water by cooling down the water and minimizing the amount of the water exposed to air. Floating solar panels can cut water evaporation by as much as 33% in natural lakes and ponds and roughly 50% in man-made environments.
- ✓ Because floating solar employs the same widely available solar panels, it is more affordable than single axis tracking solar systems installed on roofs and on the ground.
- ✓ In many nations, federal subsidies, grants, and incentive programs are available for floating solar systems, just like for land-based solar installations.
- ✓ Simple installation process, as typical since the floatation structures are assembled without heavy equipment and the at location.

6 Challenges/Issues

The most difficult aspect of installing a floating solar project is the system design, which must be suitable for staying afloat and withstand force. During the installation of the floating solar power plant, the following issues will be addressed:

- ✓ Solar modules may be affected by high moisture levels as they are surrounded by water for optimal system functioning.
- ✓ Corrosion and unfavorable environmental conditions may have an impact on the floating structure's strength.
- ✓ It is important for the Floating system to be able to handle environmental elements including temperature changes, current in the water, evaporation, oxygen, growth of fish and algae, and other living things.
- ✓ Waves, strong winds, cyclones, floods, and other natural disasters can cause swift or unpredictable movement in floating solar systems. These natural factors must not be able to affect the floating PV system.
- ✓ Two significant obstacles to the growth of the floating solar panel market are the high initial installation and maintenance costs.
- ✓ In the early years of its development, the cost of generating power from solar panels was approximately ten times higher than that of alternative fossil fuel-based methods.
- ✓ The performance of the floating solar panel system in generating power is also impacted by the high wind speed in the sea.

- ✓ Early planning stages should involve public participation and involvement from pertinent organizations to guarantee public approval.
- ✓ Floating structures are subject to corrosion, primarily because of float degradation brought on by UV radiation.

7 Conclusion

The widespread adoption of FPV technology could pave the way for new developments in renewable energy and present advantages for various geographical areas and consumer segments. The installed PV systems across the globe might have doubled capacity using FPV technology, which does not require land, unlike ground-mounted PV systems. Because floating solar technology has the potential to address the enduring land issue, it would prove to be a groundbreaking development. We anticipate that these floating solar panels will maintain their coolness and generate more electricity compared to their land-based counterparts. We need to research to understand saltwater's impact on the PV structure and module performance.

The superior performance of FPV power plants, including increased efficiency, less water evaporation, and decreased CO2 emissions, has resulted in their widespread use in several countries. In nations with dry and somewhat dry areas, where there is a significant issue about water scarcity, using FPV modules to decrease the pace of water evaporation is a suitable decision. Typically, the solar radiation in these countries is significantly more advantageous [6].

When it comes to maximizing profits, minimizing negative environmental effects, cutting costs, improving water quality, reducing water evaporation, and making better use of existing gearbox assets, the advantages of FPV technology can make it an appealing option for investors, private companies, policymakers, and stakeholders. In this scenario, market deployment of FPV technology entails increasing global familiarity with the technology. Incoming data show an upward trend in the economy of FPV plants, which is expected to be fully cost-competitive with peer technologies by 2050, even though their total costs are still greater than those of ground-based PVs using present technology. This trend could be hastened by further study into the utilization of semitransparent and flexible thin-film PV modules, as well as their adaptability to hydropower and endurance.

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