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A Review on Floating Photovoltaic Technology (FPVT)

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ABSTRACT: A novel energy production system which has fascinated a wide consideration because of its several benefits that are called floating photovoltaic technology (FPVT). The FPVT system that helps to minimize the evaporation of water as well as an increase in energy production. For the research purposes, both electrical and mechanical structure requires studying of these systems for the development of FPVT power plants. From different points of views, numerous researches have been directed on FPVT systems that have evaluated these systems. The present research article give a logical investigation and up to date review that shows the different features and components of FPVT systems as an energy production system is offered. This articles reviewing the FPVT that gets the attention of the scientists who have the investigational stage and involuntary inspection of FPVT systems in addition to influence of implementing these systems on the water surface. Also, a comprehensive comparison has been constructed that shows the cons and pros of various types of solar systems that could be installed in various locations. In this review, it has been found that solar energy on the roof of a dwelling house generally has a power of 5 to 20 kW, while the inhabitants of commercial buildings generally have a power of 100 kW or more. The average power capacity of a floating solar panel is 11% more of the average capacity of a solar panel installed on the ground. Studies show that 40% of the water in open reservoirs is lost through evaporation. By covering only 30% of the water surface, evaporation can be reduced by 49%. The global solar panel market exceeds 100 GW and the capacity of 104 GW will bring the annual growth rate to 6%. 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 predicted by this review that in 2025 the Solar technology including the FPVT system will increase by 7.38% that is 485.4 GW more of today installed power worldwide.

Key words: Floating photovoltaic technology (FPVT), Types of Solar PV Systems, Components of FPV System, FPV Design Factors, Future aspect of FPVT

Nomenclature

FPV: Floating Photovoltaic
FPVT: Floating Photovoltaic Technology
PV: Photovoltaic

1. Introduction

All over the world, the significances of rising the use of energy requirement as well as the diminution of fossil-fuels, growing the global warming, and emission of greenhouse gases, require the progress and dispersion of energy sources that are renewable[1)], that are decent adoptions for providing the fulfillment the demand of energy the solar photovoltaic systems get attention[2)]. Solar energy has furthermost appropriate energy sources currently that is utilized in a diversity of techniques and has the capacity to be a substitute source of power as compare to conformist resources of energy[3)]. Solar photovoltaic (PV) energy system is the utmost familiar application, that converts the light energy to produce power[4)]. The favorable utilization of the PV system is a floating photovoltaic (FPV) system, which has high productivity and it can minimize water evaporation, this technology growing rapidly[5-10)]. The first installation of the 20 kW FPV system reported in Aichi, Japan that constructed for research investigation. Trapani and Santafé[11)] investigate the floating PV developments mounted from the years 2007 to the year 2013, for example, considerable high capacity setups with the installed size of 175 kW executed in California in 2008 and a 24 kW floating PV model mounted in Spain with the goal of minimizing the loss of water as evaporation, in 2015. Ueda et al. construct the research for investigating the cooling effect and power output of FPV modules[12)]. Recently 40 MW floating photovoltaic (FPV) system have been mounted in China[13)] and apparently in the impending, the floating PV installation capacity increased rapidly. To install FPV power plant around

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25% of the world power need (in 2014) can be provided by using just 1% of natural basins areas[14]. The FPV power plants installation has initiated in many countries like Japan start building the world's largest power plant[15]. To install the FPV power system and expand power production, numerous research has been carried on. Ferrer-Gisbert et al.[16] evaluated the process of novel floating PV power setup in the field of the farming basin containing polythene floating PV panels, that have established by a Company named CELEMIN Energy and the UPV University in 2013. The important parts of the FPV power systems are along with the mooring system, separate floats structure, PV panels, electrical cables, and connections used in underwater, and power solar inverters[16]. Furthermore, Sacramento et al.[17] inspected the cooling effect of FPV panels on various water storage structures in Brazil of the area where's rainfall is moderate all over the year and related to the effectiveness of the floating PV power systems as compared to the productivity of solar PV system that mounted on the ground surface. Sahu et al.[18] furthermore to studying the connected floating PV power systems and deliberating the local structured assembly and mechanisms of the current system, explore the benefits and drawbacks of these systems, in 2016. The most significant aspect in calculating the size of FPV systems is to demonstrate the electrical network between solar panels, which shows an imperative part in partial shading conditions (PSC). Various researchers have anticipated for numerous inter-connection of PV arrangements used in FPV panels. Villa et al.[19] conferred the comprehensive research on existing PV panels inter-connection arrangements appropriate for situations in shadow condition and some connection laws for panels arrangement. Ko et al.[20] examined the photovoltaic system working beneath the PSC condition and measured the effect of PV electrical and thermal properties by put on the broken diode used as a bypass in PV modules. Satpathy et al.[21] studied the benefits of individual traditional inter-connection categories and by investigational experiments, designated to the highly favorable. Tofoli et al.[22] categories the best practical boost converter with common ground circuit arrangements and designated the qualities and disadvantages of the current structures. Azidehak et al.[23] examined the working and regulation of the power converters that deliver the PV combination and arrangements. Anurag et al.[24] construct a transformerless solar PV system that can able to connect with the grid, with a DC to DC converter for grid combined with the persistence of maintaining the productivity in the voltage of the grid. The research paper correspondingly delivers its strategy, present situation, and an impression of the FPV technology. Kim et al.[25] studied current technology on floating PV power systems of various mounted floating PV systems in South Korea from 2009 to 2014. Cazzaniga et al.[26] examined the various floating PV power setup installed on the surface of the water and the pontoon system in 2018. Additionally, various floating PV system projects have been planned to enhance the productivity of this system. This system exploiting functions such as cooling, concentrating, and tracking have precisely been deliberated and the outcomes have designated an important influence of cooling and tracking on the system competence. In recent years, renewable energies have grown rapidly worldwide. Due to its power and duration, solar energy is considered the most interesting substitute source of energy. Solar energy is available for free worldwide[27]. Through a photovoltaic (PV) system is the most common utilization of sunlight energy. The most sustainable, efficient, and environmentally responsive system in the field of renewable energy is a Photovoltaic (PV) system[28-33]. The mounting of photovoltaic solar panels will bring a lot of lands, which will always be a quality product. Different countries have distinct reservoirs, which can reduce land savings and power generation costs[34]. Therefore, the purchase of a photovoltaic solar system can be a very reasonable choice for utilizing solar energy by the water resources and helps improve the economic stability of solar projects. Although the energy obtained from photovoltaics is renewable energy, long-term use can maintain the efficiency of less than 15[35]. The cooling effect of water generates more electricity than floating solar supports and roofing systems. It also reduces the evaporation and growth of algae in shaded tanks. The floating platform can be recycled 100 times using high-density polyethylene that resists ultraviolet rays and corrosion.

2. Why Floating PV is rising?

In some countries where deficiency of land usage, the prevalence of using solar panel systems to generate electricity has been hampered by a lack of space and space limitations on the roof. Local PV companies are constantly competing for land, including agriculture, industry, and population growth. These companies have recently discovered innovative alternatives. The installation of floating panels on lakes, dams, reservoirs, and the sea. Floating solar technology is very advantageous for countries with weak land electrical networks.

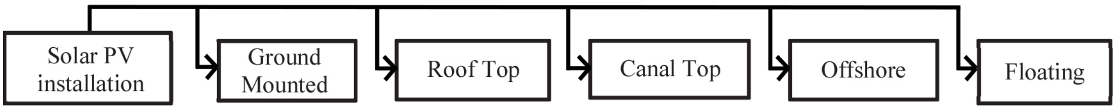

Fig. 1. Classification of solar[18)]

Governments and investors are beginning to recognize these benefits and are drawing attention to a wide range of countries in Africa, Asia, and Latin America. In particular, Japan should supervise floating solar panels due to the low availability of land associated with limited natural resources. Japan has 73 of the 100 largest floating solar power plants in the world. The largest FPV Plant is at the Yamakura dam. This unique installation can supply more than 5,000 homes. The project also saves more than 8,000 tonnes of CO_2 per year. Nearly half of the floating solar power plants in Japan are located in a state called Hyogo Region. This is likely because there are more than 40,000 agricultural reservoirs in the state and there is enough space to install floating panels. Installed in lakes, reservoirs, and dams, floating solar panels save precious space on the ground. In addition, it is 16% more efficient than onshore solar power plants. This is because of the cooling effect of the system provided by the water under the panel. The fact that this results in very significant savings is that these systems are easier to connect to the grid than remote wind farms. The system occupies most of the water area in which it is installed. In other words, the water evaporates very low due to less exposure to direct sunlight and wind. This saves significant freshwater in agricultural areas. It also slows the growth of algae, which is harmful to fish species[36)].

2.1 Types of Solar photovoltaic setups

The solar photovoltaic system is classified according to its use and location, so, the categories of various solar photovoltaic setups are shown in Fig. 1. Table 1 shows the comparison between recompenses and shortcomings of several PV systems.

2.1.1 Conventional land based and ground mounted solar setups

For the installation, ground-mounted photovoltaic systems are usually highly efficient solar systems. The solar modules are placed in frames or a rack position fixed setup to the auxiliary equipment on the ground and field assistants include: (Fig. 2):

- A pole holder fixed with concrete in the ground.
- Foundation substrates, such as cast stabilities or concrete slabs.

Fig. 2. Ground mounted solar PV[51)]

Fig. 3. Roof top solar power PV plant[52)]

- Ballast accessory holders, such as bases with steel-reinforced concrete, use heavy objects to protect the solar photovoltaic modules in place and require no grounding. This cultivation system is suitable for places that cannot be excavated, such as closed soils and soils, and it is easy to dismantle or move the solar module system.

2.1.2 Roof top solar project

A photovoltaic system on the roof (Fig. 3) is a solar photovoltaic system in which solar modules are mounted on the rooftop of a housing or profitable construction or structure[37)]. The parts comprise of solar inverters, photovoltaic modules, mounting systems, cables, and other electrical components. Rooftop PV systems either on-grid or off-grid can be utilized in combination with additional energy sources (such as wind turbines, diesel generators, etc.). The setup can provide constant power. The roof system is smaller than the ground-mounted photovoltaic systems in the megawatt range. Photovoltaic systems on the roofs of housing constructions generally have a power of between 5 and 20 kW, while occupants of profitable constructions generally reach 100 kW or more.

Fig. 4. Canal top solar systems[53)]

Fig. 5. Offshore solar systems[54)]

2.1.3 Canal top solar system

Traditionally, solar power plants are planted on the ground, which requires a large area. To avoid obtaining huge tracts of land, the idea of installing photovoltaic plants on the canal is considered new. Not only was deforestation avoided by eliminating land use, but deforestation by beautifying the environment was also encouraged (Fig. 4).

2.1.4 Offshore solar PV system

More than 70% of the earth's surface covers the ocean and other water bodies. They received a lot of solar energy. Using solar photovoltaic technology, existing solar energy resources can be used to compete with current electricity production. Due to the scarcity of land, the beach is a beach environment that can take maximum benefit of the sunlight throughout the day time and is an excellent choice for planting photovoltaic systems (Fig. 5). Cadmium Chloride is the main constituent of photovoltaic solar cells that is very poisonous and costly, so it will influence the production progression and the cost of solar cells. Saltwater comprises magnesium chloride, that can substitute extremely poisonous and expensive cadmium chloride.

2.1.5 Reservoir/Lake based floating solar system

Floating photovoltaic power generation system is a novel idea, not commercially implemented, and only a limited number of demonstration projects have been implemented worldwide[38)] There are sufficient photovoltaic power generation devices in many parts of the world. world. There is not enough land, mainly in Japan, Singapore, South Korea, the Philippines, and many other islands. Japan, the United States, South Korea, Australia, Brazil, India, and other countries have started to request floating photovoltaics. This demand could expand and extend all around the world. Floating photovoltaic solar systems can be mounted on an aquatic surface such as oceans, lakes, ponds, reservoirs, irrigation ponds, wastewater treatment plants, dams, and canals. Depending on the type of solar cell and the weather conditions, electricity is used. The remaining solar radiation is transformed into heat, which increases the photovoltaic temperature[39,40)]. The output power of solar cell changes with changes in temperature. Since the ease of use of the photovoltaic modules depends on the temperature, if a solar photovoltaic system is installed on the surface of the water because of the cooling effect from the water[33,41-43)], the ambient temperature below this sign cannot be recognized. If an aluminum frame is used to support the external photovoltaic solar module, the cooling temperature of the water will also increase, thus reducing the allover heat of the PV module (Fig. 6). The normal capacity of the solar module is 11% more than the average capacity of solar modules placed on the ground[44)].

Fig. 6. Floating solar power plants[55)]

3. Floating PV system concept

The use of aquatic technology to install photovoltaic solar systems on water bodies is a new idea. The miscellany of PV system technology and floating PV technology[34)] that can generate electricity combined. This technology has replaced photovoltaic plants in precious location. The floating photovoltaic system contains an independent float structure or oat, a morning structure, solar PV modules, and cables (Fig. 7). As studied, the use of floating bridges and photovoltaic panels to effectively cover the tank has reduced the water vapor in the

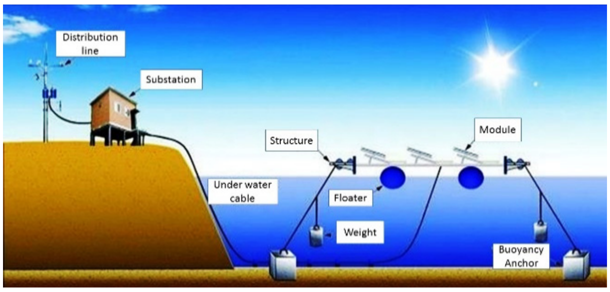

Fig. 7. Floating solar power plant layout[44)]

tank. Studies in Australia have shown that 40% of the water in the open tank is lost during evaporation[45)].

The most important parameter for evaluating FPV performance is the ability of photovoltaics to convert effectively into operating conditions, which influences energy production and is, therefore, the highest valued device of this module. The power conversion of the photovoltaic module is given by the relationship between the intensity of the energy generation and the total solar radiation. As per the next expression,

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

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

3.1 Floating PV system components

3.1.1 Pontoon

A pontoon is an automatic structure that can automatically load a large amount of buoyancy. This series is designed with an appropriate quantity of PV modules in combination with parallel based on the requirements of the platform and available space[46,47)]. Fig. 8 and Fig. 10 show the structure of floats and Pontoon.

3.1.2 Structure

Add weight-effective plastic recesses several times to form a larger pontoon. Floats are generally made of HDPE (high-density polythene), which is identified for its precise, non-renewable strength, UV resistance and, corrosion resistance. GRP (Glass fiber reinforced plastic) can also be used to create float platforms. HDPE is typically used to fuel tanks production, bottles and, pipes for water supply and can also be reprocessed.

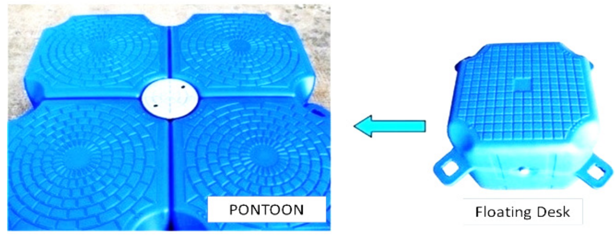

Fig. 8. Pontoon Structure[18)]

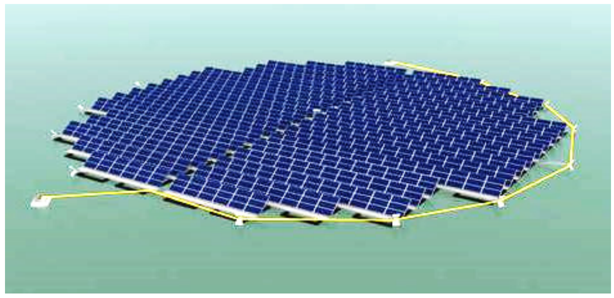

Fig. 9. Mooring system of floating PV with active cooling design[56)]

3.1.3 Mooring system

Mooring systems generally refer to permanent structures capable of storing containers. Examples include quays, wharfs, jetties, piers, anchor buoys, and mooring buoys. When the solar system is turned off, the system can keep the panel in the same position in the morning and prevent the panel from folding or turning off[48)]. Installing a mooring system in deep water can be difficult and expensive. A wire rope and a nylon harness can be used to complete the mooring system of the exit platform. The rope can be attached to the terminal on the edge and hit at any corner. the mooring system used in a power plant shown in Fig. 9.

3.1.4 Solar PV module

Until now, standard crystalline solar modules have been used in floating solar systems. Furthermore, as more and more designs are installed on the saltwater surface, specially designed modules need to be exposed to salty moist for a long time. Over time, almost all metals corrode, which is why it replaces standard aluminum frames and supports such as polymer frame is required.

3.1.5 Wiring Cables and connectors

Power comes from the solar system and is transported to the local site. As a result, electricity can be injected into the grid network or stored in batteries. So far, in the commissioned project, the cable has not been dragged underwater, but the cable has been kept on the water surface. Although there are no

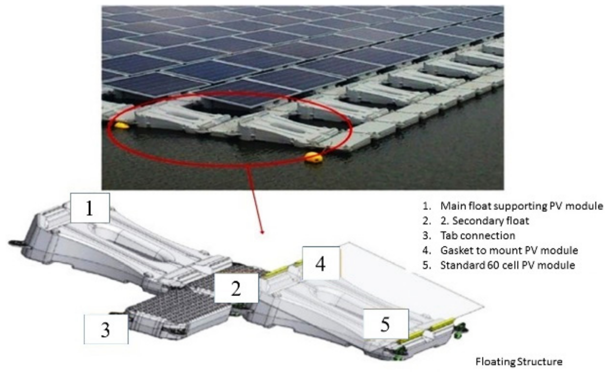

Fig. 10. Ciel & Terre's, France, Floating solar technology design[18]

underwater electrical cables and components, and waterproof junction boxes which are IP67 rated that are essential for solar floating systems. On the installed site, additional electrical instruments like solar PV inverters and batteries are still dry places. The power cables used to prevent high temperatures and waterproof that could be able to extend the system life.

3.2 Important design factors

3.2.1 Reservoir/pond/lake layout

Floating systems need an effective design that is specific to its location, development and, strategy. Furthermore, the different structural arrangements of the 3D geometry of the tank wall and the inside of the tank are not compatible. Consequently, the geometry of the floating module must be sufficiently adapted to the dissimilar interior structures of the water storage basin.

3.2.2 Floating structure

The geometry of the floating system has been intended with 2 foremost aspects in mind. First of all, the module should protect as much water as possible to avoid water evaporation Second, the size of the module imperatively adapted to the commercially available PV modules[49]. Solar problems examined included: size and angle of inclination of the photovoltaic module, number of modules to be installed, distance between rows of panels (to avoid shadow effects) and, easy access for prolongation.

3.2.3 Floating PV module orientation

Korea is located in the northern hemisphere, at 37° north latitude and 126° east longitude. The core longitudinal axis of the reservoir must be arranged with the base point and the solar panel must face towards the south[49].

3.3 Comparison between recompenses and short-comings of several FPV systems

A comprehensive comparison has been constructed in Table 1, between advantages and disadvantages of various types of solar systems *i.e.* ground-mounted, rooftop, canal top, offshore, and floating solar photovoltaic system that has been installed on various locations.

3.4 Power production and Future of Floating PV Technology

According to the first market report on solar energy produced, the use of floating solar energy has been reduced by more than 100 times in less than four years, from a global installed power of 10 MW at the end of 2014 to 1.1 GW in September 2018. According to a new report from Grand View Research, the global floating solar panel market is expected to reach $ 2.7 billion by 2025, up from $ 13.8 million in 2015. This technology is expected to experience significant growth during the forecast period due to the increasing demand for reliable production of renewable energy. In addition, the potential to reduce land costs should support demand over the forecast period. In the near future, the government's growing interest in renewable energy for energy production is expected to reduce environmental pollution and dependence on fossil fuels. The speed increased when India recently announced a plan to build 10 GW of floating solar energy. According to the World Bank, China represents the majority of 1.1 GW of floating solar energy currently installed. The cost of mounting the floating solar photovoltaic system is predictable to progress as technology advances by using conventional solar panel systems[36].

3.5 Rise of the Floating PV Technology over various other power sources installed worldwide

Renewable Energy Sources are quickly developing and their total installed power in the previous few years has been uninterruptedly growing as shown in Fig. 11, as described the in data[49], where overall installed power is specified composed for the main Renewable Energy Source technologies: hydroelectric power, wind, solar photovoltaic technology. It has been review that the 1323.1 GW of Hydropower, 681.6 GW of Wind Power, 677.2 GW of Photovoltaic Power with floating technology installed worldwide by 2020[49]. That covers 46.5%, 23.9% and 23.8% of total installed power sources respectively in 2020. One of the most perceptible information at a glance in the graph (Fig. 11) is the dramatic and rapid increase in photovoltaic with

Table 1. Comparison between recompenses and shortcomings of several PV systems

	Recompenses	Shortcomings
Ground mounted	• Increased potential and cost of installing a solar tracking system. • Ability to adjust seasonal slopes using a manual system. • Due to the large floor and roof area, large systems can be installed in rural areas. • The panel is easy to clean and maintain. • This also prevents the "cancellation of the roof warranty" because between the system and the roof there is no connection.	• Generally, the urban environment does not leave any place on the earth. • Solid foundations and concrete foundations should be built to provide a solid structure that protects against storms and strong winds. • The delay in construction is more than the other systems from the construction system.
Roof top	• Aesthetics: panels are ideally adapted to existing roofs for a more effective look. • Space optimization: You don't need to clean the world with a sunroof. • Kale: Solar panels protect the roof and protect against weathering and wear. This will increase the lifetime value of the property. • Speed: Rooftop solar systems are lighter and faster than ground-based systems.	• There can be a lot of obstacles on the roof, such as chimneys, trees, air inlets and satellite antenna. • The roof may not fit the required capacity of the system. • Lack of southern roofs that can affect yield • Hard work
Canal Top	• Save valuable and expensive plot. • It saves water from the evaporation channel. • By evaporating water from the channel, the cooling effect of solar panels produces more efficient energy than ground-based solar power plants. • Longer life and energy gain (decrease in deprivation of semiconductors).	• Channels are not available for these projects. • Socio-economic and political problems of the river and channel use. • Complex and long structure to accommodate the module. • Such systems are a problem due to insufficient maintenance. • Shadow of trees surrounding an indestructible canal to ensure soil stability and prevent erosion. • Covering these channels with solar panels destroys birds and green marshes. • Panels, structures, etc. It can cause problems with freshwater pollution. • Better (requires construction and design strategies, increases costs). • Due to the increased cable costs, it is difficult and expensive to discharge a small amount of energy over long distances. • Security problems are very important in such cases because systems distributed over such long distances cannot be protected by surrounding walls or fences.
Off Shore	• Due to the direct contact between the solar panel and water, the efficiency of the negative coefficient (% / K) of the photovoltaic junction can be used to generate more electricity for the same place on earth. • The efficiency of the panel increases when the solar panel's temperature drops. • In high-temperature circumstances, it resolves the double goal of avoids evaporation of water from underneath and generating more energy. • Make the most of the sun during the day.	• The chief factor of solar panels is cadmium chloride, which is costly and extremely poisonous, which disturbs both the industrial procedure and the cost of solar PV modules. • Investigators have discovered that saltwater comprises magnesium chloride. • The panel is waterproof. • The panel should be lightened, requiring expensive materials to make it floating. Otherwise, you should use designs that make the whole installation expensive. • Connecting the solar panels to keep them underwater and linking to the network can be a big problem for that kind of structure.
Floating solar	• Increased Efficiency: Natural cooling light reflected from water and evaporating water keeps the temperature of the solar panel below-ground temperature, which increases efficiency. • Reduced water evaporation: floating photovoltaic systems provide a shadow on the water surface to reduce evaporation. • Improving water quality: photosynthesis and algae growth decrease, which leads to improved water quality. • Less dust: in general, areas with high solar potential are generally dusty and dry. Thus, the floating photovoltaic systems operate in a less dusty environment than their counterparts on the ground. • Land Savings: Convert unused non-commercial water into profitable solar PV power plants to save valuable land for local agriculture, mining, tourism, and other incentives.	• The system is under numerous threats such as tides, storms, ocean waves, cyclones, and tsunamis. • Highly weathering of metal structures and parts that can shorten the lifespan of the setup. • This reduces the infiltration of sunlight into the water and prevents the animals, algae, etc. in the water. • Moisture and temperature changes in the panel cause negative temperature value, which can reduce total electrical efficiency. • Clay accumulated on a river/lakeshore needs to be cleaned regularly. • Depending on the location you choose, fishing and other transportation activities may be affected.

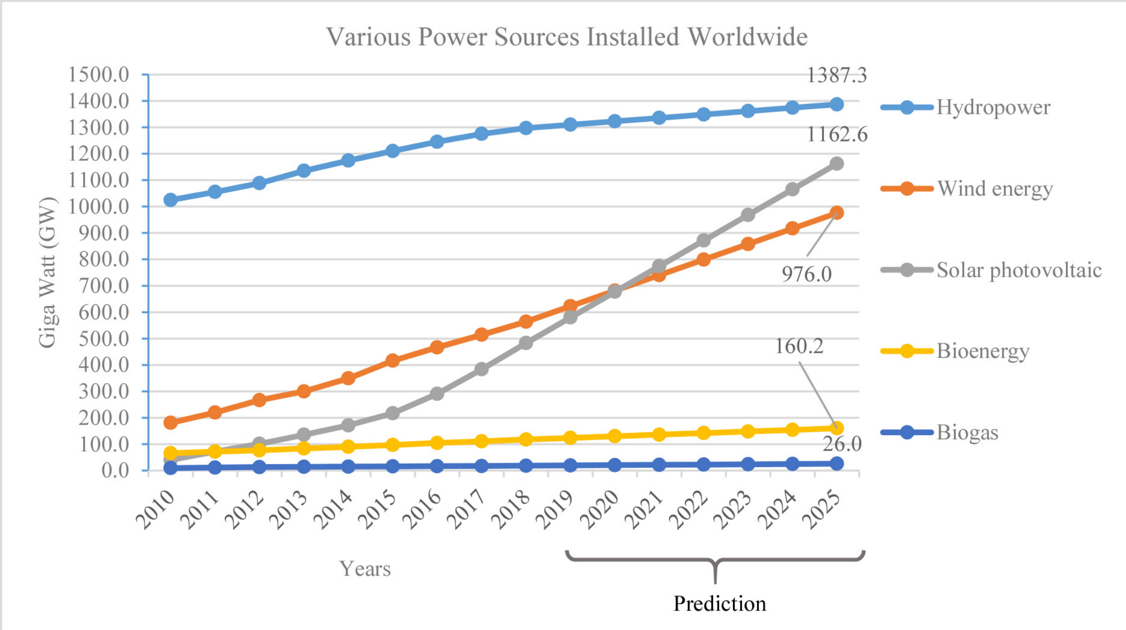

Fig. 11. Increasing the FPVT system over various power sources installed worldwide

Table 2. World Power Demand (GW) and future aspect of FPVT

	2020	%	2025	%	Rise (+) or Fall (−)
Hydropower	1323.1	46.5	1387.3	37.2	-9.28
Wind energy	681.6	23.9	976.0	26.2	2.22
Photovoltaic with FPVT	677.2	23.8	1162.6	31.2	7.38
Bioenergy	129.9	4.6	160.2	4.3	-0.27
Biogas	20.5	0.7	26.0	0.7	-0.02
Total	**2847.0**		**3730.1**	**Prediction**	

floating technology installations which have reached the accumulation of wind power in less than 10 years. It has been also predicted by this review that in 2025 the PV technology with the FPVT system will increase 7.38% that is 485.4 GW more of today installed power and installation of Hydropower will decrease 9.28% of today installed power worldwide as predicted in Table 2.

4. Technical design parameters for installing FPV

4.1 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.

$$E = P \times n \times t \; (kWh/day)$$

where E is energy demand, P is power in watt (W) of each electrical device, n is No. of items, t is time required to operate in hours (h).

4.2 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.

4.3 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 T_a = 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/m^2.

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

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

4.4 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.

4.5 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}

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

No. of modules in series N_{ms}

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

4.6 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, P_a is running power of the appliance[50].

5. 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 CO_2 green house 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 big 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 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. 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%. The global solar panel market exceeds 100 GW and the capacity of 104 GW will bring the annual growth rate to 6%. 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 predicted by this review that in 2025 the Solar technology including the FPVT system will increase by 7.38% that is 485.4 GW more of today installed power worldwide.

6. Suggestions

Considering the reviewed works in this paper, recommendations for future research are as follows:

- Corrosion in salt water is generally not a problem since most FPV systems float on fresh water, such as lakes and reservoirs. However, for offshore applications, it is necessary to verify the effect of sea water on the structure and functioning of the photovoltaic modules.

- Further research is needed to analyze the impact of installing electrical devices such as converters on the surface of water, on efficiency and performance.
- In future projects, the impact of the FPV system on the ecological footprint, water quality and other environmental factors should be further studied.
- It is recommended that optimization studies be continued to improve the performance of FPV power plants.
- It is recommended to determine the cost of saving water and reducing CO_2 emissions by using FPV panels.
- The design of the FPV system connection and the FPV system grounding system must be verified, a very important aspect from the point of view of safety and reliability.
- To ensure reliable system operation, a more in-depth study of the power transmission of the floating system on the ground is required.
- To reduce the impact of the use of FPV modules on the aquatic environment, translucent photovoltaic panels can be used, which is why the use of thin film silicon modules should be further studied.

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References

1. Das, U. K., Tey, K. S., Seyedmahmoudian, M., Mekhilef, S., Idris, M. Y. I., Van Deventer, W., Horan B., Stojcevski, A., "Forecasting of photovoltaic power generation and model optimization: A review," Renewable and Sustainable Energy Reviews, Vol. 81, pp. 912-928, 2018.
2. Gholami, H., Khalilnejad, A., Gharehpetian, G. B., "Electro-thermal performance and environmental effects of optimal photovoltaic–thermal system," Energy conversion and management, Vol. 95, pp. 326-333, 2015.
3. Ram, J. P., Babu, T. S., Rajasekar, N., "A comprehensive review on solar PV maximum power point tracking techniques," Renewable and Sustainable Energy Reviews, Vol. 67, pp. 826-847, 2017.
4. Kumari, P. A., Geethanjali, P., "Parameter estimation for photovoltaic system under normal and partial shading conditions: A survey," Renewable and Sustainable Energy Reviews, Vol. 84, pp. 1-11, 2018.
5. Zhou, X., Yang, J., Wang, F., Xiao, B., "Economic analysis of power generation from floating solar chimney power plant," Renewable and Sustainable Energy Reviews, Vol. 13, No. 4, pp. 736-749, 2009.
6. Trapani, K., Millar, D. L., "Proposing offshore photovoltaic (PV) technology to the energy mix of the Maltese islands," Energy Conversion and Management, Vol. 67, pp. 18-26, 2013.
7. Shahinpour, A., Moghani, J. S., Gharehpetian, G. B., Abdi, B., "High gain high-voltage z-source converter for offshore wind energy systems. In the 5th annual international power electronics," Drive Systems and Technologies Conference (PEDSTC 2014), IEEE., pp. 488-493, 2014.
8. Maghrebi, M. J., Nejad, R. M., "Performance evaluation of floating solar chimney power plant in Iran: Estimation of technology progression and cost investigation," IET Renewable Power Generation, Vol. 11, No. 13, pp. 1659-1666, 2017.
9. Mittal, D., Saxena, B. K., Rao, K. V. S., "Floating solar photovoltaic systems: An overview and their feasibility at Kota in Rajasthan," In 2017 International Conference on Circuit, Power and Computing Technologies (ICCPCT), IEEE., pp. 1-7, 2017.
10. Astuti, Y. D. R. W., Hudaya, C., Putri, R. K., Sommeng, A. N., "Photovoltaic installation in Floating Storage and Offloading (FSO) vessel," In 2018 2nd International Conference on Green Energy and Applications (ICGEA), IEEE., pp. 119-123, 2018.
11. Trapani, K., Redón Santafé, M., "A review of floating photovoltaic installations: 2007–2013," Progress in Photovoltaics: Research and Applications, Vol. 23, No. 4, pp. 524-532, 2015.
12. Ueda, Y., Sakurai, T., Tatebe, S., Itoh, A., Kurokawa, K., "Performance analysis of PV systems on the water," In 23rd European Photovoltaic Solar Energy Conferencem, pp. 2670-2673, 2008.
13. Kenning, T., World's Largest Floating Solar Plant Comes Partially Online in China, 2017.
14. Tina, G. M., Cazzaniga, R., Rosa-Clot, M., Rosa-Clot, P., "Geographic and technical floating photovoltaic potential," Thermal Science, Vol. 22(Suppl. 3), pp. 831-841, 2018.
15. Vaughan, A. Japan begins work on 'world's largest' floating solar farm. The Guardian, 2016.
16. Ferrer-Gisbert, C., Ferrán-Gozálvez, J. J., Redón-Santafé, M., Ferrer-Gisbert, P., Sánchez-Romero, F. J., Torregrosa-Soler, J. B., "A new photovoltaic floating cover system for water reservoirs," Renewable energy, Vol. 60, pp. 63-70, 2013.
17. do Sacramento, E. M., Carvalho, P. C., de Araújo, J. C., Riffel, D. B., da Cruz Corrêa, R. M., Neto, J. S. P., "Scenarios for use of floating photovoltaic plants in Brazilian reservoirs," IET Renewable Power Generation, Vol. 9, No. 8, pp. 1019-1024, 2015.
18. Sahu, A., Yadav, N., Sudhakar, K., "Floating photovoltaic power plant: A review," Renewable and sustainable energy reviews, Vol. 66, pp. 815-824, 2016.
19. Villa, L. F. L., Picault, D., Raison, B., Bacha, S., Labonne, A., "Maximizing the power output of partially shaded photo-

voltaic plants through optimization of the interconnections among its modules," IEEE Journal of Photovoltaics, Vol. 2, No. 2, pp. 154-163, 2012.
20. Ko, S. W., Ju, Y. C., Hwang, H. M., So, J. H., Jung, Y. S., Song, H. J., Song, H. E., Kim, S. H., Kang, G. H., "Electric and thermal characteristics of photovoltaic modules under partial shading and with a damaged bypass diode," Energy, Vol. 128, pp. 232-243, 2017.
21. Satpathy, P. R., Jena, S., Jena, B., Sharma, R., "Comparative study of interconnection schemes of modules in solar PV array network," In 2017 International Conference on Circuit, Power and Computing Technologies (ICCPCT), IEEE., pp. 1-6, 2017.
22. Tofoli, F. L., de Castro Pereira, D., de Paula, W. J., Júnior, D. D. S. O., "Survey on non-isolated high-voltage step-up dc–dc topologies based on the boost converter," IET power Electronics, Vol. 8, No. 10, pp. 2044-2057, 2015.
23. Azidehak, A., Chattopadhyay, R., Acharya, S., Tripathi, A. K., Kashani, M. G., Chavan, G., Bhattacharya, S., "Control of modular dual active bridge DC/DC converter for photovoltaic integration," In 2015 IEEE Energy Conversion Congress and Exposition (ECCE) IEEE., pp. 3400-3406, 2015.
24. Anurag, A., Deshmukh, N., Maguluri, A., Anand, S., "Integrated dc–dc converter based grid-connected transformerless photovoltaic inverter with extended input voltage range," IEEE Transactions on Power Electronics, Vol. 33, No. 10, pp. 8322-8330, 2017.
25. Kim, S. H., Yoon, S. J., Choi, W., Choi, K. B., "Application of floating photovoltaic energy generation systems in South Korea," Sustainability, Vol. 8, No. 12, pp. 1333, 2016.
26. Cazzaniga, R., Cicu, M., Rosa-Clot, M., Rosa-Clot, P., Tina, G. M., Ventura, C., "Floating photovoltaic plants: Performance analysis and design solutions," Renewable and Sustainable Energy Reviews, Vol. 81, pp. 1730-1741, 2018.
27. Kumar, V. A., Rashmitha, M., Naresh, B., Bangararaju, J., Rajagopal, V., "Performance analysis of different photovoltaic technologies," In 2013 International Conference on Advanced Electronic Systems (ICAES), IEEE., pp. 301-303, 2013.
28. Rahman, M. M., Hasanuzzaman, M., Rahim, N. A., "Effects of various parameters on PV-module power and efficiency," Energy Conversion and Management, Vol. 103, pp. 348-358, 2015.
29. Kumar Pankaj, John Sibu Sam, Shukla Akash K, Sudhakar K, Arbind K., "Performance analysis of 68 W flexible solar PV," J Energy Res Environ Technol., Vol. 2, No. 3, pp. 227–231, 2015.
30. Shukla, K. N., Rangnekar, S., Sudhakar, K., "A comparative study of exergetic performance of amorphous and polycrystalline solar PV modules," International Journal of Exergy, Vol. 17, No. 4, pp. 433-455, 2015.
31. Sudhakar, K., Srivastava, T., "Energy and exergy analysis of 36 W solar photovoltaic module," International Journal of Ambient Energy, Vol. 35, No. 1, pp. 51-57, 2014.
32. Kumar, B. S., Sudhakar, K., "Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India," Energy Reports, Vol. 1, pp. 184-192, 2015.
33. Gotmare, J. A., Prayagi, S. V., "Enhancing the performance of photovoltaic panels by stationary cooling," Int J Sci Eng Technol, Vol. 2, No. 7, pp. 1465-1468, 2014.
34. Sahu, Y., Shahabuddin, M., Agrawal, P., "Floating solar photovoltaic system an emerging technology," In National Seminar on the Prospects and Challenges of the Electrical Power Industry in India, Vol. 2, pp. 219-227, 2015.
35. Nikhil, P. G., Premalatha, M., "Performance enhancement of solar module by cooling: An experimental investigation," Int J Energy Environ, Vol. 3, No. 1, pp. 73-82, 2012.
36. IRENA, Renewable Capacity Statistics, International Renewable Energy Agency, Abu Dhabi, 2020.
37. Deo, A., Tiwari, G. N., "Performance analysis of 1.8 kW p rooftop photovoltaic system in India," In 2nd International Conference on Green Energy and Technology, IEEE., pp. 87-90, 2014.
38. Trapani, K., Millar, D. L., Smith, H. C., "Novel offshore application of photovoltaics in comparison to conventional marine renewable energy technologies," Renewable Energy, Vol. 50, pp. 879-888, 2013.
39. Dubey, S., Sarvaiya, J. N., Seshadri, B., "Temperature dependent photovoltaic (PV) efficiency and its effect on PV production in the world–a review," Energy Procedia, Vol. 33, pp. 311-321, 2013.
40. Azmi, M. S. M., Othman, M. Y. H., Ruslan, M. H. H., Sopian, K., Majid, Z. A. A., "Study on electrical power output of floating photovoltaic and conventional photovoltaic," In AIP Conference Proceedings, American Institute of Physics, Vol. 1571, No. 1, pp. 95-101, 2013.
41. Dash, P. K., Gupta, N. C., "Effect of temperature on power output from different commercially available photovoltaic modules," International Journal of Engineering Research and Applications, Vol. 5, No. 1, pp. 148-151, 2015.
42. Fesharaki, V. J., Dehghani, M., Fesharaki, J. J., Tavasoli, H., "The effect of temperature on photovoltaic cell efficiency," In Proceedings of the 1stInternational Conference on Emerging Trends in Energy Conservation–ETEC, Tehran, Iran, pp. 20-21, 2011.
43. Baskar, D., "Efficiency improvement on photovoltaic water pumping system by automatic water spraying over photovoltaic cells," Middle-East Journal of Scientific Research, Vol. 19, No. 8, pp. 1127-1131, 2014.
44. Choi, Y. K., "A study on power generation analysis of floating PV system considering environmental impact," International journal of software engineering and its applications, Vol. 8, No. 1, pp. 75-84, 2014.
45. Tsoutsos, T., Frantzeskaki, N., Gekas, V., "Environmental impacts from the solar energy technologies," Energy policy, Vol. 33, No. 3, pp. 289-296, 2005.
46. Rosa-Clot, M., Rosa-Clot, P., Tina, G. M., Scandura, P. F., "Submerged photovoltaic solar panel: SP2," Renewable Energy, Vol. 35, No. 8, pp. 1862-1865, 2010.

47. Redón-Santafé, M., Ferrer-Gisbert, P. S., Sánchez-Romero, F. J., Torregrosa Soler, J. B., Gozalvez, F., Javier, J., Ferrer Gisbert, C. M., "Implementation of a photovoltaic floating cover for irrigation reservoirs," Journal of cleaner production, Vol. 66, pp. 568-570, 2014.
48. Sharma, P., Muni, B., Sen, D., "Design parameters of 10 KW floating solar power plant," In Proceedings of the International Advanced Research Journal in Science, Engineering and Technology (IARJSET), National Conference on Renewable Energy and Environment (NCREE-2015), Ghaziabad, India, Vol. 2, 2015.
49. Ferrer-Gisbert, C., Ferrán-Gozálvez, J. J., Redón-Santafé, M., Ferrer-Gisbert, P., Sánchez-Romero, F. J., Torregrosa-Soler, J. B., "A new photovoltaic floating cover system for water reservoirs," Renewable energy, Vol. 60, pp. 63-70, 2013.
50. Umoette, A. T., Ubom, E. A., Festus, M. U., "Design of stand alone floating PV system for Ibeno health centre," Science Journal of Energy Engineering, Vol. 4, No. 6, pp. 56-61, 2016 .
51. https://newportsolarri.com/projects/north-scituate-ground-mount-system/ (Accessed on 29-06-2020).
52. https://genprodigital.com/blog/https-genprodigital-com-blog-marketing-for-solar/ (Accessed on 29-06-2020).
53. https://nationnews.in/state-potential-1500-megawatt-installation-canal-top-solar-power-projects-power-minister/ (Accessed on 29-06-2020).
54. https://energi.media/innovation/dutch-plan-build-giant-offshore-solar-power-farm/ (Accessed on 17-06-2020).
55. http://en.people.cn/n3/2017/1212/c90000-9303399.html (Accessed on 29-06-2020).
56. http://www.floating-solar.com/technologies.html (Accessed on 29-06-2020).