International Journal of Environmental Science and Technology
https://doi.org/10.1007/s13762-018-2080-5

REVIEW

Prospects of floating photovoltaic technology and its implementation in Central and South Asian Countries

M. Abid[1] · Z. Abid[2] · J. Sagin[3] · R. Murtaza[4] · D. Sarbassov[3] · M. Shabbir[1]

Received: 22 June 2018 / Revised: 2 September 2018 / Accepted: 16 October 2018

Abstract

Many regions around the globe, especially South Asia including Afghanistan and Pakistan and Central Asia, have extreme difficulties in accessing portable water and a stable energy supply. Some areas are covered with arid soil and salty water, while others have power transmission problems. Water evaporation from reservoirs is also another problem during high temperatures, thereby posing additional energy and water demands. This paper discusses the multiple prospects of floating photovoltaic technology in different regions of the world and highlights the importance of such technologies in already water-scarce regions like South Asia and Central Asia. This technology will prove to be highly feasible as it is an environment friendly and cost efficient and will help in reducing evaporation, achieving sustainable water supply and clean energy production and reducing greenhouse gas emissions. There is very minimal work done on floating solar technology; thus, there is immense need to explore and research on this technology on every level through information sharing.

Keywords Clean energy · Evapotranspiration · Floating · Photovoltaic · Submerged PV panels · Sustainable · Power

Introduction

Floating photovoltaic system (FPVS) is a novel idea in renewable energy production without putting additional burden on water and land resources. Since FPVS is a relatively new concept, only a few demonstrator projects have been deployed worldwide (Trapani 2013). Because FPVS can be installed in water bodies such as oceans, lakes, lagoons, reservoir, irrigation ponds, wastewater treatment plants, wineries, fish farms, dams and canals and also because of insufficiency of land, a reasonable demand of FPVS installations in Japan, USA, Korea, Australia, Brazil, India and other countries is observed and is likely to increase worldwide. A typical overland photovoltaic (PV) module, depending upon the type of solar cells and climatic conditions, converts 4–18% of the incident solar energy into electricity. The rest of the incident solar radiation is converted into heat, which significantly increases the temperature of the PV (Dubey et al. 2013; Syahriman et al. 2013). Being installed on water, a FPVS has significant lower ambient temperature in virtue to the cooling effect of water. Consequently, efficiency of floating-type solar panels is 11% higher compared with ground-installed solar panels (Gotmare et al. 2014; Dash and Gupta 2015; Fesharaki et al. 2011; Baskar 2014; Choi 2014).

The pilot study on floating PV technology was completed in 2007, while the first pilot floating PV plant was built in California in 2008. By the end of 2014, a total of 22 photovoltaic power plants had been built in the world with the installed capacity from 0.5 to 1157 kW (Liu et al. 2017). At present, the developments on marine floating PV systems are in pipeline to examine the effects of corrosion of seawater on unit and PV configuration and the link with energy production efficacy (Oshima et al. 2001).

Editorial responsibility: Hari Pant.

✉ M. Abid
drabid@ciitwah.edu.pk

1 Interdisciplinary Research Centre, COMSATS University Islamabad, Wah Campus, G T Road, Wah Cantt, Pakistan

2 Department of Environmental Sciences, Quaid-i-Azam University, Islamabad, Pakistan

3 Nazarbayev University, 53 KabanbayBatyr Ave, Astana, Kazakhstan

4 Centre for Climate Research and Development (CCRD), COMSATS University Islamabad, Islamabad, Pakistan

Published online: 22 October 2018

Methodology

This review paper is designed to assess the prospects and highlight the importance of floating solar panel technology. Critical assessment of multiple studies on solar technologies' implementations has been done. The study time span is 2001–2017, which makes 17 years. Multiple keywords were used to search the relevant articles and research studies on solar technology such as clean energy, evapotranspiration, floating photovoltaic technology, microencapsulated phase change material, submerged PV panels and sustainable water supply. The database is produced in the paper using relevant search engines such as google.com and journal websites such as Sciencedirect, Elsevier, Springer and IWAP. At the end, inclusion and exclusion criteria were used to cite the relevant articles in a review study.

Overview of presently implemented floating photovoltaic systems

Several countries have studied the effectiveness of floating solar panel technology and are discussed as follows:

- A prototype has been developed to study the benefits of solar PV panels for local farmers in Spain. Most of the farms have water reservoirs for irrigation. Despite changes in feed-in tariffs in Spain, the system remains economical and highly attractive (Ferrer-Gisbert et al. 2013). An improvement in output energy generation is achieved using microencapsulated phase change material (MEPCM)-PV unit to be floated on water surface. (Ho et al. 2015).
- The Colignola power plant called Floating Tracker Cooling Concentrator (FTCC) couples PV panels and reflectors. The combination of cooling effect of water and reflection of the mirrors increases efficiency of solar panels, thereby reducing the cost by about 20% than overland PV systems.
- The German SUNdy structure from Det Norske Veritas has implemented a hexagonal-shaped structure which brings potentially interesting properties such as easy arrangement of modules. The system shows flexibility by resisting the waves and retaining its shape. Finally, the larger installations at Kato City, Japan, are designed to withstand typhoons. However, corrosion may be a concern since most of these systems are designed for water. Long-term issues need to be observed and considered.
- The governments in different countries such as Japan, UK, Brazil, India and USA are promoting installation of floating solar plants owing to the numerous benefits associated with the technology. Japan accounted for 50% of the overall market share in 2015. In addition, the Japanese government has sanctioned over 100 plants that are going to be installed in the next 5 years. The political factor is also playing an important role in the growth of technology in the country (Grand View Research 2017).
- China, being one of the largest coal-based thermal power generating countries, introduced 40 MW floating solar power plant, thereby highlighting the importance of using renewable energy sources (Brandon 2017) (Fig. 1).
- Similarly, India's largest floating solar PV plant of 100 kW is installed in Kerala (Sengupta 2017), while

Fig. 1 The world's largest 40 MW floating solar power plant at Huainan, China. (*Source*: Brandon 2017)

10 kW solar plant is planned to be installed in Kolkata and Banasura Sagar reservoir in Wayanad.

- The scientific and monetary investigations on FPVS of 20 kW prototype covering 350 m^2 area, mounted on reservoirs, were conducted in Agosto Alicante, Spain. The successful performance of prototype directed to a full-scale installation of 1458 PV panels supported on 750 pontoons covering an area of 4490 m^2. The panels are now producing clean energy at a trifling power of 300 kW (Gozálvez et al. 2012). In an agriculture reservoir, one-to-one plant was built to study the performance of system near Alicante, Spain. The surface area of reservoir top was 4700 m^2, but just 7% area was covered by static solar system (Ferrer-Gisbert et al. 2013).
- Based on the preliminary simulation of FPVS of 240 kW on a pool in Khuzestan province in Iran, it was observed that the FPVS can annually produce 380 MW power and can be added into the main power supply system. Moreover, the water stored due to reduced evaporation could be as much as 13,950 m^3/year, which makes up about 24% of the reservoir's storage capacity. Thus, FPVS is considered to be an efficient key for agro-energetic policies for countries around the globe (Nazififard et al. 2017) and for water pumping due to sufficient amount of solar radiations available over large area (Vick and Clark 2009).
- Two floating PV test plants with generating capacities of 2.4 kW and 1000 kW, respectively, were evaluated in Korea. Their capacity was increased by 10% due to the cooling effect of water.
- An exclusive FPVS was developed jointly by Universidad Politécnica de Valencia and CELEMIN ENERGY. This FPV technology was composed of polyethylene floating units that along with elastic fasteners and tension producing elements are proficient to adjust for changing water levels in reservoir. The whole surface reservoir was covered, i.e., 4490 m^2 at 300 kWp (Santafé et al. 2014).
- The energy generation of FPVS is estimated and related to ground-based PV plant. Generally, the power production of floating solar unit in China during June to August is meaningfully higher but lower during September to October (Lee et al. 2014).
- FPVSs on Pit Lake in mines of Korea were assessed with the help of fish-eye-type lens camera and modeling approach, i.e., digital elevation model (DEM). In order to group the zones suitable for FPVSs, shading analysis was performed. The FPVS was designed and constructed by bearing in mind the array spacing of PV panels and most favorable tilt angle (Santafé et al. 2014). The energy simulations were completed using system advisor model (SAM) by National Renewable Energy Laboratory, USA, based upon the system design and weather data. It is studied that future PV system would be able to produce energy of 971.57 MWh/year. The fiscal examinations exhibited that the total cost will be 897,000 US$ with return time period of about 12.3 years, while the yearly reduction in greenhouse gases will be 471.21 tCO_2 (Song and Choi 2016).
- The deployment of crystalline PV systems with pontoon-type structures in offshore environments was assessed. Thin-film-based PV is reasonably inexpensive for offshore wind power activities (latitudes ranging from 45N to 45S). The specific output in GWh/km^2 was higher for thin-film PV as compared to tidal barrage systems, wind and wave. The specific installed capacity measured in MW/km^2 was larger than traditional technologies apart from tidal current turbines (Trapani et al. 2013).
- The integration of floating solar panels with ground-based systems is also observed useful. The offshore location nearby the Maltese islands was used for launching PV panels floating on sea surface. The yield was combined with current traditional electricity production structure which relies on steam and gas turbine systems (Trapani and Millar 2013).
- A thin-film flexible floating PV array technology is implemented and evaluated on water reservoirs in Sudbury, Canada, where water cooling effect increased its efficiency up to 5% (Trapani and Millar 2014).
- The current capacities of dams can be used in association with PV modules on surface of water bodies. About 60% of the total population in Santa Maria, Southern Brazil, is receiving drinking water from Val de Serra. The Homer software used in pre-feasibility observations thus revealed that 227 kW hydroelectric facility can be operated together with 60 kW PV modules (Teixeira et al. 2015).
- The cooling effect of water also generates more energy with floating solar plant. According to a study, the potential of floating PV systems can reach 160 GW in China, covering about 2500 km^2 water surface, and will save 2054 m^3 water from evaporation a year and greatly ease the competition for land resources, especially in the east region in China. Using 3D finite element analysis based on the water cooling effect, an increase in the efficiency of 1.58–2.00% of floating PV systems is observed compared with the traditional terrestrial PV systems (Liu et al. 2017).
- The integration of GIS-based techniques and remote sensing can also help in improving and determining the potential of FPVSs (Sahu et al. 2016). In addition, artificial neural networks (ANNs) developed are implemented to forecast power generation for big scale PV plants (Mellit et al. 2013).

Technical and economic feasibility of floating photovoltaic systems (FPVSs) compared with overland PV systems

Floating photovoltaic systems have numerous technical and economic advantages over overland PV systems and are discussed as follows.

Technical feasibility

- FPVSs are highly feasible systems as they are convenient and provide increased energy efficiency (Tina et al. 2011)
- One of the greatest benefits is easy arrangement of modules; they can be either be fixed or equipped with the tracking system depending upon the external conditions and can also adjust to the changing water levels to maximize the energy output.
- In order to conserve natural resources such as land and water, the installation of solar PV system on water bodies, wastewater treatment plants, wineries and fish farms is an effective option. With the given technology, up to 33% evaporation on natural lakes and ponds and about 50% in man-made facilities are prevented (Choi 2014) and water levels during extreme summers are preserved in storage reservoirs of water. This can lead to efficient supply of drinking water. Tsoutsos et al. 2005 claim that up to 40% of open reservoir's water could be lost during evaporation. It has been studied that a large portion of water can be conserved in small water bodies and canals by implementing floating solar technology as it reduces the evaporation from reservoirs by about 70% (Sharma et al. 2015).
- Vladan and Zeljko (2017) concluded that one of the main positive ecological effects of the building of the FPVS is the reduction in the water evaporation which would amount to about 5.41 million m^3/year.
- This floating system is durable, cost effective, and supple. The technology is not time-consuming when it comes to installation. Old tires and bamboo are used to firm floating solar system and in a short time of up to 3 months. Flexible solar panels are inserted on floating foil, so the system can be easily rolled up and transported
- The implementation of FPVSs is easy compared with overland PV systems.
- Vladan and Zeljko (2017) studied a proposed Floating Photovoltaic Power Plant with annual production of almost 186.05 GWh/year, providing about 20.78% electrical energy needs.
- The marine sites are envisioned to comprise coated thin-film PV which allows the arrangement to be supple, while submergible arrays are inundated in unkind weather situations. Moreover, they can also withstand typhoons because of their flexibility to resist waves and shape-retaining property. Using submerged photovoltaic (PV) panels at different depths, 20% increase in efficiency is observed achieving a temperature difference of 30 °C with reduction in light reflection and absence of thermal drift (Rosa-Clot et al. 2010).
- The cleaning of FPVS is easy since water for cleaning is readily available. In addition, compared with the ground-based systems, floating PV technology experiences less dust. It also proves to be environment-friendly technology as it has less impact on land (Majid et al. 2014).
- With its successful implementation, this technology can be helpful in establishing a solar-friendly real estate on industrial ponds, inland freshwater bodies, mine lakes, hydroelectric dams and irrigation reservoirs.

Factors for technical feasibility

Performance of the floating PV system is observed dependent on the type and size of modules, phase change material (PCM), floating and support structure, construction of modules (single or multilayer), thickness of modules, temperature of modules and inclination of modules which is optimal (Bahaidarah et al. 2013). In addition, the system's technical and economic feasibility can be ensured by assessing weather conditions, water depth, solar radiation distribution, solar pathfinder, flow modeling, system connection and connectivity with power system and by determining a mooring method to ensure the adaptation of buoyant materials to substantial changes in water level (Ueda et al. 2008).

One of the technical benefits of FPVS is accounted for by the use of two microencapsulated phase change material layers on the backside of the PV panels. The output of energy generation increased by 1.48% with two 3-cm-thick MEPCM layers of melting point 30 °C and 26 °C, respectively, while the power generation yield of two 5-cm-thick MEPCM layers enlarged by 2.03% during summers at 30 °C and 26 °C due to the effects of MEPCM layers on the temperature control of PV cell and energy production efficiency of PV unit during the day (Ho et al. 2015).

Interest and present discussions on this technology, mostly in Asia, predict larger installations in near future (Trapani and Redón Santafé 2015; Sharma et al. 2015).

Economic feasibility

- The cost of building the supporting floating structure can represent up to 25% of the total project cost and is often less than buying and preparing the equivalent area of land, i.e., civil works and seismic proof foundations.

- They can be installed with ease as no heavy equipment is required (Choi et al. 2013). The amount of steel structures in plant is also reduced because no boilers and chimneys are required in FPV. The PV panels can also be mounted on a rigid pontoon structure. As a result, cost of implementation is not much.
- Operation and maintenance cost of FPVS is comparatively less compared with land-based systems as water for cleaning is available at source and components were less likely to overheat (Lu et al. 2015). Saltwater corrosion is not normally a problem since most floating PV is sited on freshwater bodies such as lakes and reservoirs. Floating PV is potentially less prone to shading, and there is no maintenance associated with clearing away ground-based vegetation (Smyth et al. 2011)
- Shetty and Kulkarni (2014) have calculated the payback period of 5 years for 1 MW Floating Solar Power Plant (PSPP) with 4000 modules of capacity 250 each with minimum plant life of 25–30 years and highlight its economic feasibility. Total installation cost taken was crore 8; selling cost per unit Rs/kWh 9; total generation hours 1920; total generation (MU) MU/per day 0.008; earning per year crore 1.728, hence providing savings after 10 years crore 9.28.
- On the basis of construction materials, cost analysis for constructing FPVS of power 1 MWp was performed by Kim et al. (2017). It was concluded that investment costs were significantly lower for lighter structures made of fiber-reinforced polymer. Investment costs will drop with the growth of total installed capacities as well of unit power.

Effect on the environment

- FPVS can conserve land for agriculture, mining, tourism and other land-incentive activities and is an environment-friendly technology with less impact on land (Sahu et al. 2016).
- Vladan and Zeljko (2017) concluded from their detailed study that FPVS contributes significantly to the reduction in carbon dioxide gas emissions by 83.42 kt CO_2/year.
- The algae formation in the water bodies is also decreased due to reduced rate of photosynthesis in water (Woody 2011).
- Reduction in the evaporation and more retained water would be beneficial for animals and vegetation in the area where FPV panels are installed.
- Ecosystems of flora and fauna can be affected (Gair 2014/2015). Biodiversity can get affected as underwater electric cables can affect aquatic ecosystems. Fishing and other transportation activities can be hampered. However, more research is needed to predict the effects of FPV panels on animal life (Sahu et al. 2016).
- Vladan and Zeljko (2017) concluded that considering the proposed Floating Photovoltaic Power Plant planned on an isolated and shallow part of Skadar Lake whose water level in the summer months decreases to a critical height that isolates it from the rest of the lake, the effect of evaporation reduction has a very positive effect on the survival of living organisms in this part of the lake.

Recommendation for implementation of floating PV systems in Central and South Asia

The relatively new technology of photovoltaic systems can be used efficiently in Central Asia where the level of evapotranspiration is larger than the level of precipitation (Sorg et al. 2014), P/PET < 0.5 (150/500) (Li et al. 2014) in different regions, especially in arid and semiarid locations. Most of the water collection technologies are related to the open surface water reservoirs in Central Asia; therefore, desertification over its territories is becoming a complicated issue. There are considerable water losses in open reservoirs via salty water creation and evaporation. Keeping and recharging the water in aquifers is an alternative solution for reducing the rate of evaporation from water bodies. During Central Asian summers, the water resources continue to dry up, thus giving rise to irrigation issues. The Central Asia receives solar radiations by about 1300–2200 kWt/h on one square meter, which makes the region suitable for enforcement of PV technologies as mentioned in Fig. 2 by Winarso (2017).

Keeping in view the success of the floating solar plant technology mostly in South Asian region, it is suggested that such implementations should be extended to Pakistan, Afghanistan and Iran and especially to Central Asian countries where a large amount of water reservoirs, rivers and channels of different sizes are available. Implementation of this sophisticated technology in Pakistan, Afghanistan and Central Asia was discussed in Indus Basin Knowledge Forum held in Colombo, Sri Lanka, and included in the Ten-Point Agenda Actions for the future (http://www.iwmi.cgiar.org/research/sustainable-growth/governance-and-gender/indus-basin-knowledge-forum/).

The territory of the Indus Basin is shared by Afghanistan, China, India and Pakistan. The Indus Basin originates from Tibetan Plateau, China, and is nourished by major tributaries of Karakoram, Hindu Kush and Himalayan region. In basin territories, almost 300 million people live and depend upon the basin resources for energy and food. It is discussed that Pakistan and Afghanistan must benefit from the Central Asian Countries' experiences related to climate change, snowmelt processes, flood and drought. Decision in Indus Basin Forum will help in addressing the renewable energy production and evaporation mitigation techniques. Therefore, a huge scope is

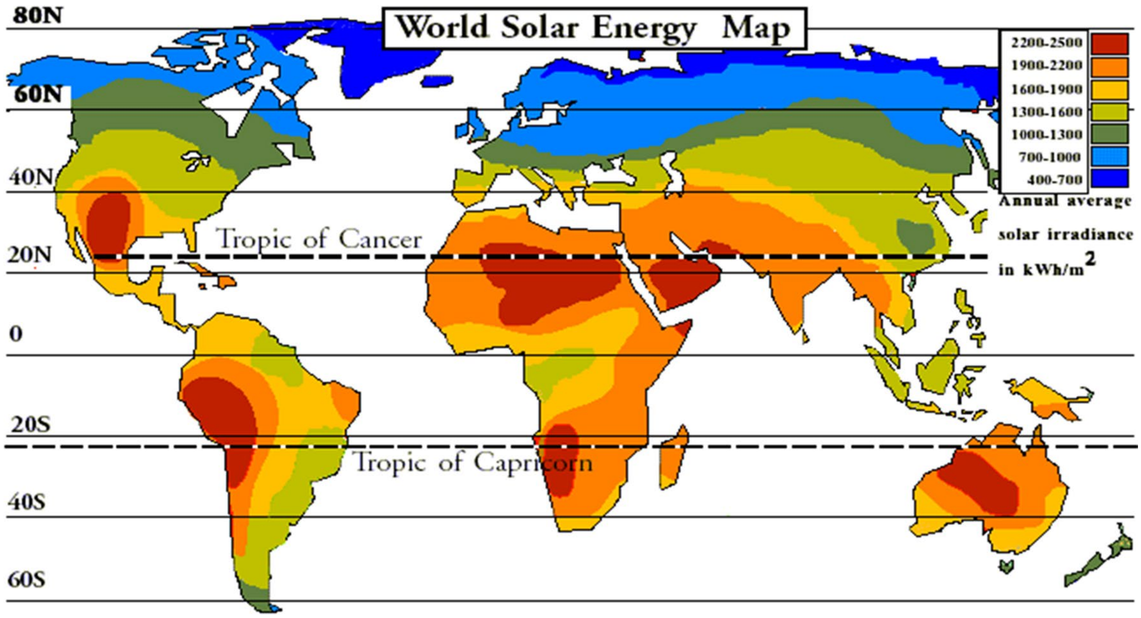

Fig. 2 Global solar resource for PV technologies. (*Source*: Winarso 2017)

expected by the implementation of floating solar plants on commercial scale. In order to benefit from floating solar panels technology in Pakistan, Afghanistan and Central Asia, the current planning includes generation of a database to own all pertinent datasets like available data in a GIS surroundings and web-based GIS. This will help in understanding the hydrological setting of the area, accessing agreements to use facilities, preparing safety fences, installing floating solar panels on small water bodies and reservoirs in selected areas and providing awareness and training sessions to scientific community and people. Later on, generated database and GIS data will help in examining the spatial relationships between the acquired datasets and develop sound conceptual models. The model will then be used for the development of surface–groundwater modeling to be used in prediction analyses, thereby highlighting the criteria for installation of floating solar plants with sustainable water supply and clean energy production perspectives.

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 and Brazil. Keeping in view the potential of FPVS, it is strongly recommended that Pakistan, Afghanistan and Central Asian Countries must take challenge to implement and contribute to the share of the RE-based generation targets and save the limited water sources availability in next 5 years.

Conclusion

The concept of floating photovoltaic system is relatively new in the sustainable development related to efficient energy production and water resource use for food–energy–water NEXUS programs. This technology can be used for most of the territories of Central Asia and South Asia especially Pakistan and Afghanistan. The successful pilot projects can be expanded to other regions of South Asia, Central Asia and beyond. The applications and benefits of floating PV technology have been mentioned from multiple regions of the world. The system is in principle practicable and reasonably useful. It is concluded that the floating system will be used to cover the surface of water bodies in the near future. Also, the cooling effect of water will improve the energy efficiency of the technology. This technology will be a good source of income for reservoir hosts. Its major benefit is that water losses will be minimized through this technology. Moreover, for agro-energetic plans and policies and demand of water tools in agricultural industry, the FPVS can be a competent way out. It has also been concluded that the installation of floating solar PV technology will solve the problems of land acquisition. In terms of implementation, solar tracking system to check the tilt and angle solar radiations is required and maintained. This technology also proves to be environment friendly as it reduces greenhouse gas emissions and reduces the growth of algae. However, underwater biodiversity can be affected and further studies need to be conducted to assess this aspect. Monetarily, implementation and maintenance of FPV systems is less costly as compared to overland PV systems. Furthermore, the effect of saltwater on PV technology must be taken into account while designing such technologies. The integration of GIS-based techniques and remote sensing can also help in improving and determining the potential of such technologies. However, FPV technology is still a new type of power generation technology; therefore, there is still a need to work in this area to benefit in full.

Acknowledgements The research was supported by the USAID PEER program, Grant Award Number = AID-OAA-A-11-00012. We appreciate the efforts of all researchers who have worked diligently in this review paper.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

References

Bahaidarah H, Subhan A, Gandhidasan P, Rehman S (2013) Performance evaluation of a PV (photo voltaic) module by back surface water cooling for hot climatic conditions. Energy 59:445–453

Baskar D (2014) Efficiency improvement on photovoltaic water pumping system by automatic water spraying over photovoltaic cells. Middle-East J Sci Res 19(8): 1127–1131. ISSN 1990-9233

Brandon S (2017) World Economic Forum. China just switched on the world's largest floating solar power plant. https://www.weforum.org/agenda/2017/06/china-worlds-largest-floating-solar-power/. Accessed 4 Sept 2017

Choi YK (2014) A study on power generation analysis of floating PV system considering environmental impact. Int J Softw Eng Appl 8(1):75–84

Choi YK, Lee NH, Kim KJ (2013) Empirical research on the efficiency of Floating PV systems compared with Overland PV Systems. CES-CUBE2013, Guam, USA

Dash PK, Gupta NC (2015) Effect of temperature on power output from different commercially available photovoltaic modules. PK Dash Int J Eng Res Appl 5(1): 148–15, Part 1

Dubey S, Sarvaiya JN, Seshadri B (2013) Temperature dependent photovoltaic (PV) efficiency and its effect on pv production in the World a review. Energy Proc 33:311–332

Ferrer-Gisbert C, Ferrán-Gozálvez JJ, Redón-Santafé M, Ferrer-Gisbert P, Sánchez-Romero FJ, Torregrosa-Soler JB (2013) A new photo voltaic floating cover system for water reservoirs. Renew Energy 60:63–70

Fesharaki V, Jafari DM, Jafari FJ (2011) The effect of temperature on photovoltaic cell efficiency. In: Proceedings of the 1st international conference on emerging trends in energy conservation—ETEC Tehran, Tehran, Iran, 20–21 Nov 2011

Gair Kai Xiang Melvin (2014/2015) Experimental study of the effect of floating solar panels on reducing evaporation in Singapore reservoirs. https://cpb-us-w2.wpmucdn.com/blog.nus.edu.sg/dist/b/4438/files/2015/04/FYP-Final-report-14ijhop.pdf

Gotmare JA, Prayagi SV (2014) Enhancing the performance of photovoltaic panels by stationary cooling. Int J Sci Eng Technol 2(7):1465–1468

Gozálvez JJF, Gisbert PSF, Gisbert CMF, Santafé MR, Soler JBT, Puig EP (2012) Covering reservoirs with a system of floating solar panels: technical and financial analysis. In: 16th international conference on project engineering, Valencia, 11–13 July 2012, pp 177–187

Grand View Research 2003 Floating solar panels market size to reach USD 2.70 billion by 2025. http://www.grandviewresearch.com/press-release/global-floating-solar-panels-market. Accessed 6 Oct 2017

Ho CJ, Chou WL, Lai CM (2015) Thermal and electrical performance of a water-surface floating PV integrated with a water-saturated MEPCM layer. Energy Convers Manag 89:862–872

https://cpb-us-w2.wpmucdn.com/blog.nus.edu.sg/dist/b/4438/files/2015/04/FYP-Final-report-14ijhop.pdf

http://www.iwmi.cgiar.org/research/sustainable-growth/governance-and-gender/indus-basin-knowledge-forum/

Kim S, Yoon S, Choi W (2017) Design and construction of 1 MW class floating PV generation structural system using FRP members. Energies 10:1–14

Lee YG, Joo HJ, Yoon SJ (2014) Design and installation of floating type photo voltaic energy generation system using FRP members. Sol Energy 108:13–27

Li L, Chen X, Tol C, Luo G, Su Z (2014) Growing season net ecosystem CO_2 exchange of two desert ecosystems with alkaline soils in Kazakhstan. Ecol Evol 4(1):14–26

Liu L, Wang Q, Lin H, Li H, Sun Q (2017) Power generation efficiency and prospects of floating photo voltaic systems. Energy Proc 105:1136–1142

Lu HL, Ku CR, Chang YH (2015) Water quality improvement with artificial floating islands. Ecol Eng 74:371–375

Majid ZAA, Ruslan MH, Sopian K, Othman MY, Azmi MSM (2014) Study on performance of 80 watt floating photo voltaic panel. J Mech Eng Sci 7(1):1150–1156

Mellit A, Sağlam S, Kalogirou SA (2013) Artificial neural network-based model for estimating the produced power of a photo voltaic module. Renew Energy 60:71–78

Nazififard M, Taheri SM, Nazififardarani K (2017) Novel floating photo voltaic cover systems generating electricity and prevent evaporative losses for agriculture industry in Iran. The third international energy management and technology conference, Shahid Beheshti University, Tehran, 28–29 Feb 2017, pp 1–5

Oshima H, Karasawa K, Nakamura K (2001) Water purification experiment by artificial floating Island. Proc JSWE 35:146

Rosa-Clot M, Rosa-Clot P, Tina GM, Scandura PF (2010) Submerged photo voltaic solar panel: SP2. Renew Energy 35(8):1862–1865

Sahu A, Yadav N, Sudhakar K (2016) Floating photo voltaic power plant: a review. Renew Sustain Energy Rev 66:815–824

Santafé MR, Soler JBT, Romero FJS, Gisbert PSF, Gozálvez JJF, Gisbert CMF (2014) Theoretical and experimental analysis of a floating photo voltaic cover for water irrigation reservoirs. Energy 67:246–255

Sengupta D (2017) NTPC installs India's largest floating Solar PV Plant in Kerala. https://economictimes.indiatimes.com/industry/energy/power/ntpc-installs-indias-largest-floating-solar-pv-plant-in-kerala/articleshow/57577004.cms. Accessed 29 Sept 2017

Sharma P, Muni B, Sen D (2015) Design parameters of 10 KW floating solar power plant. In: International advanced research journal in science, engineering and technology (IARJSET), National Conference on Renewable Energy and Environment (NCREE-2015), vol 2

Shetty VJ, Kulkarni K (2014) Estimation of cost analysis for 500 kW grid connected solar photovoltaic plant: a case study. Int J Curr Eng Technol 4(1):1859–1861

Smyth M, Russell J, Milanowski T (2011) Solar energy in the winemaking industry. Springer, London

Song J, Choi Y (2016) Analysis of the potential for use of floating photo voltaic systems on mine pit lakes: case study at the ssangyong open-pit limestone mine in Korea. Energies 9(2):102

Sorg A, Mosello B, Shalpykova G, Allan A, Clarvis MH, Stoffel M (2014) Coping with changing water resources: the case of the Syr Darya river basin in Central Asia. Environ Sci Policy 43:68–77

Syahriman M, Azmia M, Othmana M, Yusof H, Ruslanb M, Hafidz H, Sopianb K, Azran AMZ (2013) Study on electrical power output of floating photovoltaic and conventional photovoltaic. AIP Conf Proc 1571:95. https://doi.org/10.1063/1.4858636

Teixeira LE, Caux J, Beluco A, Bertoldo I, Louzada JAS, Eifler RC (2015) Feasibility study of a hydro PV hybrid system operating at a dam for water supply in Southern Brazil. J Power Energy Eng 3(09):70

Tina GM, Rosa-Clot M, Rosa-Clot P (2011) Electrical behavior and optimization of panels and reflector of a photovoltaic floating plant. In: Proceedings of the 26th European photovoltaic solar energy conference and exhibition (EU PVSEC'11), pp 4371–4375

Trapani K, Millar DL (2013) Proposing offshore photo voltaic (PV) technology to the energy mix of the Maltese islands. Energy Convers Manag 67:18–26

Trapani K, Millar DL (2014) The thin film flexible floating PV (T3F-PV) array: the concept and development of the prototype. Renew Energy 71:43–50

Trapani K, Redón Santafé M (2015) A review of floating photo voltaic installations: 2007–2013. Prog Photo Volta Res Appl 23(4):524–532

Trapani K, Millar DL, Smith HC (2013) Novel offshore application of photo voltaics in comparison to conventional marine renewable energy technologies. Renew Energy 50:879–888

Tsoutsos T, Frantzeskaki N, Gekas V (2005) Environmental impacts from the solar energy technologies. Energy Policy 33:289–296

Ueda Y, Sakurai T, Tatebe S, Itoh A, Kurokawa K (2008) Performance analysis of PV systems on the water. In: 23rd European photo voltaic solar energy conference, Valencia, Spain

Vick BD, Clark RN (2009) Determining the optimum solar water pumping system for domestic use, livestock watering or irrigation. In: American solar energy society solar conference, p 8. http://www.cprl.ars.usda.gov

Vladan D, Zeljko D (2017) Analysis of the potential for use of floating PV power plant on the Skadar Lake for electricity supply of aluminium plant in Montenegro. Energies 10:01505

Winarso PA (2017) Indonesia solar power study using secondary data. J Climatol Weather Forecast 5:191

Woody T (19 April, 2011). Solar on the water. Retrieved from The New York Times. http://www.nytimes.com/2011/04/20/business/energyenvironment/20float.html?_r=0