

A REVIEW ON LIQUID SOLAR ARRAY SYSTEM

Siddhi S. Shinde¹, Dr. S.L. Nalbalwar², Dr. S.B. Deosarkar³

^{1,2,3}Department of Electronics and Telecommunication Engineering, Dr. Babasaheb Ambedkar Technological University, Lonere, Maharashtra India

Abstract: Power crisis problem and increasing demand of fossil fuels and its constant depletion is the major concern that shifts our focus to use renewable energy sources which are sustainable to environment and mainly unlimited source of energy. Out of the some renewable energy sources solar energy is excellent alternative to use as it is not area specific. Most of solar project of government is in hot and dry region or higher radiation region which affects the efficiency of solar panel. Besides its all advantages land acquisition is the major problem associated with solar power plant installed on land which is solve by liquid solar array concept. Liquid solar array can be installed on any water bodies and it will raise the amount of generation by cooling effect of water. This paper reveals review regarding the liquid solar array plants installed on water bodies in the world.

Keywords: fossil fuels, renewable energy, land acquisition, solar projects, liquid solar array.

1. INTRODUCTION

One of the biggest problem in our country is power crisis. 65% of energy is generated with the help of coal, so percentage of coal consumption of industry is 70 percent out of total coal. Load shedding, daily shutdown affects the irrigation and industry production. So it is high time to explore renewable energy sources [1].

Now a days renewable energy sources are growing not just in India but all over the world. Solar energy is most abundant and promising alternative of energy as it is not area specific & mainly it is clean and efficient source. Solar energy is used to reduce green house gases so thus decrease green house effect [1]. Taking consideration of India which have good sunshine and seventh largest in the world by area wise. Solar energy is excellent solution to power crisis problem but problem associated with land mounted solar system is the requirement of land which is scarcely available and costly to get it. India proposes the generation of solar power from renewable energy sources up to 1.75 GW and 1 GW of solar PV power in next 10 years. The country is innovating as per the policies declared. As on date around 5000 MW has been commissioned in different parts of country, as per the Jawaharlal Nehru National Solar Mission [1]. To achieve the goal mentioned, the progress noted so far is not sufficient and requires hard effort by each state and state departments to make the country consuming green power in the world.

LSA, Liquid Solar Array is a PV concentrator which uses extremely light in weight plastic concentrators which float on water bodies, mounted on anchored rafts float on the surface of irrigation canals, water reservoirs, quarry lakes, and tailing ponds. Several systems exist in France, India, Japan, Korea, the United Kingdom and the United States.^[31-34]

These systems reduce the need of valuable land area, save drinking water that would otherwise be lost through evaporation, and show a higher efficiency of solar as the panels are kept at a cooler temperature than they would be on land [35]. It will reduces algae growth [11] Liquid solar array is also called as 'FLOTVOLTAIC' or 'FLOATING PV' or 'Floating Solar'.

2. LIQUID SOLAR ARRAY SYSTEM

Liquid solar array systems are photovoltaic systems that float on water bodies such as quarry lakes, irrigation canals, ponds. A small exist in France, India, Japan, South Korea, the United Kingdom, Singapore and the United States [4],[5],[6],[7],[8].

The cost of land is more expensive, and there are fewer rules and regulations for structures built on bodies of water not used for recreation. Unlike most land-based solar plants, floating arrays can be unobtrusive because they are hidden from public view. They achieve higher efficiencies than PV panels on land, because water cools the panels. The panels have a special coating to prevent rust or corrosion [9].

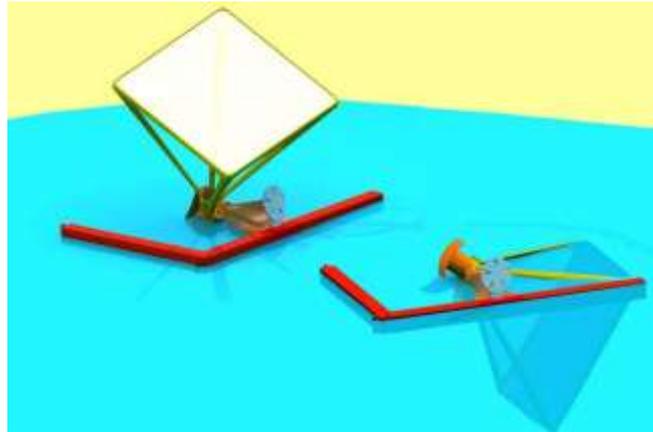


Figure1. System design of floating solar

3. OBJECTIVES OF SYSTEM

The Principal highlights are: (1) To improve efficiency and conductivity of panels; (2) To cool panel automatically, as it improves the efficiency; (3) To reduce the evaporation of water and To track sunlight with help of mirror assembly on panel; (4) To reduce the growth of algae and improve the water quality; (5) Nearby street light or irrigation system can be powered through the solar plant.

4. TYPES OF LIQUID SOLAR ARRAY SYSTEM

Types of liquid solar array systems are: (1) Liquid solar array System: In this system thin plastic focusing concentrator used to track the sun daily. Photovoltaic cells are fit in photovoltaic container that mounts near water to keep it cool and efficient. In bad weather lens is protected by rotating it to avoid damage in high winds Focusing concentrator lens rotates slowly to track the sunlight. Water becomes vital Structural component cooler protector [7]; (2) High Density Polyethylene floating platform: It is also used for mounting solar modules. It is easy to adapt any electrical configuration, installation & dismantle is also easy; (3) Novation’s solar islands: It is the platform which is compatible with technologies having 17m-100m diameter but yet they are not in operation; (4) Smart floating farm: It is the combination of solar energy and poly-culture implemented on megacities or in dense populated area with physical water access; (5) Individual floating module: They can be mounted in very high wind region & they are self regulatory.

5. COMPONENTS OF LIQUID SOLAR ARRAY SYSTEM

In real time project main components are composed of following: 1) Pontoon 2) Floats 3) Mooring system

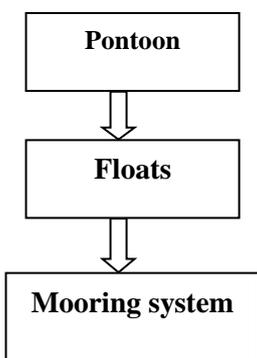


Figure2. Construction details of system

Pontoon is floating device which is made up of polymer. It has efficiency to float on water with heavy load placed on it. It can be mounted according to requirement. The structure is design to hold number of solar panels.

The floats used generally are of glass fibre reinforced plastic or High density polyethylene floats. They are connected in series form.

It has big role in keeping the panels in definite position. It is done with nylon wire slings. A mooring refers to any permanent structure to which a floating structure may be secured. A floating structure is secured to a mooring to forestall free movement of the floating structure on the water. An anchor mooring fixes a floating structure's position relative to a point on the bottom of a waterway without connecting the floating structure to shore.

Apart from that cabling is also important. Due to their outdoor usage, solar cables are specifically designed to be resistant against UV radiation and extremely high temperature fluctuations and are generally unaffected by the weather.

6. VARIOUS LIQUID SOLAR PV INSTAALLATION

The propriety nature of the technology somewhat limits the literature available on floating PV installations. System is categorised into 3 divisions according to size and power capacity.

6.1 SMALL SIZE POWER PLANTS: Those plants which have power capacity of up to 500 kWp are called small size power plants. Examples of these systems are Benacre , UK 100 kWp [35]; ,HApcheon, korea 100 kWp[44] ; Pommeraiie France 100 kWp[44]; Far Niente, CA USA, 175 kWp[43] ;Petra's Winery, Italy 200 kWp[44].

6.2 MEDIUM SIZE POWER PLANTS: Those plants which have power capacity of 500 kWp to 1500 kWp are called medium size power plants. Examples of these systems are Tokushima, Japan 632 kWp[37]; Wargrave, UK 201 kWp[37];Tenri city Japan 1125 kWp[37].

6.3 LARGE SIZE POWER PLANTS: Those plants which have power capacity of above 1500 kWp are called large size power plants. Examples of these systems are kasai city Japan 2313 kWp[37], Takaoka city Japan 2870 kWp[37],Walton thames UK 6338 kWp[35].

7. VARIOUS LIQUI SOLAR ARRAY PROJECTS

7.1 PROJECTS CARRIED UPTO 2010

The Aichi project was the first solar project known to have ever been constructed on water. It was realized by a group of researchers from the National Institute of Advanced Science and Technology in Japan[12], financed by the Japanese Ministry for the Environment[13]. Objective was to introduce the concept of floating PV systems as well as an analysis of the effect of module temperature on the PV sys-tem performance.

The Far Niente Wineries claimed to have the first significant, grid-connected solar system installed on water. The installation was managed by SPG Solar. Has in-built walkways between each row of panels to allow for ease of access for cleaning and maintenance .



Figure 3. Far Niente, Napa valley, California

A second vineyard in California, Gundlach Bundschu, also adopted the same approach as that constructed in Far Niente, The installation was also managed by SPG Solar. The difference between the two systems was the PV array size.

One of the largest projects called “Flotovoltaico”, in Imola Italy is 500kWp rated system situated in a lake done by effort of two local companies and made up of polyethylene cubes at the two sides of an array connected by struts for the panels to sit on [13],[17].

The next floating solar project was established in Italy in 2009 called the 'Lotus Project', its power capacity is 20kWp sit on top of an irrigation pond, with ducts below the panels for air-cooling. The array is tilted at an angle of 8° to use more panels in the given space and system is easily accessible.



Fig. 4. Lotus Project, Solarolo Italy [18]

The only project installed in 2010 was at a Winery in Suvereto, Italy. The difference between this system and any of the systems discussed is in a tracking mechanism which rotates the array according to the motion of the sun; also a reflector is installed in front of the panel to maximize on the amount of solar radiation received.

7.2 PROJECTS CARRIED BETWEEN (2010-2013):

Research group who investigated the Petra's Winery above (Section 3.1) also developed the following installation in a Lake in Pisa, Italy. This time, the panels were placed horizontally with reflectors forming a V-shape to maximize the amount of incoming radiation. The panels were in closer proximity to the water and observed increase of 60-70% in annual output compared to land based system [12],[19],[20].



Figure 5. system in pisa

A Ciel et Terre construct a floating PV system in a vacant and flooded quarry at Piolenc in France (Fig. 9). Metal struts used to hold the array together the floats are specifically made from High density polyethylene (HDPE) for particular resistance to UV and corrosion.

The next floating solar system seen in 2011 was installed at a water treatment plant in New Jersey, USA. It was designed with mooring structure which allows the array to rise and fall with the water level of the reservoir while still holding the array securely. In fact, this was the most challenging part of this project.

The last project presented in 2011 by the Korea Water Resources Corporation (K-Water), This 100 kWp solar system is situated in a South Korean dam called Hapcheon. The materials chosen for this structure contain enhanced water and moisture resistant [22],[23].

Scintec and Koinè Multimedia is built project in Cheogju, south Korea by Techwin was particularly challenging since the panels were to be placed in water which is subject to freezing in the winter months special attention was given while selecting each individual component to be able to withstand both the seasonal freezing and thawing cycles [24].



Fig. 6. 20kWp FTCC System in Cheogji, South Korea with can withstand water freezing temperatures

A research project, located in 'Bishan Park', Singapore developed by Phoenix Solar as a pilot project. The structure is moored to the lake bed from the 4 adjacent points [25].

Another project set up in 2013 on a small pond in Sudbury, Canada. New concept in this is solar cells are not mounted on a pontoon or float .The idea behind this is to make use of laminated thin film solar cells with air pockets to allow for a flexible floating concept [19]

The largest floating solar project known so far was Okegawa, Japan with a capacity of 1,157kWp, developed by Ciel et Terre,

The US Naval Research are looking into solar 25 cells capable of absorbing the small wavelength spectrum of visible light available at certain depths underwater [26]. Specific semiconductors (GaNP cells) have been used in such experiments. Silicon cells have analyzed less efficiently once they are placed more than a few centimetres below the water's surface [27].

7.3 PROJECTS CARRIED BETWEEN (2014-2017):

Born in France, the Hydrelio system is an innovative system to realize water based solar power generation. Hydrelio is a float module system developed by Shell Tail. The basic module consists of two floats made of high density polyethylene (HDPE)[29].

REC is showcasing its floating solar photovoltaic (PV) installation at a government site in West Java for the first time in Indonesia [28].Made of high density polyethylene (HDPE), they can be in-stalled safely on drinking water reservoirs and UV resistant.

Young-Kwan Choi *et al* has compared and analyzed empirical data of the generation efficiency of floating and land photovoltaic systems. Floating PV has shown greater generation efficiency by over 10% compared with the general PV systems installed overland [23].

Jinyoung Song and Yosoon have analyzed the potential of floating PV systems on a mine pit lake in an open pit mine in Korea. According to this research it have environmental and economic gains [30].

7.4 PROJECTS CARRIED 2017 ONWARDS:

According to the first market report on floating solar produced by world bank group and SERIES capacity is 1.1 gigawatts .

The shapoorji pallonji group a diversified company which is emerging as an upcoming solar pv developer in the Indian market, has won contract to develop India's first large floating solar power plant. This 50MW plant tendered in 2018 May.

The largest floating solar plant to date is 2MW one in Vishakhapatnam. Another is 500KWH plant built by kerala state by kerala state electricity board at banasura sagar dam.

Maharashtra government has finally come with a policy to build liquid solar array capacity of 1000MW of solar on ujjani dam in solapur district.

8. CONCLUSION

Liquid solar array is the new era in solar. The review presented in this paper shows the timeline of concepts and floating solar PV projects that have been established till date. These systems were either constructed for research purposes or for commercial use. All grid connected systems are kept using pontoons or floats or High density poly ethylene with panels rigidly connected to these floats.

REFERENCES

- [1] Armstrong, Robert (12 November 2014). "The Case for Solar Energy Parking Lots". Absolute Steel. Retrieved 15 November 2014.
- [2] "Photovoltaic power generation in the buildings. Building integrated photovoltaic-BIPV" (PDF). Bef-de.org. Retrieved 2011-06-20.
- [3] Elhodeiby, A.S.; Metwally, H.M.B; Farahat, M.A (March 2011). "Performance Analysis of 3.6 kW Rooftop Grid Connected Photovoltaic System in Egypt" (PDF). International Conference on Energy Systems and Technologies (IC-EST 2011): 151–157. Retrieved 2011-07-21.
- [4] "Kyocera, partners announce construction of the world's largest floating solar PV Plant in Hyogo prefecture, Japan". SolarServer.com. 4 September 2014.
- [5] "Running Out of Precious Land? Floating Solar PV Systems May Be a Solution". EnergyWorld.com. 7 November 2013.
- [6] "Vikram Solar commissions India's first floating PV plant". SolarServer.com. 13 January 2015.
- [7] "Sunflower Floating Solar Power Plant In Korea". CleanTechnica. 21 December 2014.
- [8] "Short Of Land, Singapore Opts For Floating Solar Power Systems". CleanTechnica. 5 May 2014.
- [9] Erica Goodemay, New Solar Plants Generate Floating Green Power, *New York Times*, 20 May 2016.
- [10] Maloney, Elbert S. Charles Frederic Chapman (1996). *Chapman Piloting, Seaman-ship & Small Boat Handling* (62 ed.). Hearst Marine Books. ISBN 978-0-688-14892-8.
- [11] Paritosh Sharma *et al* "Design Parameters of 10 kW Floating Solar Power Plant" International Advanced Research Journal in Science, Engineering and Technology (IARJSET) Vol. 2, Special Issue 1, May 2015.
- [12] K. Trapani, M. Redón Santafé, "A review of floating photovoltaic installations: 2007–2013". Prog. Photovoltaics Res. Appl. doi: 10.1002, 2014, pg2466
- [13] Y. Ueda, T. Sakurai, S. Tatebe, A. Itoh, K. Kurokawa, "Performance Analysis of PV System on the Water", Proceedings of the 23rd European Photovoltaic Solar Energy Conference, Valencia, Spain, 2008 Pgs. 2670-2673.
- [14] "Solar on Water", the New York Times, April 20th 2011.
- [15] Sustainable Practices (Online) <http://farniente.com/napa-wine-estate/sustainability/>
- [16] Sustainability for Gundlach Bundschu (Online) <http://www.gunbun.com/solar>
- [17] Struttare Per Impianti Fotovoltaici Galleggianti (Online) http://www.fotovoltaicogalleggiante.com/photovoltaic_floating_plants.html.
- [18] The First Floating Photovoltaic Plant <http://www.luceonline.it/web/en/ricerca/costruzione-del-primo-impianto-fotovoltaico-galleggiante-in-puglia/>
- [19] R.Cazzinga, M. Rosa-Clot, P. Rosa-Clot, G.M. Tina, " Floating Tracking Cooling Concentrating System", Proceedings of the 26th European Photovoltaic Solar Energy Conference, Hamburg, Germany, 2012.
- [20] G.M. Tina, M. Rosa-Clot, P. Rosa-Clot, "Electrical behaviour and optimization of panels and reflector of a photovoltaic floating plant", Proceedings of the 26th European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC'11) 2011. 4371–4375.
- [21] Design, financing and operation of large-scale rooftop, ground-mount and floating solar PV systems (Online) <http://ciel-et-terre.net/english/realisations/detail/Piolenc---84/53/> [27-May-17, 11 AM].
- [22] K-Water Starts Construction of Floating Photovoltaic Power Systems at 31 Dams (Online) <https://energy.korea.com/archives/46350>.
- [23] Y. K. Choi, N. H. Lee and K. J. Kim, "Empirical Research on the efficiency of Floating PV systems compared with Overland PV Systems", CES-CUBE 2013, Guam, USA, (2013) July 19.
- [24] From Land to Water (Online) <http://www.pv-magazine.com/archive/articles/beitrag/>.
- [25] Floating PV in Singapore (Online) <http://www.greenbusiness.sg/2013/06/10/floating-pv-in-singapore-press->.

- [26] Submerging Solar: New Frontiers for Renewable Energy(Online)<http://www.ecomagination.com/submerging-solar-new-frontiers-for-renewable-energy>.
- [27] L. Mule' Stagno, "Floating Photovoltaics – Technological Issues, Cost and Practical Implications", Sustainable Energy 2014: The ISE Annual Conference.
- [28] Floating PV in Indonesia (Online) <http://www.recgroup.com/en/recs-floating-solar-installation-debuts-indonesia>.
- [29] Hydrelío system, Ciel & Terre France, www.cieletterre.net/ [27-May-17, 11 AM] .
- [30] Jinyoung Song and Yosoon Choi, "Analysis of the Potential for Use of Floating Photovoltaic Systems on Mine Pit Lakes: Case Study at the Ssangyong Open-Pit Limestone Mine in Korea", *Energies* 2016, 9, 102; doi:10.3390/en9020102
- [31] "Kyocera, partners announce construction of the world's largest floating solar PV Plant in Hyogo prefecture, Japan" SolarServer.com. 4 September 2014.
- [32] "Running Out of Precious Land? Floating Solar PV Systems May Be a Solution". EnergyWorld.com. 7 November 2013.
- [33] "Vikram Solar commissions India's first floating PV plant". SolarServer.com. 13 January 2015. Archived from the original on 2 March 2015
- [34] "Sunflower Floating Solar Power Plant in Korea". [CleanTechnica](http://CleanTechnica.com). 21 December 2014 *"Napa Winery Pioneers Solar Floatovoltaics". Forbes. 18 April 2012. Re-trieved 31 May 2013*
- [35] http://www.cieletterre.net/essential_grid_category/europe/ [14-Feb-17, 3 PM]
- [36] <http://www.solarserver.com/solarmagazine/solarnews/topsolarnews.html> [9-Feb-17, 3 PM]
- [37] http://www.cieletterre.net/essential_grid_category/floating-solar-system/ [26-May-17, 5 PM].
- [38] <https://cleantechnica.com/2014/12/21/sunflowerfloatingsolarpowerplantkorea/> [9-Feb-17, 4 PM] .
- [39] http://www.cieletterre.net/essential_grid_category/south-asia/ [27-May-17, 11 AM].
- [40] <http://www.energymatters.com.au/renewable-news/em3880/> [27-May-17, 11 AM] .
- [41] <http://www.thehindu.com/news/national/kerala/ksebtogoforsolarpowerplantonconcretefloaters/article7968556.ece> [19-Aug-16, 6 PM] .
- [42] <http://indianexpress.com/article/cities/chandigarh/chandigarhgetsfloatingspvpowerplant2918830/> [19-Aug-16, 6 PM]
- [43] <http://inhabitat.com/floatovoltaicsfarnientewynerys-floating-solarpower/floatovoltaicsfarnientewinery-solar-power-napa-valley-solar-power-floating-solar-panels-irrigation-pond-solar-pontoon-solar-solar-power-solar-energy-renewable-energy-photovoltaic/> [27-May-17, 11 AM]
- [44] <http://www.cieletterre.us/clients-references/>[27-May-17, 11 AM]