Performance Evaluation of a Floating Photovoltaic System in Saudi Arabia

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Summary

This study reports the potential of Floating Photovoltaic (FPV) systems in the Saudi Arabian environment. As the temperature of PV module increases, its efficiency drops depending on its rated temperature coefficient. The solar panel back surface is mostly affected by the temperature due to heat encapsulation. The temperature difference between the ground mounted and the FPV systems reached a maximum of 16.15 ºC during May. Even a moderate reduction in PV module temperature can play an important role in large scale solar power plants over a long period of time. This demonstration set up includes the design of an FPV system of 171.9 kWp capacity installed on the water surface a lake around the centre of KFUPM campus.

Keywords

Floating Photovoltaic (FPV) Plant, PV efficiency, Back Surface Temperature, Energy Output

Introduction

To reach the CO_2 emission target set by the VISION 2030 of the Kingdom of Saudi Arabia, the share of renewables in its energy mix has to be increased significantly. Towards the set goal, the proposed system will be an excellent option for power generation at places having bounded water bodies. In the proposed modern "LINE" cities in the RED SEA areas; such systems will be extremely useful to generate power efficiently and at the same time conserve water by minimizing the surface water evaporation losses. As of 2014, there were 482 dams in the country with total capacities of 2.08 Billion cubic meters of water. Some of these dams are located in Al-Baha (22), Asir (16), Jazan (2), Madina (5), Mecca (11), Najran (1), Riyadh (6) and many others. Such dams and water reservoirs can be utilized to deploy the floating PV systems and can generate power for the local communities. As an example, Baysh dam is a gravity dam on Wadi Baysh about 35 km northeast of Baysh in Gizan, as shown in Figure 1. Its catchment area is 4,843 km^2 and volume capacity is 675,000 m^3.

Fig. 1. The Baysh dam near Gizan

Fig. 2. A 10 KW FPV plant [7]

FPV is relatively a new concept, with few commercial deployments. However, proof of concept type of implementations is available around the world. To conserve the valuable land & water, installing Solar PV system on water bodies like oceans, lakes, lagoons, reservoirs, irrigation ponds, waste water treatment plants, wineries, fish farms, dams, and canals can be an attractive option [1]. Floating type solar photovoltaic panels have numerous advantages compared to ground based solar PV plants, including fewer obstacles to block sunlight, convenient, energy efficiency, and higher power generation efficiency owing to its lower temperature underneath the panels. Photovoltaic technology is the most common, effective, sustainable, and eco-friendly for direct power generation in the field of renewable energy and does not involve any moving part [2–6]. Some of the existing proof of concept implementations of FPV plants in different regions of the globe are listed in Table 1. Two of such proof of concept FPV plant are shown in Figures 2 and 3 [7-8]. Generally, FPV systems are are similar to the regular ground or roof mounted PV ones, with the exception that the panels and the inverters are mounted on a floating structure, called floats. The DC current generated by PV modules is directed towards combiner boxes and converted to AC current by inverters. Generally, in small plants which are very close to shore, inverters can be placed on land. Some extra arrangements are necessary for floating PV compared to regular PV systems.

Fig. 3. A proof of concept implementation of a 500 KW FPV plant at Wayanad in Kerala [8]

Table 1. List of some of the existing FPV plants around the globe

S. No	Capacity (kW)	Location
1	175	Napa valley's Far Niente Wineries, California, USA
2	2,300	Hyogo prefecture, western Japan
3	4,000	Jamestown, South Australia
4	30	Gundlach bunshu wineries, California, USA
5	500	Bubano, Italy
6	300	Agost, Spain
7	14	Piolenc, France
8	20	Cheongju, South Korea
9	5	Bishan Park, Singapore
10	0.5	Sadbury, Canada
11	200	Sheeplands farm, Barkshire, UK
12	50,000	West Kallada, Kerala India

System Description (Figure 4)

- **Pontoon/floats**
- **Mooring and anchoring system**
- **Waterproof cables and connectors**
- **Lightning Protection System**
- **PV Panels**
- **Combiner box**
- **Central inverter and Transformer**

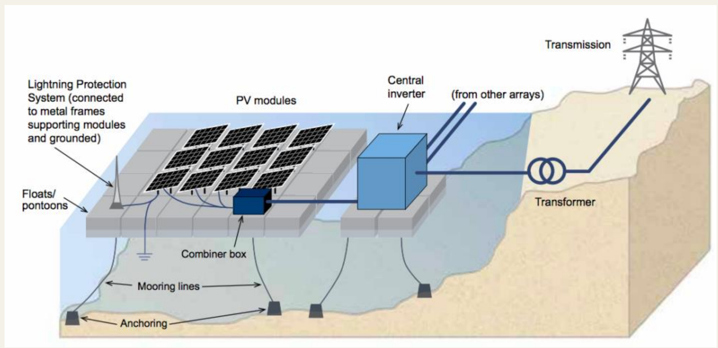
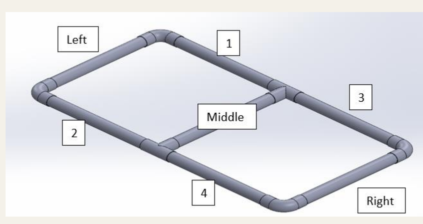
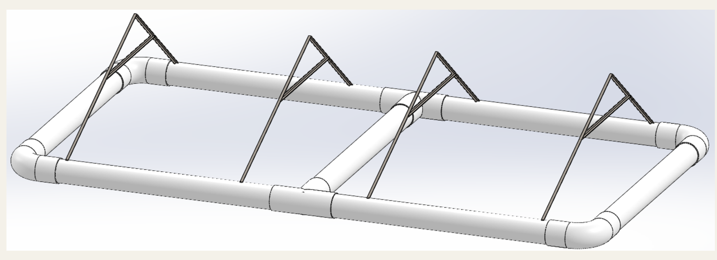


Fig. 4. Schematics of an FPV power plant [8].

Fig. 5. Experimental set up of the FPV assembled in-house





Results and Discussion

After monitoring the FPV system, it was observed that the highest temperature was recorded on the back side of the panel, as shown in the graph below (Figure 6).

Fig. 6. Temperature data of the floating PV system.

To compare with ground based PV panel temperature, another panel was installed on ground in the vicinity of the floating PV system. The sensor was installed on the back surface of the ground mounted panel. Figure 7 compares the temperature of the two sensors, ground and FPV mounted.

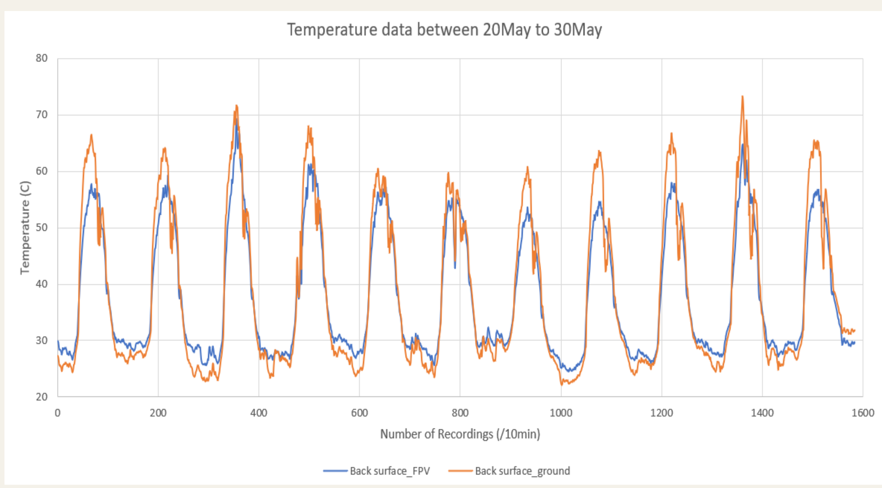


Fig. 7. Temperature difference between FPV and ground mounted system.

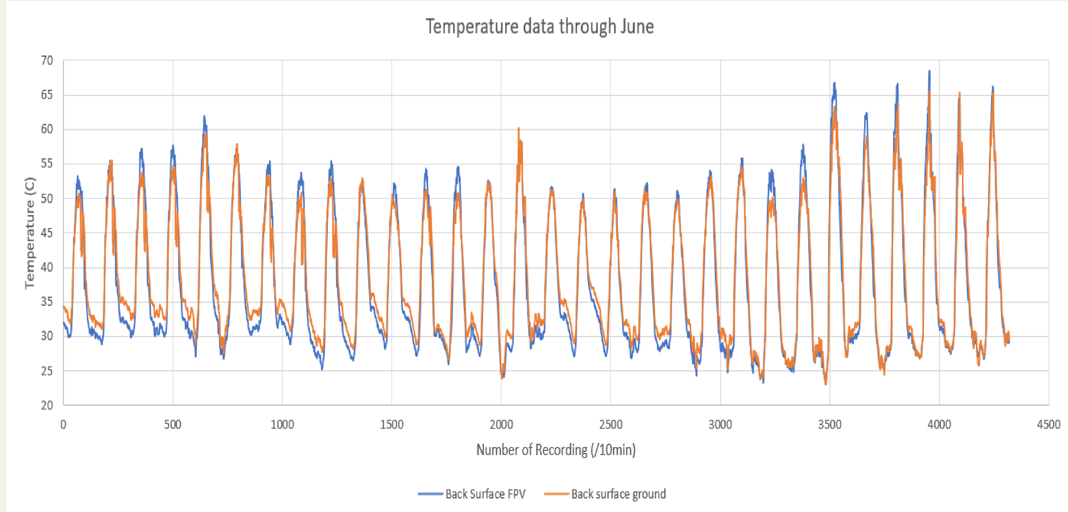


Fig. 8. Temperature data through June.

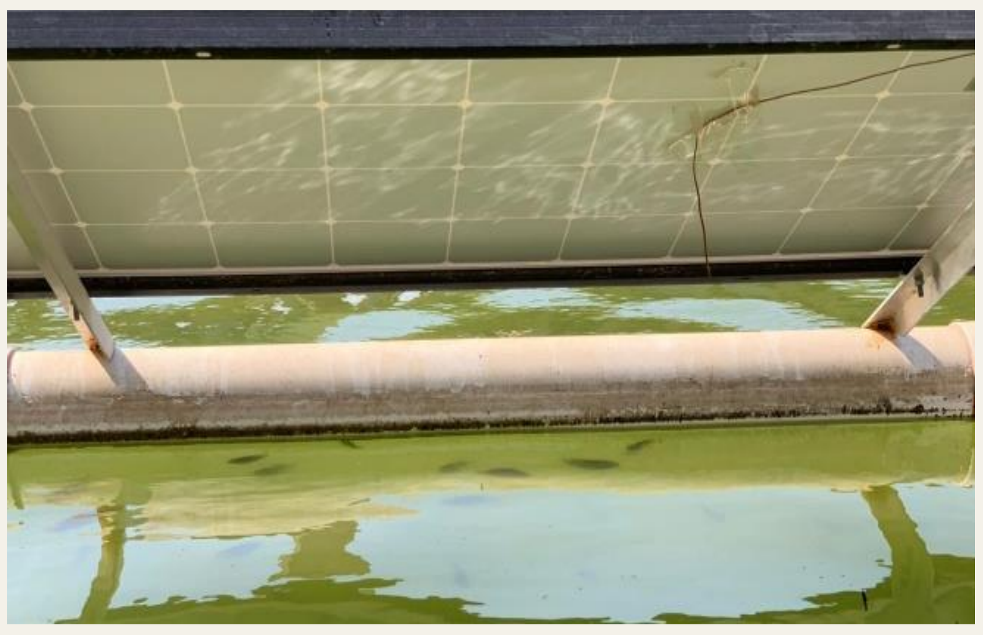


Fig. 9. Sun light reflection on the back surface of the solar panel.

Cell type	**Mono crystalline silicon 156mm X 156mm (36 cells)**
Max power	150 W
Max power voltage V_{mp}	18.62 V
Max power current I_{mp}	8.06 Amp
Open circuit voltage V_{OC}	22.33 V
Short circuit current I_{sc}	8.53 Amp
Cell efficiency	17.96
Temperature coefficient	-0.30% / C
Dimensions	(1480 X 670 X 40) mm
Weight	13 Kg

Table 2. Technical specifications of the PV panel

Conclusions

In the present scope of the work, a total capacity of 300 W floating photovoltaic system is designed, sized, assembled, and monitored in the months of July and August.
The performance of both the systems FPV and ground bases is monitored by sensors installed on the back and front surfaces of the PV panels.
Relatively lower temperatures are observed on the back surface of the panels of the FPV system compared to that installed on the ground surface.
The temperature difference is found to be small between the two systems which could be accounted for a shallow depth of the water (only 70 cm).
Such systems are expected to be more effective where the water depths are more than 2 m.
The present system, though exhibited small temperature difference, might increase the power output from the FPV system.
It is recommended to test such a system in water bodies with deeper water.
For the experimental setup, different tilt angles should be tried to find the optimum tilt that would provide the best performance for FPV systems. Beside that, there should be a continuous monitoring for at least a year to observe the annual trend and the advantage of FPV over ground mounted system in the Saudi Arabian region.

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