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Techno-Financial Analysis of Floating Solar Photovoltaic System in Nepal

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Abstract

Floating Solar photovoltaic system is one of the fast growing PV technology in Asia. This system helps in cooling down of solar PV modules which ultimately increases the efficiency and energy production of the solar PV system. This research includes experimental technical and financial analysis of a floating solar PV system and its comparison with the land based Solar PV system. A solar panel was installed on the pond behind center of energy studies (CES) which is inside Pulchowk Campus. Another Solar panel of same capacity was installed on land on the same site. For their comparison, measurements of temperature, open circuit voltage and short circuit current were taken for 10 days. The result shows increase in the power of floating solar PV system by 11-12% in comparison to the land based solar PV system. The irradiance absorbed by floating solar PV system was nearly 1.5% more than the land based solar system. Financial analysis of a 1MW floating solar power plant was done on the basis of the obtained data.

Keywords

Floating solar photovoltaic system (FSPV), PV cell efficiency, Solar Irradiance, Techno-financial analysis

1. Introduction

Solar energy is currently one of the most promising renewable technologies. Solar energy is the most abundant resource on earth, encouraging the use of technological solutions to efficiently convert this energy. Among solar energy technologies, the fastest growing solution is solar energy. In 2020, the world's cumulative solar PV capacity was 773.2 GW, with 138 GW of new PV capacity installed in the same year.PVES costs have fallen 59% in the industry over the past decade[1]. We escalated manufacturing and gradually improved our technology with new materials and technology for power electronics[2].
The construction of a large-scale photovoltaic system first requires sufficient land, and many countries are facing land shortages. However, in a sustainable economy, soil plays an important role in agriculture and economic life. Similarly, the implementation of solar power projects often faces land issues such as land acquisition and substation capacity and availability. Later, projects are planned in large remote areas, increasing the investment cost of power transportation. On the other hand, the performance of photovoltaic systems is strongly affected by temperature. As the temperature rises, the absorption of the PV module increases, the temperature of the module rises, and the performance of the PV system decreases[3]. Since then, there has been great interest in controlling such temperature changes. In fact, improving the efficiency of solar energy is the key to making these technologies more profitable.
To overcome these two main problems, a new concept has been developed that proposes installing photovoltaic systems underwater thanks to floating structures. A niche market a few years ago, the floating solar market has now reached hundreds of megawatt installations worldwide, with most installations in Asia being connected. Floating solar applications are of particular interest to countries with irregular seabeds such as: B. Mountainous or coastal areas with very high population densities and high activity densities. In addition, solar modules installed on floating structures are affected by natural convection due to the low water temperature. High water availability is a very useful parameter when considering complex cooling strategies. Floating solar applications therefore have great potential in hot and dry countries where the operating temperature needs to be adjusted to optimize system performance[4].

Interest in floating PV is early The weighted variation PV REC value, which was 1.0 until 2012, has increased since it became effective. In 2013, it was 1.5, putting it on par with BIPV (Building Integrated Photovoltaic System). this is, The surface of the water produces more power than the ground, so it is an efficient way to generate energy. production can be achieved.[5].FPV, on the other hand, benefits from natural cooling from water puddles, making it more energy efficient compared to ground or roof-based PV systems.[6]

The trends indicated by the project timeline are Establishment of floating solar power generation technology and development on a scale of several megawatts Floating solar power system. Interest and ongoing negotiations, especially in Asia, show that we are there Watch for larger facilities to emerge in the near future. Floating solar power generation system A leader in renewable energy technology plants[7].

The FPV system reduces water evaporation by about 17% for partial coverage and about 28% for full coverage.[8].

The main objective of the thesis was to perform the techno-economic Analysis of Floating Solar Photovoltaic system in Nepal. The specific objectives were to analyze the effects of change in tilt angle and manual tracking system on the FSPV system

2. Methodology

The foremost step in conducting a project is its literature review. As a part of the literature review, the study about the different FSPV system was done. For literature review, related journals, research articles, textbooks was consulted. project period.

The pond behind Center for Energy Studies (CES) wass used as a site for the experiment. The pond is about 1.5 m deep. Due to the presence of trees and CES building, there is shading problem but on a sunny day, enough sunlight falls on the pond.

The data were taken for two weeks. The parameters measured were temperature, open circuit voltage and short circuit current. There was unavailability of pyranometer to measure the solar irradiance at the experimental site. The solar irradiance data was provided by Department of Hydrology and Meteorology, Ministry of Energy, Water Resources and Irrigation.

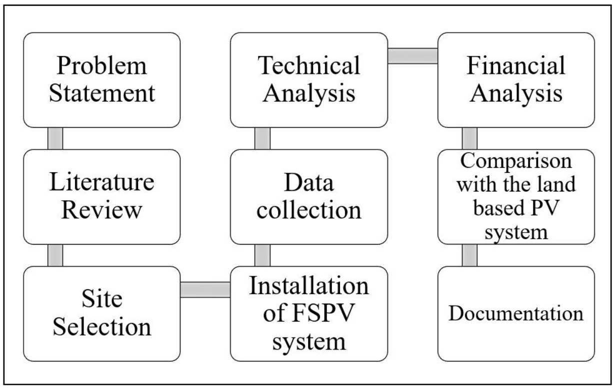

Figure 1: Methodology

First of all, a 3D model was made for the floating structure. Then, it was fabricated and installed at the site. A solar panel of same capacity was installed nearby mounted on the land for comparison. The floating structure of the FSPV system is designed as shown in the figure. It consists of a frame mounting structure which is made of L-shaped angular iron.

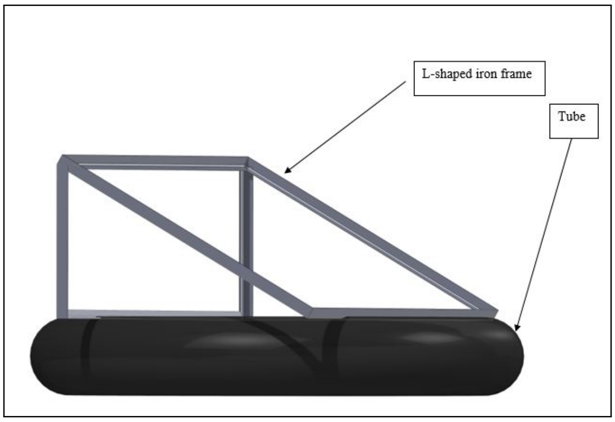

Figure 2: 3D model of the floating structure

The mounting structure floats on a tube of a truck tyre.A monocrystalline solar panel of rated power 120 watts is used. It has 36 Solar cells. The specifications of the solar module are as follows:

Area:0.98901 sq. meter

Rated Power: 120 Watts

Open circuit voltage: 21 Volts

Short circuit Current: 7.7 Amperes

(The above values are rated at 1000Watt/m^2 solar irradiance and 25° cell temperature.)

3. Results and Discussion

Two solar panels of same capacity were installed at the site. One was mounted on the floating structure in water and other was mounted on land. The tilt angle was fixed at 30°for the first five days for both systems for comparison. The measurements were taken for two weeks and the results are as follows:

3.1 Temperature difference

We can clearly observe in the graph below that the temperature outside FSPV system is less than that of the land based solar PV system. The temperature drop helps in increasing the efficiency of the Solar PV cells.

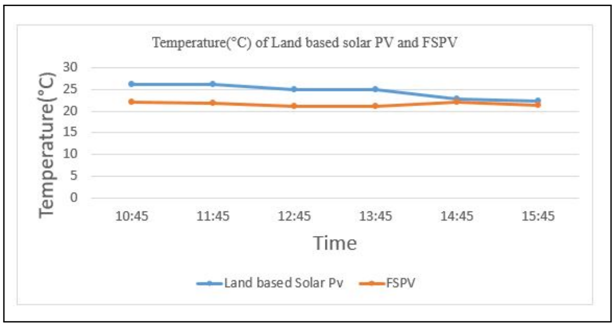

Figure 3: Temperature Difference

3.2 Power Comparison

The values of open circuit voltage and short circuit current were taken to calculate the power of both the system for the comparison. We can see in the graph below that the power produced by FSPV system is mostly higher than tha land based solar PV system.

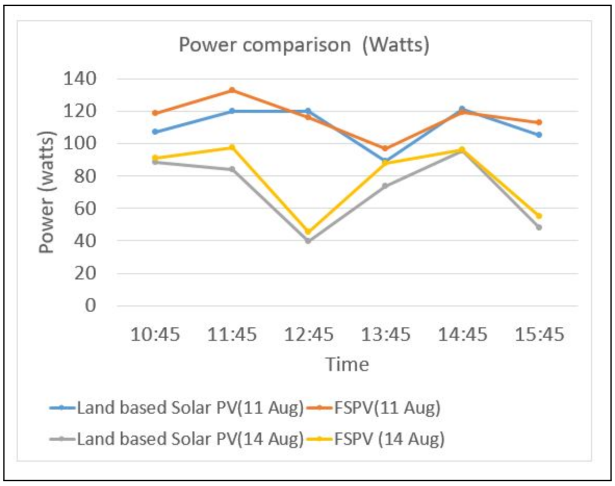

Figure 4: Power comparison

The graph shows the power difference between land-based and FSPV system of two days. On both days, power produced by FSPV system was more than the land based system. On the average, FSPV system produced 12% more power than land based PV system.

3.3 Percentage of irradiance used comparison

The percentage of irradiace used by both the solar panels to convert into electricity was calculated by using the power and area of the solar panel. It was observed that the irradiance used by solar panel of FSPV system was more than the land based system.

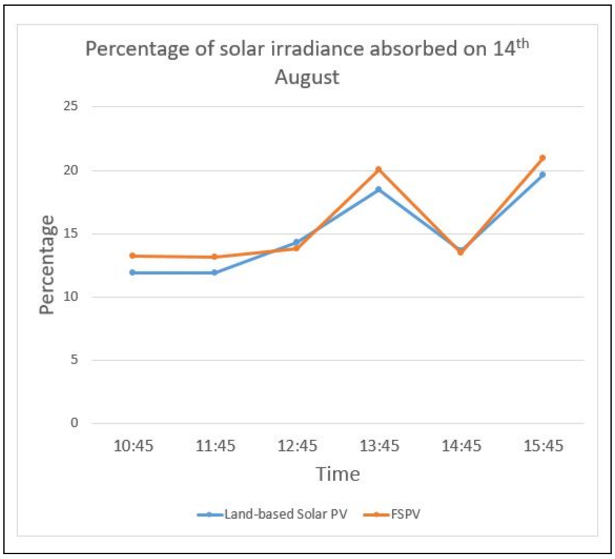

Figure 5: Irradiance used

In the above graph, the irradiance absorbed by both land based PV system and FSPV system are shown. The irradiance absorbed by FSPV system that is converted into electrical energy is nearly 1.5% more than that of FSPV system.

3.4 Effect of change in tilt angle

The tilt angle was changed from 30°to 25°,26°,27°and 28°on 18,19,20 and 21 of August respectively and the effect can be seen in the table below.

Table 1: Tilt angle = 25°

Time	Radiation (Watt/m^2)	Power (watts)	%Irradiance used
10:45	863.2	110.23	12.91
11:45	990.2	115.69	11.81
12:45	775.4	102.12	13.31
13:45	790.7	110.23	14.09
14:45	592.3	75.49	12.89
15:45	432.3	47.26	11.05

At tilt angle 25°, the percentage of irradiance converted to electrical output was in the range 11-14%.

Table 2: Tilt angle = 26°

Time	Radiation (Watt/m^2)	Power (watts)	%Irradiance used
10:45	818.2	92.08	11.37
11:45	978.7	97.81	10.10
12:45	714.7	79.26	11.21
13:45	845.7	79.89	9.55
14:45	728.3	79.68	11.06
15:45	273.1	32.30	11.96

At tilt angle 26°, the percentage of irradiance converted to electrical output was in the range 9-11%.

Table 3: Tilt angle = 27°

Time	Radiation (Watt/m^2)	Power (watts)	%Irradiance used
10:45	825.2	121.76	14.91
11:45	1006.9	115.69	11.62
12:45	850.8	73.38	8.72
13:45	691.3	44.32	6.48
14:45	609.4	41.31	6.85
15:45	215.6	11.62	5.45

At tilt angle 27°, the percentage of irradiance converted to electrical output was in the range 5-15%. The weather was also very inconsistent which maybe a major factor in the wide range.

Table 4: Tilt angle = 28°

Time	Radiation (Watt/m^2)	Power (watts)	%Irradiance used
10:45	947.5	127.81	13.64
11:45	1059.3	124.76	11.91
12:45	1088.5	131.77	12.24
13:45	879.3	121.09	13.92
14:45	913.8	125.77	13.92
15:45	789.6	113	14.47

At tilt angle 28°, the percentage of irradiance converted to electrical output was in the range 11-14.5%.
From the above tables, we can observe that the change in tilt angle from 25° to 28° has little effect on the performance of the FSPV system.

3.5 Effect of manual tracking system

The azimuth angle of the FSPV system was manually changed according to the position of the sun to analyze the effect of the manual tracking system. The

Table 5: Date:22 August 2022

Time	Radiation (Watt/m^2)	Power (watts)	Azimuth angle
10:45	925.9	118.43	125
11:45	1019.6	130.21	160
12:45	884	125.33	210
13:45	1045.8	129.88	240
14:45	893.4	127.38	255
15:45	759	117.91	265

weather was sunny 22August day and the tracking system led to consistent power output.

Table 6: Date:23 August 2022

Time	Radiation (Watt/m^2)	Power (watts)	Azimuth angle
10:45	881.2	117.26	125
11:45	1040.8	114.69	160
12:45	906.7	116.25	210
13:45	497.3	69.78	240
14:45	199	-	255
15:45	492	-	265

There was rain on 23 August on the later part of the day, so data could not be taken. But the power output was consistent when the sun was out.

Table 7: Date:24 August 2022

Time	Radiation (Watt/m^2)	Power (watts)	Azimuth angle
10:45	885.9	116.45	125
11:45	948.3	124.19	160
12:45	724.2	115.19	210
13:45	910.8	133.29	240
14:45	715.4	115.20	255

From the above tables, we can observe that by introducing tracking system, the performance of the FSPV system can be made consistent. Although it will be difficult to automate the automatic tracking system. The power output of FSPV was enhanced by 18% as compared to the on-ground PV system [9]. But in this experimental study, it wae enhanced by 11-12%.

3.6 Financial analysis of the FSPV system

Floating solar photovoltaic system are installed on various types of natural and artificial water bodies.The capital cost of FSPV system are higher tan conventional land based solar Pv system as FSPV system cost depends on the site specifics, the floating structure and anchoring solution[10]. The key cost items for FSPV system are site staging, floats, anchoring and mooring and other electrical components. For the financial analysis, a FSPV system of 1MW was assumed. Following assumptions are used in the model:
Total installed capacity : 1 MW
Project cost: US$1 million
Debt:Equity ratio: 70:30
DC capacity factor: 21.6%
Annual Output for Year 1 (MWh): 1,764
Degradation Factor: 0.60%
System lifetime: 25 years
Operation and Maintenance Cost (O& M): US$5/KW/year
OM Costs Escalator (%/yr): 2.00%
Inverter replacement time (in Years): 10
Debt Interest rate: 12.00% Debt period in years: 12
Discount Rate: 12.00%

Financial model reults Compared to land based solar PV system, FSPV systems are expensive as the cost of floating structure constitute of 50% of the total cost of project. As compared to existing benchmark project cost of US$0.6-0.8 million/MW, floating solar almost costs US$1-1.2 million/MW[11].The Internal Rate of Return is calculated to be 13.282% which is just above discount rate of 12%.The project NPV was calculated as US$136,899 and the B/C ratio is 1.02 which is above 1.

4. Conclusion

A solar panel was installed on the pond behind center of energy studies (CES) which is inside Pulchowk Campus. Another Solar panel of same capacity was installed on land on the same site. For their comparison, measurements of temperature, open circuit voltage and short circuit current were taken for 10 days. The result shows increase in the power of floating solar PV system by 11-12% in comparison to the land based solar PV system. The irradiance absorbed by floating solar PV system was nearly 1.5% more than the land based solar system.There was little effect on the performance of the FSPV system in changing the tilt angle from 25° to 28°. The power output of the FSPV system was consistent in introducing manual tracking system. Financial analysis of a 1MW floating solar power plant was done on the basis of the obtained data and it was compared to the existing land based solar PV system. The capital cost is comparatively high for the FSPV system.The Internal Rate of Return is calculated to be 13.282% which is just above discount rate of 12%.However, FSPV systems are promising in the photovoltaic sector due to their higher energy production compared to terrestrial PV systems. In general, there are several issues that hinder the development of PV systems in Nepal and also affect the growth of floating PV systems.

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References

[1] Statista. Cumulative installed solar pv capacity worldwide from 2000 to 2020.

[2] R Precup, Tariq Kamal, and Syed Zulqadar Hassan. Solar photovoltaic power plants. *Singapur: Springer*, 2019.

[3] E Radziemska. The effect of temperature on the power drop in crystalline silicon solar cells. *Renewable energy*, 28(1):1–12, 2003.

[4] Antoine Dizier. Techno-economic analysis of floating pv solar power plants using active cooling technique: A case study for taiwan, 2018.

[5] Young-Kwan Choi, Nam-Hyung Lee, An-Kyu Lee, and Kern-Joong Kim. A study on major design elements of tracking-type floating photovoltaic systems. *International Journal of Smart Grid and Clean Energy*, 3(1):70–74, 2014.

[6] Raniero Cazzaniga and Marco Rosa-Clot. The booming of floating pv. *Solar Energy*, 219:3–10, 2021.

[7] Kim Trapani and Miguel Redón Santafé. A review of floating photovoltaic installations: 2007–2013. *Progress in Photovoltaics: Research and Applications*, 23(4):524–532, 2015.

[8] Hamza Nisar, Abdul Kashif Janjua, Hamza Hafeez, Nadia Shahzad, Adeel Waqas, et al. Thermal and electrical performance of solar floating pv system compared to on-ground pv system-an experimental investigation. *Solar Energy*, 241:231–247, 2022.

[9] G Srinivasa Murthy and Suryanarayana Gangolu. Fault detection in floating pv system using dc leakage current. *Control and Measurement Applications for Smart Grid: Select Proceedings of SGESC 2021*, 822:179, 2022.

[10] Vignesh Ramasamy and Robert Margolis. Floating photovoltaic system cost benchmark: Q1 2021 installations on artificial water bodies. Technical report, National Renewable Energy Lab.(NREL), Golden, CO (United States), 2021.

[11] Herman Zahid, Abdullah Altamimi, Syed Ali Abbas Kazmi, Zafar A Khan, and Abdulaziz Almutairi. Floating solar photovoltaic as virtual battery for reservoir based hydroelectric dams: A solar-hydro nexus for technological transition. *Energy Reports*, 8:610–621, 2022.