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Comparative Performance Analysis of Fixed Ground Mount and Floating Solar PV Systems

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Abstract- The rapid expansion of solar photovoltaic (PV) technology has intensified the need for innovative installation approaches that enhance energy yield while minimizing land usage and performance losses due to environmental conditions. Among emerging solutions, Floating Solar Photovoltaic (FPV) systems have gained significant attention as an alternative to conventional Fixed Ground Mount (FGM) PV installations. This paper presents a comprehensive comparative performance analysis of FGM and Floating Solar PV systems based on experimental data collected under identical climatic conditions. The study evaluates key environmental parameters, electrical output characteristics, and performance indicators including irradiance, ambient temperature, module cell temperature, voltage, current, power output, efficiency, performance ratio (PR), capacity factor (CF), and fill factor (FF). The results demonstrate that Floating Solar PV systems consistently outperform Fixed Ground Mount systems due to enhanced natural cooling effects, leading to reduced thermal losses, improved voltage stability, higher power output, and superior overall performance. The findings confirm the technical advantages of floating PV installations, particularly in regions experiencing high humidity, elevated temperatures, and limited land availability.

Keywords: Floating Solar PV, Fixed Ground Mount PV, Performance Ratio, Capacity Factor, Efficiency Analysis, Renewable Energy.

I. INTRODUCTION

Solar photovoltaic (PV) technology has emerged as a cornerstone of global renewable energy strategies due to its scalability, environmental sustainability, and declining installation costs. Conventional Fixed Ground Mount (FGM) PV systems have been widely deployed across open land areas; however, their performance is often limited by elevated operating temperatures, land-use constraints, and reduced efficiency under adverse climatic conditions. High module temperatures, in particular, significantly degrade PV performance by reducing output voltage and overall energy yield. Floating Solar Photovoltaic (FPV) systems have recently emerged as a promising alternative, where PV modules are installed on buoyant structures over water bodies such as reservoirs, lakes, and ponds.

The presence of water beneath the modules provides a natural cooling effect, reducing cell temperatures and associated thermal losses. In addition to improved performance, FPV systems offer advantages such as reduced land consumption, lower water evaporation, and improved energy density.

Despite increasing interest in floating PV technology, a detailed experimental comparison between FGM and Floating PV systems under real outdoor conditions remains essential for assessing their practical performance benefits. This study aims to address this gap by presenting a detailed comparative performance analysis of both systems operating under identical environmental conditions. [1].

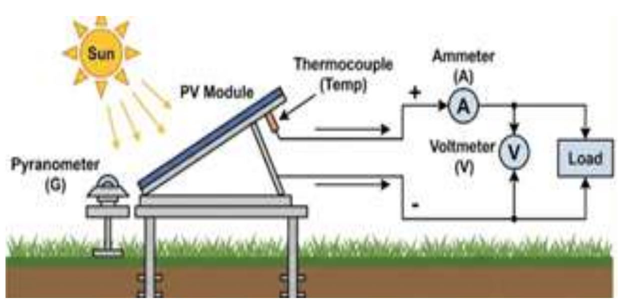

Figure 1. Block diagram of Fixed Ground Mount Solar Photovoltaic (PV) Systems

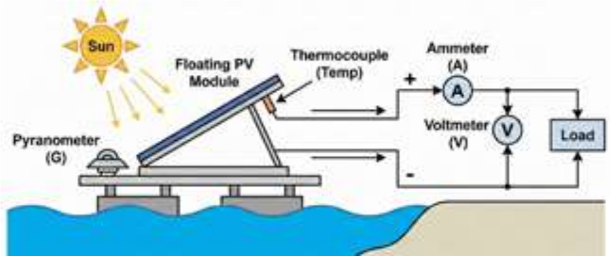

Figure 2. Block diagram of Floating Solar Photovoltaic (PV) Systems

II. LITERATURE REVIEW

Floating solar has been an innovative technology to enhance solar PV project development. This researchreflects the expected negative and positive ecological impacts of solar cell manufacturing, with a particularinterest in running solar cells on a general and large scale. This research focuses on and considers outcomes atall project execution stages; this includes forest-based provisioning, development, activity, decommissioningand reset. Common impacts related to project designation, such as deforestation (for the company's executionand access location), bird mortality, degradation, overfishing and climate change, are expected to reach largescale during the execution of mainstream PV projects. The results also show the advantages of liquid PVcompared to conventional PV during operation and shutdown phases [6].

The world is moving towards a net-zero emissions future in which solar energy is a key component. However,land use requirements for solar installations pose a challenge due to increasing population density and landprices. Floating solar photovoltaic (FPV) systems solve this by installing solar photovoltaic (PV) systems onwater bodies. FPV is becoming a viable option for many countries, with 1% global reservoir coverage generating 404 GWh of renewable electricity generation. FPV offers several advantages over ground-mounted PV, but research on its effects on water quality and living organisms is still lacking.

This review examines theadvantages, disadvantages, and future prospects of FPV, including its potential for integration with othertechnologies. A review of floating photovoltaic (FPV) systems found that while they offer many advantages,they also have known and unknown disadvantages. Benefits include cooling, reduced land use, reduced waterevaporation, pollution and algal blooms. Disadvantages include the effects of moisture on PV modules andunknown water quality effects. FPV is best suited for fabricated water bodies such as reservoirs, irrigation ponds and industrial ponds. Hybrid systems with HPP reservoirs provide access to the grid and reduce water evaporation. Countries with high population density are considering FPV as a renewable energy source [7].

When looking at the possibilities of using a new technology, researchers study performance compared to evaporation-based technology; In this study, they showed that installing floating solar systems on US lakes would require much less space in terms of energy production than potentially installing evaporation-base solutions. If installed on the 128 largest bodies of water in the US, floating solar arrays can generate 24/ continuous electricity equivalent to 100% of the US's electricity demand. If liquid PV were used on all th lakes considered for the evaporative engine study, it would generate ten times more energy. They also demonstrated and compared floating PV systems connected to hydropower plants operating in the reservoir currently under study; Floating PV is much more space efficient.

They can now generate the same amount of electricity as hydropower by covering 1.2% of their surface with solar panels. The discovery could provide important opportunities for water managers. Managers can focus on acquiring options. Assume that hydropower production through turbines can be reduced or eliminated as a reservoir management objective by installing floating PV on a very small percentage of the reservoir area. In that case, goals like flood control and adequate water supply can be achieved [8]. In this research, energy-based parametric techniques are applied to understand the realistic performance of photovoltaic (PV) modules and the energy conversion process in both aquatic and terrestrial environments. Three amorphous silicon thin film PV modules installed using land PV, floating PV and submerged PV routes are investigated to further understand the energy performance. Experimental results show that each installation method has different energy efficiency. Therefore, the efficiency of solar cell methods should be 3.07 percent higher than floating solar cell systems and 43.5 percent higher than solar cell systems on land [9].

III RESULTS & DISCUSSION

The results presented in Figures 3 to 13 provide a comprehensive comparative performance analysis of the Fixed Ground Mount (FGM) Solar PV system and the Floating Solar PV system for 10 August 2024 (Rainy Seasons). The analysis captures the influence of environmental conditions on electrical output and key performance indicators throughout the daytime operating hours (10:00 AM –16:00 PM)

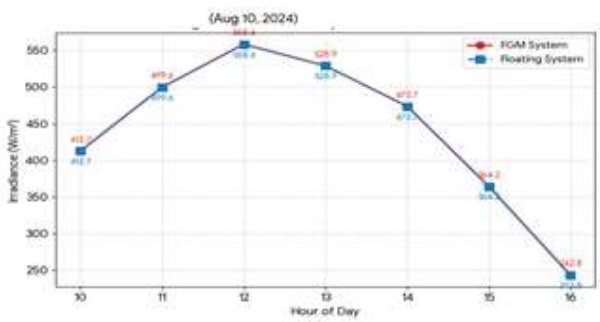

Figure 3 Irradiance comparison analysis of Fixed Ground Mount Solar PV system Vs Floating Solar PV system Dated 10 August 2024 (Rainy Seasons).

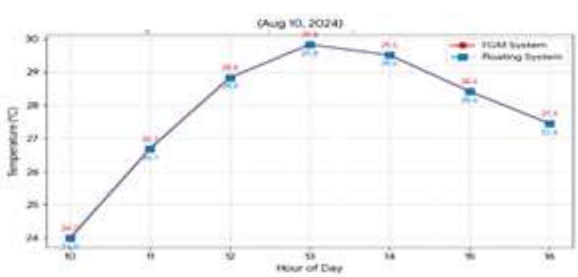

Figure 4 Ambient Temperature comparison analysis of Fixed Ground Mount Solar PV system Vs Floating Solar PV system Dated 10 August 2024 (Rainy Seasons).

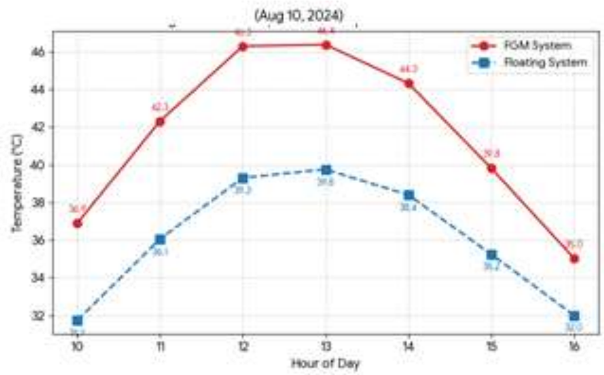

Figure 5 Cell Temperature comparison analysis of Fixed Ground Mount Solar PV system Vs Floating Solar PV system Dated 10 August 2024 (Rainy Seasons).

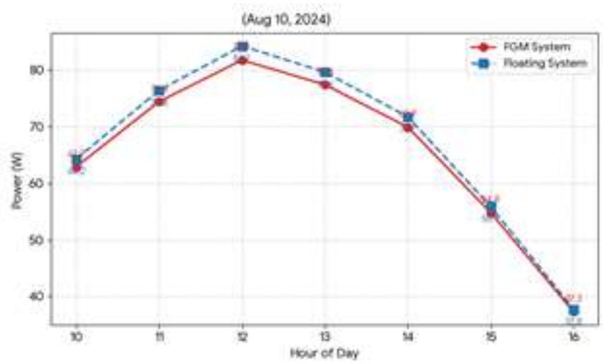

Figure 6 Voltage output comparison analysis of Fixed Ground Mount Solar PV system Vs Floating Solar PV system Dated 10 August 2024 (Rainy Seasons).

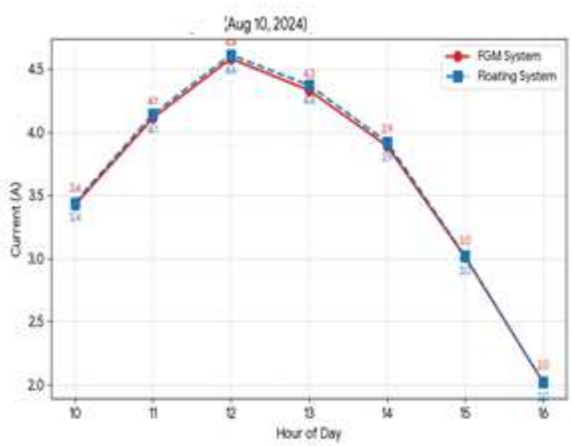

Figure 7 Current output comparison analysis of Fixed Ground Mount Solar PV system Vs Floating Solar PV system Dated 10 August 2024 (Rainy Seasons).

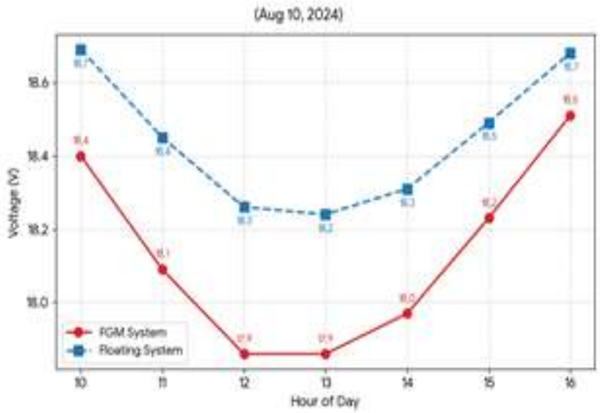

Figure 8 Power output comparison analysis of Fixed Ground Mount Solar PV system Vs Floating Solar PV system Dated 10 August 2024 (Rainy Seasons).

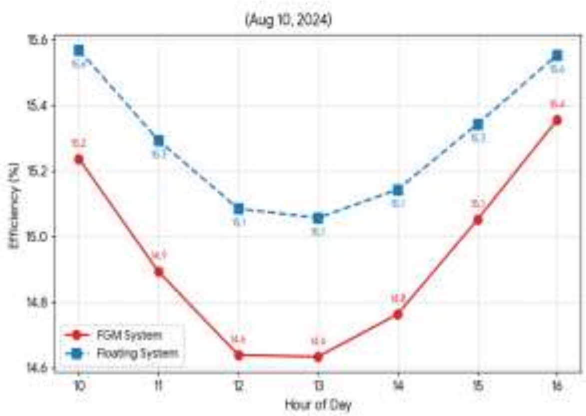

Figure 9 Efficiency comparison analysis of Fixed Ground Mount Solar PV system Vs Floating Solar PV system Dated

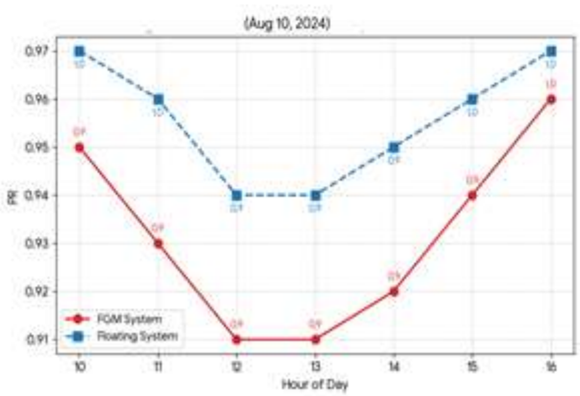

Figure 10 Performance Ratio (PR) comparison analysis of Fixed Ground Mount Solar PV system Vs Floating Solar PV system Dated 10 August 2024 (Rainy Seasons).

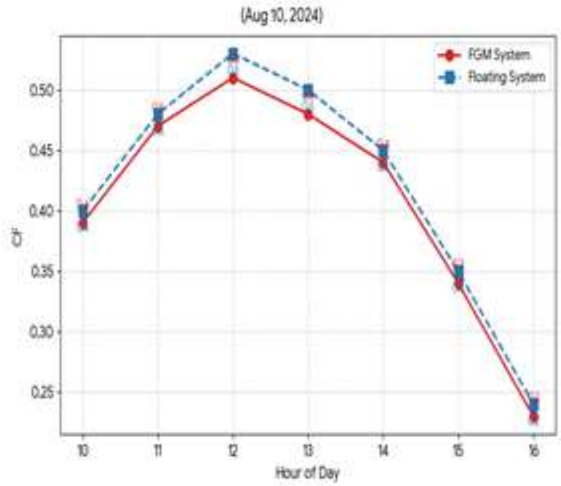

Figure 12 Capacity Factor (CF) comparison analysis of Fixed Ground Mount Solar PV system Vs Floating Solar PV system Dated 10 August 2024 (Rainy Seasons).

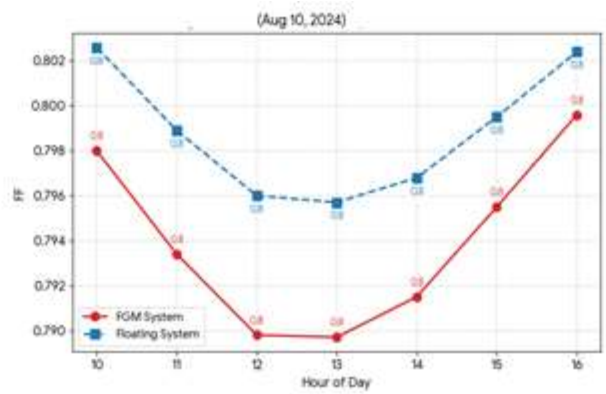

Figure 13 Fill Factor (FF) comparison analysis of Fixed Ground Mount Solar PV system Vs Floating Solar PV system Dated 10 August 2024 (Rainy Seasons).

IV. CONCLUSION

This paper presented a comprehensive comparative performance analysis of Fixed Ground Mount and Floating Solar PV systems under identical outdoor operating conditions. The experimental results clearly demonstrate that Floating Solar PV systems offer superior electrical performance and energy efficiency compared to conventional ground-mounted installations. Lower module temperatures, improved voltage and power output, higher efficiency, and enhanced performance indicators collectively establish the technical advantages of floating PV technology. The findings highlight the strong potential of Floating Solar PV systems as an effective solution for maximizing solar energy generation, especially in regions facing land scarcity and high thermal stress.

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