Floating Solar PV Array Design for Water–Energy Integration at Kun Chaung Dam

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Abstract – This paper presents the design and performance analysis of floating solar photovoltaic (PV) system on the Kun Chaung Dam, located in the Bago Region of Myanmar. The study emphasizes the role of floating PV technology in advancing water–energy integration by utilizing existing water surfaces for clean energy generation while supporting water resource management. Comprehensive calculations and simulations were conducted, including PV array sizing, inverter and charge controller selection, and cell temperature estimation for both floating and land-based configurations. The P–V and V–I characteristic curves of the selected PV modules were analyzed under varying temperature and irradiance conditions to assess system behavior and efficiency. Technical, environmental, and economic factors were collectively evaluated to ensure feasibility and sustainability of the proposed system. Results indicate that the floating PV design at Kun Chaung Dam achieves higher energy yield and improved cooling performance compared to conventional ground-mounted systems, demonstrating its potential as an effective solution for integrated water–energy resource development.

Keywords: Floating solar photovoltaic, Kun Chaung Dam, renewable energy, photovoltaic characteristics

I. INTRODUCTION

The transition toward renewable energy has become a defining element of the global effort to mitigate climate change and enhance energy security. Among various renewable technologies, solar photovoltaic (PV) systems stand out for their scalability, environmental compatibility, and abundant energy potential [1,2].

In this context, floating solar PV (FSPV) systems have emerged as an innovative approach that addresses both land scarcity and rising electricity demand by utilizing the surfaces of reservoirs, lakes, and dams for power generation [3,9]. Beyond producing clean electricity, these systems offer additional advantages such as reducing water evaporation, curbing algae growth, improving water quality, and enhancing the overall efficiency of nearby hydropower plants by lowering water temperature fluctuations [2,4]. This dual-purpose utilization of water bodies represents a key step toward optimizing the water–energy nexus while minimizing ecological disruption and land-use conflicts [3,5].

This study focuses on the design, modeling, and optimization of a floating solar PV system specifically for the Kun Chaung Dam in the Bago Region of Myanmar [6,7,8]. The work develops a systematic framework for selecting and sizing PV modules, inverters, and charge controllers to ensure operational efficiency, structural stability, and long-term durability [6,7]. Furthermore, the thermal and electrical performance of the PV array is analyzed under varying irradiance and temperature conditions to evaluate its adaptability to real environmental scenarios [2,5,9]. The outcomes of this research aim to strengthen the technical foundation for large-scale floating PV deployment and contribute to sustainable energy–water resource integration in similar hydropower and reservoir-based infrastructures [3,9].

II. CASE STUDY AND RESEARCH OBJECTIVE

The Kun Chaung Dam, located on the Kun Chaung River in the Bago Region of Myanmar, serves as an exemplary site for the deployment of a floating solar photovoltaic (FSPV) system. Characterized by its expansive reservoir surface area and favorable solar irradiance levels, the site provides optimal conditions for large-scale solar energy harvesting. Its strategic location within a solar-abundant region and proximity to existing hydropower infrastructure further enhance its potential for integrated renewable energy generation. The combination of solar and hydropower resources enables more stable and diversified energy output, contributing significantly to regional energy resilience and environmental sustainability.

Fig. 1. Location map of the surface of Kun Chaung Dam

Geographically, the Kun Chaung Dam lies on a tributary of the Sit Taung River, approximately 9 miles southwest of Phyu City, at coordinates 18°29′ N latitude and 96°26′ E longitude. The reservoir encompasses a total water surface area of approximately 10.03×10^6 m², providing substantial space for the installation of floating solar arrays. The proposed floating PV layout on the reservoir surface is illustrated in Figure 1, demonstrating the spatial feasibility of the design.

By leveraging the untapped solar potential of reservoirs like the Kun Chaung Dam, the transition towards a sustainable and resilient energy future while unlocking new opportunities for water resource management and ecosystem conservation can be accelerated.

III. METHODOLOGY

This study presents a comprehensive design framework for the deployment of a floating solar photovoltaic (FSPV) system on the Kun Chaung Dam [1,3,9]. The proposed framework integrates multidisciplinary considerations encompassing technical feasibility, environmental sustainability, economic viability, and structural engineering requirements to ensure optimal system performance and long-term reliability [2,4]. Emphasis is placed on the synergistic operation of floating solar and hydropower systems, demonstrating how integrated water–energy configurations can enhance overall generation efficiency and grid stability [3,5,9].

The research further aims to establish methodological guidelines for the systematic planning, design, and implementation of FSPV projects in reservoir environments [6,7,8]. The outcomes of this work are intended to serve as a reference for policymakers, engineers, and researchers engaged in renewable energy development, while contributing to the broader goals of sustainable energy transition and efficient water resource utilization [1,3].

The design process of a Floating Solar Photovoltaic (FSPV) system fundamentally commences with a thorough assessment of the available water surface area [6,7]. This preliminary evaluation is essential for establishing design boundaries. Following the site assessment, the design procedure proceeds to the detailed configuration and integration of the key system components, which include:

- Anchoring and mooring system
- Floating platform
- PV modules
- Inverters

In designing the Floating Solar Photovoltaic (FSPV) plant for the Kun Chaung Dam in Bago, specific considerations related to the facility must be taken into account. For the simulation, the FSPV's total capacity is set at 5 MW, corresponding to a dam area of approximately 27996 square meters. Fig. 2 illustrates the dimensions of the FSPV.

Fig. 2. Installed PV System Area on Kun Chaung Dam

The design principles of floating Solar Photovoltaic (FSPV) system closely parallel those of conventional land-based PV systems; however, specific modifications are required to adapt the installation for aquatic environments. The structural foundation of the system is floating platform engineered to support the photovoltaic modules, inverters, combiner boxes, and associated electrical components [1,3].

This platform is designed to ensure mechanical stability, buoyancy, and durability under varying hydrodynamic and meteorological conditions.

Typically, the floating structure is fabricated using materials such as high-density polyethylene (HDPE), fiber-reinforced plastic (FRP), or corrosion-resistant metal alloys, selected for their strength, longevity, and resistance to ultraviolet radiation and biofouling [1,6,9]. These materials collectively provide a stable base for the PV array while minimizing maintenance requirements and environmental impact [1,3,9].

A. Anchoring and mooring system

The anchoring and mooring system constitutes a vital subsystem of any Floating Solar Photovoltaic (FSPV) installation, serving to maintain the structural stability and positional integrity of the floating platform under dynamic environmental conditions [1,6]. This system is typically composed of a combination of anchors, mooring lines, cables, and chains that secure the floating array to fixed reference points—either on the reservoir bed, along the shoreline, or on auxiliary buoyant structures. Proper design of the mooring configuration is essential to ensure long-term operational reliability, minimize mechanical stress on the floating modules, and preserve optimal orientation for solar energy capture.

Table 1. Monthly Averaged Insolation Incident on a Horizontal Surface (kWh/m^2/day)

Lat 18 Lon 96	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	5.24	5.95	6.43	6.60	5.49	4.04	3.91	3.79	4.47	4.76	4.76	4.91	5.02

Table. 2. Minimum, Maximum and Average Daily Temperature (°C)

Lat 18 Lon 96	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	22.5	24.6	27.3	29.0	27.2	25.6	25.2	25.1	25.0	24.6	23.3	22.0	25.1
Minimum	17.0	18.3	21.1	24.3	24.2	23.4	23.0	22.8	22.6	21.9	19.9	17.7	21.3
Maximum	28.2	30.1	32.3	33.2	30.2	27.8	27.6	27.8	28.0	28.1	27.4	27.0	29.0

Table.3. Monthly Averaged Wind Speed (m/s)

Lat 18 Lon 96	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	3.19	3.49	3.43	3.01	2.69	3.45	3.39	3.16	2.52	2.52	2.96	3.12	3.07

B. Anchoring and mooring system Floating platform

The floating platform, often referred to as the pontoon structure, forms the primary supporting foundation of a Floating Solar Photovoltaic (FSPV) system [1,6,9]. It is typically composed of interconnected high-strength polymer or fiber-reinforced plastic (FRP) floats. The modular configuration of these floats allows for structural flexibility, facilitating adaptation to varying reservoir geometries and water-level fluctuations [3,5].

Although the platform exhibits substantial load-bearing capacity, its buoyant nature permits limited movement in response to hydrodynamic forces. In large-scale installations such as those on hydropower reservoirs, the magnitude of wind and wave forces necessitates additional reinforcement [4,5]. Floating bridge or auxiliary anchoring framework is incorporated to secure the PV array and counteract displacement caused by external environmental loads [1,6,9]. The schematic representation of a typical floating solar anchoring configuration is illustrated in Figure 3.

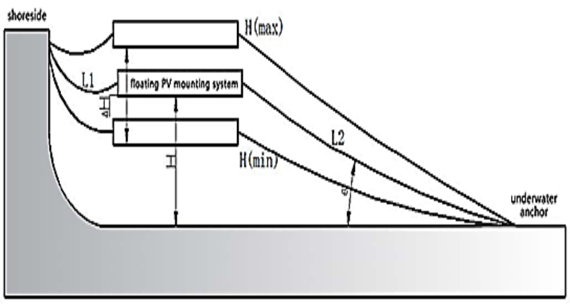

Fig. 3. Typical Floating Solar Anchoring System Design

The floating structure is fabricated from high-density polyethylene (HDPE) modules, engineered for high strength, buoyancy, and long-term durability in aquatic environments [1,6,9]. Each float unit features dimensions of 507 × 507 × 400 mm with a wall thickness of 3 mm and internally reinforced ribs to enhance structural rigidity. The design provides a load-bearing capacity of approximately 95 kg per module, ensuring adequate support for the mounted photovoltaic components and ancillary equipment [3,6,9].

C. Meteorological Parameters and floating PV cell temperature

The operating temperature of photovoltaic (PV) cells in floating solar installations is governed by multiple environmental parameters, including solar irradiance intensity, ambient air temperature, wind velocity, and the thermal characteristics of the underlying water surface [2,4,5]. Floating Solar Photovoltaic (FSPV) systems exhibit lower cell temperatures than their land-based counterparts, primarily due to the natural cooling effect provided by the water body beneath the modules [1,3,9].

For the Kun Chaung Dam site, long-term meteorological data—comprising average solar radiation (Table 1), minimum and maximum daily temperatures (Table 2), and mean wind speeds (Table 3) were obtained from the NASA Surface Meteorology and Solar Energy database.

The recorded air temperature and wind speed values were subsequently adjusted to represent near-surface water conditions, ensuring improved accuracy in estimating the thermal behavior of the floating PV modules [2,4,5].

Cell temperature on land is given by

$$T_{cl} = 0.943 * T_a + 0.0195 * G - 1.528 * v_{wl} + 0.3529 \quad (1)$$

$T_{cl} -$ cell temperature

$T_a -$ Ambient temperature(°C)

$G -$ Standard test conditions (STC) irradiation $(1000W/m^2)$

$v_{wl} -$ land wind speed

$$T_{cw} = 0.943 * T_w + 0.0195 * G - 1.528 * v_{ww} + 0.3529 \quad (2)$$

$$T_w = 5 + 0.75\, T_a = 26.75°C \quad (3)$$

$T_w - water\ temperature$ (°C)

$$V_{ww}=1.62+1.17v_{wL} \quad (4)$$

$$T_{fpv} = 1.8081 + 0.9282.T_a + 0.0221.G - 1.2210.V_{w,w} + 0.0246T_{cw} \quad (5)$$

$T_{fpv} -$ floating cell temperature(°C)

D. Cell Derated Daily Output Energy of Floating PV Array

The derated daily output energy of a floating PV array refers to the expected energy production from the system after accounting for various factors that reduce its performance below its theoretical maximum [3,7,8,9]. These factors may include shading, soiling, temperature effects, and losses in electrical components such as inverters and cables. To calculate the derated daily output energy, the theoretical daily energy output of the PV array based on its rated capacity and local solar irradiance data would be typically started with [2,4]. Then, to account for the aforementioned losses and inefficiencies, derating factors would be applied [3,7,9]. Therefore, the daily energy output from PV array can be calculated as follows:

temperature on water is given by

$$E_{PV} = W_P\left(f_{\frac{dc}{ac}}\right)\left(\frac{G}{G_{STC}}\right)[1 + \beta(T_{cw} - T_{STC})] \quad (6)$$

W_P	-	Rated capacity of PV array in [kW or wa meaning power output under (STC)
$f_{dc/ac}$	-	DC to AC derating factor [%] =0.7782
G	-	Solar radiation incident on PV array in $\left[\frac{kW}{m^2}\right]$
β	-	Temperature coefficient of power (%/°C)
T_{cw}	-	PV cell temperature current time step (°C)
T_{STC}	-	PV cell temperature under STC (°C)

E. Sizing of Floating PV Array

The system design comprises thirty PV arrays of 1 MW each, yielding a total installed capacity of 30 MW. The LONGI LR5-72HBD 535–555 W module was selected for its high efficiency, durability, and proven suitability for large-scale floating installations. Table 5 summarizes its key electrical and physical parameters, including rated power, voltage, current, and temperature coefficients. This selection ensures optimal energy yield, operational reliability, and long-term performance for the proposed floating solar PV system.

Table 4. PV Module Parameters

No	Parameters	Rating
1	Module Power	550 W
2	Voltage at Maximum power	41.95 V

3	Current at maximum power	13.12 A
4	Short-circuit current (I_{sc})	13.99 A
5	Open-circuit voltage (V_{oc})	49.8 V
6	Cells per module	144 cells

$$V_{Dc\ Link} = 2\sqrt{2}V_{rms} = 2\sqrt{2} * 400 \sim 1150\ V \tag{7}$$

$$\text{Numbers of Modules } (N_m) = \frac{\text{String Voltage } (V_{\text{string}})}{\text{Voltage at Maximum Power Point } (V_{\text{mpp}})} \cong 28\ Modules\ per\ String$$

$$\text{Number of strings in an array } (N_{\text{string}}) = \frac{1 \times 10^6}{15.4 \times 10^3} = 64.5 \sim 65 = 65\ strings$$

Number of arrays for a total 30MW power generation can be calculated as,

$$N_{\text{array}} = \frac{P_{\text{total array}}}{P_{\text{array}}} \tag{8}$$

$$N_{\text{array}} = \frac{P_{\text{total array}}}{P_{\text{array}}} = \frac{30 \times 10^6}{1 \times 10^6} = 30\ arrays$$

The total number of modules for the system is given by,

$$N_{T,Sys} = N_m \times N_{\text{string}} \times N_{\text{array}} \tag{9}$$

$$N_{T,Sys} = 28 \times 65 \times 30 = 54600 \text{ modules}$$

Where $N_{T,Sys}$ is total number of modules for the system.

F. Design and Simulation Results

An analysis of the V-I and P-V characteristic curves of the selected PV array is conducted. These curves, depicted in Figures 4, 5, 6 and 7, provide valuable insights into the system's behavior under various conditions. Figure 4 illustrates that PV cell temperature is lower in FPV than on land, resulting in higher power output, while Figure 5 compares the daily energy generation across months for FPV and land-based systems. The results indicate that as cell temperature rises, the open-circuit voltage decreases, leading to reduced power output. Although the short-circuit current may marginally increase with temperature, overall efficiency decreases, causing a decline in power output.

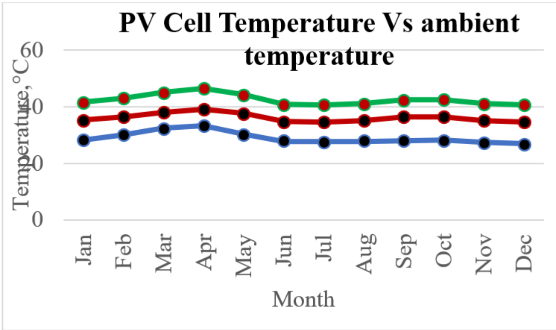

Fig. 4. Cell temperature vs ambient temperature

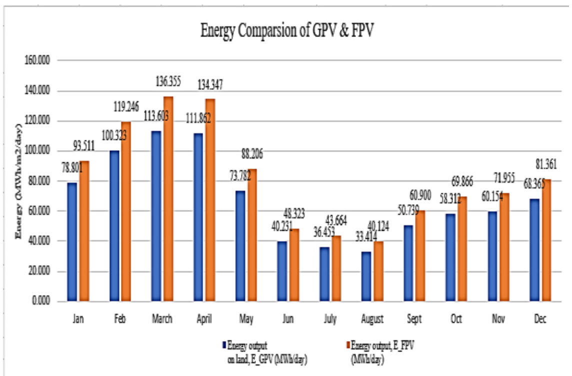

Fig. 5. Energy Output on land vs FPV Energy Output

Additionally, as solar irradiance increases, the current output rises proportionally, shifting the maximum power point of the system to higher voltages and power outputs. Understanding these characteristics is crucial for optimizing system performance and efficiency under various environmental conditions.

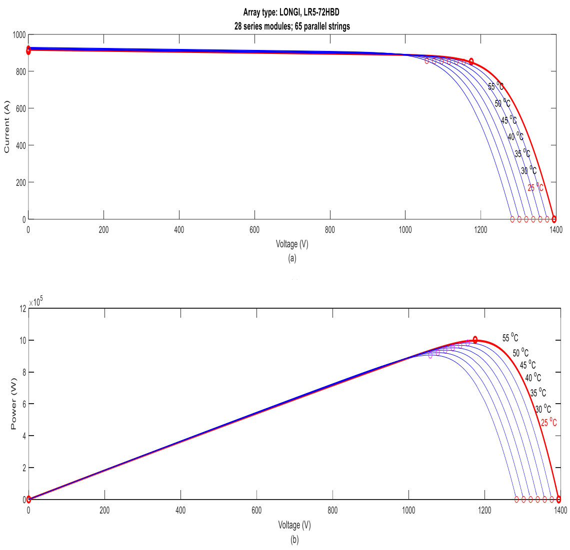

Fig. 6. (a). V-I characteristic curve, (b) V-P characteristic curve of PV array at different temperature

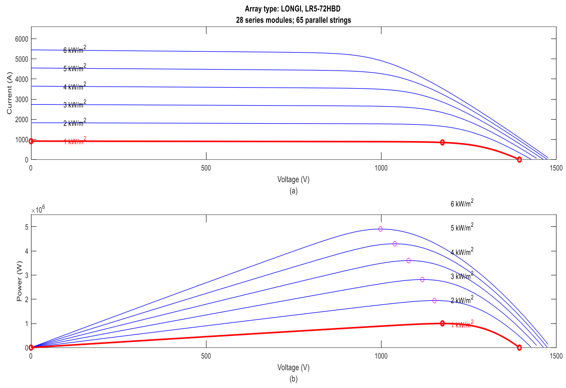

Fig.7. (a) . V-I characteristic curve, (b) V-P characteristic curve of PV array at different irradiance

IV. DISCUSSION

The study demonstrates that floating solar photovoltaic (FPV) systems at Kun Chaung Dam effectively integrate water and energy resources. The water's cooling effect reduces PV cell temperature, enhancing efficiency and energy yield compared to land-based systems. The design ensures stability, durability, and sustainability through proper material selection and anchoring. Overall, the FPV system offers higher performance, environmental benefits, and a practical solution for renewable energy expansion in Myanmar.

V. CONCLUSION

With the inclusion of Figure 4 comparing PV cell temperature between floating and grounded systems, as well as Figure 5 depicting monthly energy output for both systems, the proposed floating solar PV system at Kun Chaung Dam demonstrates clear performance advantages. Based on the tabulated data, the FPV modules operate on average about 19.3°C cooler than land-based modules and deliver 8.6% higher annual energy output (241.43 MW vs. 222.33 MW). The FPV system achieves a maximum monthly output of 27.36 MW in March, outperforming the ground system in every month of the year. This enhanced performance results from the cooling effect of water, which maintains lower cell temperatures and improves efficiency. Overall, the study confirms that the floating solar PV design effectively optimizes reservoir surface utilization, increases renewable energy yield, and provides a technically, environmentally, and economically sustainable solution for water–energy integration at Kun Chaung Dam.

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