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INSTRUCTIONS FOR EXTENDED ABSTRACTS

FLOATING PHOTOVOLTAIC SYSTEMS AND WATER SURFACE COVERAGE: A SIMULATION OF TECHNICAL, ENVIRONMENTAL, AND ECONOMIC ASSUMPTIONS FOR BOURGET LAKE

Summary

Floating Solar Photovoltaics (FPV) is emerging as a solution to land scarcity, rising energy demand, and the need for low carbon power generation. By installing PV systems on water bodies, FPV improves efficiency through water-based cooling and avoids land-use conflicts. This paper compares FPV with urban PV across environmental, economic, social, and regulatory dimensions, supported by a literature review and a thorough simulation for Le Bourget du Lac to stand on the variable aspects on determining the Lake's coverage ratio. Results show that FPV offers higher energy performance, minimal land use, water evaporation saving, cheaper and cleaner source of electricity per kWh compared to other sources of electricity but faces challenges related to biodiversity, regulation, public acceptance but most importantly weather conditions affecting solar irradiance, investment and lack of necessary data to support the spread of use. Overall, FPV presents a promising and scalable option for sustainable energy expansion.

Keywords: System-level modelling, Lake-based PV applications, Environmental impact assessment; Techno-economic analysis; Ground coverage ratio (GCR).

Field of application for the findings: Sustainable energy transition

Addressed audience: PV OEM companies, R&D sectors for PV solar power and Local governments.

1. Introduction (Aim and approach)

This paper aims to find the answer for the following questions: What determines the water surface coverage ratio of FPV systems, and how to determine the optimal coverage ratio based on the objective of FPV system deployment?

The 1st question is approached by a literature review in which several papers were taken into account to stand on the key main aspects to be considered to carry out an FPV project. Selected studies discussed on the review, explored a range of contexts amongst geographic, the type of waterbody and analytical approach whether pilot experiments, techno economic simulations, national-scale assessments, and environmental impact studies

The literature review work laid the grounds to conduct a simulation for The Bourget Lake given that it's a natural lake with fresh water, expands over a 44.5 km2 of area making it the biggest in France and bears many challenges for the FPV deployment business such as: i) Lake's ecosystem and biodiversity, ii) European, French regulations and social acceptance, iii) Shading losses from surrounding mountains. So, to answer the 2nd question, 6 aspects were chosen to assess the feasibility of deploying an FPV plant on the lake; which are : energy yield, evaporation saved, temperature change, biodiversity, economical aspects and shading losses. The first 4 aspects are considered through MathCad coding softwere to plot the change in covering ratio function from (0 – 100%) among all 4 aspects, while SAM softwere assess the financial feasibility and PVgis assess the shading losses to finally stand on a pareto optimal covering ratio where all trade-offs are admissible.

2. Scientific innovation and relevance

The simulation started by assessing the FPV project while considering the 4 previously mentioned aspects (Energy, Evaporation, Temperature and Biodiversity) the challenge was finding the link between all 4. Firstly, the main goal of the paper was to find the "Golden Ratio" between all 4 aspects in which the coverage ratio is Pareto optimal, that an increase of the coverage ratio is going to perform a significant impact on any of the 4 aspects. Thus, the idea of writing all formulas as a function of the coverage ratio (f) which is represented by a matrix with a range of [0,1] and step of 0,01 and consecutively writing all formulas and assumptions as a function of this matrix. This approach resulted in a close estimation – based on the assumptions- for the aspects findings compared to the other findings from SAM & PVGIS. Although, it gave a clear relation between all 4 aspects and the coverage function represented by (X – Y Plots) following [Fig. 1].

Moving forward, applying the Peak power obtained from MathCad sheet and system losses from SAM software; a simulation for solar mask, irradiance and horizon height was conducted using PVGIS. Valuable data like annual average daily solar production, average daily production of and annual production with an annual variability error of (3.74%). Later, these data were applied to SAM software to generate a full financial report employing (Boviet Solar Technology Co. Ltd. BVM7612M-550-H-HC) solar module developed by Sungrow; the leading company in renewable technologies. Plus (BYD Auto Industry Company Limited: BEG500KTL-U) Inverter module for DC-AC inverting.

Similarly for Evaporation savings, the formulas to determine the evaporation losses are written as a function of coverage ratio; but there's also another variable that had to be added to the formulas which is the evaporation reduction coefficient from PV panels (ηFPV). Determining the coefficient itself relies on other factors like the panel module, heat transfer between surfaces and the type of waterbody, whether natural lake or dam reservoir.

The temperature change and biodiversity parts represent the measures taken to preserve the environment and biodiversity of the lake, meaning that covering the lake with maximum FPV and gaining maximum power isn't any different -in terms of pollution- to using polluting electricity generating sources. Low coverage ratio but high enough to generate substantial amount of electricity efficiently while taking the the lake's ecosystem preservation measures is the study's main objective. Assessment of FPV coverage-variables; like the cooling gain of PV panels (γcool), albedo (α), temperature change and Light attenuation coefficients in water were considered through the formulas based on (Mouhaya et al., 2025), (Ilgen et al., 2024) and (Kirk., 1994)'s book on Light and photosynthesis in aquatic ecosystems.

A financial feasibility study was conducted using SAM software. The levelized cost of electricity (LCOE) based on fixed change rate (FCR) calculator was determined. SAM also provided us with an estimation for the Previously mentioned variables that are vital for the project feasibility.

Simultaneously, the work on PVgis and SAM was executed to maintain the consistency with the MathCad sheet. Based on the weather data introduced to SAM and PVGIS, a complete sizing for the cable, inverter, and PV losses was conducted. The data collected from PVGIS were introduced to SAM to size the array. A fixed orientation with (37°) tilt, (178°) azimuth, Ground coverage ratio (GCR) of (0.3) and no Backtracking option, since the tracking option increased the total cost to levels exceeded the few outcome of increase in electricity generation. SAM estimated the number of modules to generate (100 MW DC) for (181,400 module) covering an area of approximately (0.49 km2 – 1.1% coverage ratio for the lake).

3. Preliminary results

To conclude, it was found that the real challenges were not the amount of energy yield nor evaporation saved since those values can be achieved by easily increasing the coverage ratio. But in fact, it was the preservation of the environment and ecology through the temperature change and biodiversity aspects, while certainly keeping the financial costs and maximizing the electricity produced through evading shading losses. The Temperature and biodiversity aspects for GCR of (3.7%) coverage results, shown that it was adequate to increase the coverage ratio to (5-6%), which is viable. However, it will contradict with the financial and shading aspects, Increasing the investment capital, simultaneously decreasing the efficiency due to shadings.

Another challenge facing the study is the FPV degradation, FPV installations still lack fully adapted design tools for predicting mechanical stresses, humidity effects, and long term energy yield, that's beside other degradation factors like moisture ingress, corrosion, biofouling, and continuous mechanical fatigue from wind–wave interactions. FPV infrastructure is highly susceptible to corrosion of frames, junction boxes, and anchoring hardware, as well as encapsulant degradation and delamination due to persistent moisture and, in certain regions, saline aerosols. Those degradation factors are a must to consider for any FPV deployment project.

Regarding the viability of the project considering all 6 aspects, it was found that the average daily solar irradiance time is (3.8 hr), which is low given the shading from adjacent mountains and gloomy weather. However, the project maintained significant results, the module managed to have specific yield (Esp = 1088 kWh/kWp*yr), while avoiding carbon dioxide emissions of (CO2, avoided = 3673 ton/yr) and providing (20000) households with clean solar electricity power that are still enough to support the cities surrounding the lake with clean solar energy as can be seen in [Tab. 1].

4. Tables and figures

4.1. Tables

Tab. 1: FPV coverage ratio of (f = 1.1%) results.

Aspects (function of coverage area)	Module Ratio	Aspects (function of coverage area)
A(FPV)	1.1% = 0.49 km^2	Area FPV
GCR (1.1%)	3.67% = 1.633 km^2	Ground coverage ratio
E(1.1%)	9.519 * 10^7 [kW*hr/yr]	Energy yield
V_{saved}(1.1%)	4.99 * 10^5 [m^3/yr]	Evaporation saved
ΔT_{mix}(3.67%)	-3.41 [Δ°C/yr]	Mixed-Layer Temperature Response
PP(3.67%)	0.957	Relative Primary Productivity Response
E_{sp}(1.1%)	1.08 * 10^3 [kW*hr/kWp*yr]	Specific yield
$CO2_{avoided}$(1.1%)	3.673 * 10^3 [ton/yr]	CO_2 Emissions Avoided
$N_{households}$(1.1%)	2 * 10^4 [households]	Number of Households Powered

4.2. Figures

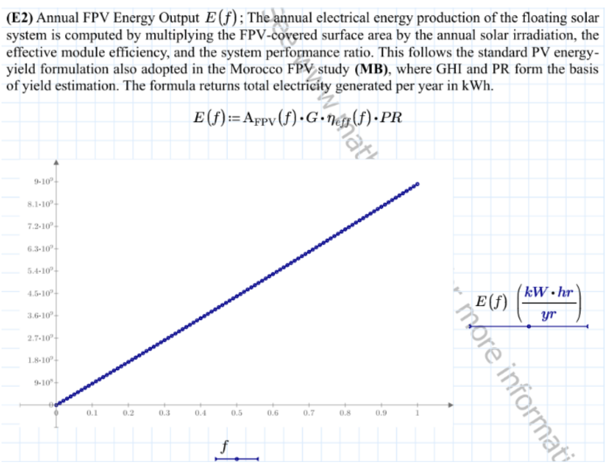

Fig. 1: Energy Yield as a function of coverage ratio E(f).

5. References

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