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Overview of the coupling between Floating PV and Hydroelectric Power Plants

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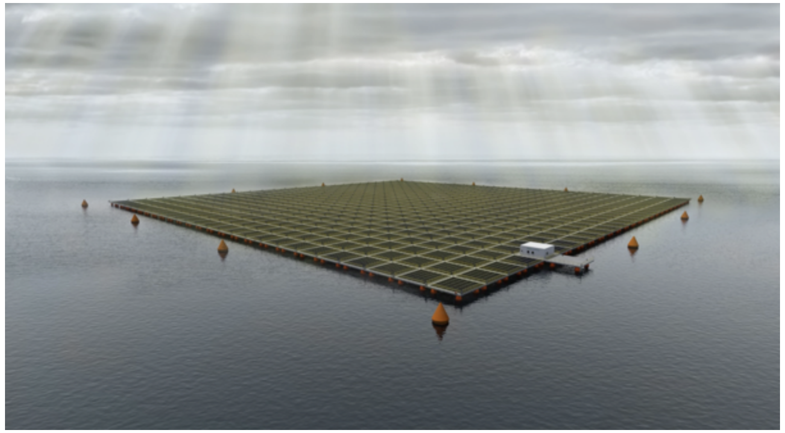
- Introduction
- Energy optimization in hybrid systems
- Advantages of HPP and FPV coupling
- Energy potential analysis
- Overview of the FPV-HPP
- Enviromental impact
- Conclusions

INTRODUCTION

Floating photovoltaic can utilize the mostly unused water surfaces and the abundant solar energy from the sun, especially in driest seasons.



In rainy seasons, the natural accumulation of water from the catchment area will maximize the potential for piezometric jump and therefore producibility.

Floating solar photovoltaic (FPV) coupled with the existing hydro-power entities are becoming an impactful competitive option.

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ENERGY OPTIMIZATION IN HYBRID SYSTEMS

Hybrid systems are created by allocating floating photovoltaic modules in pre-existing hydroelectric plants.

Case study in southern Brazil:

- Pre-existing hydroelectric power plant;
- Consideration to add power through 60 kW photovoltaic panels.

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ENERGY OPTIMIZATION IN HYBRID SYSTEMS

Hybrid systems are created by allocating floating photovoltaic modules in pre-existing hydroelectric plants.

Another study was conducted to compare the power and energy density between HPP and FPV:

- the quantities ρP, H and ρE, H (for hydroelectric plants) and ρP, FPV and ρE, FPV (for floating photovoltaic plants) were defined;
- the results obtained showed that the factor ρE, FPV is much greater than the ρE, H.

ADVANTAGES OF HPP AND FPV COUPLING

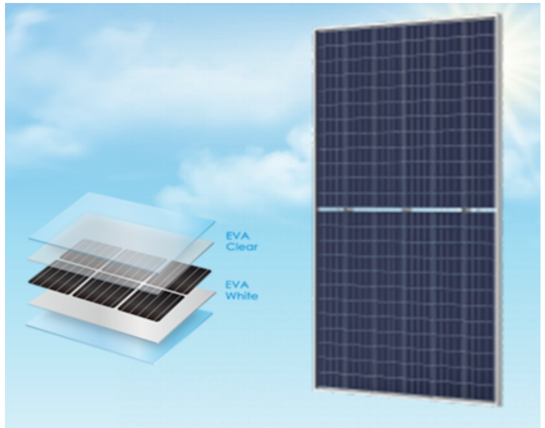
There are several ***advantages*** that lead to the coupling of floating photovoltaic systems and hydroelectric plants:

- Connection to the grid;
- Reduction in the annual fluctuations in electricity production;
- The installation does not involve irreversible effects of any kind;
- The presence of water reduces the loss of efficiency of the panels in hot seasons;

ADVANTAGES OF HPP AND FPV COUPLING

- Non-use of land;
- The reduction of surface water evaporation with the total or partial coverage of basins;
- The floating modules do not modify the albedo of the ground as the albedo of the water and panels is quite similar and around 5%, so not altering the energy balance.

ENERGY POTENTIAL ANALYSIS



The largest hydroelectric power plants of each European state were analyzed, present on database, and various hypotheses were proposed, with two different technologies, of installable power.

P_{max} = (Cell Efficiency / 100) x (E / A_c) = (17,3 / 100) x (1000 W/m^2 / 1,98 m^2) = 342,54 W - 10% = ***308,29 W***;

- ***Multicrystalline*** cells, of 1,98*1,00
- Cell efficiency of 17,3%
- Production capacity up to 342,54 W
- Support of the panel as being about 10% total

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ENERGY POTENTIAL ANALYSIS

P_{max} = (Cell Efficiency / 100) x (E / A_c) = (21,4 / 100) x (100 W/m^2 / 2,56 m^2) = 548,93 W – 12,5 % = ***480,31W***.

- ***Monocrystalline*** cells, of 2,27*1,13 m
- Cell efficiency of 21,4%
- Production capacity up to 548,93 W
- Support of the panel as being about 12.5% total

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ENERGY POTENTIAL ANALYSIS

It is therefore possible to calculate the power that can be installed in the largest hydroelectric plants in Europe with three different coverage hypotheses (5%, 30% and 50%).

Mequinenza Dam is a concrete gravity dam in the province of Zaragoza, Spain with area of 75,4 km^2 with installed capacity of 384 MW.

By occupying 5% of the surface plus

- Efficiency of 17,3%: installable power of 0,59 GW,
- With the highest efficiency panels, it would have 0,71 GW of installable power.

With an occupied surface of 30%

- 3,54 GW
- 4,26 GW.

By occupying 50% of the basin surface:

- 5,90 GW
- 7,10 GW

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ENERGY POTENTIAL ANALYSIS

The Solina Dam is the largest dam in Poland with an area of 22 km^2 and an installed capacity of 200 MW.

<u>By occupying 5%</u> of the surface:

- with an efficiency of 17,3% - installable power of 0,17 GW
- with the highest efficiency panels - 0,21 GW of installable power.

With an <u>occupancy of 30%</u>

- 1,02 GW
- 1,26 GW of installable power

<u>By occupying 50%</u>

- 1,79 GW
- 2,10 GW with the two different panel technologies.

The installable power per surface unit has been calculated. For the silicon panel with multicrystalline cells it will be 155,7 W / m^2, for the panel with monocrystalline cells it will be 187,6 W / m^2.

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$P_{inst,surf.unit}$ = Installable power [W] / occupancy surface unit [m^2]

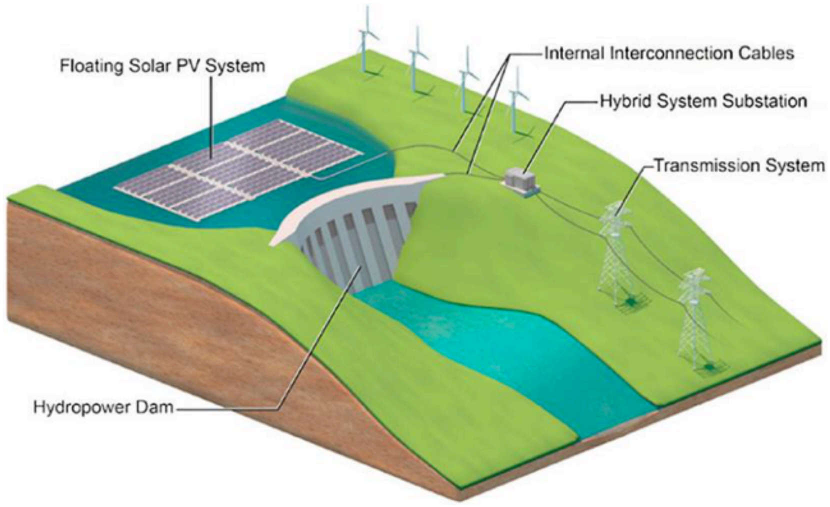
OVERVIEW OF THE FPV-HPP

The unpredictability of rain patterns and the increase of drought over the years have led to the installation of a large number of traditional power plants which significantly increase coal emissions.

Thanks to the advantages deriving from the integration of these two systems, various benefits can be obtained, such as:

- An increase in the energy collected;
- The FPV’s construction do not interfere with any surfaces of soil for agricultural use;
- Allows the use of already existing transmission infrastructure;
- No power variations in FPV due to the intermittent solar radiation profile;
- FPV output can compensate power reduction from hydropower plants;
- The power output from FPV prevents the consumption of water from hydropower plants which can be otherwise used during peak load conditions.

From an energy point of view in the Brazilian scenario, and thanks to the synergy between the two systems, the energy gain by the hybridization is 76%, while the capacity factor increases by an average of 17,3%.



ENVIRONMENTAL IMPACT

The shading exerted by the panels allows sunlight not to reach the water, preventing the growth of algae.

A failure of these factors would endanger fishing and the habitat, posing a risk to the wildlife, such as water birds.

Algae in the basins play an important role as they use sunlight to activate the photosynthesis process to produce carbohydrates and are also the food for protozoa and zooplankton.

Shading can also reduce the bloom of blue-green algae which produce the surface foam, **host** cyanobacteria and **contribute** to **unpleasant** odors due to decomposition.

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Challenges and future scenarios

In the coming years, the production of electricity from hybrid plants will likely face **many challenges:**

- **Environmental impact** to be minimized (shading of the panels);
- Design of an **adequate anchorage** (impact of the wind on the FPV*'s and prevent* waves from generating **micro-cracks** that could lead to a loss of power in the modules);

In addition, future scenarios could be related to the ***use of energy produced by hybrid plants***

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CONCLUSIONS

The coupling between pre-existing hydroelectric plants and floating photovoltaic systems, gives rise to a significant increase in production of electricity from renewable sources with a lower economic and environmental impact than the construction of a new terrestrial photovoltaic system.

The strategy hypothesized in this article will make it possible to reduce the quantities of swirling water needed and depleted by the reservoir while still ensuring the supply of energy into the network even during peak daytime hours.

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CONCLUSIONS

- ***90 GW*** considering the hypothesis of less heavy coverage and the panels with lower efficiency;
- ***108 GW*** assuming the same percentage of coverage and the panels with greater efficiency;
- ***an increase in producibility of 20%*** evaluating the most efficient scenario with panels made with the latest technologies.

- *The various hypotheses of coverage were conducted for an improvement of the harmonization of the floating system, with respect to the flora and fauna of the sites considered.*

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Thank you for your attention

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