Potential of offshore photovoltaic solar technology in the north of Chile.

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Abstract

The main objective of this study is to know the generation potential in Chile through marine solar technology, in terms of generated energy, exploitable area and delimiting factors for its installation using georeferencing tools for the application of restrictions, as well as economic tools for sensitivity analysis and the study of the economic feasibility of these projects on the Chilean coast. Concluding that the chosen configuration is economically viable at high levels of installed capacity, primarily subject to the variability of the energy selling price as the most significant factor contributing to the sensitivity of the NPV (Net Present Value).

Introduction

The northern region of Chile, with its high solar irradiance and extensive coastline, emerges as a favourable setting for solar energy generation. However, the lack of knowledge regarding the potential of photovoltaic solar energy over the sea poses challenges in terms of suitable locations, regulations, environmental impact, and costs. Internationally, this technology offers benefits such as lower module operating temperatures and weather conditions that reduce soiling. While the installation of these plants presents technical and environmental challenges, the internship focuses on assessing their technical, economic, and environmental viability. In the long term, the implementation of this technology could significantly contribute to decarbonization and the diversification of the energy matrix.

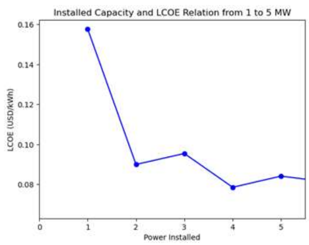

Fig.7 Installed capacity and LCOE relation from 1 to 5 MW.

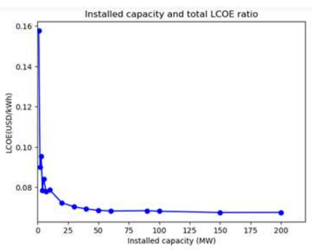

Fig.8 Installed capacity and total LCOE ratio.

Methodology

The temperature of a photovoltaic module can be stated by comparing the ambient temperature and radiation with the stc situation (standard test condition) as shown on the Fig. 1. For its part, the monthly energy generation can be expressed as the product of the performance ratio, efficiency, area and incident radiation (Fig. 2). Based on Figure 1 and 2, the expression that considers the lower temperature operation factor of the photovoltaic panels in the sea can be developed as shown on the Figure 3. Where PR is the performance ratio, a value that discount all the loses in the system, the efficiency (Ƞ), array area (A) , radiation (G), Temperature of module (Tm), and gamma as a thermal coefficient. Were the left part of the equation is a correction based on the operation temperature of the solar panels.

The next part of the methodology involves selecting the mechanical system, which, in this particular case, is the galvanized steel used in salmon farms. Finally, the cost associated with this system and the generation model are used to estimate the economic indicators.

$$T_m = T_{env_i} + \left(\frac{TONC - T_{env}}{G}\right)_{stc} G_i$$

Fig.1 Photovoltaic module temperature.

$$E_{pv_i} = PR \cdot \eta \cdot A \cdot G_i ; i\epsilon[1, \ldots, 12]$$

Fig.2 Energy Generation

$$E_{pvi} = \left[\frac{(1 + \gamma(T_m - 25) + 100)}{100}\right](PR \cdot \eta \cdot A \cdot G_i); i\epsilon[1, \ldots, 12$$

Fig.3 Mathematical Model

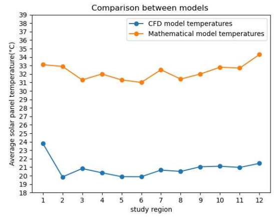

Fig.4 Comparison between mathematical model and Machine learning model.

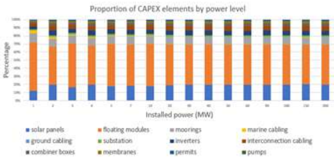

Fig.5 Proportion of CAPEX elements by power level.

Results

- When comparing a mathematical model with one based on environmental data, it is found that the mathematical model underestimates the cooling capacity of solar panels by 54%. This translates to a 9% increase in energy generation capacity (Fig.4).
- Based on the climatological data, the only restrictive parameter is the bathymetry under 100 meters. The total potential of this technology is estimated at 67 GW, surpassing the geothermal and onshore wind potential of the country [1][2].
- The study highlights that investment costs are primarily driven by the cost of floating modules, followed by the number of panels and moorings, emphasizing the importance of these components in the overall cost structure (Fig 5).
- OPEX components, which include variable and fixed costs, do not significantly change across different power levels (Fig 6).
- The Levelized Cost of Energy (LCOE) is evaluated for various installed capacity levels, demonstrating that LCOE decreases as installed capacity increases. For lower capacities, the relationship is shown in Fig. 7, while for higher capacities, it is detailed in Fig. 8. The lowest LCOE, at 0.0674 USD/kWh, is achieved with an installed capacity of 200 MW, indicating economies of scale in reducing energy costs. This finding underscores the financial advantages of scaling up solar power installations.
- For power levels below 20 MW, onshore technology has lower installation costs. However, for higher capacities, the CAPEX of offshore plants is lower. This comparison highlights the cost-effectiveness of offshore solar technology for large-scale installations, making it a competitive alternative to onshore power generation technologies at higher capacities (Fig.9).
- The Net Present Value (NPV) analysis, assuming a 10 km distance to the coast and connection point with a selling price of 0.05 USD/kWh, reveals that projects with installed capacities between 1 and 7 MW have negative NPVs. This is because the PPA price is below the LCOE, making returns insufficient to cover expenses. This indicates the need for higher energy prices or cost reductions to achieve profitability.

Conclusions

- The generation model shows that decreasing panel temperature, based on radiation and ambient temperature, can improve generation by 7% compared to land-based panels.
- In terms of economic indicators, it can be said that, in CAPEX terms, the most significant cost is that of the modules. The economic indicators of NPV, IRR, and Payback, the NPV of projects at different power levels under the assumption of a PPA contract with an energy selling price of 0.05 USD/kWh presents negative results in all cases.
- This study demonstrates that at high levels of installed capacity, the LCOE is competitive with other renewable technologies, and installation costs can even be lower than those of wind and conventional solar technologies on land. In terms of installation potential, offshore solar technology shows promising figures compared to onshore wind and conventional solar.

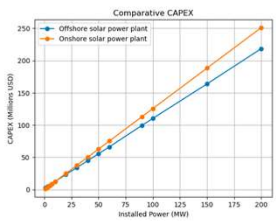

Fig 9. Comparative CAPEX.

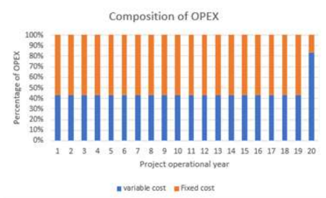

Fig 6. Composition of OPEX.

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