EVALUATION OF ELECTRIC POWER GENERATION FROM HYDROELECTRIC, PHOTOVOLTAIC, AND HYDROGEN ENERGY IN THE HYBRID MODEL

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ABSTRACT

This study assesses the feasibility of integrating hydro and solar power with a Hydrogen-based Electrical Energy Storage System (H2EESS) at the Serra da Mesa hydroelectric Brazilian power plant. Hydrogen would be produced through water electrolysis, taking advantage of the available excess renewable energy, and subsequently converted back into electricity through fuel cells. The integration of hydro and solar power with H2EESS resulted in an increase of 11.10% in the energy produced compared to conventional hydroelectric generation, with 36.06% of this increase coming from H2EESS. Additionally, there was a 9.71% increase in the utilization of substation capacity. These results highlight the feasibility and benefits of integrating hydro and solar power with H2EESS.

Keywords: Energy storage; Hydrogen; Hydro solar integration.

INTRODUCTION

The intermittency and seasonality of renewable sources such as solar and wind energy pose significant disadvantages for their efficient utilization. The availability of sunlight and wind varies according to the region and time of year, thereby affecting energy generation [1]. To address this challenge, a possible solution is the integration photovoltaic (PV) solar generation with hydroelectric generation, which utilizes water reservoirs to store energy in hydroelectric power plants (HPP), provides a more consistent production, even during periods of low solar irradiation or wind intensity. Conversely, PV solar generation offers low generation costs and reduced emissions of polluting gases [2].

An emerging alternative is the utilization of Hydrogen-based Electrical Energy Storage Systems (H2EESS) [3]. Hydrogen, generated through electrolysis, is considered a primary form of clean hydrogen production as it does not emit polluting gases during the production process. H2EESS can harness surplus renewable energy to produce hydrogen via water electrolysis. This gas can be converted back into electricity when needed, through fuel cells, which are devices capable of cleanly and efficiently transforming hydrogen into electrical energy [4].

From this perspective, this study examines the potential of hydro-solar integration and the utilization of hydrogen-based energy storage at the Serra da Mesa HPP. The analysis encompasses the energy aspects and the collaborative operation of these systems, emphasizing the elevated potential of hydrogen storage to optimize the utilization of natural resources and enhance the operational efficiency of HPP, without necessitating additional investments in infrastructure. In this way, the analyzes presented in this work lead to an important collaboration in order to enhance the use of hydrogen as an energy vector in the current energy transition scenario.

MATERIALS AND METHODS

With the intention of evaluating the potential for hydro-solar integration and the use of stored hydrogen for the generation of electrical energy in a HPP, the proposed methodology is:

a) analyze historical electric generation data from the Serra da Mesa HPP;

b) quantify the need for photovoltaic solar generation on the surface of the water reservoir of the Serra da Mesa HPP;

c) examine possible generation of electrical energy through fuel cells (FC) powered by hydrogen originating from the use of renewable energy;

d) analyze the integration capacity of the solar energy generation system through hydrogen storage using the existing infrastructure of the hydroelectric plant's energy substation.

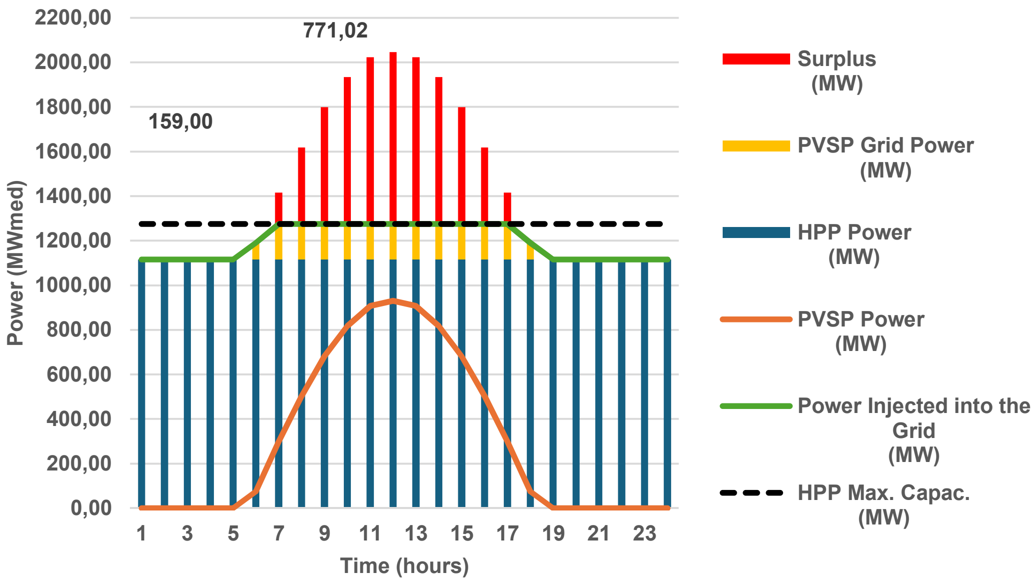
The case study of this paper it the Serra da Mesa HPP, situated in Goiás (GO), Brazil, that occupies a prominent position along the main course of the Tocantins River, approximately 1.790 km from its estuary. The Serra da Mesa reservoir stands as Brazil's largest water body, boasting a voluminous capacity of 54.4 billion m³ and encompassing an expansive area of 1,784 km² [5].

RESULTS AND DISCUSSION

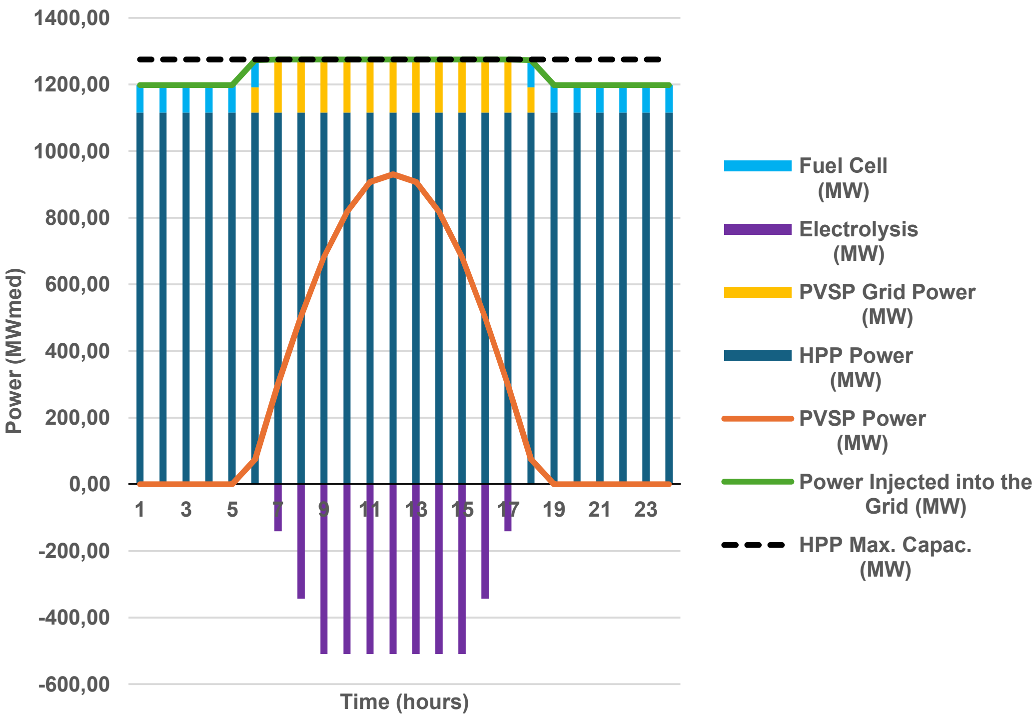
In order to quantify the surplus power generated by the photovoltaic solar plant, a comparative analysis was conducted between its operation and the maximum power output of the hydroelectric generation. By examining the daily energy generation between 2018 and 2022, the maximum recorded hydroelectric energy generation was 27GWh [6]. This value corresponds to 87.5% (1,116 MWavg) of the total power capacity (TPC) of the HPP (1,275 MW), indicating the potential for increased production without altering the infrastructure of the HPP.

The analysis of the PV plant's operational behavior throughout the day, as depicted in Fig. 1(a), highlights the occurrence of excess photovoltaic generation between 7:00 a.m. and 5:00 p.m., with a peak power of 771.02 MW. The excess energy generated corresponds to the amount of energy produced by the plant that exceeds the substation's transmission capacity. Furthermore, it is observed that the increase in HPP contributes to the increase in surplus photovoltaic generation.

Fig. 1(b), shows the respective contribution of each component regarding the total energy production. It was determined that hydroelectric generation, photovoltaic solar energy, and fuel cells account for 87.53%, 6.21%, and 3.5% respectively, of the utilization of the substation's capacity. When combined, these values amount to a total utilization of 97.24% of the available infrastructure.



(a)



(b)

Figure 1. (a) Average daily operation of the Serra da Mesa HPP generation, PVSP plant 1,732.94 MWp) (b) Idem (a) assisted by a H2EESS.

CONCLUSION

The obtained results indicate that the integration of hydro-solar systems with hydrogen-based energy storage applied is capable of augmenting energy production by 2.97 GWh during periods of peak energy availability, representing an 11.10% increase in the maximum generation capacity of the plant.

The required areas for the installation of PVSP correspond to a negligible fraction of the evaluated reservoir, amounting to merely 0.83% of the total area.

The H2EESS enabled the recovery of a significant surplus, equivalent to 44.63 MWavg, which represents 3.5% % of the HPP's maximum production. In this context, the implementation of H2EESS assumes relevant roles, as it becomes possible to harness the excess energy generated by the PVSP during peak PV production and enhance the energy supply during non-PV generation periods.

These findings suggest that the utilization of H2EESS holds promise as a solution to optimize the generation of electric power in hydroelectric plants.

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