THE ROLE OF SMALL HYDROELECTRIC POWER PLANTS IN THE CONTEXT OF THE ENERGY TRANSITION

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ABSTRACT

Brazil plays a significant role on the global stage when it comes to the use and generation of Renewable Energy. This present work aims to present the importance of Small Hydroelectric Power Plants (SHPPs) in the context of the energy transition. The methodology involves exploratory research conducted with government agencies, Brazilian regulations, and resolutions to study the energy potential of SHPPs. An example is the production of Green Hydrogen (GH_2) in hybrid generation systems, meaning producing GH_2 from renewable energy sources such as SHPPs and associated Photovoltaic (PV) Plants. This proposal will make GH_2 prices more competitive in the medium and long term, especially in the Southeast/Central-West region of Brazil, where the highest number of SHPPs in operation and the largest installed solar energy capacity are concentrated. This work also aims to contribute to the planning studies of the National Hydrogen Plan and stimulate discussions on this topic.

Keywords: Energy Transition, Green Hydrogen, Hybrid Systems, Small Hydroelectric Power Plants.

Introduction

Electricity generation and consumption are among some of the variables considered for a country to be classified as developed [1]. The increasing demand for energy over the years has stimulated studies and projects on new, cleaner, and environmentally friendly energy sources, which has led to a search for Small Hydroelectric Power Plants, or simply SHPPs [2]. Unlike fossil fuel-powered plants such as thermal power plants, SHPPs produce electricity with minimal carbon emissions. Hydroelectric power plants help reduce greenhouse gas emissions, expand renewable energy generation, and distribute national energy generation. This is especially true for Small Hydroelectric Power Plants [3]. SHPPs play an important role in diversifying Brazil's energy matrix.

Furthermore, SHPPs prove to be an affordable choice for distributed generation, reducing losses in transmission to major urban centers. Beyond meeting the demands of isolated regions, i.e., areas not served by the interconnected transmission system, they drive the development of remote regions in the country and enable the replacement of thermal generation, including the logistics of fuel transportation and storage [4]. Energy generation from SHPPs offers a reliable option because its generation follows the seasonality of water resources, decentralizes generation, and has a smaller environmental impact since the projects have smaller or no reservoirs at all. Therefore, there is a degree of predictability in energy generation.

Brazil has more than 427 SHPs in operation, totaling over 5,784 MW of licensed capacity, accounting for almost 3% of the licensed capacity in the energy matrix [5]. According to the Ministry of Mines and Energy (MME) [6], Brazil is a global example of energy transition, with over 85% of its electrical matrix coming from clean and renewable sources and 48% renewability in its total energy matrix.

Regarding the energy transition, Brazil is ahead compared to other countries in the world. Due to its diversification in the renewable energy matrix, the production of Green Hydrogen (GH_2) can make GH_2 prices economically viable in the medium and long term. In this regard, it is important to create a

DOI: 10.55592/ISE.2023.9139974

discussion about GH_2 production in a hybrid model. According to BNDES [7] for green hydrogen to become viable, a significant reduction in production costs is still needed, coupled with a policy that taxes greenhouse gas emissions.

Combining the production of GH_2 from intermittent sources like solar with more consistent sources like SHPPs can be a viable strategy for the energy transition. An example of a project in this area is the green hydrogen generation study plant inaugurated at the Itumbiara Hydroelectric Plant (MG/GO) in December 2021[8]. Studies by BNEF [9] indicate that Brazil is projected to have the lowest production cost for low-carbon hydrogen and its derivatives. Brazil has the technical potential to produce 1.8 gigatons of hydrogen per year. Wind, solar, and hydro energy together account for more than 18.1 million tons per year [10].

This work aims to consider Small Hydroelectric Power Plants (SHPPs) in the National Hydrogen Plan for the production of Green Hydrogen. This involves combining Hydrogen (H_2) production from SHPPs and PV Plants competitively in the Southeast and Central-West regions of Brazil, considering their significant potential. Additionally, it aims to stimulate discussions on this topic.

Materials and Methods

This study involves the use of exploratory research to investigate information regarding the Hydropower Potential from Small Hydroelectric Power Plants (SHPPs) in Brazil. It aims to establish a study to associate the production of GH_2 through a Hybrid System between Small Hydroelectric Power Plants (SHPPs) and Photovoltaic (PV) Plants in the Southeast/Central-West region. The objective is to demonstrate that the price of GH_2 can become increasingly competitive nationally and contribute to the study of a National Hydrogen Plan in Brazil. To achieve this, official information from Brazilian government agencies and organizations, as well as Brazilian legislation related to water resource generation and operation, and solar parks were taken in consideration.

Results and Discussion

According to the Generation Information System of ANEEL, [5] (Brazilian Electricity Regulatory Agency), the states in the Southeast and Central-West regions, namely Goiás (GO), Mato Grosso (MT), Minas Gerais (MG), Espírito Santo (ES), Mato Grosso do Sul (MS), and Rio de Janeiro (RJ), currently operate a total of 271 Small Hydroelectric Power Plants (SHPs) with a combined licensed capacity of 3,973,976.17 kW. Additionally, when we add the potential of solar generation to this scenario, which reaches 55,402,728.64 kW, we obtain a promising outlook.

Table 1, presented below, illustrates the combined licensed capacity of Small Hydroelectric Power Plants (SHPs) and Photovoltaic Plants (PVs) in the Southeast and Central-West regions. This combination results in an extraordinary potential of over 59,376,704.81 kW.

Table 1: Licensed Capacity of SHPs and PVUs in the Southeast and Central-West Regions.

Type	Quantity	Licensed Capacity (kW)	Inspected Capacity (kW)	Inspected Capacity (%)
PVs	4545	55,402,728.64	4,523,240.52	56.67
SHPPs	271	3,973,976.17	3,458,372.17	43.33
Total	**4816**	**59,376,704.81**	**7,981,612.69**	**100%**

Source: [5]

Given the energy potential of SHPPs and PVs in the Southeast and Central-West regions of Brazil, the creation of a hybrid model for Green Hydrogen (GH_2) production can become increasingly accessible and competitive in this region. This is particularly significant since it houses the largest consumer hubs in Brazil. It is expected that, in a few years, this production will become more

DOI: 10.55592/ISE.2023.9139974

economically viable when compared to the production of gray hydrogen, which is derived from fossil fuels.

The strategy for producing GH_2 in hybrid systems, as proposed in this study, is based on several factors: economic considerations in terms of market conditions, efficiency and storage, resource utilization, electricity pricing, among others.

It is advisable to produce H_2 under the following circumstances: when there is a significant demand for H_2, whether for industrial, healthcare, or transportation applications; in cases where the electrolysis process or other H_2 production technology has negligible losses in energy conversion. It is not advisable to produce H_2 when electricity prices are more competitive, especially when electricity tariffs are on the rise. In such cases, the best alternative is to produce electricity and inject it into the grid. Another strategy is to store the produced H_2, allowing for its later use when demand is higher or electricity supply is lower.

According to the Energy Research Company [11], out of the 19 authorized oil refineries for operation in Brazil, 11 have hydrogen generation units. Currently, all of them are operating below their maximum installed capacity, indicating an idle capacity of approximately 200,000 tons per year. Figure 1 depicts the hydrogen production projection in Brazil for the next 10 years.

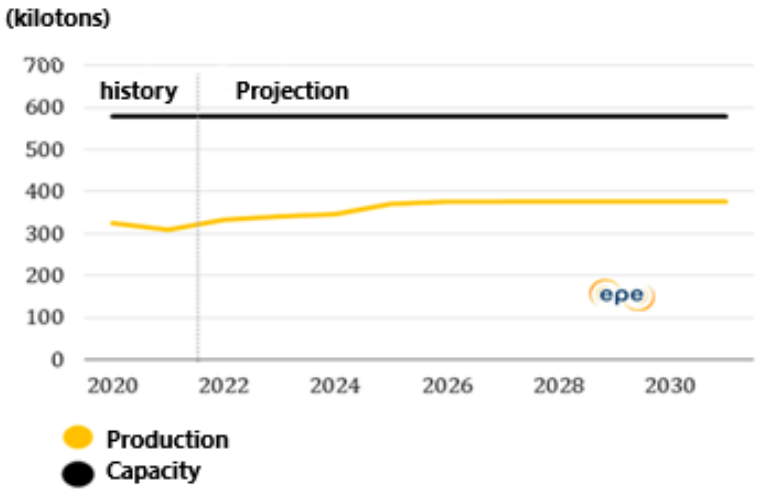

Fig. 1 - Hydrogen production in Brazilian refineries, with a projection for the next 10 years
Source: [11]

The projected scenario, as envisioned by Energy Research Company, suggests that this production is intended for internal consumption within refineries, as there is currently no established market for buying and selling this product. It could potentially be commercialized in the event of the development of the hydrogen market, regulatory changes, and increased investment in the coming years. Energy Research Company also emphasizes that it would likely be limited to commercial agreements with nearby industrial ventures.

Currently, a significant portion of the hydrogen produced in Brazil originates from natural gas and is consumed by traditional markets such as fertilizers, refining, and other uses (industrial and medical gases). However, with the expansion of hydrogen production, especially GH_2, new markets may emerge in the public transportation sector, hydrogen-powered electric light and heavy vehicles, fuel for navigation and aviation, and other industrial processes, as well as for energy storage and subsequent conversion into electrical energy for use during periods of high electricity demand.

Brazil emerges as one of the leading potential producers of GH_2 in the world, which, in the context of the energy transition, represents a significant promise to contribute to sustainable development, particularly concerning the planet's decarbonization. In this context, the existing SHPPs (Small Hydro Power Plants) network in Brazil is an important source of additional energy for GH_2 production. For Brazil to establish itself as a major global producer of Green Hydrogen (GH_2) in the

coming years, it is crucial to open up to foreign investments, invest in cutting-edge research, and continually strengthen public policies. In this regard, Brazil has instituted Resolution CNPE No. 6, dated June 23, 2022, for the National Hydrogen Program - PNH2, with the aim of bolstering the hydrogen market and industry as an energy vector in Brazil. Additionally, the country has been establishing various research centers throughout Brazil.

Conclusion

It is essential to consider the role of SHPPs in the context of the Brazilian energy matrix as a source that could lead to a greater reduction in carbon emissions compared to other conventional energy sources. Thus, encouraging investment policies for the modernization of SHPPs, creating optimal operation methodologies for energy generation, among other considerations, is crucial to stimulate and invest in this energy matrix.

In the context of the Energy Transition, considering SHPPs in hybrid models for GH_2 production will, in the medium and long term, prove to be an effective measure in reducing carbon globally. The challenges of climate change prompt us to contemplate the use of environmentally friendly energy with low carbon emissions. In this regard, SHPPs emerge as a fundamental strategy as a support to ensure a more sustainable future.

Acknowledgments

Our thanks to Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) for financial support in the preparation of this research; the colleagues in the research group at the Laboratory of Alternative Energies and Electric Systems Protection (LEAPSE), and the School of Electrical Engineering (FEELT) at Universidade Federal de Uberlândia (UFU) for the physical installations used and the resources offered in its premises.

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DOI: 10.55592/ISE.2023.9139974