Power Generation in Goiás: Infrastructure Limitations and Opportunities for Distributed Generation

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ABSTRACT

Data mining plays a crucial role in the analysis of energy data by enabling the extraction of valuable information from large and complex datasets. In the energy sector, this technique helps identify patterns, trends, and correlations that are not easily detectable through traditional methods. When combined with data visualization tools like PowerBI, it provides decision-makers with clear and actionable insights, facilitating strategic planning and operational efficiency. In the context of the energy transition, this article presents an analysis of data on installed generation capacity in the State of Goiás in Brazil. Data analysis revealed a clear trend in the adoption of distributed solar photovoltaic generation across most projects in the state and concluded that the southern and central regions possess the greatest potential for energy generation.

Keywords: Data Mining, Distributed Generation, Eletricity Generation, Energy Planning, PowerBI.

INTRODUCTION

The evolution of electrical grids in Brazil follows a path marked by challenges and opportunities, especially considering the national energy planning guidelines established by Empresa de Pesquisa Energética (EPE), [1]. The modernization of the electricity sector, driven by technological advancements and regulations promoting energy efficiency, seeks not only to meet the growing demand for electricity but also to ensure the reliability, sustainability, and resilience of the electrical infrastructure.

In the specific context of the state of Goiás, an economic growth dynamic that surpasses the national average can be observed. Over the past 12 months, up to June 2024, the economy of Goiás recorded an accumulated growth of 5.4%, compared to the national growth of 1.6%, according to data from the Regional Economic Activity Index (IBCR) published by the Central Bank, [2]. This impressive economic performance has been sustained by factors such as fiscal balance, the quality of public service delivery, and strategic investments, which make Goiás an attractive hub for new ventures. In the first half of 2024, the state recorded the highest production volume for the period in its entire historical series, highlighting its potential for continuous development.

Alongside economic growth, the distributed generation (DG) sector has emerged as an increasingly significant trend in Goiás' energy matrix. Regulatory advancements, aligned with the pursuit of renewable sources and the decentralization of energy generation, have driven the adoption of DG systems, particularly in urban and rural areas seeking local and sustainable solutions for energy supply. This trend reflects a national and global movement toward greater energy autonomy, reduced transmission and distribution losses, and the promotion of clean and efficient generation.

Considering this scenario, this paper proposes an analysis of the evolution of installed capacity in the state of Goiás, with the aim of identifying the limitations of the regional electrical infrastructure to support the advancement of distributed generation and exploring the opportunities that this generation model can offer the state. The discussion will be based on recent data on economic growth, regulatory developments, and the prospects for the energy sector in the state, offering a comprehensive view of the challenges and potential factors to be considered in the planning of the expansion of Goiás' energy matrix.

MATERIALS AND METHODS

The application of data mining techniques in the analysis of centralized and distributed generation energy data makes it possible to identify patterns and understand the variation in the number of projects considering all the energy sources currently exploited in the country, [3]-[4]. Continuous progress in information technology has made it possible to store vast and diverse databases, providing new opportunities for in-depth and strategic analytical investigations.

This data can be collected and accumulated for multiple purposes, being widely used in statistical studies aimed at answering crucial questions, such as variations in the number of energy generation projects and changes in the behavior of primary sources, with a special focus on the energy transition. Data mining stands out as an essential tool for converting large volumes of dispersed data into valuable and actionable information, enabling more informed and strategic decision-making. In this study, data mining was applied to a database with more than one million records on Brazil's energy potential, both in distributed and centralized generation. This data was initially filtered to limit it to the state of Goiás and data from the last 10 years were selected. The data was obtained from public sources, such as the open data available by the Agência Nacional de Energia Elétrica - ANEEL [5] and went through several stages of processing so that they could finally be presented appropriately. Tools such as Phyton and PowerBI were used to achieve this. The diagram shown in Figure 1 shows how these tools were linked to visualize and analyze the main data.

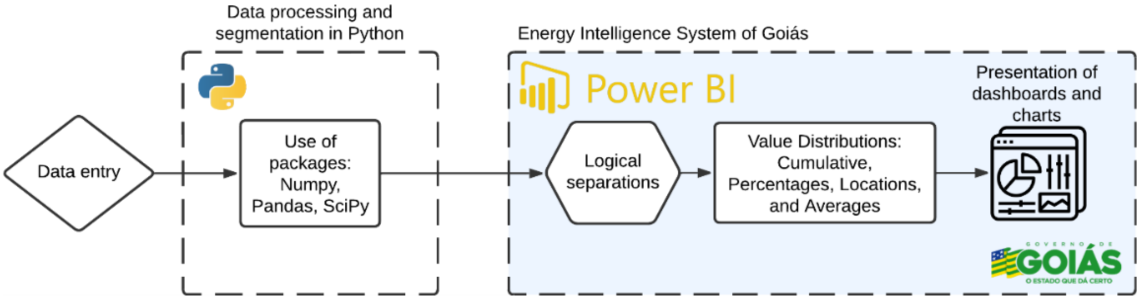

Figure 1. Data Processing Flowchart.

Initially, the government databases were accessed, and then a preliminary analysis was carried out to understand the structure of the data, identify its variables and detect any problems, such as missing values or inconsistencies. After this initial inspection, the data went through a rigorous debugging process, where null values were treated, irrelevant data was discarded and inconsistencies corrected. Therefore, the data was then imported into Power BI.

Due to the significant volume of data, a direct connection to the database was chosen to ensure more efficient processing. After the import, the main aspects of the data were explored, resulting in the construction of initial dashboards with different visualizations, such as bar charts, maps, sector charts and summary tables. This phase enabled the identification of patterns, trends and initial insights that guided subsequent, more detailed analysis.

In the last stage, interactive visualizations were developed in Power BI to present the results in a clear and intuitive way. Various types of graphs and visual resources were used to make the analysis more accessible, facilitating data interpretation and allowing the extraction of strategic information.

RESULTS AND DISCUSSION

As mentioned, the behavior of the installed power in the State of Goiás over the past 10 years is analyzed. Firstly, Figure 2 shows the annual installed capacity as well as the accumulated power over these years. Observe that the installed power in the distributed generation category has increased significantly since 2019 and the even with the introduction of the distributed generation regulation in Brazil around 2012, the State was slow to adopt this new model, exhibiting a somewhat conservative.

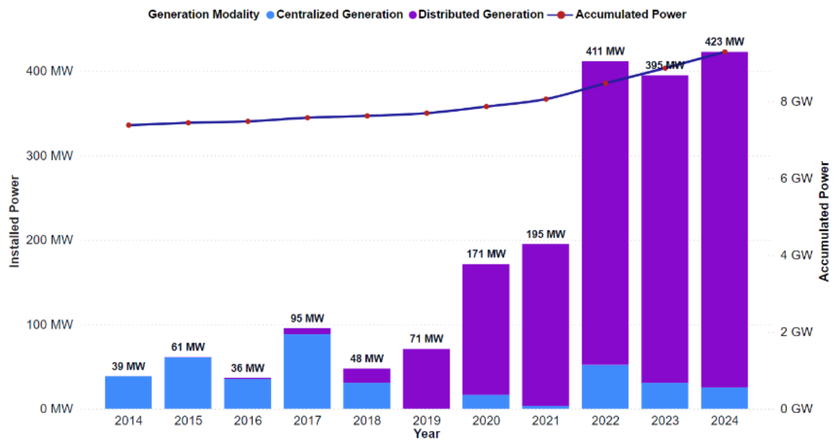

Figure 2. Annual Installed Capacity (2014-2024).

During these years, UFV (Photovoltaic Solar Power Plants) dominate with 1.55 GW, which accounts for 79.9% of the total installed capacity, indicating that solar energy is the primary source of power generation in the State as shown in Figure 3. Thermal energy (UTE) contributes 11.44% to the total representing a significant portion, showing the importance of thermal power in the energy mix. Regarding generation from water sources, Small Hydroelectric Power Plants (PCH) contribute 163.63 MW, or 8.42% of the total capacity and Hydroelectric Generating Stations (CGH) have a much smaller contribution of 4.60 MW, representing just 0.24% of the total, showing that hydro plants play a relevant role in the overall energy generation yet. Finally, wind power (EOL) has the smallest share, contributing only 20.56 kW, which is a negligible part of the overall installed capacity.

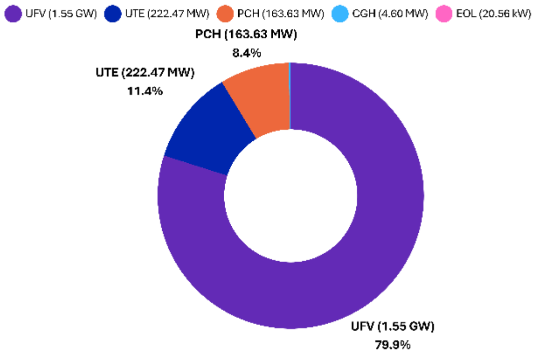

Figure 3. Distribution of installed capacity across different energy sources.

That distribution can be justified because in Goiás high solar irradiation levels are verified and its geographical landscape, coupled with generally favorable weather conditions throughout the year, provides an ideal setting for the expansion of these energy sources. On the other hand, wind power in Goiás is negligible, although the State does not have the same high wind speeds as coastal areas, there are certain regions, particularly in elevated areas, that show potential for wind power development. Technological advancements in wind turbines, which can operate efficiently at lower wind speeds, make it feasible to explore this renewable energy source further. Although wind energy is currently a minor part of the state's energy matrix, with the right investments and research, Goiás could diversify its energy portfolio and increase its reliance on wind power.

Considering the five mesoregions of the State defined by IBGE [6], it can be observed in Figure 4 that the Southern Region has the highest installed power, with generation capacity of 790.47 MW, which is approximately 39.9% of the total capacity. The Central Region of the State is also representative with 748.26 MW, comprising 37.8% of the total while the other regions make up the remaining 22%.

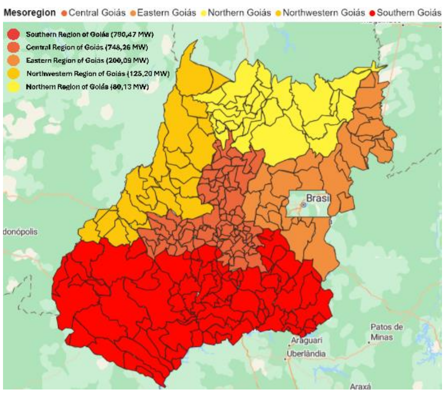

Figure 4. Heatmap of Distribution of installed capacity by mesoregion

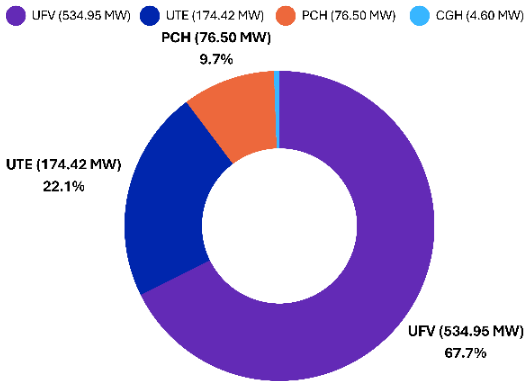

Figure 5. Distribution of installed capacity by energy sources - Southern Region

In the Southern region, solar photovoltaic energy is predominant, representing 67.67% of the total capacity, as shown in Figure 5. The significant growth of this source demands strategic planning for the upgrading and revitalization of the electrical grid infrastructure, which is already widely used for irrigation systems that support agricultural services. This network faces significant limitations in accommodating new solar plants, making investments in expansion and modernization essential. The decentralization of energy generation can be a solution for agricultural services, but it is crucial to adapt the existing infrastructure. Furthermore, the region's high potential favors the application of battery energy storage systems (BESS), which are essential for improving the reliability and dispatchability of the electrical system. Integrating BESS would mitigate the intermittency of solar generation and strengthen the grid's resilience, providing a strategic alternative to expand DG and add value to the energy system.

CONCLUSION

The approach presented in this paper highlights the relevance of using data mining and data visualization tools, such as Power BI, in the analysis of large volumes of energy data, significantly contributing to a better understanding of the regional energy landscape and decisively assisting in strategic decision-making, particularly in the context of the energy transition. Particularly in the state of Goiás, a tendency to adopt the distributed generation model was verified, highlighting photovoltaic solar energy. Furthermore, the southern region of the state was identified as having the greatest generation potential in recent years.

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