

HYBRID POWER PLANTS IN THE CONTEXT OF THE ENERGY TRANSITION

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Overview

The article presents an in-depth analysis of the role of hybrid power plants in the context of the energy transition, highlighting their significant contribution to building a more sustainable and efficient energy future. By examining the various aspects of these plants, from their economic and operational benefits to their ability to mitigate greenhouse gas emissions and diversify the energy matrix, it becomes clear that they play a key role in improving the security and reliability of energy supply. Furthermore, through practical examples of implementation in different regions of Brazil, the text illustrates the potential of hybrid plants to stimulate local and regional development, create jobs, strengthen energy resilience and promote social inclusion.

However, in order to reap the full benefits of these innovative technologies, it is essential to maintain and even increase investment in research and development. In addition, policies and regulations that encourage the deployment of hybrid power plants need to be promoted, fostering collaboration between governments, industry, academia and civil society. It is through this interdisciplinary collaboration that the challenges of the energy transition can be more effectively addressed and a cleaner, safer and more sustainable future can be built for all. It is clear that hybrid power plants are not only a viable solution to today's energy challenges, but also an opportunity to positively shape the future of energy on a global scale.

Methods

This study aims to investigate the role and opportunities of hybrid power plants in the energy transition using a methodological approach that combines literature review and case study analysis. The methodological process is divided into five main stages:

1. Bibliographic review:
 - A comprehensive literature review will be conducted to examine the concept of hybrid power plants, their different technological configurations and applications. Academic sources, technical reports and relevant regulations will be considered, including Normative Resolution No. 954 of the National Electric Energy Agency (Aneel).
2. Analysis of the Impacts of Renewable Energies Variables:
 - The impact of increasing variable renewable energy, with a focus on solar, will be analyzed. Case studies from different countries such as California, Spain, Australia and Brazil will be examined to understand the changes in the energy demand curve and the challenges faced by grid operators.
3. Introduction to hourly energy pricing and hybrid power plants:
 - The introduction of hourly energy pricing in different countries and its impact on energy generation strategies will be studied. Examples of hourly pricing systems, such as the spot markets in Portugal and Spain, will be analyzed to determine how hybrid power plants can benefit from these new pricing mechanisms.
4. Hybrid power plants and decarbonization of isolated systems:
 - The role of hybrid power plants in decarbonizing isolated power systems will be explored, with a focus on initiatives such as the Energias da Amazônia program in Brazil. Examples of hybrid power plant projects in remote areas, such as the diesel-solar power plants in Roraima and the "Brilha Amazônia" program, will be presented to illustrate the potential of these technologies to reduce emissions and promote sustainable development.
5. Examples of Hybrid Power Plants in Brazil:
 - Examples of hybrid power plant projects in Brazil will be presented, including the Neoenergia Renewable Complex in Paraíba, CEMIG's floating photovoltaic plants in Minas Gerais, and Statkraft's projects in Bahia. The analysis of these cases will provide insights into the current state of hybrid power plant implementation in the country and their impact on the energy transition.
6. Hybrid Power Plant Research Agenda:
 - In addition to the previous steps, we emphasize the importance of a continuous research agenda on hybrid power plants. The introduction of these plants into the national electricity system opens up opportunities for academic and professional research. In this context, the Energy Institute of PUC-Rio is committed to developing further studies on the subject. One

of the ongoing initiatives is the construction of a hybrid pilot plant at the PUC facilities in partnership with GALP. This plant aims to validate models in expert software, considering different types of operational loads and available generation sources. The goal is to develop optimal generation hybridization strategies that take into account demand characteristics, hourly energy prices, and technological advances. This initiative will make a significant contribution to advancing knowledge and improving hybrid power plant technologies, thereby driving the energy transition to a more sustainable and efficient system.

These methods will provide a comprehensive overview of the role of hybrid power plants in the energy transition, identifying opportunities and challenges for their implementation and contribution to a more sustainable and resilient power system.

Results

The results of this study provide a comprehensive insight into the role of hybrid power plants in the current global energy transition. By exploring the concept and applications of these plants, we highlight their unique ability to combine different energy sources to optimize power generation. An in-depth analysis of the impact of variable renewable energy, particularly distributed solar energy, reveals the challenges and opportunities associated with managing the variability of solar generation in power systems.

Practical examples from different countries illustrate the dilemmas faced by grid operators in managing the growing share of solar generation and the resulting impact on energy demand curves. We also examine the introduction of hourly energy pricing models in different electricity markets and show how hybrid power plants can benefit from these mechanisms to optimize profitability and contribute to grid stability.

We also explore the opportunities for hybrid power plants in decarbonizing isolated power systems, highlighting initiatives such as the Energias da Amazônia program in Brazil. Specific projects, such as diesel-solar plants in Roraima and the Brilha Amazônia program, were presented as concrete examples of how these technologies can reduce greenhouse gas emissions and promote sustainable development in remote regions.

Examples of hybrid power plant projects in Brazil were shared, providing insight into the current implementation landscape of these technologies in the country and their potential to drive the energy transition at both local and global levels.

Finally, considering that the introduction of hybrid power plants into the electricity system presents opportunities for academic and professional research development, the PUC-Rio Energy Institute is conducting studies based on a pilot plant currently under construction. The main objective is to validate specialized software models with different types of operational loads. The results will provide valuable insights for policy makers, investors and energy sector professionals interested in understanding the role of hybrid power plants in shaping a more sustainable and resilient energy future.

Conclusions

After exploring the various facets of hybrid power plants in the context of the energy transition, it is clear that these technologies have a critical role to play in building a more sustainable and energy-efficient future. Throughout this study, we have analyzed not only the economic and operational benefits of hybrid power plants, but also their ability to contribute to the reduction of greenhouse gas emissions, the diversification of the energy mix, and the improvement of energy security and reliability.

The introduction of hybrid power plants not only opens up new opportunities for investment and technological development, but also challenges existing paradigms in the electricity sector, particularly with regard to the integration of variable renewable energy sources and the efficient management of energy supply and demand. Furthermore, the examples of hybrid power plant projects presented in different regions of Brazil demonstrate the potential of these technologies to promote sustainable development at local and regional levels.

To maximize the benefits of hybrid power plants, it is critical to continue to invest in research and development, as well as policies and regulations that encourage the adoption of these innovative technologies. Collaboration between government, industry, academia and civil society is essential to meet the challenges of the energy transition and build a cleaner, safer and more sustainable future for all.

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