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Contributions and Benefits of Accumulation Systems to the Electrical System

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Abstract

Energy storage systems play a crucial role in the modernization and stability of the electrical system. The objective is to explore the different types of storage systems and their contributions to energy efficiency, the integration of renewable energies, and the improvement of the reliability of the electricity supply. A qualitative investigation was carried out, and the bibliographic review and the inductive-deductive method were used as a methodology, the result was that accumulation systems have less economic and environmental impact, standing out as the most innovative technologies and possible implementation at a global level, these Results indicate that the adoption of these systems not only improves grid stability, but also facilitates a faster transition to a sustainable energy future.

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1 Introduction

Energy accumulation systems are under development with the appearance of new materials that contribute to the development of technology, these systems and other storage devices are playing an increasingly essential role in the transition towards a more flexible electrical system. sustainable and resilient. These allow energy to be stored at times of low demand or high production, and released during demand peaks or when energy production, especially from renewable sources, is insufficient (Ibrahim et al., 2008). By mitigating fluctuations that can arise due to the intermittent nature of renewable sources, such as solar and wind, the energy generated can be stored for times when it is needed, stabilizing the electrical grid (Barton & Infield, 2004).

Accumulation systems provide the integration of renewable sources into the electrical system, which is essential to reduce dependence on fossil energy sources and reduce greenhouse gas emissions. These contribute to improving the operational efficiency of the electrical system by reducing the need to keep backup power generation plants in operation, which are usually less efficient, more polluting, and expensive in terms of operation (Aneke, & Wang, 2016).

The International Energy Agency (IRENA) highlights the essential role of energy storage to facilitate the integration of renewable energies and guarantee the stability of the electrical system and also points out how a decrease in costs in the market is expected by 2030 (Irena, 2017). Energy storage systems are necessary for the development and implementation of smart grids, which allow for more efficient and flexible management of energy flow, facilitating rapid response to fluctuations in demand and improving reliability. of the electrical supply (Barton & Infield, 2004)

Storage systems interact with renewable energy sources, underlining the importance of storage to maintain the stability of the network in their combination they enhance the electrical system, increasing the improvement and quality of the energy. The variability and intermittency of electricity supply increases due to the large number of variable renewable sources, which affects the reliability of the network and the ideal functioning of traditional electrical systems. Energy producers are forced to spend a lot of money to meet higher demands and fluctuating electricity prices due to deregulated electricity markets (Zakeri & Syri, 2015). This study provides an analysis of different energy storage systems, highlighting their contribution to electrical system efficiency, cost reduction, and carbon footprint reduction.

2 Materials and Methods

An exhaustive review of the existing literature on energy accumulation systems was carried out, and scientific articles, technical reports, and case studies from various regions of the world were analyzed. A qualitative approach was used to evaluate the benefits and challenges associated with the implementation of accumulation systems; In addition, interviews were conducted with experts in the energy field to obtain a practical and up-to-date perspective on the topic.

3 Results and Discussions

Data collection focused on obtaining a comprehensive view of different storage technologies, their practical applications, and their impact on the power system (Luo et al., 2015). Comparative analysis methods were used to evaluate the advantages and disadvantages of each technology, as well as its economic viability and environmental sustainability. There are different types of storage batteries in figure 1, some of them are shown.

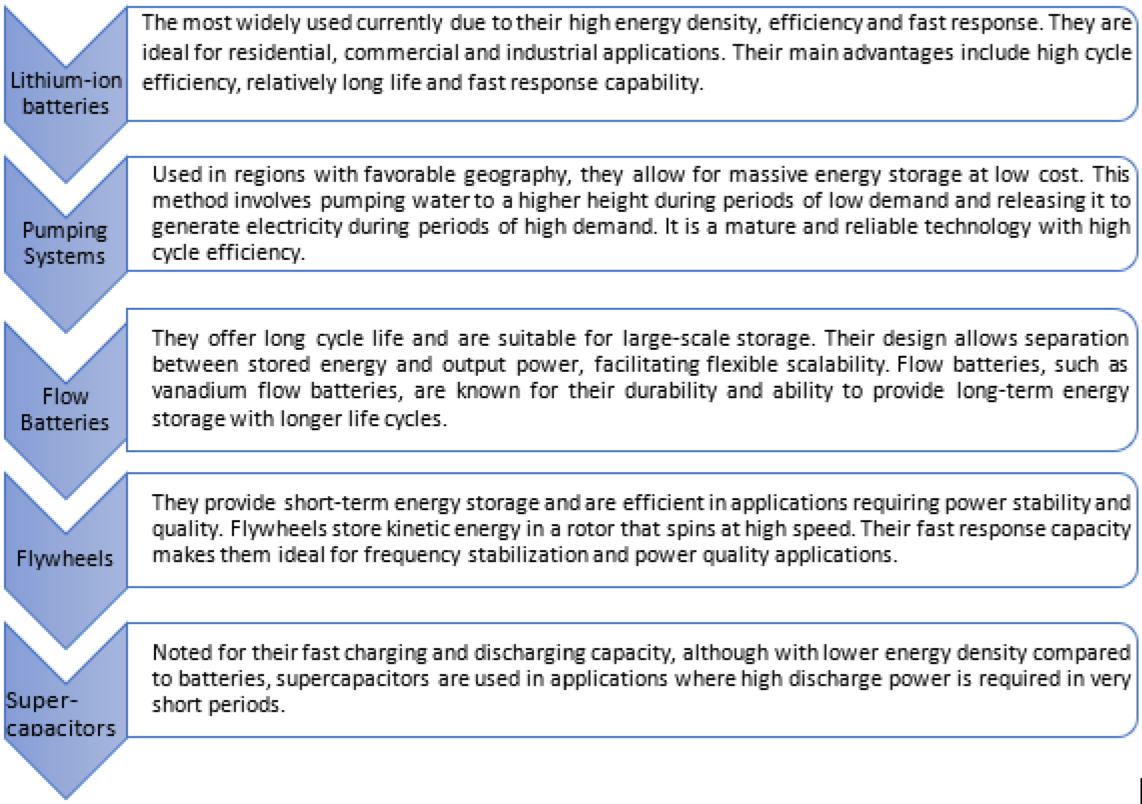

Figure 1. Types of storage batteries

Some types of energy accumulators that are in operation today are shown, but these can have their disadvantages, for example, Lithium has a relatively high cost, and concerns about the availability of lithium and the recycling of used batteries.

Flow Batteries present challenges that include high initial costs and the need for specific materials.

In the case of flywheels, they also have their limited storage capacity compared to other technologies. Superconductors are known for their long life and high cycle efficiency, but their storage capacity is significantly lower than that of traditional batteries.

Contributions to Energy Efficiency

Accumulation systems allow energy to be stored in periods of low demand and released at peak times, reducing transmission and distribution losses. This optimizes the use of existing infrastructure and improves the operational efficiency of the electrical system, in addition, it reduces the need to keep reserve generation plants in operation, which are usually less efficient (León Robaina et al., 2023). Optimizing the use of generation facilitates more efficient operation of the plants by allowing better management of demand and supply (Divya, & Østergaard, 2009). This results in less need to generate additional energy in less efficient plants, in addition to reducing wear on them, prolonging their useful life, and reducing operating costs.

Integration of renewable energy sources (fre)

The variability of generation from fre, such as solar and wind, can be compensated with storage systems, providing a reliable and continuous source of energy. This is decisive in maintaining the stability of the electrical grid and guaranteeing an uninterrupted supply of electricity, even when climatic conditions are not favorable for the generation of renewable energy (Díaz-González et al., 2012; Gómez-Ramírez et al., 2021).

By storing excess energy generated during periods of high production and low demand, you avoid wasting renewable resources. Storage systems allow unused renewable energy to be stored and released when demand is high, improving the overall efficiency of the system and maximizing the utilization of renewable energy sources (Jossen et al., 2004; Jaramillo et al., 2022).

Improving the Reliability of the Electrical Supply

Storage systems can act as a backup power source during power outages, improving grid resilience. This is especially important in regions prone to natural disasters or power outages. Accumulation systems provide an immediate energy source that can keep essential services and critical infrastructures operational (Saltos-Arauz et al., 2024).

They also facilitate the implementation of demand response programs, where consumers can adjust their consumption in response to market signals, balancing supply and demand more effectively (Sterner & Stadler, 2014). This not only improves grid stability but also allows consumers to actively participate in energy management and reduce their electricity costs.

Another advantage is related to the economic and environmental impact, where a reduction in operating costs of the electrical system can be considered by optimizing the use of existing infrastructure and reducing the need for investments in additional generation capacity. Furthermore, by reducing transmission losses and improving the efficiency of generation plants, storage systems contribute to an overall decrease in energy production costs.

The current situation of the planet due to the high levels of pollution requires technological changes that lead to decarbonization. In this context, storage systems, by favoring the integration of energy sources and reducing dependence on generation plants based on fossil fuels, contribute significantly to the reduction of greenhouse gas emissions. This is essential to meet the emissions reduction objectives established in international agreements on climate change and to promote sustainable development (Castro López & Castillo Rodríguez, 2024).

Technological Innovations and Future Trends

Solid-state batteries represent a significant evolution over traditional lithium-ion batteries. They offer greater energy density, safety and useful life, in addition to eliminating the risks associated with flammable liquid electrolytes (Espinoza, 2023). The hydrogen produced from fre can be stored and converted back into electricity through fuel cells. This technology is promising for large-scale and long-term storage, especially for industrial and transportation applications (Aranibar Ramos & Olarte Pacco, 2024).

The integration of storage systems with smart grids allows for more efficient energy management. Smart grids use advanced communication technologies to monitor and manage the flow of energy in real-time, improving the efficiency and reliability of the electrical system (Brito et al., 2024). Compressed air accumulators are systems that use electrical energy to compress air and store it in underground tanks. This air is subsequently released to generate electricity when needed. They are suitable for large-scale storage and offer a profitable and sustainable alternative.

The thermal storage of energy in the form of heat allows its subsequent use in industrial processes or for the generation of electricity. This technology can take advantage of waste heat from other activities and is especially useful in regions with high heating demand. In a general sense, energy accumulation systems represent a key technology for the future of the electrical system. Its benefits range from improving energy efficiency and the integration of renewable energies to supply reliability and reducing environmental impact. The global adoption of these technologies, supported by appropriate policies and technological advances, will enable a faster and more efficient transition towards a sustainable and resilient energy system (Aranibar Ramos & Olarte Pacco, 2024; Dongxu et al., 2023; Kadiri et al., 2012).

The continued evolution of storage technologies, along with the integration of smart grids and the development of innovative solutions such as solid-state batteries and green hydrogen, offers a promising outlook for the future of energy storage. These innovations will not only improve the efficiency and reliability of the electrical system but will also contribute to long-term environmental and economic sustainability.

Energy accumulation systems are essential for the modernization and stability of the electrical system. Its large-scale implementation will allow better integration of renewable energy, greater energy efficiency, and a significant reduction in carbon emissions, thus contributing to a more sustainable and resilient energy future (Uzar, 2020; Khan et al., 2020; Ramos et al., 2018; Gámez et al., 2016).

4 Conclusion

Research and case studies demonstrate that storage systems are not only a viable solution to current power system challenges but are also essential to ensuring a secure and sustainable energy supply in the future by incorporating investment in development and implementation. of policies that promote the adoption of these technologies to take full advantage of their benefits.

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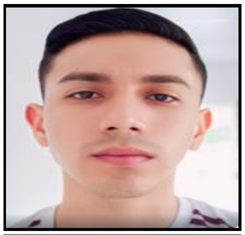

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