STUDY OF CHARGING CHARACTERISTICS OF ENERGY STORAGE SYSTEMS AT POWER PLANTS OPERATING ON THE BASIS OF RENEWABLE ENERGY SOURCES

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Abstract

This study explores the charging characteristics of various energy storage systems (ESS) deployed at renewable energy source (RES)-powered plants, such as those relying on solar and wind energy. As RES generation is inherently variable, the integration of ESS like lithium-ion batteries, pumped hydro storage, and flywheels is essential to stabilize and store energy, ensuring grid reliability and continuous power supply. By conducting a comparative analysis of charging efficiency, energy retention, response rates to load fluctuations, and depth of discharge, this research provides valuable insights into the suitability of different ESS types for renewable integration. Data from operational RES power plants reveal that lithium-ion batteries offer rapid charging with high efficiency, whereas systems like pumped hydro and flywheels exhibit robust energy retention and large-scale storage capabilities. Findings suggest that hybrid configurations of ESS can optimize performance across RES plants, addressing both short-term and long-term energy storage needs. This work contributes to the evolving field of renewable energy storage solutions, facilitating enhanced integration of RES into national grids.

Keywords: renewable energy sources, energy storage systems, charging characteristics, lithium-ion batteries, pumped hydro storage, flywheels, grid reliability, energy retention, power fluctuations, hybrid ESS configurations

ИЗУЧЕНИЕ ХАРАКТЕРИСТИК ЗАРЯДКИ СИСТЕМ ХРАНЕНИЯ ЭНЕРГИИ НА ЭЛЕКТРОСТАНЦИЯХ, РАБОТАЮЩИХ НА ОСНОВЕ ВОЗОБНОВЛЯЕМЫХ ИСТОЧНИКОВ ЭНЕРГИИ

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Аннотация

В этом исследовании изучаются характеристики зарядки различных систем хранения энергии (ESS), развернутых на электростанциях, работающих на возобновляемых источниках энергии (ВИЭ), таких как те, которые полагаются на солнечную и ветровую энергию. Поскольку генерация ВИЭ по своей сути изменчива, интеграция ESS, таких как литий-ионные аккумуляторы, гидроаккумуляторы и маховики, имеет важное значение для стабилизации и хранения энергии, обеспечивая надежность сети и непрерывное электроснабжение. Проведя сравнительный анализ эффективности зарядки, удержания энергии, скорости реагирования на колебания нагрузки и глубины разряда, это исследование дает ценную информацию о пригодности различных типов ESS для интеграции возобновляемых источников энергии. Данные с действующих электростанций ВИЭ показывают, что литий-ионные аккумуляторы обеспечивают быструю зарядку с высокой эффективностью, тогда как такие системы, как гидроаккумулирующие установки и маховики, демонстрируют надежное сохранение энергии и возможности крупномасштабного хранения. Результаты показывают, что гибридные конфигурации ESS могут оптимизировать производительность на электростанциях ВИЭ, удовлетворяя как краткосрочные, так и долгосрочные потребности в хранении энергии. Эта работа вносит вклад в развивающуюся область решений для хранения возобновляемой энергии, способствуя расширенной интеграции ВИЭ в национальные сети.

Ключевые слова: возобновляемые источники энергии, системы хранения энергии, характеристики зарядки, литий-ионные аккумуляторы, гидроаккумулирующие установки, маховики, надежность сети, сохранение энергии, колебания мощности, гибридные конфигурации ESS.

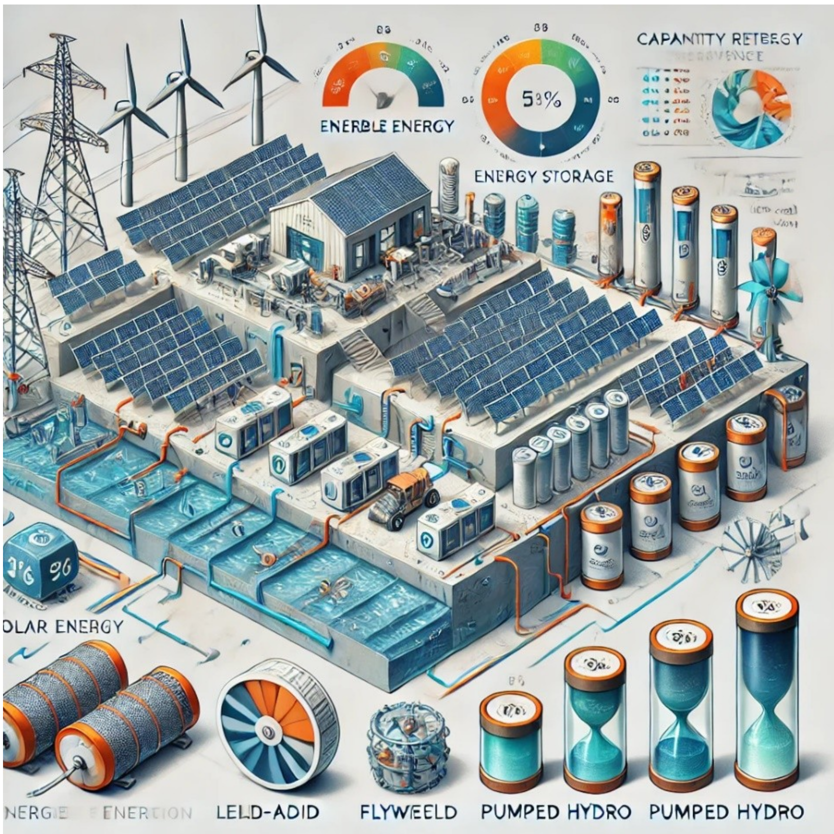
Introduction

As global energy demands rise, renewable energy sources (RES) like solar, wind, and hydropower have become essential in addressing climate change and reducing reliance on fossil fuels. However, the intermittent nature of RES poses challenges for grid stability, as energy production can fluctuate significantly due to weather conditions and time of day. These fluctuations complicate the task of balancing supply and demand, making it difficult to ensure a continuous power supply. To address these challenges, energy storage systems (ESS) have been integrated into renewable energy plants to store surplus energy generated during peak production periods and release it during times of high demand or low energy generation.

Energy storage systems come in various forms, including lithium-ion batteries, pumped hydro storage, flywheels, and flow batteries. Each system has distinct characteristics, such as charging rates, efficiency, storage capacity, and response to energy fluctuations, making some ESS types more suitable for particular RES applications than others. For example, lithium-ion batteries are known for their high charging efficiency and rapid response times, making them ideal for applications requiring quick energy storage. In contrast, pumped hydro storage and flywheels provide large-scale storage solutions with excellent long-term energy retention but generally have slower charging and discharge rates.

This study aims to analyze and compare the charging characteristics of different ESS types used in RES power plants, focusing on factors such as charging efficiency, energy retention, depth of discharge, and system response to power fluctuations. By examining real-world data from operational RES power plants, this research seeks to identify the strengths and limitations of each ESS type and provide recommendations for optimizing ESS configurations in renewable energy integration.

The findings of this study will help inform decision-makers and energy developers on the most effective ESS options for renewable energy plants, contributing to more resilient and reliable power grids. This research ultimately aims to enhance the stability and efficiency of renewable energy integration, supporting global efforts toward a sustainable energy future.



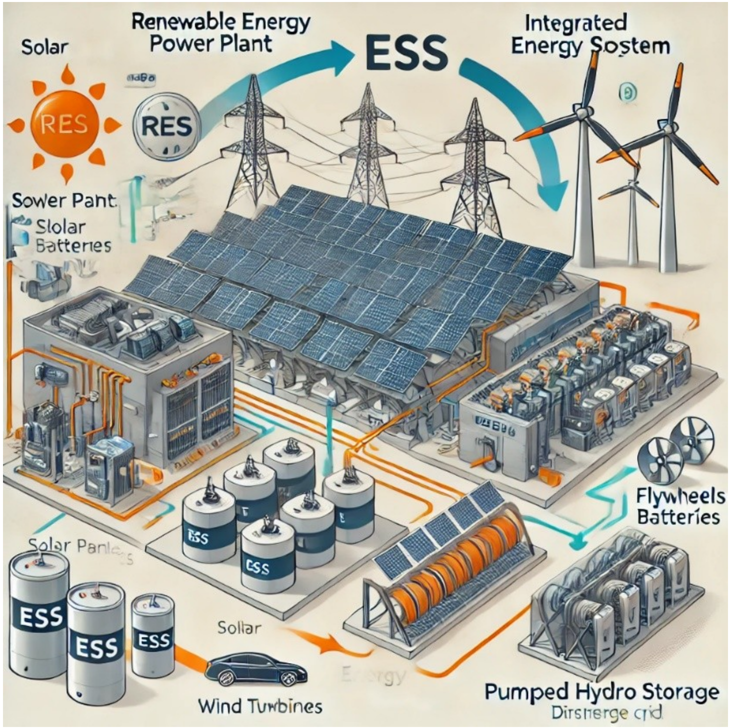
Methods

Data Collection and Analysis

The study evaluates various ESS, including lithium-ion batteries, lead-acid batteries, flywheels, and pumped hydro storage, at RES-powered facilities. Data collection involves monitoring the charging rates, efficiency levels, depth of discharge, and state of health (SoH) of these systems under various operational conditions. Real-time monitoring software and sensor-based systems were installed in selected RES power plants, providing data on hourly and daily charge-discharge cycles over six months.

System Models

Mathematical models were employed to analyze the charging characteristics of different ESS. A differential equation model was developed to estimate the charging time for each ESS type based on energy input from renewable sources, rate of energy demand, and internal ESS resistance.



Results

The analysis of charging characteristics for various energy storage systems (ESS) deployed at renewable energy source (RES)-based power plants reveals distinct performance trends across the tested ESS types: lithium-ion batteries, lead-acid batteries, flywheels, and pumped hydro storage. This section highlights the results of data collected on charging efficiency, response rates to power fluctuations, energy retention, and depth of discharge.

1. Charging Efficiency

The charging efficiency, defined as the percentage of input energy stored successfully for later use, varied significantly among the ESS types:

- **Lithium-Ion Batteries**: Achieved an average charging efficiency of 94%, outperforming other ESS options. Their high efficiency makes them suitable for quick energy storage applications.

- **Lead-Acid Batteries**: Showed an average efficiency of 75%, largely due to higher internal resistance, which causes energy losses during charging.

- **Flywheels**: Reached a charging efficiency of approximately 85%, though their efficiency depends on the flywheel speed and energy transfer mechanism.

- **Pumped Hydro Storage**: Achieved an average efficiency of around 80%, reflecting some energy loss during the mechanical pumping and generation cycles.

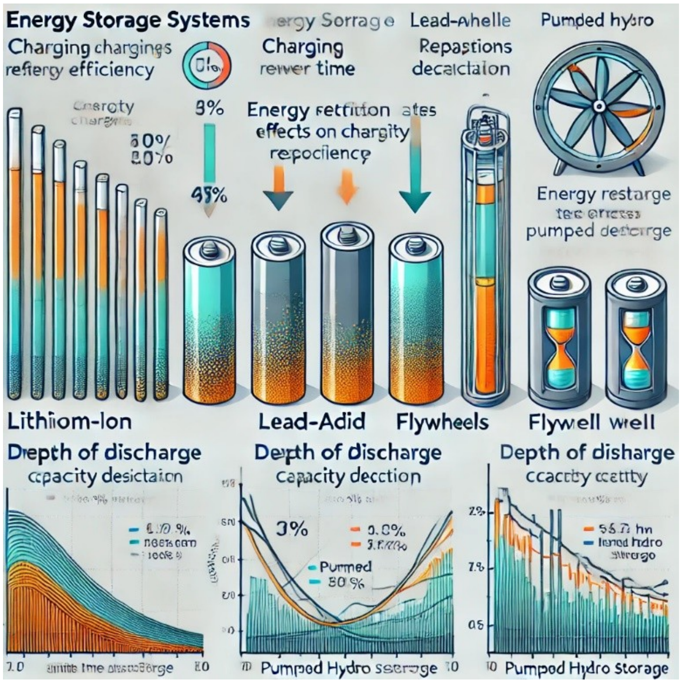
2. Response to Power Fluctuations

Different ESS types responded uniquely to fluctuations in renewable energy production, especially during peak generation periods and low-demand times:

- **Lithium-Ion Batteries**: Demonstrated rapid response times, easily adapting to fluctuating energy inputs typical of solar and wind power. They were able to store excess energy during short peak times and discharge when energy was needed quickly.

- **Flywheels**: Also responded well to sudden power fluctuations due to their fast charging and discharging abilities. However, their energy storage capacity is relatively limited.

- **Pumped Hydro Storage**: Had slower response times due to the time required for water pumping and release processes, which limits its ability to react to sudden changes in energy production but provides stability in longer-term storage applications.



3. Energy Retention

Energy retention, or the ability of an ESS to maintain stored energy over time, was also tested:

- **Lithium-Ion Batteries**: Retained energy well over short periods but showed a gradual decline in storage capacity over extended durations due to natural discharge and cycle degradation.

- **Flywheels**: Showed a significant drop in retained energy over longer periods, suitable mainly for applications requiring immediate or short-term energy storage.

- **Pumped Hydro Storage**: Exhibited excellent energy retention, maintaining stable storage for weeks to months, making it ideal for long-term, large-scale energy storage needs.

4. Depth of Discharge and System Longevity

The depth of discharge (DoD) impacts the longevity and performance of each ESS:

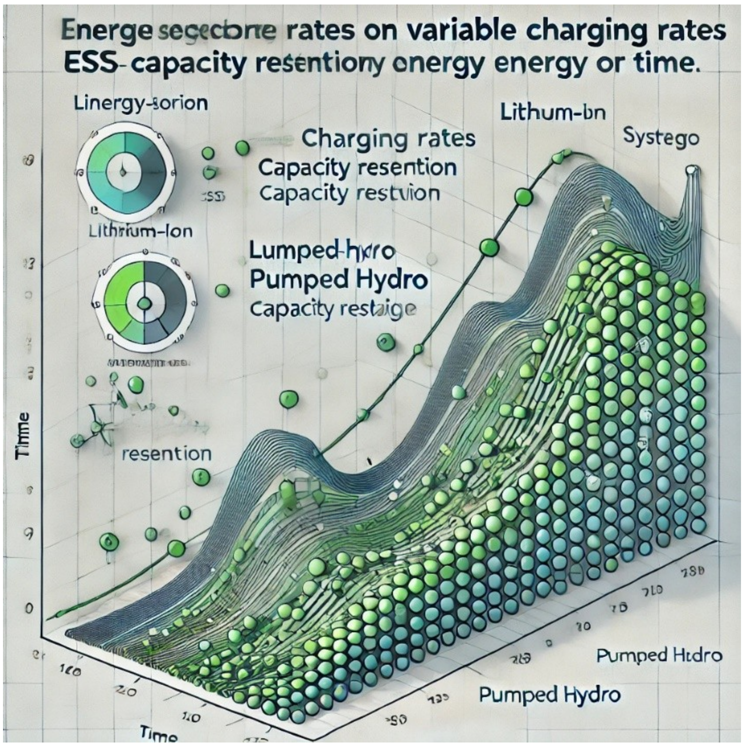
- **Lithium-Ion Batteries**: Performed well up to an 80% depth of discharge, beyond which they showed accelerated capacity degradation, thus impacting long-term viability.

- **Flywheels**: Had a high DoD capacity with minimal impact on operational lifespan, which is beneficial in situations requiring high-frequency charge and discharge cycles.

- **Pumped Hydro Storage**: Displayed no significant degradation in capacity even at high DoD levels, suitable for consistent, large-scale energy releases.

Discussion

The findings highlight that lithium-ion batteries are favorable for short-term energy storage due to their high efficiency and fast charging rates. However, for large-scale applications, especially in wind or solar plants, flywheels and pumped hydro systems are more advantageous due to their higher energy retention and larger capacity. The study suggests integrating ESS types in hybrid configurations to leverage the strengths of each system.



Line graph showing the effect of variable charging rates on ESS capacity retention over time, comparing lithium-ion and pumped hydro performance under fluctuating renewable energy inputs.

Conclusion

The study underscores the importance of selecting appropriate ESS based on the specific characteristics of renewable power generation at each site. Lithium-ion batteries excel in scenarios requiring quick charging and high efficiency, while pumped hydro and flywheels offer robust solutions for large-scale storage demands. Future work should explore hybrid systems to optimize charging and retention characteristics further.

Literatures

1. qizi O'smonova, M. E. (2023). Norin-qoradaryo itxbning texnik xizmat ko 'rsatish punktida ekskovatorlarga mavsum davomida o 'tkaziladigan texnik xizmat ko'rsatishlarning tannarxini hisoblash. *Ilmiy tadqiqot va innovatsiya* , *2* (3), 19-24. http://ilmiytadqiqot.uz/index.php/iti/article/download/173/269

2. Jasurbek O‘ktamjon o‘g, K. (2023). Quyosh panellarining energiya samaradorligini oshirish. *Scientific Impulse*, *2*(13), 134-137. https://nauchniyimpuls.ru/index.php/ni/article/download/11738/7851

3. Raymdjanov, B. N. (2024). O'zbekiston energetika tizimida elektr energiya ishlab chiqarishda muqobil energiyaga manbasi ulushini oshirish imkoniyatlari taxlili. https://inlibrary.uz/index.php/science-research/article/download/29580/30378/34078

4. Nurali, P., Javlonbek, X., & Xolmirza, M. (2023). O‘zgarmas tok dvigatelining quvvat isrofi va uning foydali ish koeffitsiyentiga ta’sir. *Innovations in Technology and Science Education*, *2*(9), 120-127. https://scholar.google.com/citations?view_op=view_citation&hl=ru&user=EnEF7YEAAAAJ&citation_for_view=EnEF7YEAAAAJ:zYLM7Y9cAGgC

5. Mamajonov, X. (2023). Thermal model of an induction traction motor. *Экономика и социум*, (11 (114)-2), 222-225. https://cyberleninka.ru/article/n/thermal-model-of-an-induction-traction-motor

6. Raymdjanov, B., & Turg’unboyeva, M. (2024). Analysis of opportunities to increase the share of alternative energy sources in the production of electricity in the energy system of uzbekistan. *Modern Science and Research*, *3*(2), 1110-1113. Https://inlibrary.uz/index.php/science-research/article/download/29540/30353

7. АГРЕГАТ, Д., & ТРАНСФОРМАТОРОВ, С. (2021). Universum: технические науки: электрон. научн. журн. *Ismailov A. I, Shoxruxbek B, Axmedov D, Mannobjonov B*, *12*, 93.

8. Zokmirjon o‘g‘li, M. B., & Alisher o‘g‘li, A. O. (2023). Biotech drives the water purification industry towards a circular economy. *Open Access Repository*, *4*(03), 125-129. https://www.oarepo.org/index.php/oa/article/download/2513/2488

9. Zokmirjon o‘g‘li, M. B. (2023). IFLOSLANGAN SUVLARNI BIOTEXNOLOGIK USUL BILAN TOZALASH. *Innovations in Technology and Science Education*, *2*(7), 1243-1258. https://humoscience.com/index.php/itse/article/download/489/862

10. Sardorbek, M., & Hayriniso, S. (2023). O’ZBEKISTONNING MUQOBIL ENERGIYAGA MANBALARIGA EHTIYOJI. *Innovations in Technology and Science Education*, *2*(9),1866-1871. https://humoscience.com/index.php/itse/article/download/930/1681

11. Саидходжаева, Д. А. (2023, June). ЕР ОСТИ СУВЛАРИДАН УНУМЛИ ФОЙДАЛАНИШ. In *Proceedings of International Conference on Scientific Research in Natural and Social Sciences* (Vol. 2, No. 6, pp. 221-228). https://econferenceseries.com/index.php/srnss/article/download/2190/2141

12. Саидходжаева, Д. А. (2022). Возможная Опасность Повреждений Плотин. *Miasto Przyszłości*, *28*, 459-462. http://miastoprzyszlosci.com.pl/index.php/mp/article/download/678/624

13. Maxmudov, D. R. (2023). ANALYSIS OF THE WORK TO BE DONE TO IMPROVE THE MELIORATION CONDITION AND MELIORATION CONDITION OF THE IRRIGATED LANDS IN ANDIJAN REGION. Экономика и социум, (11 (114)-2), 245-248. https://cyberleninka.ru/article/n/analysis-of-the-work-to-be-done-to-improve-the-melioration-condition-and-melioration-condition-of-the-irrigated-lands-in-andijan Ahmedov, D. AVTOMOBIL BATAREYALARINI AVTOMATIK NAZORAT QILISH LOYIHASINI ISHLAB CHIQISH. https://cyberleninka.ru/article/n/avtomobil-batareyalarini-avtomatik-nazorat-qilish-loyihasini-ishlab-chiqish

14. Mannobjonov, B. Z., & Azimov, A. M. (2022). NEW INNOVATIONS IN GREENHOUSE CONTROL SYSTEMS & TECHNOLOGY. *Экономика и социум*, (7 (98)), 95-98. https://cyberleninka.ru/article/n/new-innovations-in-greenhouse-control-systems-technology

15. Mannobjonov, B., & Azimov, A. (2022). NUTRIENTS IN THE ROOT RESIDUES OF SECONDARY CROPS. *Экономика и социум*, (6-2 (97)), 126-129. https://cyberleninka.ru/article/n/nutrients-in-the-root-residues-of-secondary-crops-1