

## **Potential Analysis of Flywheel Energy Storage in Renewable Energy Power Grids**

As the global energy system transitions toward low-carbon and renewable sources, intermittent power generation from wind and solar is increasingly integrated into the grid. However, the variability and unpredictability of renewable energy pose challenges to grid stability, frequency regulation, and supply-demand balance. To accommodate high shares of renewable energy while ensuring reliable operation, energy storage technologies have become essential. Among them, flywheel energy storage (FES) has emerged as a promising solution due to its high power density, rapid response capability, and long cycle life, making it particularly suitable for mitigating fluctuations and enhancing renewable energy utilization.

Flywheel energy storage works by converting electrical energy into mechanical kinetic energy stored in a high-speed rotating flywheel, which can be rapidly converted back to electricity when needed. Compared with chemical batteries, FES offers advantages such as fast response, high charge-discharge efficiency, long lifespan, and environmental friendliness. It is especially effective for grid frequency regulation, instantaneous power balancing, and voltage support. In wind and solar power systems, FES can reduce curtailment, smooth renewable output, and enhance the dynamic stability of the power grid.

The practical potential of flywheel storage involves considerations of capacity sizing, power matching, system economics, and reliability assessment. Optimal design requires a comprehensive understanding of load characteristics, renewable generation patterns, and storage system response to achieve efficient energy management and cost-effective operation. Recent studies integrating intelligent control, predictive algorithms, and multi-energy system dispatch strategies further expand the applicability of FES in distributed grids and microgrids.

This study aims to systematically analyze the potential of flywheel energy storage in renewable energy power grids, focusing on its role in energy balancing, renewable energy utilization, system stability, and economic performance. Through

theoretical analysis and simulation case studies, the findings are expected to provide technical guidance and decision support for storage deployment, operational optimization, and the development of low-carbon power systems.