

# Design and Development of Hybrid Renewable Energy System with Energy Storage

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**Abstract:** The rising world energy demand, combined with the necessity of curbing carbon emissions, has expedited the advancement of hybrid renewable energy systems (HRES) that have several energy sources. This article gives the design and development of a hybrid renewable energy system with solar, wind, and hydro power and an energy storage system to provide a constant and reliable power supply. By taking advantage of the complementary characteristics of these renewable resources, the system will maximize energy reliability, efficiency, and sustainability.

The system to be proposed will maximize power generation by utilizing a smart energy management approach that dynamically adjusts the contribution of each source in accordance with real-time environmental conditions and load demands. Solar photovoltaic (PV) panels produce electricity during the day, while wind turbines generate power when it is windy to supplement solar power generation. Hydro power is also a steady source of energy, especially for areas with available water resources, to ensure reliable power generation even when solar and wind resources are low.

Simulation and experimental studies are performed to analyze the performance of the suggested hybrid system under different operating conditions. Findings show that the hybrid renewable energy system with energy storage effectively enhances power stability and lessens dependency on traditional grid-based electricity. The results point to its prospects for use in remote and off-grid areas, rural electrification, and sustainable energy programs.

This study contributes to the development of hybrid renewable energy technologies by introducing an optimized method for combining multiple renewable sources with energy storage. Through the use of such a system, it is feasible to attain a more robust, efficient, and sustainable energy solution, facilitating the global shift toward renewable energy and carbon neutrality.

**Keywords:** Hybrid Renewable Energy System (HRES), Solar Energy, Wind Energy, Hydro Power, Energy Storage, Smart Energy Management, Power Optimization, Grid Independence, Sustainable Energy, Renewable Energy Integration