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ENHANCING SOLAR ENERGY CAPTURE IN SWARM SATELLITES WITH A HYBRID PARTICLE SWARM OPTIMIZATION AND GRAVITATIONAL SEARCH ALGORITHM APPROACH

Abstract

In swarm satellite missions focused on solar exploration and extended space operations, the efficient capture of solar energy is critical for ensuring continuous functionality and maintaining data integrity. Traditional solar tracking algorithms often encounter significant limitations when faced with dynamically changing sunlight conditions, which arise from variations in distance, angle, and interference from cosmic factors and fluctuations in solar irradiance. These environmental changes can lead to inconsistent power generation, heightening the risk of operational interruptions that jeopardize mission objectives. This paper introduces an innovative method that combines Particle Swarm Optimization (PSO) with the Gravitational Search Algorithm (GSA) to tackle these challenges. The hybrid PSO-GSA algorithm is modelled to enhance Maximum Power Point Tracking (MPPT) through a dual mechanism: the broad exploratory capabilities of PSO facilitate the rapid identification of potential peak power zones; the precise local search capabilities of GSA enable fine-tuning of satellite orientations for optimal alignment with solar irradiance. The integration of PSO and GSA leverages the adaptive strengths of both algorithms, resulting in significant improvements in convergence rates and stabilization times. This enables the satellite swarm to swiftly adapt to complicated environmental changes, thus enhancing energy capture. By minimizing overshoot and oscillatory behaviour around maximum power points, the hybrid approach achieves substantially higher energy capture efficiency compared to conventional methods that lack such adaptive precision. Simulation results across various irradiance scenarios demonstrate that the PSO-GSA hybrid algorithm provides robust performance, effectively minimizing power interruptions and maintaining operational efficiency. This advancement in autonomous satellite energy management is crucial for future solar-focused and deep-space exploration missions, offering a sustainable energy solution that enhances the resilience and adaptability of swarm satellite systems. Through this research, the PSO-GSA hybrid algorithm represents a foundational step toward developing highly efficient, autonomous energy systems for extraterrestrial exploration, facilitating mission sustainability through real-time adaptive power optimization.