"My Battery Is Low, And It's Getting Dark": An Evaluation of Energy Recovery Efficiency of Solar Panel Cleaning Strategies Under Simulated Martian Dust Conditions

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This project investigates the issue of dust accumulation on solar-powered Martian rovers, testing the efficiency of three cleaning methods: automatic tilting, wiping, and Electrodynamic Dust Shield (EDS), to quantify energy-recovery efficiency and energy break-even times under Martian Regolith Simulant loads. The project addresses the limitations of prior studies, which focus solely on dust removal percentages. A novel, automated testing rig was constructed, integrating a 5V solar panel, simulated sunlight under a grow light, and a Maximum Power Point Tracking load-selection system. 0.1 g, 0.4 g, and 0.8 g loads of MGS-1 simulant were consistently applied using custom-designed 3D-printed stencils. I–V curves for clean, dusted, and recovered energy measurements were recorded to depict efficiency. Furthermore, the energy consumed by the methods during cleaning was measured to determine break-even times. Due to safety constraints, EDS performance was modeled using published data and then adjusted for expected Martian degradation to simulate real-world performance. Results demonstrate that dust accumulation significantly degrades panel performance by reducing short-circuit current (Isc), while open-circuit voltage (Voc) remains stable. Although recovery efficiency decreased at higher dust loads, break-even times shortened due to larger absolute power gains. Wiping achieved the highest immediate recovery, while EDS demonstrated superior long-term consistency due to minimal energy use and no mechanical wear. Limitations include the modeled rather than physically implemented EDS system and the inability to fully replicate Mars' gravity and electrostatic conditions. Future research should explore telemetry-based or hybrid cleaning methods to extend overall rover lifespans.

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