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LIGHT-WEIGHT, FOLDABLE SOLAR POWER ARCHITECTURE FOR A SWARM OF WIND-DRIVEN TUMBLEWEED MOBILE IMPACTORS

Abstract

Conventionally, Mars exploration is characterized by complex missions featuring high mission costs and long timelines. Furthermore, there is a gap in Martian datasets between highly localized data generated by conventional surface missions and remote sensing from orbit. The Tumbleweed Mission is a low-cost Mars surface mission that uses a swarm of wind-driven mobile impactors and, as a result, addresses this gap in currently available data by generating planetary-scale, long-term surface datasets of Mars.

Due to the stringent mass and cost requirements that come with such wind-driven mission architecture, conventional solar power architectures have insufficient power densities to support critical capabilities required by a Tumbleweed Rover. Furthermore, physical integration with the foldable structure requires high mechanical flexibility to comply with packaging constraints. The predominantly energy generation technologies used in the legacy Mars missions are too heavy, rigid, and brittle to be implemented in our Electrical Power System (EPS) architecture. Therefore, our objective is to develop a lightweight, foldable, robust solar power electrical system that is capable of withstanding deep space and the Martian environment.

In this work, we present a trade-off analysis between different flexible, lightweight, thin-film solar cells like Organic, Perovskite, and Gallium Arsenide (GaAs) solar panels that ultimately accomplish the mission's energy generation requirements. Furthermore, the tumbling motion on the Martian surface constitutes unprecedented challenges in terms of Maximum Power Point Tracker (MPTT) algorithms. We present a justification of the selection process of different MPPT algorithms.

A numerical model of the EPS is also implemented. The Martian environment data, such as solar irradiance, temperature, and black body radiation, is implemented in this model. The aforementioned PV technologies' performances are modeled as well, together with different DC-DC converter topologies, and MPPT algorithms.

We propose an EPS architecture that consists of thin film GaAs PV and a Power Conversion Unit with Array Power Regulators, containing a combination of MPPT algorithms like Perturb and Observe, incremental conductance, constant voltage, or current algorithms. We select a push-pull Weinberg DC-DC topology that supplies the consumers through a Latching Current Limiter (LCL) Power Distribution Unit and charges the Li-Ion battery through a Battery Charging and Discharging Regulator (BCDR).

Therefore, we achieve a compact, lightweight, cost-efficient EPS, that performs by several orders of magnitude better than the current architectures, in terms of power density. It is achieved by having higher

energy conversion efficiency, faster dynamic response, and higher charging and discharging efficiency using lighter technologies.