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OPTIMIZING SOLAR CELL PERFORMANCE IN LOW EARTH ORBIT: EXPERIMENTAL ANALYSIS OF TEMPERATURE AND IRRADIANCE EFFECTS ON MAXIMUM POWER POINT VOLTAGE AND FEASIBILITY OF TEMPERATURE-BASED MPPT

Abstract

Solar cells are essential for generating power in earth orbiting satellites. Maximum Power Point Tracking (MPPT) is often used to continuously adjust the solar cell to the optimal operating voltage, which changes based on environmental conditions like cell temperature and incident irradiance. Perturb & Observe is a common MPPT method, but it under performs in rapidly changing environmental conditions. For increasingly miniaturized satellites it is more difficult to perform attitude control, which leads to mission scenarios in which the satellite's attitude is changing quickly, causing rapid cyclical changes in solar panel temperature and incident irradiance. Utilizing standard MPPT approaches in such conditions is therefore a formidable challenge for the design of small satellites, including for the Delfi satellite program here at TU Delft. One possible solution is temperature-based MPPT, which is believed to be more responsive to changing environmental conditions.

This study focused on characterizing the performance of a COTS solar cell that has been previously used on Delfi satellites, with the purpose of evaluating how well temperature-based MPPT would perform on such a cell. The I-V curve of the Spectrolab XTJ triple junction solar cell was experimentally determined across the typical range of temperature and irradiance conditions in low earth orbit (0° to 50° C temperatures and 1353 W/m^2 equivalent solar irradiance at angles of incidence from 0° to 45°). The variation in voltage at maximum power point (V_{MPP}) with respect to temperature was then compared to a linear temperature-based MPPT formula. The experimentally measured change in V_{MPP} with respect to temperature was found to be quite linear and of similar value to the solar cell datasheet value. The level of incident irradiance did not have a significant impact on V_{MPP}, indicating that the single-input temperature approach is capable of accurately estimating the optimal operating voltage of a solar cell. There was, however, a significant offset in the experimental V_{MPP} values and those predicted based on the datasheet maximum power point. This could be attributed to degradation in the solar cells over their lifetime or non-ideal aspects of the experimental setup. This result emphasizes the importance of calibrating a temperature-based MPPT system with at least some experimentally determined solar cell data.