IAF ASTRODYNAMICS SYMPOSIUM (C1)
Interactive Presentations - IAF ASTRODYNAMICS SYMPOSIUM (IPB)

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A CONSTELLATION DESIGN FOR ORBITING SOLAR REFLECTORS TO ENHANCE TERRESTRIAL SOLAR ENERGY

Abstract

Orbiting solar reflectors (OSRs) are flat, thin and lightweight reflective structures that are proposed to enhance terrestrial solar energy generation by illuminating large terrestrial solar power plants locally around dawn/dusk and in night hours. The incorporation of OSRs into terrestrial energy systems may offset the shortfall of energy delivery thereby reducing the energy prices at those hours. OSRs operate by reflecting an image of the solar disk onto solar power plants and a previous study showed that a maximum of approximately 35 MWh of solar energy can be delivered to 10-km-diameter stationary targets by a 1-km-diameter equivalent flat reflector, from a 1000-km polar orbit [Çelik, O. McInnes, C. R. (2022), Advances in Space Research, 69(1), 647-663]. However, such a level of energy delivery may not be effective to influence energy markets due to its relatively low quantity and short duration delivery.

To increase both the quantity of energy delivered and enable longer pass durations, this paper proposes a constellation of multiple reflectors in LEO. Circular near-polar orbits are considered in a Walker-type constellation as a preliminary analysis. Such orbits are selected to keep parameter space small, avoid eclipses and include Sun-synchronous orbits. The orbits are propagated in the two-body problem, including the Earth's oblateness up to the second-degree zonal harmonics, i.e., J_2. The constellation geometry is optimised by a genetic algorithm to maximise the pass duration and the quantity of energy delivered to 12 large terrestrial solar power farms that currently exist, albeit they are assumed 10-km-diameter disks to provide a generalised model. The order of passes and the pass geometry of the reflectors over different solar power plants are assessed through an analytical slant range expression in the algorithm and through including manoeuvering time between the passes. The quantity of energy delivered is calculated within the optimisation process by a newly developed, generic semi-analytical algorithm that includes the Earth's rotation and oblateness, as well as eclipses. Preliminary results show that, for the same number of reflectors, the total quantity of energy delivered is approximately linearly increasing with the number of reflectors. A small angular separation between the reflectors results in shorter passes with a higher quantity of energy delivery at certain hours, which becomes lower and more uniform throughout the pass if the angular separation is higher.