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INVESTIGATION OF SPACE-BASED SOLAR POWER BEAMING KINEMATIC EFFICIENCY FOR MOLNIYA ORBITS

Abstract

With recent advances in wireless power transmission and on-orbit robotic assembly, alongside decreasing launch costs, the idea of space-based solar power as a new alternative energy solution has been revived. In the literature, several space-based solar power conceptual designs have been proposed, with considerable investigation into the modular flat-plane sandwich configuration over the last decade. This design configuration appears as a promising candidate as it lends itself well to modularity and minimizing system mass, which can streamline the manufacturing process and improve stowability within launch vehicles. However, it is apparent from the literature, that the intrinsic coupling nature of sunlight collection and power beaming presents unique challenges on the attitude and orbits of space-based solar power systems. Several studies have focused on investigating equatorial orbits, such as geostationary orbits, that require continuous periodic attitude control, which increases the mass and, consequently, the cost of the system. Furthermore, attitude control of large space-based solar power systems can pose significant challenges due to unintended structural-dynamic interactions of the large flexible structures. Therefore, the task of minimization of control effort, while maximizing power beaming, remains to be solved. This paper investigates the orbital and attitude kinematics of space-based solar power satellites in Molniya orbits. While the results demonstrate promising performance for short-term duration operations of power beaming systems placed in Molniya orbits without active attitude control, the Sun's movement in the ecliptic plane presents unique periodic challenges that can be partially mitigated through providing the system with an initial angular velocity. For this problem, an optimization approach is developed that takes the orbital and attitude parameters along with the ground stations' locations as design variables. The orbital and attitude kinematics relative to the Sun and Earth impose constraints on the relative geometry, such as the satellite elevation angle, eclipse period, power-steering angle, and solar incidence angle. A set of requirements considering a typical space-based solar power system are established, and near-optimal orbits and attitudes that maximize power beaming to the ground are determined. The methodology and results outlined in this paper establish a foundation for assessing power beaming systems and provide a framework for more complicated analyses that consider various forms of perturbations.