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FAMILIES OF DISPLACED NON-KEPLERIAN POLAR ORBITS FOR SPACE-BASED SOLAR ENERGY APPLICATIONS

Abstract

Orbiting Solar Reflectors (OSRs) are ultralight, thin membrane structures that can be used to reflect sunlight locally to terrestrial solar power plants. This would enhance terrestrial solar energy generation in critical hours of the day, such as dawn/dusk hours when solar plant output is low, but demand can be high. This paper will investigate a range of displaced highly non-Keplerian orbits for OSRs and assess their operational use.

Displaced polar orbits can, in principle, change the geometry of passes of OSR over terrestrial solar power plants. Such non-Keplerian orbits can be obtained by orienting the reflector at a fixed pitch angle with respect to the Sun line, such that the solar radiation pressure (SRP) induced force would shift the orbit plane in the anti-Sun line [McKay, R. J., Macdonald, M., Biggs, J., McInnes, C. (2011). Survey of highly non-Keplerian orbits with low-thrust propulsion. Journal of Guidance, Control, and Dynamics, 34(3), 645-666]. This, in principle, would allow extending night-time solar energy delivery without eclipses. In this paper, displaced polar orbits are generated in the two-body problem and the rotating reference frame considering the Earth's oblateness up to J_2 and the SRP force. First, their linear stability is discussed and a range of stable and unstable non-Keplerian orbits is identified for solar energy applications. In order to exploit the unstable orbits in practical cases, the controllability of these non-Keplerian orbits is investigated with the J_2 effect included. Simple control strategies such as pitch angle control or reflector area control are proposed in this higher fidelity model.

As an alternative to single reflector OSR systems, a compound reflector system is also proposed as a novel application of highly non-Keplerian orbits. This consists of a large Sun-facing parabolic collector in a polar orbit displaced in the anti-Sun direction and a smaller, agile free-flying flat director placed at the focus of the parabolic collector, displaced by reflected SRP in the Sun direction. This compound system offers the advantage of separating the collecting and directing functions, with the large collector passively Sun-pointing. The orbit dynamics of such a system dictates that the SRP-induced force needs to be balanced across the synchronized motion of the collector and director, which also determines the size of the latter. The conditions for such synchronized displaced non-Keplerian orbits in the J_2-enhanced model are investigated alongside the quantity of solar energy that can be delivered to solar power plants.