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ATTITUDE DYNAMICS AND INTEGRATED ROBUST CONTROL OF THE MULTI-ROTARY JOINTS SOLAR POWER SATELLITE

Abstract

Recent years have witnessed the resurgence of space-based solar power research, and in particular the solar power satellite (SPS) paradigm has received much attention. Different SPS concepts and technologies have been proposed by various organizations. Among these recent concepts, is the multi-rotary joints solar power satellite (MR-SPS), which has just been proposed by the China Academy of Space Technology. Unlike other proposed designs, the MR-SPS has the characteristics of an unique structure and modular design, such as multiple modularized solar arrays, the extra-large-size main truss and antenna. Additionally, the MR-SPS has a planned mission lifetime of more than 20 years. The scale of the satellite and the duration of the mission mean that attitude maneuvers, including Sun and Earth pointing modes, could be significantly affected by environmental perturbations caused by solar radiation pressure and gravity gradients. Meanwhile, the mission requirements for Sun and Earth pointing of the MR-SPS are obviously different, giving rise to problematic challenges to achieve accurate attitude control. Currently, very few results on the dynamics and control of the MR-SPS have been reported in literature.

This paper aims to address this lack of results by investigating the attitude dynamics and integrated robust control of the MR-SPS in the presence of perturbations, model uncertainties and bandwidth constraints. The MR-SPS is modelled here as a multi-rigid-body structure. A coupled dynamic model, that describes the attitude motions of multiple solar arrays, a main truss and a microwave antenna simultaneously, is firstly established. The perturbations that affect solar array pointing towards the Sun and antenna pointing to the ground are then investigated. The mission requirement for of attitude control is to achieve Sun-pointing of solar arrays, attitude stabilization of the main truss and high-precision Earth-pointing of the antenna. Hence an integrated robust output feedback control system, including three sub-controllers, is developed, and the approach of bandwidth isolation is proposed. It should be noted that larger control gain and higher bandwidth are primarily required for antenna Earth-pointing, with bandwidth for Sun pointing and attitude stabilization being one order of magnitude lower, due to different control requirements. Besides, a feedforward item and a disturbance rejection filter are then integrated into the controllers to reduce pointing errors considering perturbations and model uncertainties. The numerical simulation is finally provided, and the results demonstrate that the proposed control approach can achieve higher pointing accuracy and better robustness than PID control.