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ADAPTIVE FAULT-TOLERANT COULOMBIC SATELLITE ATTITUDE CONTROL

Abstract

Magnetic actuators pose problems in magnetic shielding and often lead to malfunctioning of magnetic sensitive instruments on-board. In addition, static charges generated due to the interaction of the satellite with the extra terrestrial charged particles and high energy photons pose serious problems. The charging may raise the surface potential to the order of 20 kV in magnitude. The raised potential interferes with the telemetry producing spurious commands causing control malfunctioning, damage to the satellite surface, and may also paralyze the integrated circuit rendering the satellite useless. To combat this static charge management system is required. However, this problem can be used advantageously to actively actuate the satellite by channelizing the spurious charges to actuating surfaces as proposed in this paper. Flat Coulombic surfaces are designed to serve as Coulombic actuators. Equation of motion of the satellite actuated by Coulombic charges in the terrestrial magnetic field is developed. The dynamical equation for this satellite system is reducible to a standard form. However, the equation for the torque produced by the charged surface gets complicated due to the spreading of the charges over the flat surface. But a wide flat surface is necessary to reduce the electric field due to the charges, thereby reducing energy loss in charging this surface. Spurious charges can be easily diverted to this surface instead of purging. The wide flat surface increases the moment arm making this system more effective in controlling the attitude. The charges located at different points have different velocity due to the orbital and rotational motions, therefore all these are accounted in formulating the equation of motion. System controllability is shown for high angular velocity. An adaptive control is designed which provides three axes control on an average. Stability of the Coulombic system is proved in the presence of destabilizing gravity gradient. If the control torque along one of the body axes fails still such a system maintains its performance without any extra energy consumption. It is shown that the failed system is stable for high angular velocity while for the small angular velocity it is exponentially stable. Simulations are carried out for various initial conditions of orientation and angular velocity to prove the efficacy of the proposed adaptive fault-tolerant system. A comprehensive physical analysis of the system dynamics for both the intact and the failed cases is presented. These results are compared against the magnetically actuated satellite.