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FAULT TOLERANT SATELLITE ATTITUDE CONTROL USING COMBINED LORENTZ FORCE AND MAGNETIC ACTUATORS

Abstract

Satellite attitude control using magnetic actuators although is an under actuated system at every instant of time, but remains three axes controllable on an average. Still, instantaneous controllability remains an issue. In the past, combining the magnetic and Lorentz force actuators has been suggested making the system instantaneously controllable and thereby ensuring stability of the system. This is based on the fact that in the case of Lorentz force actuator the resultant torque lies in a plane containing the magnetic field and velocity vectors, whereas the torque for the magnetic actuator lies perpendicular to the magnetic field vector. This implies that torque generated by the magnetic and Lorentz force actuators are mutually perpendicular to each other and can be utilized for three axes torque generation instantaneously. However, this lacks a rigorous mathematical proof of the three axes instantaneous controllability and also fault tolerant capacity of the system including possibility of reconfiguration. In this paper, a systematic mathematical proof is presented for the instantaneous three axes controllability and stability, using either the magnetic actuator or the Lorentz force actuator as a primary actuation device and the other can be treated as a secondary one. It is proved that failure of one actuator from each of the actuation system does not affect the three axes instantaneous controllability. This is because the same torque can be generated by increasing either the magnetic dipole moment of the magnetic actuator or the charge on the Coulomb shells of the Lorentz force actuator. However, if two actuators from either category of the actuating systems fail, three axes instantaneous controllability cannot be guaranteed. Moreover, it is shown that under functioning of either actuating system leads to reduction in the available torque, however three axes instantaneous controllability is ensured unless one of the actuating systems completely fails or is disabled. Keeping in view the above characteristics of the combined system, a fault tolerant reconfigurable sliding control is proposed and implemented in this paper. Finite-time stability is proved and it is shown that the combined system is globally stable in the presence of gravity gradient torque and external disturbances. Complete failure of any of the two systems makes loose three axes instantaneous controllability but remains controllable and stable in an average sense as mentioned above. Numerical simulations show convergence within a fraction of the orbit for compensation by either of the actuating system.