ABSTRACT

A magneto-Coulombic satellite system is proposed. Equation for charge required on Coulomb shells is derived and is used to find available torque. Controllability of the system is proved for very high angular velocities. It is shown that the system is globally stable and locally exponential stable in neighborhood of the origin in conjunction with a proposed proportional-differential control. It is shown that the eigenvalues of the average control matrix in the body reference frame converge to those in the orbital reference frame as time tends to infinity irrespective of the initial conditions. Simulations show efficacy of the proposed magneto-Coulombic system for controlling the satellite. The physics behind the system behavior is explained. Further, a new nonlinear sliding manifold is proposed for designing an averaged finite-time continuous sliding control for the closed loop stability analysis of the averaged system dynamics. A real and finite-time continuous sliding control is proposed and it is proved that this gets reduced to the averaged finite-time continuous sliding control and ensures global stability and finite-time reachability of the system in the presence of disturbance and destabilizing gravity gradient torque. Simulation results show its superiority in terms of less charge requirement and better convergence of states over the proportional-differential control. It is shown that keeping the moments of inertia constant and varying the distance between the shells does not alter the results qualitatively or quantitatively except for scaling of the charge. In addition, a fault-tolerant magneto-Coulombic satellite system is proposed, which uses two pairs of statically charged shells for the three axes attitude stabilization in the post failure scenario. It is shown that the torque available before and after the failure of one pair of the charged shells along any of the body axes remains the same if the control is reconfigured. Controllability of the failed system for very high angular velocity is proved. It is shown that an iso-inertia magneto-Coulombic satellite can be stabilized using time invariant feedback control after the failure, which is not possible even using time variant conventional control for other control systems. The global stability of the failed magneto-Coulombic system is proved for the proposed proportional-differential control input, in addition to its local exponentially stability in the neighborhood of the origin. Simulation shows that the power consumption before and after the failure remains almost the same.