

# ABSTRACT

Three new attitude control architectures of a satellite actuated using a double-gimbal variable-speed control moment gyro (DGVSCMG) are proposed in this thesis. The mathematics of a satellite-DGVSCMG system with and without an unbalanced rotor is comprehensively developed in the framework of geometric mechanics, accounting for the rotational dynamics of the DGVSCMG and the large angular motion of the satellite. It is shown that coupling between the DGVSCMG gimbal motors and satellite bus dynamics exists, and accounting for this coupling allows high-precision satellite attitude control. The analytical results presented facilitates computation of the torques of the gimbals and rotor motors in a closed-loop control form. A novel model predictive static programming (MPSP) based control architecture for the attitude control of a satellite using a DGVSCMG is proposed and developed to avoid the control input saturation and the gimbal lock singularity issues of the DGVSCMG. To accommodate the gimbals and rotor motor control system, a novel cascaded attitude control architecture for the satellite-DGVSCMG system is proposed, wherein the respective rotor and gimbals motor torque can be calculated in the closed-loop control form using any suitable control algorithm. However, the steering law used in the proposed cascaded control architecture causes mathematical control singularity, making the system underactuated at the gimbal lock configuration even though the system is physically three-axes steerable. To address this issue further, a single-loop control architecture is proposed to achieve singularity-free attitude control of the satellite-DGVSCMG system wherein the respective motor torques of the DGVSCMG are computed directly using only one controller without requiring the steering law. It is shown that the proposed single-loop control formulation along with the proposed control law does not lead to an offset in the rotor spin rate post attitude maneuver. This eliminates the need of momentum dumping of the rotor, unlike the steering-law-based control, leading to cost and space savings. A fast finite-time sliding control and a fixed-time adaptive sliding control are formulated and implemented for the satellite-DGVSCMG system. Moreover, a new switching logic between the original and shadow modified Rodrigues parameters sets is proposed in order to ensure an unwinding-free and kinematic singularity-free attitude maneuver using the sliding mode control technique. Simulation results are presented to substantiate all the claim made assuming the rigid satellite to be equipped with only one DGVSCMG.