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Model Predictive Control of Attitude Maneuver of a Geostationary Flexible Satellite Based on Genetic Algorithm

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Abstract

This article presents an application of Model Predictive Controller (MPC) to the attitude control of a geostationary flexible satellite. SIMO model has been used for the geostationary satellite, using the Lagrange equations. Flexibility is also included in the modeling equations. The state space equations are expressed in order to simplify the controller. Naturally there is no specific tuning rule to find the best parameters of an MPC controller which fits the desired controller. Being an intelligence method for optimizing problem, Genetic Algorithm has been used for optimizing the performance of MPC controller by tuning the controller parameter due to minimum rise time, settling time, overshoot of the target point of the flexible structure and its mode shape amplitudes to make large attitude maneuvers possible. The model included geosynchronous orbit environment and geostationary satellite parameters. The simulation results of the flexible satellite with attitude maneuver shows the efficiency of proposed optimization method in comparison with LQR optimal controller.

Key words: Flexible Satellite, Geostationary Satellite, Genetic-Algorithm, MPC

1. INTRODUCTION

Many different 3-axis stabilized geostationary satellites (CTS, INTELSAT, SATCOM, INSAT and ARABSAT) have large solar panels with significant structural flexibility. The structural mode interaction with the attitude control system has been one of the primary concerns for the design of 3-axis stabilized satellites [1-3]. This paper presents design of discrete control system for a flexible geostationary satellite.

MODEL predictive control (MPC) is an advance control technique which is suitable for control of multivariable systems. This control method handles multivariable control problems naturally and can take account of actuators constrains which would be idealistic for geostationary satellite problems that need different parameters to be handled simultaneously. MPC is based on the idea to produce control input as a solution to real-time optimization problems. The main principle of MPC is how to select appropriate control measures to solve the problem of repetition in the optimum control. In this case, we solve the problem of flexibility impact on attitude angles during maneuvering of a geostationary flexible satellite using MPC modelling techniques in an optimal way.

Although MPC finds the optimal control law for the system, the MPC parameters must be tuned carefully to achieve the best performance of the system. Therefore, a successful implementation of MPC involves the setting of a considerable number of parameters, which must be appropriately tuned [4]. [5] presents a survey about the history and progress of model predictive control.

Many studies have been done for tuning the MPC parameters. [6] provides a review of the available tuning guidelines for model predictive control, from theoretical and practical perspectives. In [7] a systematic approach has been introduced in order to find optimal controller parameter for SISO systems using convex optimization. This method has been expanded for MIMO systems in [8]. [8] introduces an approach to determine MPC tuning parameters for unconstrained MIMO systems. The tuning approach is based upon the specification of the closed-loop performance in the frequency-domain. The optimization problem is SDP problem which is solved using convex optimization solver. In [9] Control system parameters are obtained by solving a multi-objective optimization problem. The set of objectives includes controllability aspects and the range of manipulated and controlled variables, expressed using the 2nd Euclidian norm. [10] proposes the tuning strategy that achieves set point tracking with minimal overshoot and modest manipulated input move sizes and is applicable to a broad class of open loop stable processes. The procedures for tuning MPC using the H_∞ loop-shaping method were outlined in [11]. The normalized left co-prime factorization optimal controller is used in this work that allows to

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