Introduction

This Software-in-the-Loop (SILS) test plan outlines the strategy for validating the reaction wheel-based attitude control system designed for a satellite using Simulink. The primary objective is to ensure the system's ability to reorient the satellite from an initial attitude of [0 0 0] degrees and angular rate of [15 -15 15] deg/sec to a final attitude of [30 50 70] degrees and desired rate of [0.2 0.2 0.2] deg/sec. This plan details the test environment, test cases, success criteria, and potential challenges to be addressed during the validation process. By rigorously testing the control system in a simulated environment, we aim to verify its performance, robustness, and readiness for potential hardware implementation.

Test Objectives

To validate the attitude control system's performance

- Verify the system's ability to achieve desired attitude and angular rates
- Test the momentum management system's effectiveness
- Evaluate system response to disturbances

Test Environment

The satellite is moving in a circular orbit around Earth at an altitude of 600 km.

The satellite contains sensors capable of measuring attitude and angular velocities.

Reaction wheels in a pyramidal configuration are used for actuation. (max torque = 0.015 Nm, Max momentum = 0.035 Nms)

A sinusoidal disturbance torque of 10^-6 Nm exists in each direction (random phase difference).

Test cases

The ability of the AOCS to steer the satellite from [0,0,0] deg attitude, [15, -15, 15] deg/s angular velocity to [30, 50, 70] deg attitude and < [0.2, .2, 0.2] deg/sec angular velocity , for different conditions is going to be evaluated based certain criteria.

1. Nominal case - Assuming no error in sensor measurements and no disturbance torques.

2. With disturbance torques

3. With Gaussian sensor noise ([0.01;0.01;0.01] deg in attitude, [0.001;0.001;0.001] deg/s in rate)

4. With disturbance torques and sensor noise

5. With uncertainty in dynamics and configuration matrix of reaction wheels

6. Monte Carlo simulations for varying magnitudes of initial error, disturbance torques, sensor noises and system uncertainties to identify failure points.

Success criteria

1. Pointing accuracy of 5 deg.

2. Angular velocity < [0.2,0.2,0.2] deg/sec

3. Setting time of < 600 seconds

4. Reaction wheel momentum and torques below saturation

Data collection

- Attitude (Euler angles and quaternions)
- Angular velocities
- Angular momentum
- Reaction wheel – momentum and torque provided by each wheel
- Unloading torque (if any)

Potential challenges

Reaction wheel modeling

- Modeling non-linear effects such as friction, imbalance, and bearing imperfections
- Representing the pyramidal configuration accurately and its impact on torque distribution

Satellite Dynamics modeling

- Modeling the coupling effects between different axes due to off-diagonal terms in the MOI matrix.

Noise modeling

- Modeling additional disturbances not explicitly mentioned (e.g., solar radiation pressure) for a more realistic simulation
- impact of temperature variations on sensor and actuator performance and the effects of radiation on electronic components
- Modeling gyroscope noise and bias for angular rate measurements
- Implementing sensor fusion algorithms to combine data from multiple noisy sources

Computational challenges

- Ensuring real-time or near-real-time performance for SILS testing
- Handling numerical precision issues, especially for small disturbance torques (10^-6 Nm)

Conclusion

The SILS test plan presented here provides a comprehensive framework for validating the satellite's attitude control system. By simulating various scenarios, including nominal operations, disturbance rejection, and sensor noise handling, we can thoroughly assess the system's performance and identify potential areas for improvement. The outlined test cases, success criteria, and data collection methods will enable a systematic evaluation of the control system's ability to meet the specified requirements. Additionally, by anticipating and addressing potential challenges in hardware modeling and noise simulation, this plan enhances the reliability of our validation process. Successful execution of this test plan will provide confidence in the control system's design and its readiness for further development stages, ultimately contributing to the overall success of the satellite mission.