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PLUG AND PLAY INNOSAT ACS SIMULATOR

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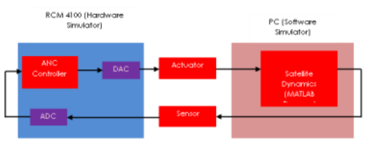
Graphical abstract



Abstract

This research proposes a novel approach of satellite simulator design where the simulator will be in the form of both software and hardware. A software simulator will represent the satellite dynamics model, incorporating all the operating conditions of the satellite in orbit. The control algorithm for Attitude Control System (ACS) will be implemented on Rabbit Micro Controller (RCM4100) and the dynamics model of Innovative Satellite (InnoSAT) plant in PC have been tested using real-time hardware-in-loop-simulation (HILS) technique. The results that have been obtained show that the InnoSAT ACS simulator can produce as good result as MATLAB simulation for the InnoSAT plants. The MSE values that have been calculated also show that there are a close match between HILS and MATLAB simulation where the MSEs different value are small. From both results, it is enough to verify that the developed protocol working satisfyingly and seems to be possible to be implemented on the actual flight.

Keywords: Innovative satellite, attitude control system, rabbit micro controller, hardware-in-loop-simulator

1.0 INTRODUCTION

Designing a standard satellite attitude controller will include creating a simulation of the controller, actuator, feed-back sensor and satellite dynamics model. The simulation will incorporate the necessary operating conditions of the satellite. Since the satellite operating conditions differ from the ground conditions, the physical ground model become complex and expensive and also have no practical value for controller performance verification. As a result, a more conventional approach in designing a satellite controller is taken by creating a software simulator. However, this approach could not guarantee the same actual performance in attitude control in real satellite operation which leads to the need of redesigning the controller in a hardware form (where its performance will normally degraded) [1, 2].

Spacecraft attitude simulator that has been developed specifically is to verify attitude control designs and flight software architectures and algorithms. Its primary goal is to provide a generic approach to satellite attitude control development by allowing scalable performance. Typically different simulators are developed throughout the satellite development to support validation and verification activities. Many universities and research centers have developed similar facilities in the study of satellite control. An early example of a three-axis spacecraft simulator was built at NASA's Marshall Space Flight Center in 1959. Since then, spacecraft dynamics simulators have been commissioned by most of the major spacecraft research centers and companies and by many technical universities [3, 4, 5, 6]. Georgia Institute of Technology (GIT) also designed a low-cost spacecraft simulator, which is used to evaluate and improve various controllers and develop new control strategies in an experimental framework [7]. Furthermore, satellite attitude control simulator have many benefits such as reducing research and development cost, optimizing system performance, evaluating various potential mission concepts, training of operators and educating lab personnel for actual operations [4, 8, 9].

2.0 HARDWARE-IN-LOOP-SIMULATION TECHNIQUE

Hardware-in-loop-simulation (HILS) is a real-time test technology which is used to test one or a set of remaining system components in a comprehensive, cost effective and repeatable manner. HILS is often used in the development and testing of embedded systems, when those systems cannot be tested easily, thoroughly and repeatedly in their operational environments. Instead of being connected to the real equipment, it is actually connected to the real time simulation [10].

HILS test concept can be applied to a wide variety of systems, from relatively simple devices such as a room temperature controller to complex systems like an aircraft flight control system. HILS has historically been used in the development and testing of complex and costly systems such as military tactical missiles, aircraft flight control systems, satellite control systems, and nuclear reactor controllers [11].

In this research, a RCM4100 is used to implement an attitude control algorithm for InnoSAT system as a hardware simulator. A computer on the other hand, simulates the attitude dynamics of the satellite as a software simulator. The software simulator integrates the dynamics equations and sends the output responses of the satellite to the RCM4100 using serial communication. The output responses are used in the control algorithm to generate necessary control signals.

Closed loop simulations can be made to work in real time to simulate the dynamics behaviour of the satellite system with the ACS to control its attitude. It is important that the ANC controller can work properly in the RCM4100 microcontroller board because it will be used for attitude control system of the InnoSAT plant. If the controller could control the satellite model in software simulator, then the same controller could be 'plug and play' on the actual InnoSAT and should be able to directly control the satellite without any modification. The attitude controller will be implemented on the actual controller boards that will, at the end be placed in the InnoSAT.

Figure 1 shows a general block diagram of HILS technique for InnoSAT plant that consists of sensor and actuator. A software simulator will represent the satellite dynamics model, incorporating all the operating conditions of the satellite in orbit.

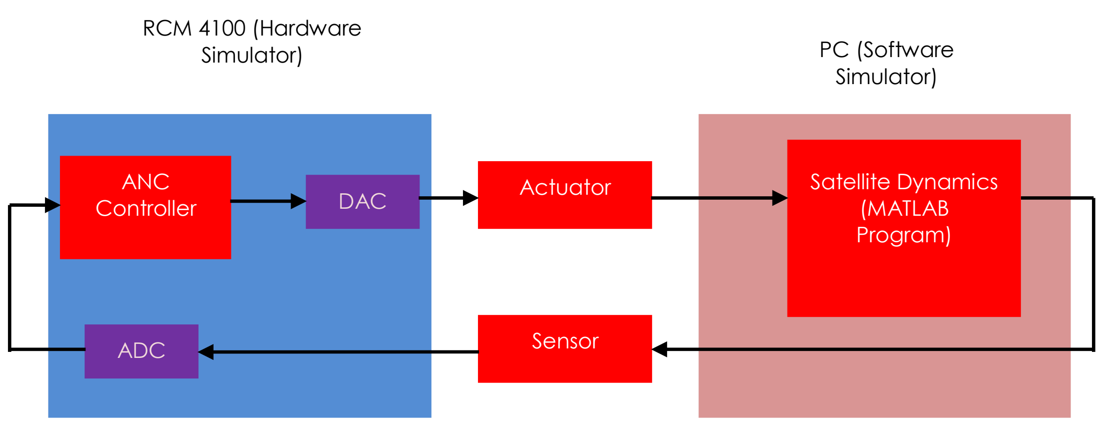


Figure 1 General block diagram of HILS technique for InnoSAT plant

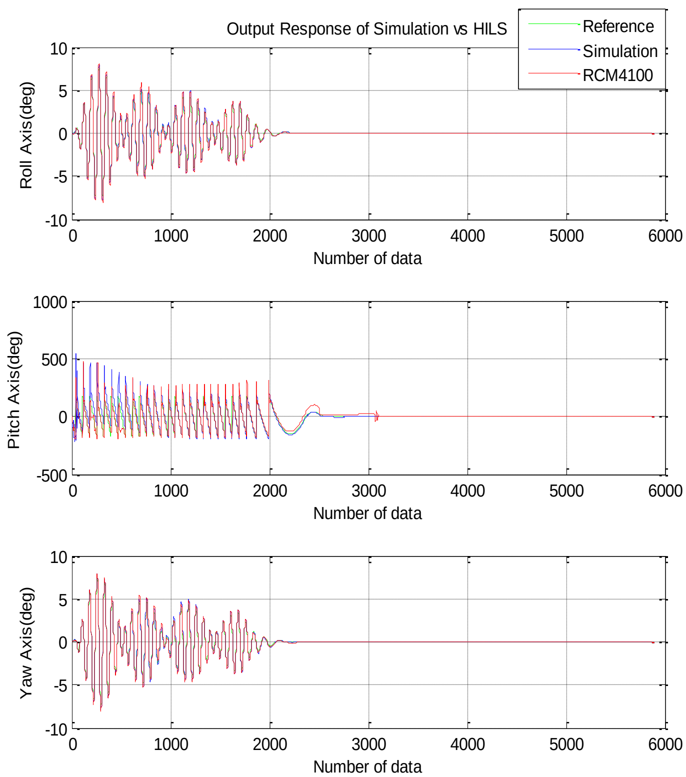
3.0 RESULT AND DISCUSSION FOR INNOSAT ACS SIMULATOR

The satellite simulator will be tested using simulated data and real data named Y-Thompson spin rate data in order to observe the performances of the controller in real time simulation.The performance for each part in the hardware simulator will be tested and modified repeatedly until the result is similar to the MATLAB simulation results. Finally, it serves (after adaptation) as a hardware-in-the-loop simulator and test platform for full system verification and on-orbit operations support tool.

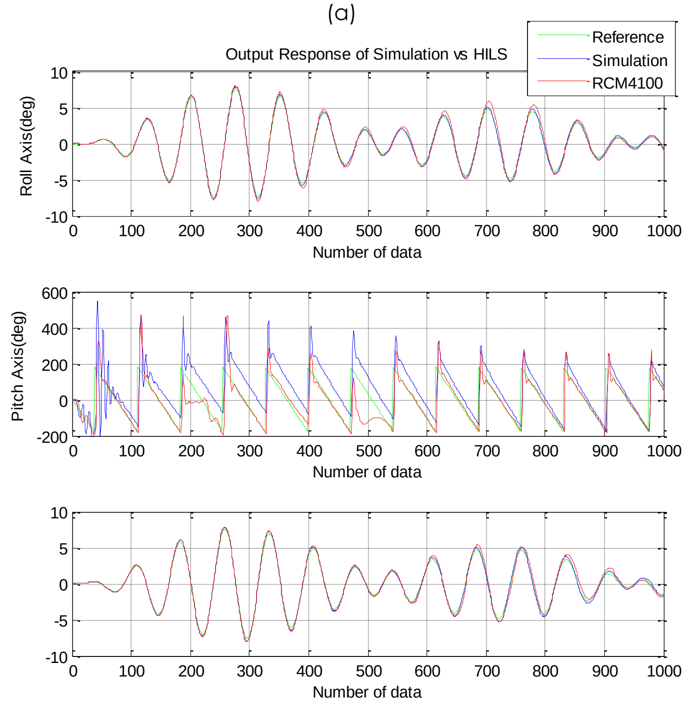
Figure 2 shows the output response of both simulations for Roll, Pitch and Yaw axes. The response shows that ANC for both simulations can track the Y-Thompson reference input quit perfectly. For both simulations, the output response of Pitch axis shows a degradation at early stage where it cannot follow the reference input very well. This is because the input data is too high and the change is very abrupt.

However, after a certain time, it managed to follow the reference input very well.

Table 1 shows the MSE value for both simulations in order to see the performance comparison of HILS and the MATLAB simulations. The MSE value of HILS is larger than the MATLAB simulation for Roll and Yaw axes. However, MSE values for Pitch axis of HILS and MATLAB simulation are the same, which shows that the HILS can provide a satisfying result as good as MATLAB simulation. From the figures as well as the MSE values, it is proven that HILS can perform satisfyingly even when real input data with large value is applied to the real time environment.



(a)



(b)

Figure 2 (a) is output response of Simulation and HILS for Y-Thompson input and(b) is the zoom out of the output response in (a)

4.0 CONCLUSION

The ACS control algorithm in RCM4100 and the dynamics model of InnoSAT plant in PC have been tested using real-time hardware-in-loop-simulation (HILS) technique. The results that have been obtained show that the InnoSAT ACS simulator can produce as good result as MATLAB simulation for the InnoSAT plants. A novel 'plug and play' simulator has been developed that can validate various intelligent controller for nano-satellite attitude control in real time environment. The 'plug and play' simulator could be used to design the attitude controller for InnoSAT satellite. There will be no need for reprogramming or interfacing and it will behave similarly to the simulated environment. This simulator can easily be modified for different types of satellite attitude controller just by changing the simulator environment formula on PC.

Table 1 MSE of Simulation and HILS for Y-Thompson input

Controllers	Mean Square Error (MSE)		
	Roll Axis	**Pitch Axis**	**Yaw Axis**
Simulation (MATLAB)	0.0200	0.0025	0.0250
HILS (RCM4100)	0.0400	0.0025	0.0353

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