SELF-CONTAINED DEPLOYMENT SYSTEM

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Abstract

Kongsberg Defence and Aerospace (KDA) has, under ESA Study Contract No. 18770/04/NL/CH, developed a Self Contained Deployment System (SeCDeS). The SeCDeS provide synchronised deployment of all panels in a solar array (SA) wing. The SeCDeS uses small stepper motors distributed at each panel hinge. The stepper motors are driven from centralised electronic and battery units. A Bread Board Model (BBM) of the SeCDeS is manufactured and functional tests performed.

Introduction

SA panels are normally deployed using mechanical springs, eddy current dampers and different types of synchronisation cables. KDA has developed SeCDeS, - a motorized deployment system with a mechanism located in each of the panel hinge lines. The mechanism is simple, has low weight, and consists of a stepper motor connected to a gear box. The mechanism can easily be adapted to all types of mechanical hinges. This new system gives accurate panel synchronisation and the achieved SA cone angles are considerably reduced compared to existing systems. Dampers and synchronisation cables are not needed.

All stepper motors are controlled from an electronic box located close to the root hinge of the spacecraft. The electronics are powered from a battery box also located close to the root hinge. The electronic design has focused towards a future FM design and all electronic components used in the SeCDeS BBM are either space qualified components or military/commercial variants of space qualified components. The electronics are simple, easy to survey, highly programmable, easily testable and can control up to14 SA panels.

SeCDeS can be applied with or without feedback sensors. If a feedback sensor is located in each panel hinge the SeCDeS will provide a very accurate panel synchronisation even if "miss-stepping" of one or more motors occur. If feedback sensors are not applied the SA panel will be deployed with the commanded stepper motor speed and only information of panel lock will be available.

SeCDeS is ideal SA deployment systems in Earth Observation spacecrafts, scientific mission spacecrafts and GEO spacecrafts.

The SeCDeS BBM hardware was used to perform tests at PCA level and functional tests at unit level, and the overall functionality and feasibility of the proposed concept were successfully verified.

The SeCDeS is self contained, but may be powered from batteries inside the spacecraft.

Design

A SeCDeS consists of one to fourteen mechanisms, controller electronic and batteries.

Mechanism

The mechanism consists of a stepper motor connected to a gear box. The output axis of the gear box provides 5 Nm continuous torque and 11 Nm repeated peak torque at a speed of 0.7 °/s. The weight of the mechanism is 360 g. The weight of the mechanism including leaf springs, for preventing gear box damages due to release of preloaded SA panels and necessary interface, is 405 g.

Motor

SeCDeS apply a lightweight hybrid stepper motor, VSS 26.200, from Phytron.

Gear Box

The gear box is a new lightweight compact 2 stage Harmonic Drive gear box. The gear box is manufactured in standard materials. Figure 1 shows the dimensions of the mechanism, the stepper motor is 47 mm long and the gear box is 41 mm long.

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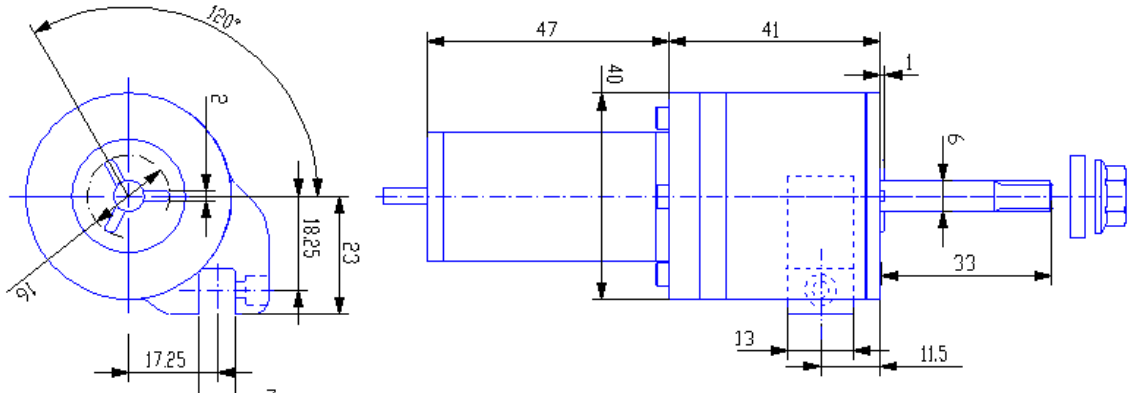

Figure 1. Dimensions of the mechanism

Figure 2 shows a picture of the mechanism interfaced to a SA hinge from DS. An inductive sensor is mounted at the end of the motor.

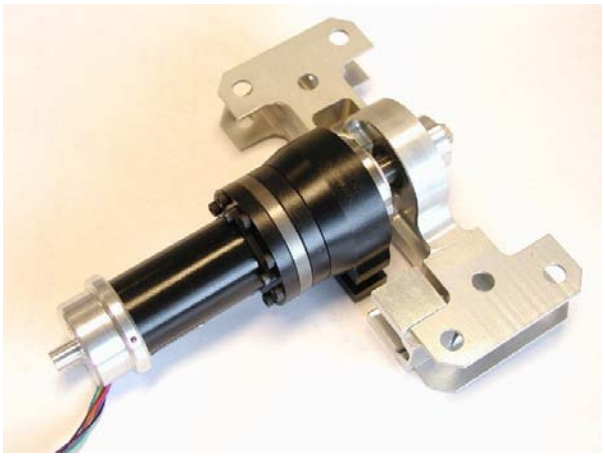

Figure 2. Mechanism interfaced to SA hinges.

Controller Electronic Design

The electronics of the SeCDeS consist of one controller printed circuit assembly (PCA) and up to maximum seven motor bridge PCAs. One motor bridge PCA can control 2 motors. The design goal has been to minimize the complexity of the electronics and thereby minimizing the recurring cost. The philosophy has been to concentrate as much of the functionality into a single FPGA, to keep the rest of the system very simple and survey able. A European field programmable gate array (FPGA), AT40KEL40, from ATMEL is used.

The SeCDeS electronic is fully redundant, and nominally operated in combined cold/hot redundancy mode. A very important aspect of the electronic is the Fault Detection, Isolation and Recovery (FDIR) functionality. When unrecoverable faults are detected by the nominal unit (FPGA), or when the FDIR interface between nominal and redundant unit is malfunctioning (detected by the redundant unit (FPGA)), the redundant unit will take control of the hinge(s). Fault detection rely upon rotary pulse sensor outputs, motor phase current measurements, miss-stepping history, supply voltages and FDIR signals for each hinge driven from the nominal to the redundant unit. The redundant controller is operated in parallel with the nominal counterpart. Both will always operate as they are driving all motors, but only the unit activated for a given hinge will activate the motor bridge driving the motor for this hinge. Hence, the inactive controller will always know the angular position of each hinge as well as the reference position.

Controller PCA

The heart of the controller PCA is AT40KEL40 from ATMEL. This FPGA provides a highly programmable, easily testable and configurable

electrical system. A 3.3 volt version of the FPGA with 5 V tolerant I/O and 3.3 V EEPROM from ATMEL are used.

Motor Bridge PCA

The H-bridge is fully controllable through four switched N- channel MOSFETs. The "Full Bridge N-Channel FET Driver" from Intersil, HS-4080ARH, is used to drive the MOSFETs. One HS-4080ARH is required for each H-bridge.

External Interfaces

- Twisted pair connection to external micro-switches.
- RS-422
- RS-422 TM: Optional telemetry interface.

Fault Detection, Isolation and Recovery

The redundancy of the system is obtained by using two identical electrical systems.

The following faults are detected by each system and make up the basis for the fault detection:

- Supply voltage levels (9 volt and 22volt)
- Motor winding or H- bridge open circuit
- Motor winding or H- bridge short circuit
- Motor miss stepping
- FDIR interface malfunction

Batteries

The electronics and motors are powered from Lithium Sulphur Dioxide, type LO35SX, batteries. A nominal and redundant battery package is included.

Manufactured Hardware

Figure 3 shows the manufactured BBM hardware to the left and the SeCDeS undergoing tests to the right. The electronic BBM has the controller PCA to the top and the motor bridge PCA below.

The controller PCA is wider than the motor driver PCA to allow location of necessary connectors and cabling.

Tests

All tests of the BBM have been performed in air. All functionalities at sub-unit and assembly level have successfully been tested, and the overall functionality and feasibility of the proposed concept were successfully verified. Figure 3 to the right shows the SeCDeS under test. The I beam represents the total inertia of a SA panel, approximately 40 kgm^2. Figure 4 shows a SA wing with assembled SeCDeS (electronic boxes, battery boxes and mechanisms).

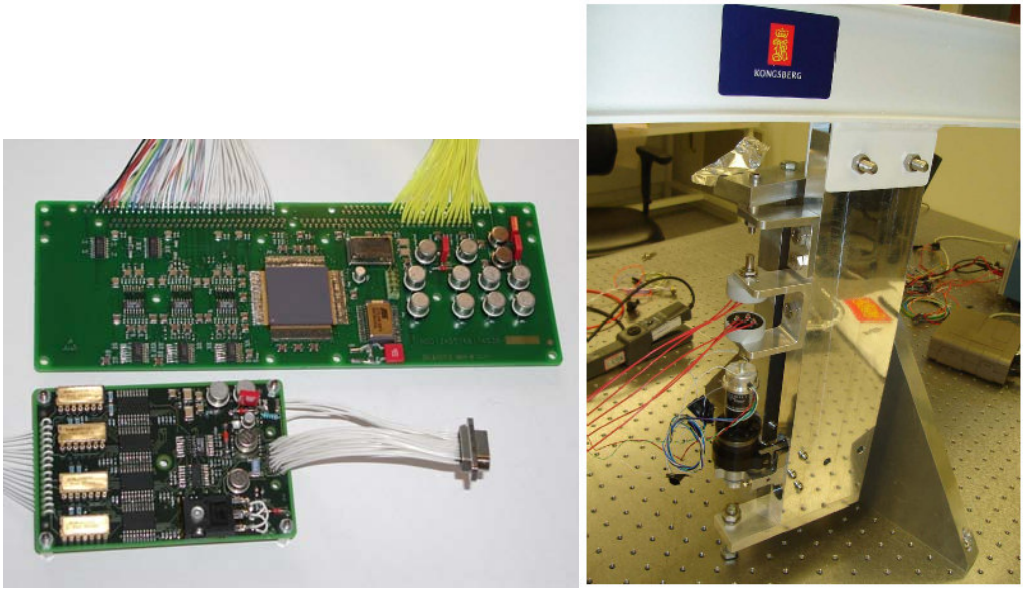

Figure 3. Manufactured hardware and test set-up.

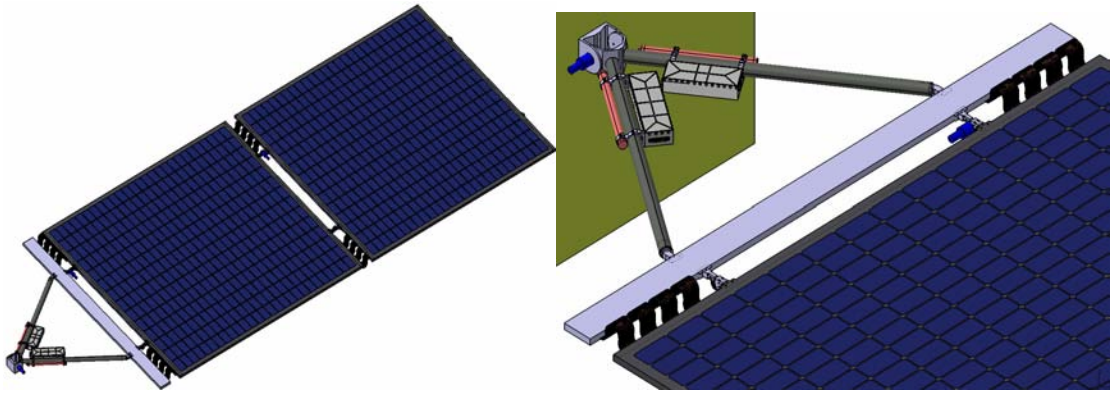

Figure 4. SA wings with assembled SeCDeS.

Application of SeCDeS

SeCDeS can easily be applied to all types of SA panels. SeCDeS will also fit other applications than SA, the motor/gear box may be applied in robots, planet rovers etc.