COMS EPS PRELIMINARY DESIGN

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ABSTRACT ... The COMS(Communication, Ocean and Meteorological Satellite) EPS(Electrical Power Subsystem) is derived from an enhanced Eurostar 3000 EPS which is fully autonomous operation in normal conditions or in the event of a failure and provides a high level of reconfiguration capability and flexibility. This paper introduces the COMS EPS preliminary design result. The COMS EPS consists of a battery, a solar array wing, a PSR(Power Supply Regulator), a PRU(Pyrotechnic Unit), a SADM(Solar Array Drive Mechanism) and relay and fuse brackets. This can offer a bus power capability of 3 kW. The solar array is made of a deployable wing with two panels. One type of solar cells is selected as GaAs/Ge triple junction cells. Li-ion battery is base lined with ten series cell module of five cells in parallel. PSR associated with battery and solar array generates a power bus fully regulated 50 V. Power bus is centralised protection and distribution by relay and fuse brackets. PRU provides power for firing actuators devices. The solar array wing is routed by the SADM under control of the AOCS(Attitude Orbit Control Subsystem). The control and monitoring of the EPS especially of the battery, is performed by the PSR in combination with on-board software.

KEY WORDS: EPS, solar array, battery, power supply regulator, pyrotechnic unit

1. INTRODUCTION

The EPS as required by the COMS mission is an enhanced Eurostar 3000 version which is fully regulated power subsystem offers a bus power capability of 3 kW. The EPS will maintain nominal performance with any single failure. It is autonomous in sunlight and eclipse conditions and provides a high level of reconfiguration and flexibility, thanks to its architecture and redundancy philosophy. If necessary, EPS and load configuration or operation can be modified by ground command. The EPS uses both hardware and software functions for protection and management concerning operation of battery and EPS FDIR(Failure Detection, Isolation and Recovery). Application software within the SCU(Spacecraft Computer Unit) provides efficient and flexible support for the power management over all satellite life.

The COMS contract to develop the COMS satellite and to provide support for system activities has been awarded by KARI to ASTRIUM France. The COMS joint project group is composed of KARI and ASTRIUM engineers.

2. COMS EPS DESIGN

2.1 EPS Configuration

The EPS block diagram is shown in Figure 1. During sunlight periods, the power provided by the solar array is regulated at 50 V± 1% on the power bus through the PSR. During eclipses, the battery supplies the spacecraft power through the BDR(Battery Discharge Regulator) modules in the PSR. The BDRs are controlled by the PSR regulation signals. They provide the battery energy to the power bus at a regulated voltage of 50 V. The control and monitoring of the EPS, especially of the battery, is performed by the PSR in combination with the on-board software EPSMAN. Finally, the solar array wing is rotated by the SADM under the control of the AOCS. The EPS uses centralised protection with double insulation for upstream harness. Bus protection is performed at two different levels: the first is a centralised protection, which consists of fuse modules, near the PSR power bus output and the second is a double insulation layer for upstream power harness (solar array to PSR, battery to PSR and PSR to centralised protection). The PRU provides power for firing safely the desired initiator and achieves the activation of each device by means of segregated prime/redundant firing lines, and protects from unwanted switching and provide disactivation of each initiator during mounting, integration and testing phases (by means of safe plugs).

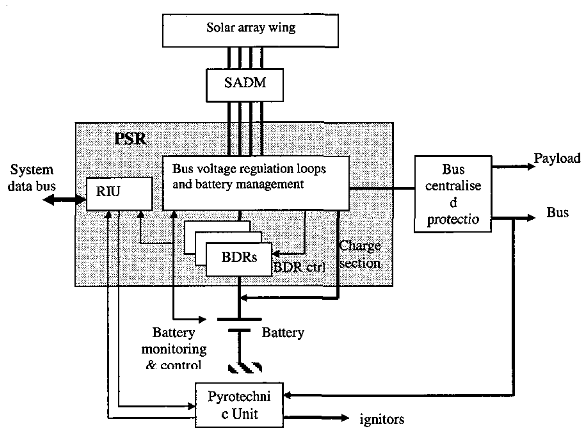

Figure 1. COMS EPS block diagram.

2.2 EPS Redundancy

The EPS has a high level of redundancy both at unit level and subsystem level using hardware and software functions. The EPS includes a high level of robustness thanks to the intensive use of redundancies and the implementation of hardware protection:

- EPS maintains its performance even with a failure of battery cell.
- solar array includes spare string
- one BDR module is added
- each BDR can be individually disconnected from battery
- over voltage load is provided for sunlight regulation in order to allow the permanent connection of a solar array section onto the bus in case of a switch failure
- bus voltage and battery charge current regulation loops are triplicated with majority voters
- cold redundancy is used for PSR data bus couplers

The FDIR is managed on board by the EPSMAN software which is in charge of battery management aspects. The software is based on the monitoring of a small number of key parameters (battery charge/ discharge current, battery voltage, sun/eclipse signals), each of which are triplicated and voted by the software in order to detect reliably any failure conditions. After failure detection, each failure is localised with redundant parameters and reconfiguration procedures are automatically initiated to ensure the spacecraft mission without any outage. The ultimate level of protection is ensured by the SCU with the MRE(Monitoring & Reconfiguration Electronics) criteria issued for the EPS subsystem from battery voltage. In the MRE triggering case, the EPS subsystem is managed with a simplified software in PROM(Programmable Read Only Memory) to ensure spacecraft safety. Payload equipments are automatically switched off and the AOCS subsystem is reconfigured in sun pointing mode. All software protections can be partially or totally inhibited.

2.3 Solar Array Configuration

The COMS deployable solar array with two panels has a design inherited from the E2000+. During launch the wing will be stowed in a folded condition by hold-down units on +Y side of the spacecraft. During transfer orbit, the solar array will be partially deployed. In the partial deployed configuration, solar cells are on the bottom of the partially deployed panel towards -Z. Transfer orbit is three axis controlled for all launchers. At the end of the transfer orbit full deployment will be activated. The wing is deployed with constant torque springs in the panel hinges and temperature compensated carbon fibre synchronization loops.

The preliminary solar array main and charge sections are shown in Figure 2. The GaAs/Ge triple junction solar cells are selected for COMS. On front side of each panel a 50 μm thick Kapton foil provides insulation between carbon face sheets and SCAs(Solar Cell Assemblies). The SCAs are bonded by means of a silicon adhesive to the panel front side. They are connected by use of Ag interconnectors of 12.5 μm total thickness. For shadow protection each solar cell is equipped with an individual integrated bypass diode. The wing consists of 7 main and 1 charge sections. The main sections are located 4 on the inboard panel and 3 on the outboard panel. The charge section is located on the outboard panel to cover power needs during transfer orbit so that battery charge is effective during transfer orbit with the wing partially deployed and consists of 11 strings in parallel. Each string consists of 28 SCAs in series. The number of solar cell assemblies in series is optimised with respect to the degradation due to space radiation, the solar array temperature, the voltage drop of the harness inclding blocking diodes, the operating voltage of 51.5 V EOL and BOL at the SADM interface connector.

The SADM provides the mechanical and electrical interface between the solar array and the spacecraft body. The SADM is controlled and driven from the AOCS, taking into account the LIASS(Linear Analog Sun Sensor) information. During eclipse, SADM is rotated at constant speed, in such a way that the solar array is nearly sun pointed at the end of eclipse. It allows also full bidirectional rotation of solar array.

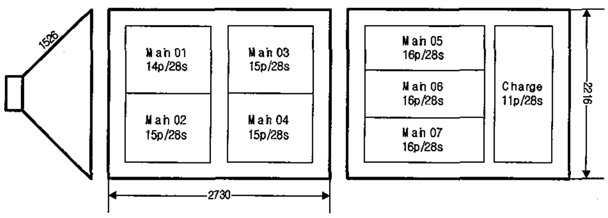

Figure 2. Solar array main and charge sections layout.

2.4 Battery Configuration

The COMS Li-ion battery consists of 10 series cell-modules with their associated electrical, mechanical and thermal hardware. Five 38.5Ah SAFT VES140 cells are connected to each cell-module in parallel. The battery cell module configuration is shown in Figure 3. The COMS battery is mounted on +Y wall of the satellite. The Li-ion cells are integrated in cell modules. The cell module structure insures the mechanical and thermal interface with the battery structure panel and the heatpipes. The cell modules are aluminium sleeves linked together in which the cells are bonded at the bottom level. A dedicated radiator covered, which dissipation will be spread using a network of embedded heatpipes, will be implemented. This will be complemented by a dedicated active thermal control, in order to meet a minimum of +10 °C temperature.

The battery functional black diagram is shown in Figure 4. The battery has the following electrical and functional interfaces with the electrical power subsystem units and other subsystems:

- BDR converters: battery provides main power to BDR converters which regulate the spacecraft power bus.
- SACS(Solar Array Charge Sections): in sunlight conditions, they provide charge and tapering charge currents to the battery.
- PSR: battery current, battery voltage and individual cell-module voltages, battery temperature are

acquired by the PSR for battery management and TM purpose. TM/TCs are also provided by the PSR for cell modules balancing network setting for cell-module state of charge balancing.

- ADE5(Actuator Drive Electronics 5th generation): TM/TCs are provided by the ADE5 for thermal control relays included in the battery.
- SCU: the SCU includes software for the battery management which operates with TM parameters and senses directly battery voltage for protection purpose in case of major on-board failures (MRE board).

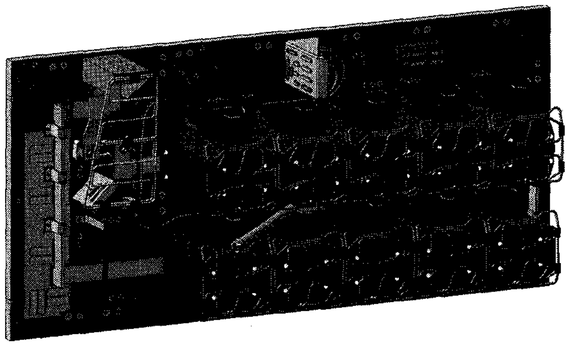

Figure 3. Battery module configuration.

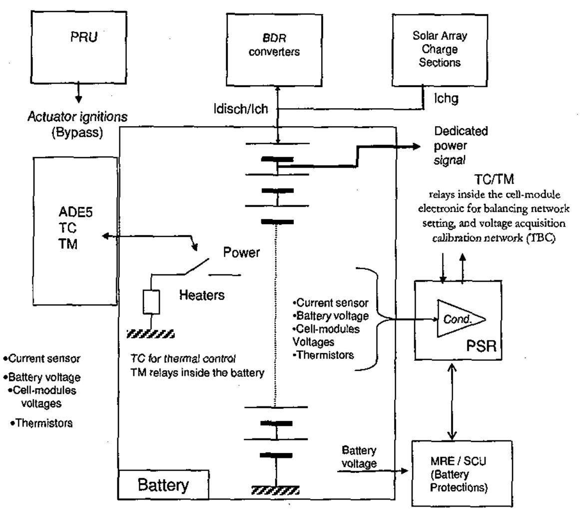

Figure 4. Battery functional block diagram.

2.5 Power Bus Regulation

The EPS regulation principle is shown in Figure 5. In the sunlight mode, the power is delivered to power bus by the PSR, each array switch being operated by a comparator referenced at different points on a voltage ladder. Thus the demand signal can only change the state of an array switch one at a time. Bus voltage is actively controlled by the PSR to 50V ± 1% regardless of the user power demand and array temperature. Fine trimming of voltage regulation is achieved through the toggling of one section associated to one shunt switch. A sudden and large unbalance between the power available for a steady state and the spacecraft needs, leads to the immediate switching of several sections to maintain voltage regulation. Each PSR switch is associated to a pair of solar array sections which are connected in parallel. The total number of power module included in the PSR is adapted to the required bus power according to the modular concept of the PSR (one solar array switch and BDR per power module): COMS PSR includes 6 power modules (4 main switches, 1 charge switch, 1 over voltage load switch).

In the eclipse mode, operation is essentially linear. The demand signal issued from the PSR triple majority voted error amplifier, commands all the BDR modules. When entering eclipse, current mode controlled BDRs smoothly supply the bus load and maintain the bus voltage throughout the eclipse period. In eclipse or when the solar array power is no longer sufficient to supply the bus loads, the power bus is supplied by the battery through the BDR modules. The required number of BDR is determined by the eclipse power consumption on the power bus, with an additional BDR module to provide the appropriate redundancy level and a good reliability (for COMS, 6 BDR).

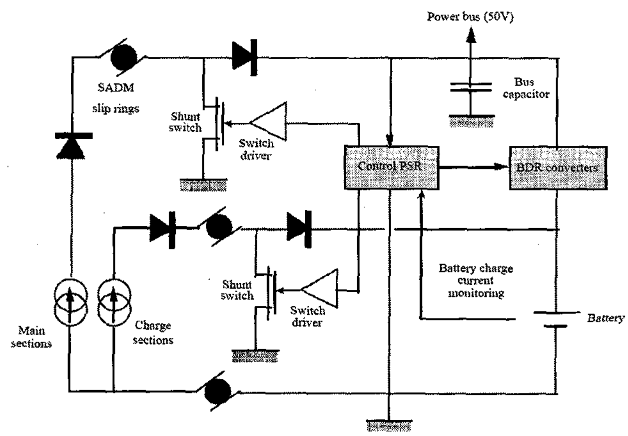

Figure 5. EPS regulation principle.

2.6 PSR Configuration

The PSR provides charge and taper charge current to battery and includes the TM/TC interface of the EPS with the TC&R(Telemetry Command and Ranging) subsystem. The PSR provides a centralised low impedance star point for distribution of spacecraft power, combines power sources from the solar array and battery and achieves the regulation of solar array and battery power under all spacecraft operating conditions. It performs active control of battery charge current, provides and conditions PSR and battery telemetry, accepts telecommands through the redundant spacecraft data bus to configure redundancy and to manage battery and interfaces with EGSE facilities.

The PSR block diagram is shown in Figure 6. In sunlight conditions, power is provided to the power bus from the solar array which is divided into sections. Each section is connected to the power bus in the well known sequential switching shunt arrangement. The analog error voltage is converted into digital signals which are used to actively control shunt MOSFET switches. The switches are controlled such that as much the load as possible is met using the full array current flowing through schottky diodes, and only one switch at any time is pulse width modulated to achieve fine control of the bus voltage. Eclipse power from battery is boost converted to the bus voltage by several active BDRs. The each BDR consists of 600 W. These regulators provide the regulated bus voltage in eclipse, controlled by a dual loop current mode controller. Battery charging is provided by the PSR using a technique that uses a subset of BDR modules called BCDR(Battery Charge and Discharge Regulator) which are operated both in eclipse and in sunlight, using the common error voltage generator in eclipse and the charge or taper charge demand in sunlight. This BDR subset is controlled by a separate control system associated to the battery, which combines available solar array charge section current, the PSR charge demand and the common error voltage. The PSR contains its own fully redundant APS(Auxiliary Power Supply), which provides low voltage power to circuits within the PSR. To protect over voltage, the SW6 in the Figure 6 switches ON a group of heaters(overvoltage load) to ensure a minimum consumption in case of very limited bus demand and of failure of a shunt switch (permanent connection of a section to the bus). The group heaters are located exterior of PSR and connected in parallel with over voltage power switch. The bus capacitor reduces the noise associated with the shunt switches and BDR modules when they deliver current to the power bus.

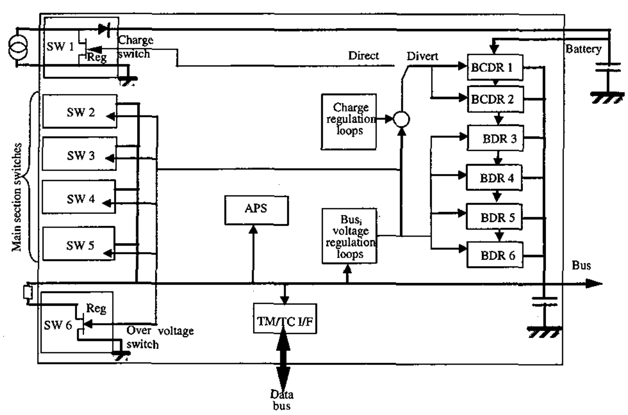

Figure 6. Power supply regulator block diagram.

2.7 PRU Configuration

The pyrotechnic relay network at board level is shown in Figure 7. The COMS PRU design is directly derived from the Eurostar pyrotechnic assembly. The PRU consists of four identical pyrotechnic boards which are functionally, thermally and mechanically segregated. Each PRU board supplies six pyrotechnic groups. Each group has at least three inhibits (Prearm, Arm, Fire). Each PRU board consists in a reliable power regulator and a relay network. Upon fire command, the regulator supplies power to the initiator only after a delay and stops the power before the end of the command. In doing so, the power regulator provides a window pulse for pyro current so as to insure that fire relays will only carry the current but never switch it. The pyrotechnic assembly is used during the early stages of the mission to configure the CPS fluid circuitry, to deploy the solar arrays and deployable reflectors and to release the radiant cooler cover of Meteorological Imager. In case of Li-Ion battery, it is also used for the complete spacecraft lifetime (10 years) to activate cell module by-pass devices in case of cell module failure.

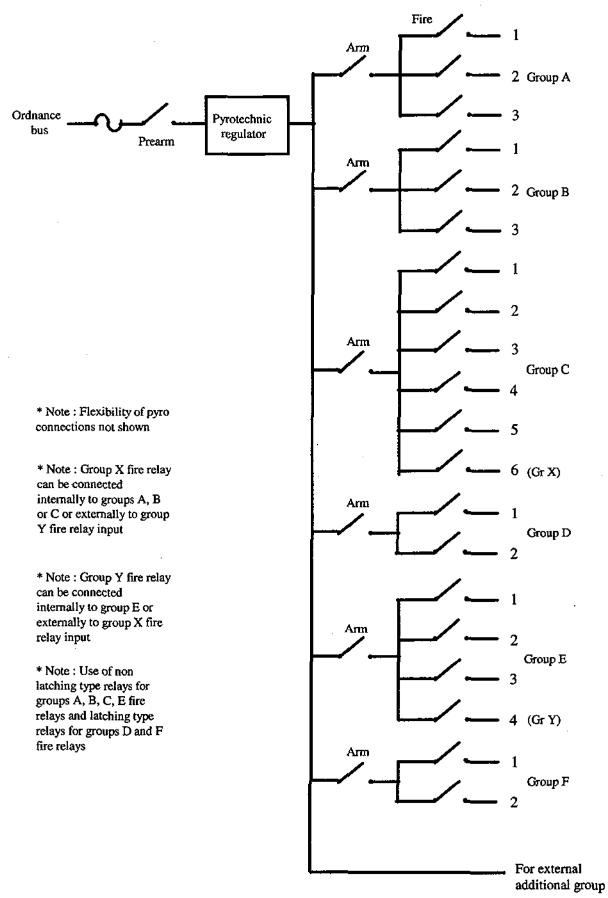

Figure 7. Pyrotechnic relay network at board level.

3. CONCLUSIONS

The solar array power, battery capacity and PSR configuration, SADM model was selected through COMS preliminary design. Also allocation for pyro channels in PRU completed during this phase.

The COMS is now critical design phase. During this phase, various EPS performance analysis will be performed after establishment of analytical power models. Also EPS compatibility will be performed for power, command and telemetry interfaces.

References from Other Literature:

J.C. KOO, 2005. COMS EPS Description. KARI, Korea.

Acknowledgements

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