HIGH POWER PROCESSING UNIT
FOR
STATIONARY PLASMA THRUSTER

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Alcatel ETCA, under ESA contract since 1996, has designed, tested and produced Power Processing Unit (PPU) to supply the first generation of Stationary Plasma Thrusters (SPT) : the Russian SPT-100 from Fakel and the PPS-1350 developed and qualified by the SNECMA company.
Based on the experience acquired with this first program, Alcatel ETCA has started the design and development activities of a new PPU product sized to drive the 6 kW class thrusters which are at the present time in progress of test or qualification.
This new product can be easily adapted to different platforms in terms of electrical interfaces : primary input bus, telecommand-telemetry communication interface, …
The flexibility of the design allows to build, quickly with minimum non recurring activities, a PPU perfectly sized to drive any type of Hall Effect Thruster in the range from 1 to 6 kW.

1. INTRODUCTION

Alcatel ETCA has started its PPU development activities since January 1996 for the French Stentor program on the basis of a specification built from the definition of :
- the electrical interfaces of the Fakel SPT-100 and Snecma PPS-1350 thrusters,
- the thermal, mechanical and electrical interfaces of most European platforms,

From 1999, a Qualification Model is connected on a SPT-100 thruster in space environment conditions, at Snecma facilities in France, in order to demonstrate the lifetime corresponding to the use of the plasmic propulsion for the North-South station keeping on a geo-synchronous satellite. In 2002, more than 6900 hours have been reached without any abnormal deviation of the equipment performances.

Eleven flight models of this PPU have already been delivered for the Stentor, Astra-1K, Smart-1, Intelsat and Immarsat satellites.

Based on this experience, we have started the design of a new generation of PPU compatible with the Hall Effect Thrusters of higher power in progress of development or qualification.
The present article, after a summary of the characteristics of the current product, describes our next PPU generation : the High Power Processing Unit – HPPU – which will cover a larger range of power up to 6 kW at least.

2. PPU MAIN FUNCTIONS

PPU is constituted by the following modules (see figure 1) :

- Interface on the Primary input power bus, insures main bus protection, voltage level conversion and galvanic isolation required by the SPT supplies.
- SPT power supplies, the 4 types of electrodes of the Stationary Plasma Thruster (anode, magnet, heater, ignitor) are supplied according to their specific power profile.
- XFC power supplies, PPU supplies the Xenon Flow Controller : opens or closes the xenon valves and controls the discharge current by the regulation of the xenon flow via the thermothrottle power supply.
- Sequencer, insures the automatic control and the survey of the thruster operation : start-up, stop, regulated thrust, failure recovery, ...
- TC/TM interface with the satellite communication bus

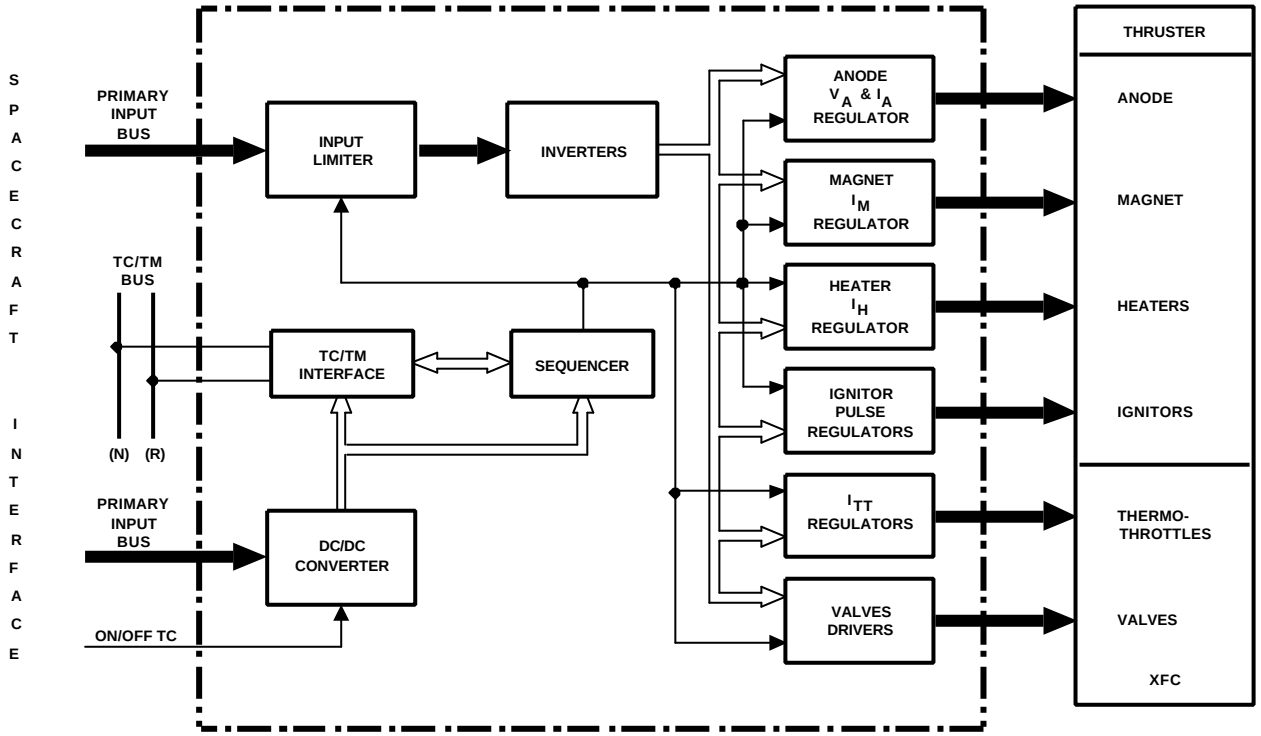

Figure 1 : PPU functional block

3. PERFORMANCES OF OUR CURRENT PRODUCT

The main characteristics of the 1.6kW class PPU are summarised hereunder.

- Compatible with Fakel SPT-100 and Snecma PPS-1350 thrusters
- Maximum Power in the thruster discharge circuit : 1600 W
- Includes SPT and XFC power supplies
- Can be equipped with or without a switching module (called TSU for Thruster Switching Unit) allowing to drive one out of two motors ; this module is typically used for North-South station keeping application on geo-synchronous satellite

- Easily adaptable to any regulated input bus in the range of 50V to 100V
- TC/TM plug-in module available for MIL-STD-1553, ML16-DS16 and OBDH-RS485 communication busses ; possibility to design other TC/TM module for any type of platform interface
- Efficiency > 91 % in nominal operating conditions
- Reliability figure for PPU with TSU : 2 836 fits
- Mass for one PPU with TSU : 10.4 kg
- Dimensions : 390 x 190 x 186 mm (LxWxH) , see figure 2.
- Fully qualified according to environment specifications of Europeans platforms
- 7800 hrs lifetime test in space vacuum conditions :
  - 6900 hrs coupled with SPT-100 thruster
  - 900 hrs coupled with thruster simulator
- Eleven flight models already delivered for the Stentor, Astra-1K, Smart-1, Intelsat and Immarsat satellites.

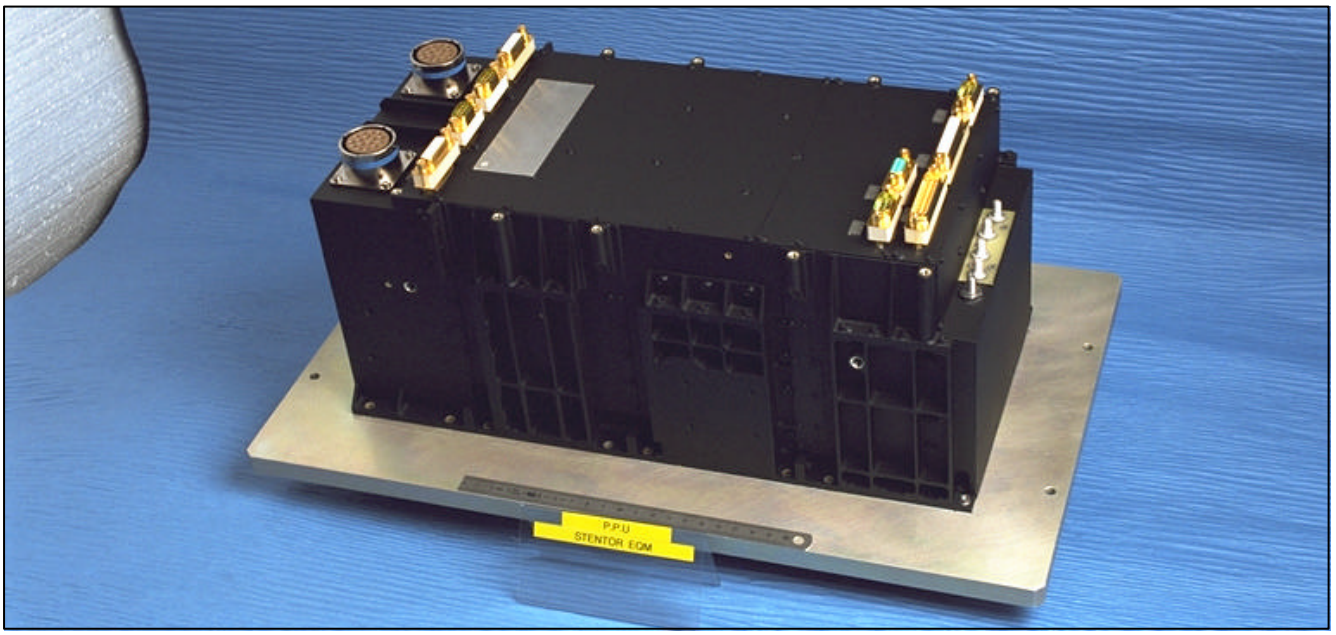

Figure 2 : 1.6kW Class PPU

4. HIGH POWER PROCESSING UNIT - HPPU

4.1. Anode supply main characteristics

The anode supply shall interface the input power bus with the plasma discharge circuit.

This function is completely functionally disconnected from the supply of the other electrodes. It may be justified by the fact that the anode voltage can fall to zero; furthermore, the nominal power adaptation in the range 1 to 6 kW only concerns the anode supply.

The input power bus standards may be:

- either 50 V, 100 V regulated bus, expandable up to 120 V bus; intermediate values shall be accessible,
- either unregulated bus, whilst this configuration is not the most probable; nevertheless, the ability to operate with unregulated bus is considered.

The anode supply is characterised by :

- a voltage regulation
- a current limitation with a specific shape.

as shown at the figure 3.

Typically, the nominal anode voltage is regulated at ± 1%.

Higher power thrusters may have 350 V anode voltage or more. This new product takes into account an anode voltage ranging from 300V up to 700 V, and anode power up to 6 kW, with growing potential up to 12kW.

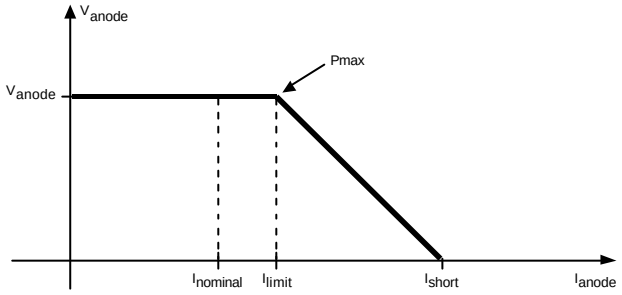

Figure 3 : V – I Anode characteristic

4.2. Main constraints of anode supply design

4.2.1. Cost and adaptability

The design shall lead to configurations minimising the complexity and consequently the cost.

In the same time, the design must lead to a maximum of flexibility for the adaptation of the PPU both to different anode voltages and power and input busses standards.

The most critical point is to choose the best power level for the elementary modules, as the final cost is the product of the modules number by the elementary module cost, the cost of an elementary module growing with its power.

4.2.2. Efficiency

At power levels up to 6 kW (nominal), efficiency has direct and heavy impact on thermal behaviour.

Too high dissipations could lead to technical impossibilities and/or drastic cost impacts.

Internal PPU implementation and interface of PPU with the satellite platform are in fact directly concerned by the dissipations.

4.2.3. Mass, volume, foot print surface

These have to be minimised but the preceding constraints seem to be of greater importance.

4.3. **Anode supply**

The topology selected for this new design, results from the trade-off activities and is based on the Stentor PPU heritage.

The anode supply is constitued of two 3kW modules interconnected. Each module includes one input switch, inverter and anode regulator (see figure 4).

Four interconnected modules could provide up to 12kW.

The output voltage and the output power limit are adjustable by serial telecommand. It is so possible to adapt the anode voltage depending on the thruster type or the mission phase (orbit raising or attitude control). It allows also to limit the maximum input current to a value lower than the platform capability.

Two 3kW anode modules breadboard are being manufactured to validate the electrical performances and to start coupled tests with thruster.

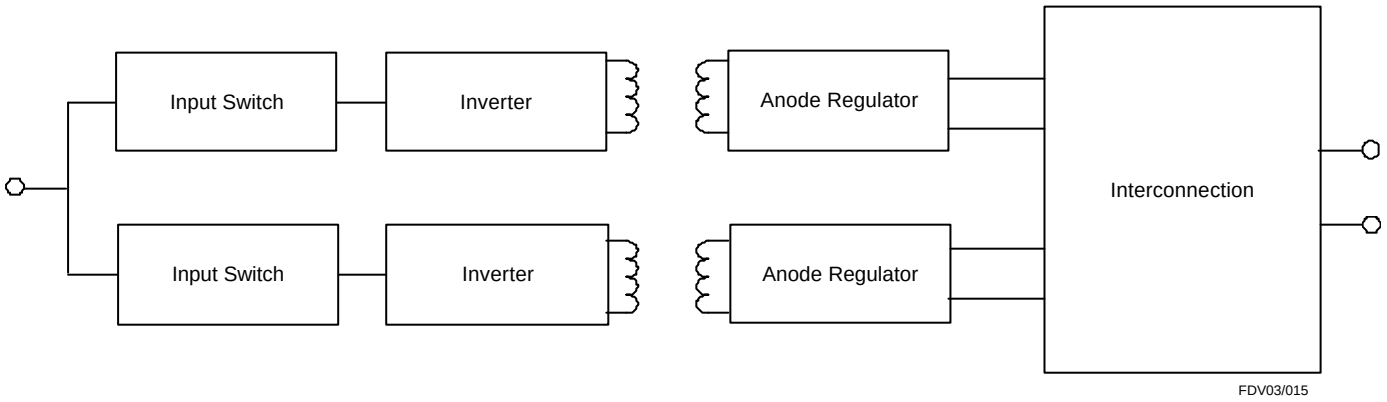

Figure 4 : Anode Topology

4.4. **Cathode Power Supplies.**

The cathode supplies include:

- a current source to heat the cathode and, after local gas ionisation, to sustain the cathode ignition

- a high voltage source to ignite the cathode

The high voltage source and the current source are adjustable by serial telecommand. It allows to easily adapt the cathode supplies to different types of cathode.

4.5. XFC Power Supplies

The XFC supplies include bi-voltage sources to command xenon valves and a current source to control the xenon flow rate.

The current source is adjustable by serial telecommand. It is used to regulate the anode current.

4.6. Thruster/Cathode switching (TSU)

The TSU is a module of the PPU. It supports the output connectors to the thruster and XFC, it contains the relays that connect the power supplies outputs to one of the thrusters or to one of the two cathodes of the selected thruster.

4.7. TM/TC controller

The TM/TC controller interfaces with the platform serial bus, the power supplies, the TSU and the analog acquisition circuits. It also insures some automatism as the anode current regulation, start-up sequence,…

The telemetries include all the output current and voltage of the DC sources and the current consumption on the primary power bus.

4.8. Performances

The objectives of :

- low recurring costs,
- high efficiency
- versatility

are the main driving parameters for the activities of design and development of the 6 kW Class PPU.

Based on the characteristics of the 1.6kW PPU already qualified by Alcatel ETCA, the following figures can be taken as realistic objectives :

- Due to the large power, up to 6 kW, transmitted by the equipment, the efficiency is among the most critical parameter and will be optimised by low-dissipation switching techniques, low conductances losses,…
- Efficiency > 95 %
- Mass ~ 13 kg in version 6 kW

5. COMMERCIAL SUCCESS

Up to 2002, eleven flight models of 1.6kW PPU have been delivered. Six flight models are being manufactured for delivery during 2003.

Customer	Program	Spacecraft	Electric propulsion use for	Models	Delivery date
CNES	Stentor	Telecom GEO	NSSK	2 FM's	1999
ASP	Astra-1K	Telecom GEO	NSSK	2 FM's	2000
ESA	Smart-1	Moon mission	Main propulsion	1 FM	2001
Astrium	Intelsat	Telecom GEO	NSSK	4 FM's	2001
Astrium	Inmarsat	Telecom GEO	NSSK	6 FM's	2002 to 2003
Astrium	Option	Telecom GEO	NSSK	2 FM's	2003

6. CONCLUSIONS

The table in the previous paragraph shows the confidence of primes and customers in the experience and the competence of Alcatel ETCA concerning the PPU equipment used to drive Hall Effect thrusters of the electric propulsion sub-system aboard satellites or spacecrafts.

Alcatel ETCA has acquired a solid experience and a very good knowledge of the electrical interfaces between thruster and PPU confirmed by the success of numerous integration tests with SPT-100 or PPS-1350 thrusters.

So, Alcatel ETCA is now well in position to continue the development of the new PPU generation which will be able to drive the higher power thruster, in development or qualification, up to 6 kW.