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 5 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 10 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. At this date, more than 6000 hours have been reached without any abnormal deviation of the equipment performances. The objective of 7000 hours would have to be completed before end of 2001.
Two 1.6kW class PPU flight models have been delivered to ASPI for the STENTOR satellite which will be launched in 2001.

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 brief 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 10 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

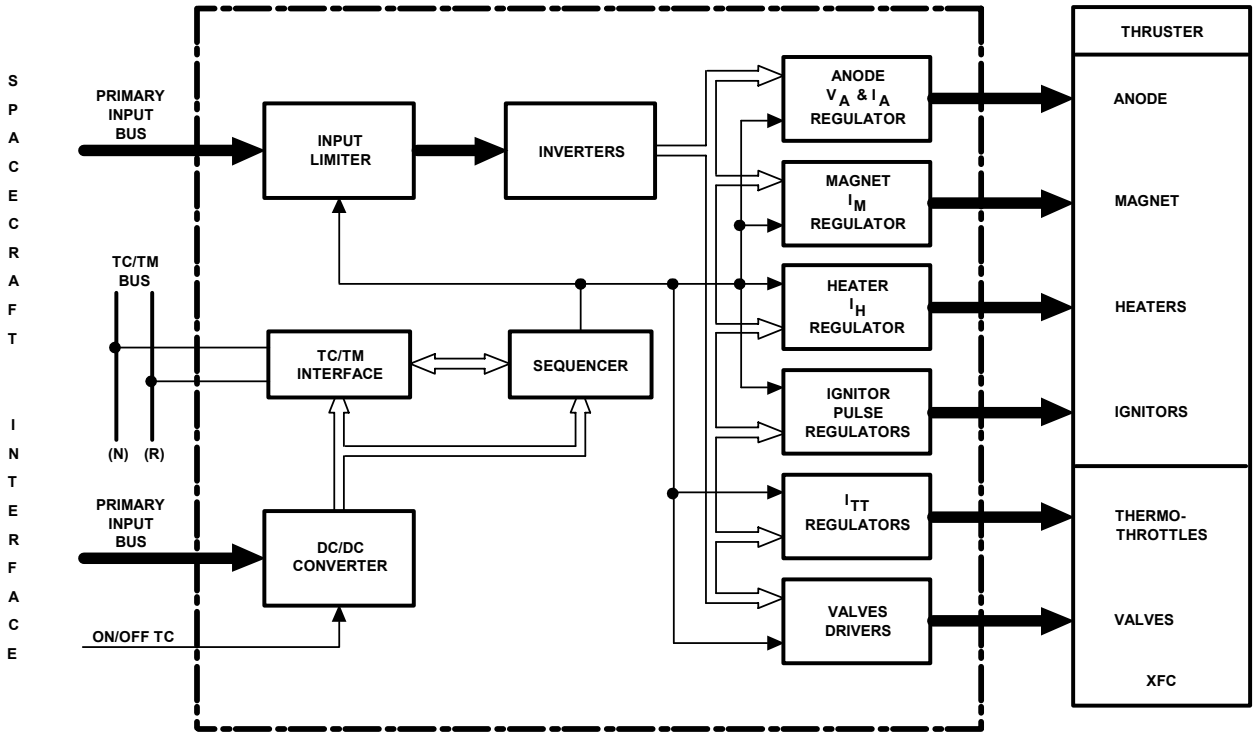

Figure 1 : PPU functional block

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 and ML16-DS16 communication busses ; possibility to design other TC/TM module for any type of platform interface
- Efficiency : 92 % in nominal operating conditions
- Reliability figure for PPU with TSU : 2 400 fits
- Mass for one PPU with TSU : 10.4 kg
- Dimensions :
  - For one PPU : 365 x 190 x 180 mm (LxWxH)
  - For one PPU with TSU : 390 x 190 x 180 mm (LxWXH) , see figure 2.
- Fully qualified according to environment specifications of Europeans platforms

- Lifetime test with SPT-100 in space vacuum conditions :
  - more than 4500 hrs reached
  - objective : 7000 hrs before end of 2001
- Two flight models already delivered to ASPI for the STENTOR satellite which will be launched at the beginning of 2001

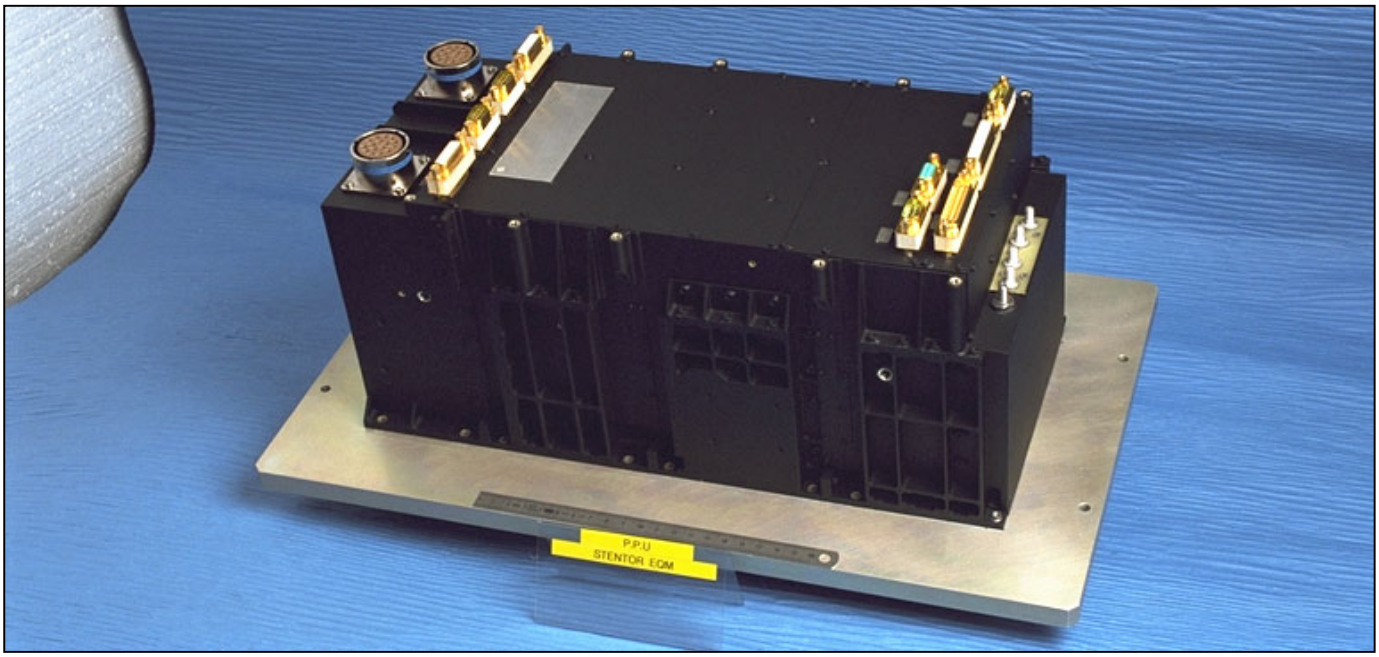

Figure 2 : 1.6kW Class PPU equipped with Thruster Switching Module

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 10 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 motors may have 350 V anode voltage; this new product will take account of the anode voltage range adaptability up to 700 V, and anode maximal power up to 10 kW.

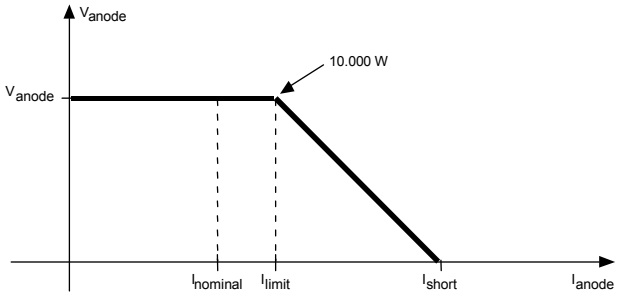

Figure 3 : V – I Anode characteristic

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 10 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 anode supply may be constituted by np branches connected in parallel; each branch being able to contain ns smarts being connected in parallel at primary level and in series at secondary level (see figures 4 & 5).

This topology allows a great flexibility with regard to the power level, the components stresses and the technological constraints.

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.

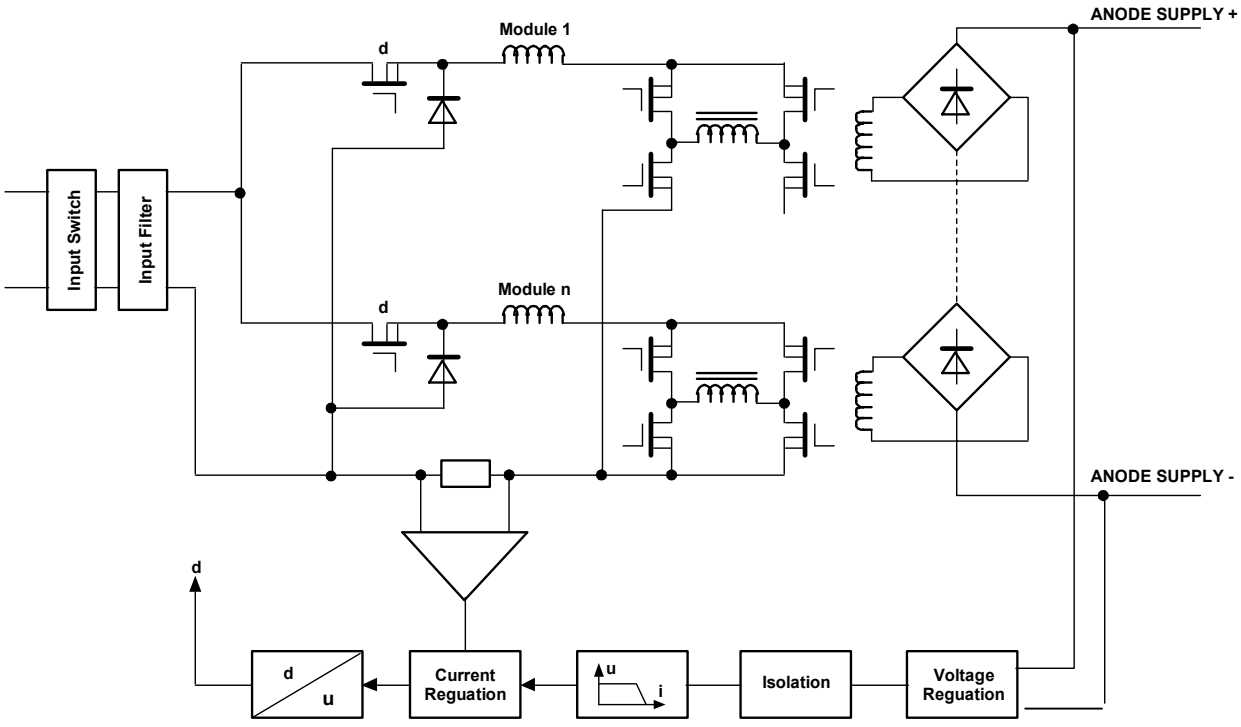

Figure 4 : Branch Smart Topology

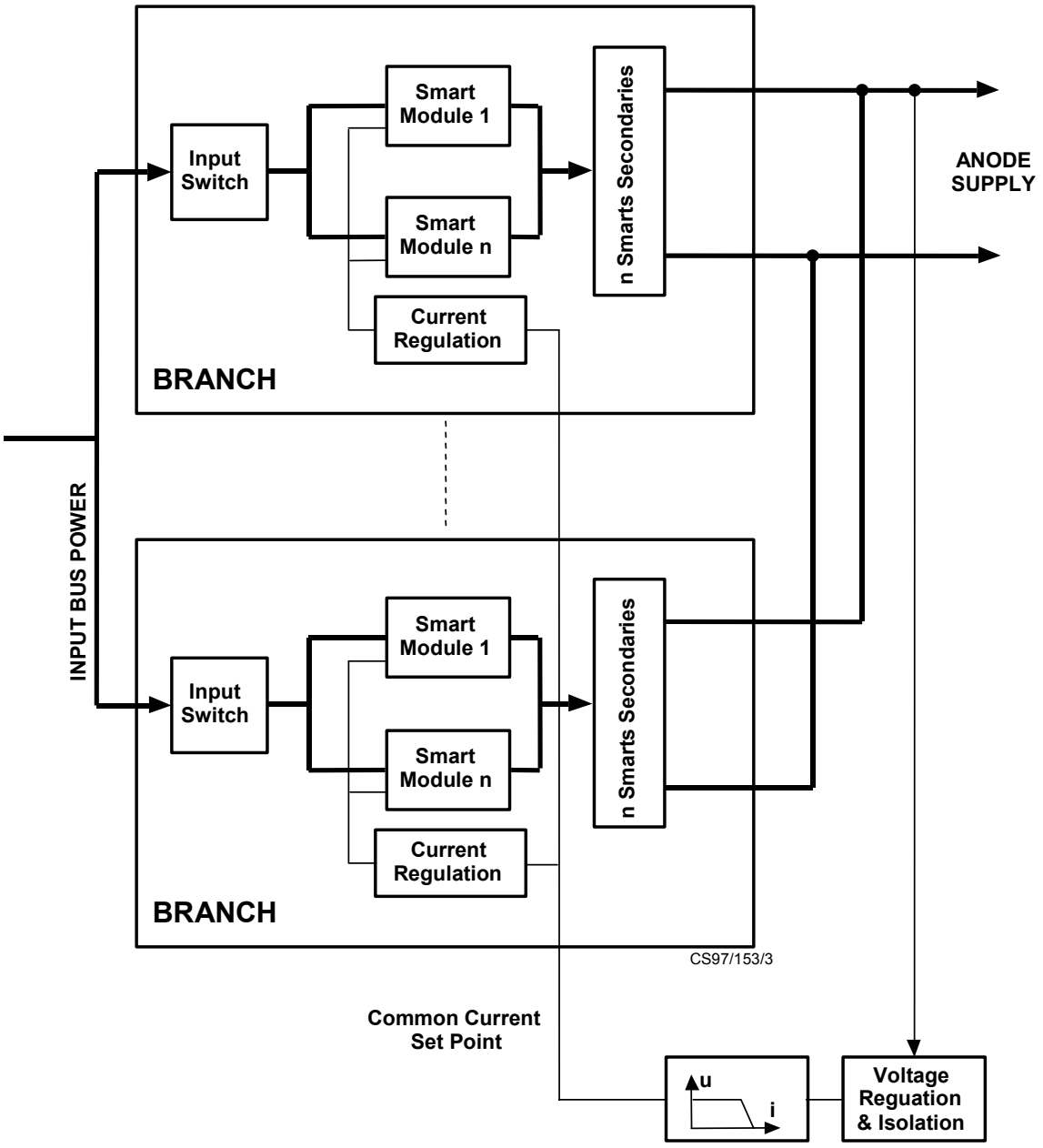

Figure 5 : HPPU : Branches in parallel

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/Catode 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 10kW 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 10 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 > 94 % (EOL), nominal target : 95 %
- Mass < 15 kg in version 10 kW ; mass ~ 10 kg in version 5 kW
- Reliability figure : 3500 fits

5- Commercial success

Independently of the two flight models already delivered to the STENTOR program, ALCATEL ETCA has received orders to deliver some 1.6 kW PPU in flight version for the following commercial programs:

Customer	Program	Spacecraft	Electric propulsion use for	Models	Delivery date
ASPI	Astra – 1K	Telecom GEO	NSSK	2 FM's	2000
ASPI	GE Americom	Telecom GEO	NSSK	10 FM's	2001 to 2002
ESA	Smart-1	Moon mission	Main propulsion	1 FM	1st half 2001
Astrium	Intelsat	Telecom GEO	NSSK	4 FM's	1st half 2001
Astrium	Inmarsat	Telecom GEO	NSSK	6 FM's	2001 to 2002
Astrium	Option	Telecom GEO	NSSK	2 FM's	2002

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 10 kW.