



Power electronics for aircraft application: push for more standardization

Olivier TACHON, Marcelo ITURRIZ, Lucien PRISSE
Airbus Operations S.A.S, Toulouse, France

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ABSTRACT

The standardization concept is identified as a major driver to reduce the costs of A/C systems.

Based on results from research in Airbus Electrical Network Engineering Department, standardization of power electronics is expected to expand the use of power electronics through reduced costs and higher reliability. Part of the cost reduction comes from the simplification in the design process that is obtained by using standard modules.

After a short overview of Integrated Modular Avionics concept, a similar standardization approach for power electronics is outlined. In particular, this paper analyzes the approaches at different levels presenting some ideas about the design of power converters based on standard power cores.

INTRODUCTION

Today with the perspective of more electrical aircraft, several studies have been launched to assess the feasibility of more electrical systems. To support this change, power electronics technology is required implying important increasing of power electronics converters in the future A/C programs.

According to the current A350 & A380 programs where specific solutions are developed for each system, standardization principles shall be considered to deliver substantial advantages in terms of cost reduction, quality improving, weights saving, maintenance simplification, etc.

Several levels of standardization could be considered to achieve these objectives. These levels can be defined according to the new A/C electrical architectures, the electrical loads, the power required by applications, the reliability of power components, the availability of power topologies...

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As the introduction of Integrated Modular Avionics concept (IMA) successfully generated standardization gains in the avionics area, this paper outlines how a similar concept may be implemented in the field of airplane power electronics and highlights the approaches at converter and power core level by showing the advantages and disadvantages of different points of views.

STANDARDIZATION APPROACH

INTEGRATED MODULAR AVIONICS (IMA) CONCEPT

The principles of integrated modular avionics concept, based on the fact that common platform resources were to be developed, originated in the beginning of the 90's for jet fighters like F-22, F-35, Rafale.

Other initiatives on this concept took place during the 90s with EASy (Enhanced Avionics System) for the Falcon 900EX and AIMS^[1] (Airplane Information Management System) for the B777 but it had not been yet standardized

IMA concept was standardized and migrated to the commercial airplane in the 2000s with A380 and B787^{[2][3]}. In particular, this approach allowed the replacing of numerous LRU (Line Replaceable Unit) by a set of standardized HW & SW components.

IMA modularity has been put in place to simplify the complexity of avionics development process (number of functions, exchange between the functions, increase of resources needs for computing and communication) and to allow weight and maintenance savings by reducing part numbers at aircraft level.

STANDARDIZATION APPLIED TO POWER ELECTRONICS

In comparison with IMA, standardization approach for power electronics doesn't exist on current programs due to the low number of application using power converters. With the perspectives of more electrical aircraft (MEA), numerous power electronics equipments are foreseen and standardization has to be studied and developed.

Systems changing to more electrical solutions use more and more power electronics (DC/AC topology supplied by HVDC network) to control electrical loads (mainly brushless DC motor). Based on this statement, it is possible to consider different cases according to the possibility to move-away or not power electronics for these loads.

In one hand, the power electronics can be fully integrated with the equipment as shown in the Fig. 1, which is presenting a mechatronic concept for a flight control actuator.



Figure 1: A380 EHA Aileron actuator

And on the other hand, power electronics can be considered as remote electronics units, and so, a high level of modularization and standardization could be achieved.

STANDARDIZATION AT POWER CONVERTER LEVEL

Today, standardization approach is based on the statement that one power converter is used to drive one electrical load (Fig. 2)

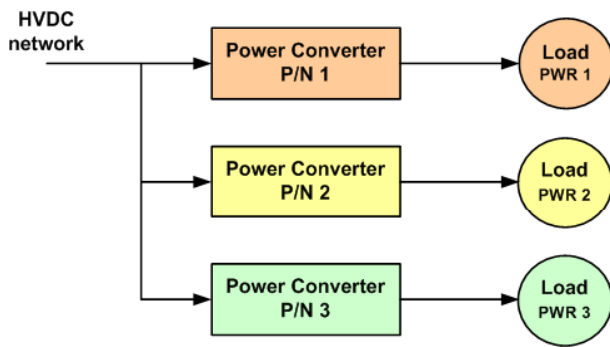


Figure 2: One power converter driving its load

First step for standardization could be achieved by using the same design to supply different loads. Indeed, research studies performed by Airbus concluded that, for a wide variety of aircraft power users, power ranges are quite similar and the same control law meets application needs in term of performances (Fig. 3).

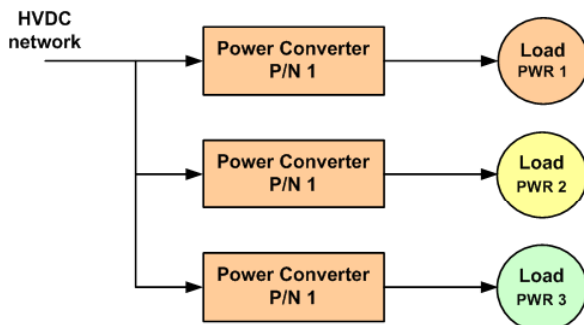


Figure 3: Loads controlled by the same design

However, Airbus identified larger gains may be leveraged by going even beyond the level of standardization previously achieved. Indeed if the loads do not operate at the same time, standardization could be introduced further using load sharing concept: one power converter is used to control different loads (fig. 4). The expectations are to reduce the power electronics part numbers, to reduce the weight, to reduce maintenance costs, to enable reconfiguration, to improve availability,

Technical feasibility of this concept was demonstrated in Toulouse thanks to a hardware prototype developed by Airbus under the proprietary project PRIMES [4].

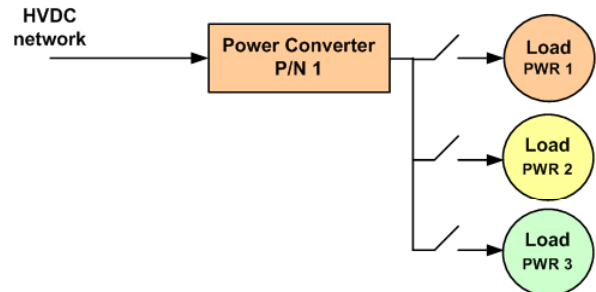


Figure 4: Load sharing of power electronics

Load sharing concept has been studied during MOET project, e.g. by considering dual-use converter for engine electrical starter and for environmental control system due to the fact that these loads do not operate at the same time during the flight. In this configuration, power converters are plugged in a power bay located in the fuselage to reduce wire lengths between the converter and the load. This power centre is in pressurized area ('friendlier' environment for electronics in comparison with the wing or belly fairing areas). Such power-electronics standardization may be expected to become soon a state-of-the-art practice in the aerospace industry as it was also identified on an airplane program being developed by other manufacturer.

STANDARDIZATION APPROACH IN MOET PROJECT

In MOET project, power converter needs have been analyzed: 4 power converters have been defined and covered the overall power range from 1 kW up to 100 kW.

The standardization approach in MOET is based on bottom-up analysis of the common functions used in the power converter: these functions have been gathered in a sub-set

called Power Core (PWC) that corresponds to the main part of the power converter.

Consequently, 4 power core have been designed and built by MOET partners:

- one Low PWC, 2 kW (for lubricating pump, steering, variable speed fan applications),
- one Mid PWC, 35 kW (for environmental cooling system application),
- two High PWC 60 kW (for electrical starter generator applications).

These PWCs correspond to motor drive applications used in different A/C zones (fuselage, nacelle, ...)

The PWC perimeter is shown in Fig. 5 and the embedded functions are:

- Power switches (power conversion stage),
- Insulated drivers to control power switches,
- Auxiliary supplies to feed insulated drivers and low-level control stages,
- Current and temperature sensors with their respective conditioning stages,
- Decoupling capacitors of HVDC network

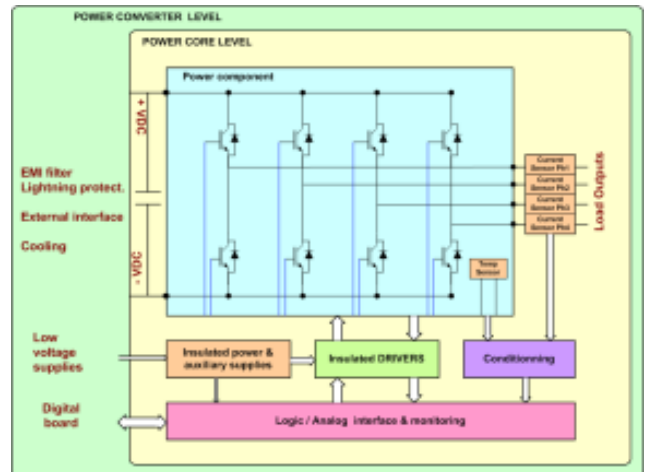


Figure 5: PWC perimeter

These functions are considered as generic and have been specified in a common core specification. For instance, for the current measurement function, current capability, level of galvanic insulation, linearity, accuracy... have been specified.

The overall PWC requirements shall be cascaded from converter level.

The EMI filter, lightning protections, external connectors, low voltage supplies, ... are considered at power converter level. Typically, EMI filtering and lightning protections depend on power converter location in A/C.

Based on MOET results, PWC could be associated in parallel to reach higher power level: for instance in environmental cooling system, two mid power core (35kW) have been associated in parallel to provide the required power equal to 70 kW). On the other side, a power core designed for an operating power P1 could also be used for a lower power P2 (P2<P1). In this case, the power core can be considered as over sizing but this approach allows components communalization (power components, insulated driver...). Consequently, sharing the same technology will contribute to increase the reliability and also reduce the costs.

In addition, the low power (2 kW) that has been designed to be compliant with harsh environment (nacelle zone) could be used at

higher power (up to 8 kW) by relaxing the environmental constraints: location in fuselage zone instead of nacelle for instance.

CONCLUSION

The power electronics standardization represents a challenge for aeronautical applications due to there is a wide disparity between the applications linked to the localization (fuselage, wings, engine areas), the integration or not to the equipment, the operating power ratings...

The approach proposed in MOET project corresponds to a bottom-up approach by identifying the generic functions that are required in power converter independently of the applications.

The technological choices to design the functions were different to assess different technologies that correspond to one objective of this research program.

The next step will be to develop a standard power converter corresponding to the needs of global A/C system e.g. Primary Flight Control System.

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CONTACT

Olivier TACHON is working for Avionics & Simulation products department at Airbus Operations S.A.S. He was coordinator of the Power electronics theme in MOET Project and involved in work package 1.14.

Olivier.tachon@airbus.com

Marcelo ITURRIZ, is working for Avionics & Simulation products department and he is Power electronics expert at Airbus Operations S.A.S. He involved in work package 1.14 for MOET project.

Marcelo.iturriz@airbus.com

Lucien PRISSE is working in the Electrical Network Engineering Department at Airbus Operations S.A.S. He was manager for the proprietary project PRIMES^[3] and involved in work packages 3.32 and 4.32 for MOET project.

Lucien.prisse@airbus.com

Low power core has been developed by Hispano-Suiza.

Medium power core have developed by Liebherr,

High Power cores have been developed by Thales AES & Goodrich UK

- **A/C** *Aircraft*
- **LRU** *Line replacable unit*
- **IMA** *Integrated modular avionics*
- **P/N** *Part number*
- **PWC** *Power Core*
- **HVDC** *High Voltage Direct Current*

**DEFINITIONS, ACRONYMS,
ABBREVIATIONS**

Insert the list (alphabetically sorted) of Definitions/Acronyms, Abbreviations used in this paper