Power electronics and motor control

Key competencies for aircraft electrical systems competitiveness

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To manage the electrical chain within the electrical system
- Potential benefits and examples of the electrical chain importance
  - EMI
  - Control law

Former and current power electronics developments of LPS

Overview of technology research efforts
- Power electronics integration
- Thermal management
- High temperature

Conclusion
To manage the electrical chain within the electrical system
The electrical chain is an important contributor to the global weight, cost and performances of the system.

The electrical chain shall be addressed globally and not just be a sum of electrical equipment.

LPS intent is to address this complex theme through different and complementary activities.

Theses identified ways are the following:

- To deal with performances and constraints at the electrical chain level
- To master the up to date technologies and competencies development
- To capitalize on LPS aircraft former development and on field feedback

LPS intent is to offer and share these developed strengths with the system supplier/customer to build together a well-fitted solution.
THE ELECTRICAL CHAIN PERIMETER

- Overview of the electrical chain perimeter

- LPS can directly address the whole electrical chain: power conversion, harnesses and machine electrical definition

- Depending of systems and customers, the whole electrical machine design and manufacturing can be included within the perimeter of the electrical chain delivery

In any case, an electrical chain approach is needed to propose to the system owner a better solution (at technical, risk and cost points of view)
ELECTRICAL CHAIN ACTIVITIES

→ The biggest lever to optimize any system design is to understand and challenge the customer needs.

→ However it requires the good level of skills to challenge the needs and propose acceptable alternate performances or solutions.

→ Two important research axes have been identified to develop our capabilities to challenge the customer needs at system level:
  - The ElectroMagnetic Interference design and modeling
  - The Electrical chain and its associated control modeling and optimization
To deal with EMI at the electrical chain level is important to:

- **Offer a relevant EMI global design:**
  - An EMI design dealt equipment by equipment has 2 main risks:
    - Non compliance (=> Design iteration => Cost increase)
    - Over specification (=> over design => weight increase)

- **To specify correctly the different equipments**
  - Maximum dV/dt or peak voltage applied on the machine, depends on power electronics and harnesses design
  - Machine leakage capacitor versus thermal behavior capability
  - Etc...
The major components of the electrical are modeled to define at the early design stage an appropriate system solution.

The accuracy and the knowledge on each components is heterogeneous, research and thesis are on progress to try to harmonize it.

This approach, led by LPS on different electrical system demonstrators, have shown promising results. Correlation enables now to propose an EMI design tools for the LPS engineering team.
To develop accurate and quick electrical chain model enables to:

- Consolidate/Validate the customer performances
- Perform close loop iteration between power electronics definition, harnesses, motor design and system performances
- Define a compromise between power electronics, harnesses and machine to define a global optimum and not a collection of optimized equipment (at identical customer needs)

This approach, applied by LPS on a demonstrator, has reduced of 50 % power electronics design constraints, and 30 to 40 % more the nominal stress on the electrical chain design.
LPS power electronics developments and experience
ETRAS® A380: The first electrical thrust reverser actuation system in the world

- Partnership Labinal Power Systems and Honeywell
- Fitted to nacelles made by Aircelle (Safran group) for the GP7200 and Trent 900 engines offered on the A380
- In production, ETRAS® has logged over 3,200,000 hours of operation (as of September 2014)

C919 Electrical Thrust Reverser Actuation System

- A work in synergy with fellow Safran companies for Aircelle:
  - Aircelle: Architecture and equipment integration in the nacelle,
  - Sagem DAV: Thrust Reverser actuation system,
  - Labinal Power Systems: TRCU (Thrust Reverser Control Unit).
- **TRCU: an innovative electronic power converter**
  - Control the thrust reverser actuation system of the COMAC C919 Nacelle developed by Nexcelle (Aircelle/GE Joint Venture)
- Based on key-enabling technologies and experience with the ETRAS® system for the A380
The first electrical braking system in the world developed for civil application by Messier-Bugatti

- Labinal Power Systems supplies the Electrical Braking Actuation Controller
- EBAC is used with Messier-Bugatti electric brakes for the Boeing 787
- 4 EBAC units control braking on the main gear’s 8 wheels.
Overview of technology research efforts
HIGH INTEGRATION POWER ELECTRONICS

- High efforts are done to increase the power density of LPS power electronics

- Introduction of new technologies (Films capacitor, new material for filters, Silicone carbide for power switches...) are strongly linked to electrical, thermal and mechanical integration issues.

- A first power converter has been designed for AC/DC, DC/DC and DC/AC conversions at voltages up to 800VDC. Featuring a modular design, for easy rack mounting in electrical cabinets, this line-replaceable unit (LRU) can operate in individual and parallel mode to control very high-power loads.
  - Output power: 45 kW continuous (150 A peak)
  - Efficiency: 99% at 15kHz (silicon carbide technology)
  - Operating temperature range: -55°C / 90°C (cold plate)
  - Power density: 9kW/kg for this demonstrator

Integration effort done by LPS are continuous and the next step of demonstrator will target the 12 kW/kg
THERMAL MANAGEMENT (1/2)

- Power electronics cooling is challenging regarding:
  - Weight consideration
  - Reliability impact
  - Cost impact

- Thermal management is addressed from equipment up to components level

- At stand alone equipment level, two types of cooling are clearly targeted
  - Natural air cooling
  - Forced Air cooling
    - With integrated fan at heatsink level
All the layers of the cooling system are worked:

- **Thermal Energy Storage**
  - *Weight reduction*

- **Cold Plate**
  - *Weight & volume reduction*

- **Vapor chamber**
  - *Integration improvement*

- **Ageing thermal interfaces**
  - *Performance controlled*

- **Loop Heat pipe**
  - *Passive heat transfer*

- **Thermally optimised composite**
  - *Local cold source optimisation*
HIGH TEMPERATURE POWER ELECTRONICS

HT inverter target
- 20A sinus
- HVDC
- 200°C maximal baseplate operation

Discrete packaging HT inverter
- Innovative material study for packaging
- Discret component for drivers board
- HT laminate Polyimide PCB
- Used more HT Silicon component
- Low integration performance: 4.7 L

MCPM packaged HT inverter
- High integration power core: 1.5L
- High reliability SiHT and SOI components
- High temperature conductive glue attach
- Thick Film and LTCC ceramic substrates

ACCITE project targets:
- 5kVA 200 C MCPM core integrated onto motor

The LPS high temperature power electronics capability will enable to answer to high integration & temperature constraints raised by our customers.
Conclusion
CONCLUSION

- Electrical chain optimization is a key point of system competitiveness

- LPS attempts to address this key competencies through the combination of:
  - Power electronics and machine experiences
  - Electrical chain engineering skills
  - R&T strong efforts
  - Industrial mindset

- Through this amount of skills and available technologies and with active exchanges with our customer, LPS will be pleased to propose and deliver more competitive power electronics products