Overview of challenges in active power conversion for the More Electric Aircraft

Pascal THALIN
VP Research & Technology/Technical Director
THALES Avionics Electrical Systems
• More Electrical Aircraft (MEA) context & challenges
• Active power conversion and motor control
• Thales portfolio for conventional & More Electric Aircraft
• Closing comments
MEA context & challenges
Airframer / Airlines expectations

- More efficient and cost-effective aircraft
  - Reduce the cost of operation and ownership
  - Cut fuel burn, increase availability, reliability & maintainability

- Going green
  - Reduced gas emissions & carbon footprint
  - Reduced noise
  - Sustainable design & manufacturing

Passenger expectations

- Improvement in flight comfort
  - Non-stop IFE, connectivity, noise, services…
  - Individual power source (laptop, mobile…)
Route to More Electrical Aircraft

More Electrical Aircraft Market environment:

- **Main expected benefits:**
  - Decrease fuel burn
  - Decrease weight
- **Through electrification of loads:**
  - Decrease power off-take
  - Move from legacy hydraulic or pneumatic energy to electricity:
    - ECS, Engine and APU start, braking, anti/de-icing...

Impact on aircraft requirements:

- **Power on-board:** +
- **Voltage transformation and motion control:** +
- **Room for both, energy generation and usage optimization:**
  - New innovative architectures

More Electrical Aircraft Market track record:

- **Airbus A380**
  - First Variable Frequency Generator, Solid-State Power Control, DC power supply with no interruption
- **Boeing 787 Dreamliner**
  - Intensive electrification: ECS, Engine and APU start, braking, anti/de-icing, Lithium-Ion Battery
  - Innovative architecture, new technology, electrical network compatible with composite structure
- **Airbus A350 XWB**
  - Electrical APU start, electrical network compatible with composite structure
- **Dassault F5X**
  - Electrical Engine and APU start
MEA ELECTRICAL CHAIN BREAKDOWN

Concurrent breakthroughs in propulsion, systems & structures for MEA
Electrification of systems is a major focus of aircraft architectures

- Variable Frequency AC network selected on the A380
- Double Voltage Variable Frequency AC on A350 & B787
- High Voltage DC network on B787

Electrification enables design, maintenance and manufacturing optimizations

- Overall system performance improvement
- Increased availability
- More flexible, reconfigurable
- Simplified maintenance operations
- Streamlined manufacturing and assembly

Weight and reliability of electrical systems are major challenges
• **Power Generation**:
  - *Low weight standalone High Speed / High Power AC Starter-Generators*
  - *High reliability Power Converters for creating HVDC source from generators*
  - *Embedded Starter/Generator technologies for the More Electric Engine & APU*

• **Distribution**:
  - *High Voltage DC Power switching devices*
  - *Improved load management for better electrical power availability*
  - *Reliable Solid State Power Controllers for secondary distribution & specific loads*
  - *Distributed power bays installed in uncontrolled environment*

• **Power Electronics**:
  - *Highly reliable & efficient Power Converters for motor drives, power supplies*
  - *High power density and high temperature operation*
  - *Resource sharing allowing dynamic power management across multiple systems*
  - *Modular, reconfigurable, fault-tolerant*

• **Motors**
  - *AC & DC brushless fault-tolerant topologies*
  - *High speed, High Power*
  - *Reversible*

• **Cabling**
  - *High voltage (partial discharge) capability*
  - *Fault detection (arc tracking, Ground Fault, short/open…)*
  - *Optimized weight through material change / system improvements*
THALES commitments to MEA Research & Technology

- **Electrical Power Generation and Start System**
  - **POA***: Electric main engine start, engine embedded technologies, HVDC architecture, high pressure shaft starter-generator, modular motor controller
  - **MEGEVE**: Electric start and main generation
  - **GENOME/CLEANSKY**: Hi-speed starter-generators for AC & HVDC networks

- **High Speed Rotating Machines and related electronics**
  - **ECS**: Environmental Control System electrification

- **Power Electronics and Power Conversion**
  - **MODERNE, MOET**: Electric start, Power conversion for all types of aircraft (weight reduction)
  - **PRISCA**: Integrated Modular Power Electronics bay feasibility
  - **CLEANSKY**: Major European program for mature environment-friendly MEA solutions for all market segments
  - **GENOME**: Starter-Generators, power electronics and power conversion
  - **GETI**: Combined optimization of MEA power and thermal systems

Thales is a major aircraft manufacturer partner for designing cleaner, quieter and more efficient solutions with deep focus on MEA technologies.

Thales spearheads development of leapfrog MEA solutions.
Active power conversion and motor control
Performance, Weight savings, Maturity and Reliability

- Regulated 28VDC buses for aircraft cabling weight savings
- Robust, ruggedized, scalable and power dense Power Electronics
- Thermal management and cooling for power electronics, power bays...
- Installation in unconventional areas (unpressurized and/or explosive atmosphere)
- Fault tolerance, Availability
- Reliability, Health monitoring, Maintainability
**BCRU (Battery Charger Rectifier Unit)** includes multiple functionalities providing aircraft level optimization:

- DC voltage regulation → AC & DC feeder resizing allowing weight reduction
- AC and DC lightning protection
- 28VDC Battery Charger
- No Break Power and Battery management capabilities

Substantial power density enhancement and aircraft cabling weight savings compared to conventional Transformer Rectifier Unit (TRU)
Active power conversion on a Long Range aircraft helps:
- doubling the power density of power conversion equipment
- cutting aircraft weight by more than 100kg
Objective: feasibility studies for optimized association of 28VDC active power conversion & energy storage architectures

- Analyze architectures combining no-break 28VDC power generation from AC power supply and battery charge function
  - Battery Charger as part of a battery represents additional weight/volume and is subject to battery location and cooling constraints
- Analyze safety impacts of proposed architectures
- Consolidate the role of contactors or disconnection systems
Rationale for Integrated Modular Power Electronics (IMPE) Bay

- Overall systems weight cannot be optimized if each system uses its own power electronics
  - Transient system operation results in dead weight penalty over aircraft life
- Integrated Modular Power Electronics Bay is the answer
  - Power Electronic Modules address both active power conversion & motion control functions for multiple systems
    - Engine start, air-conditioning, wing ant-ice, hydraulics...
  - Reconfiguration, redundancy: Improved functional « availability » & weight optimization
Power Electronics – Weight and Volume Stakes

- Modular Power Converters
- Multi-use Power Converters
- Sensorless Control
- Unpressurized Areas
- Liquid Cooling
- Air Cooling
- Power Switches (SiC, GaN)

Baseline Weight
New Tech Integration (Si/SiC IGBT, packaging,...)

Target Weight
Next Gen
New Tech

2 kW/kg

9-15 kW/kg

Modular+Multi-use power converters = Integrated Modular Power Electronics
THALES has demonstrated feasibility of IMPE Bay concept
THALES Gen 1 6kW/kg PEM with improved robustness: TRL5 reached in 2015
Thales portfolio for conventional and More Electric aircraft
Our product lines

**Thales Products**

**Electrical Power Generation**

- **AC Generators**
  - Generator Control Units
- **DC brushless Generators**
  - Generator Control Units
- **TopStart™**
  - AC Generator, Generator Control Units, Start Box Unit
- **DC Starter & Generator**

**Electrical Power Conversion**

- **Passive conversion**
  - Auto Transformer Unit, Auto Transformer Rectifier Unit, Transformer Rectifier Unit
- **Active conversion**
  - Regulated Transformer Rectifier Unit, BCU - Battery Charger Unit, SI - Static Inverter, DC/DC Converter

**Electrical Motors**

- **Actuators Motors & Controllers**
- **Air conditioning motors**
- **Pump motors**
- **Fans**
Power Conversion System (PCS)

World premiere advanced electrical power conversion

- GATU: Galley Auto Transformer Unit
- BCU: Battery Charger Unit
- Lithium-Ion APU Battery
- SPU: Start Power Unit
- ATRU x 4: Auto Transformer Rectifier Units
- ATU: Auto Transformer Unit
- MTRU x 2: Multitap Transformer Rectifier Units
- BCU: Battery Charger Unit
- EBPSU x 2: E-Brake Power Supply Units

Forward E/E Bay

Power Conversion Panels
Electrical Power Conversion System

- Main ATU x 4
  Auto Transformer Units

- Advanced TRU x 4
  Transformer Rectifier Unit

- Emergency ATU x 2
  Auto-Transformer Unit

- SI
  Static Inverter

- CFFC
  Cockpit Fixed Frequency Converter

Optimized architecture, mature power conversion technologies
Thales on board the Falcon 5X

Electrical Power Generation & Power Conversion System

A world first with major technological breakthrough solutions
Closing comments
MEA challenges

Thales is committed to delivering power-optimized architectures through a combination of innovative solutions and mature technology.

Stakes

For the aircraft manufacturers
- Reduce weight
- Optimize architecture allowing power management with greater flexibility, controllability and detectability
- Lower manufacturing costs

For the operators and the airlines
- Lower operation costs
- Reduced fuel burn & environmental footprint (CO2, NOx, noise)
- Improved efficiency
- Higher reliability and maintainability
- Increased aircraft availability and safety levels

Thales Expertise

- Field-proven expertise for every type of aircraft: air transport, business jets, regional aircraft, fighter, military aircraft, helicopter (both civil and military)
- Industrial means and qualified teams
- Active player in large scale R&T programs supporting MEA: CleanSky1/2, CORAC Genome, GETI
- Strategic partnership to develop an overall power optimized architecture

The More Electrical Aircraft is a paradigm shift in aircraft performance and economics.
◆ Provide innovations and industrial structure for power solutions
  ○ Mature solutions at Entry into Service
  ○ Across the complete aircraft lifecycle

◆ THALES constant technology effort
  ○ Integrated Modular Power electronics
  ○ Rotating machines (High speed rotors, Embedded machines in power plants)
  ○ Active power conversion / Energy storage optimization with smart functionalities

◆ Electrical Power Generation and Start System
◆ Electrical Power Conversion / Energy Storage and Power Electronics
◆ Electrical System Engineering and Architecture
The More Electric Aircraft is at hand… but needs steadfast & relentless global research !!!

夢の力

鳴かぬなら 鳴くまで待とう ホトトギス
"If the cuckoo bird won't sing, let's wait until it does."

Tokugawa Ieyasu (徳川家康)