Future Aircraft Power Systems - Integration Challenges

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Future Aircraft Power Systems- Integration Challenges

Outline

• Aircraft Electric Power Systems
  – Existing Systems
  – More-Electric-Airplanes (MEA)
    • 787 No Bleed System
    • Power Electronics
• Vision and Goals for Next Generation Electric Airplane (NGEA)
• Role of Power Electronics and System Simulation in NGEA
• Conclusions and Summary
777 Electrical System
“Traditional” Hybrid – 115Vac & 28Vdc

• Power Sources:
  – Two - 120 kVA, 115Vac, 400Hz engine driven generators
  – One 120 kVA, 115Vac, 400Hz Auxiliary Power Unit (APU) driven generator
  – Four 950 W Permanent Magnet Generators (PMG) integrated into the two backup generators
  – One 7.5kVA Ram Air Turbine (RAT)
  – Main, APU, and flight controls batteries

• Conversion Equipment:
  – Four 120 Amp DC Transformer Rectifier Units (115Vac to 28Vdc)
  – Battery chargers and inverters

• Distribution System:
  – Centralized distribution panels
  – Thermal circuit breakers and electro-mechanical relays
  – Contactors with built-in current sensing and control electronics
Simplified 777 Electrical System
One Line Diagram

- **Left IDG**
- **Left Backup Generator**
- **Flight Controls PMGs**
- **External Ground Power 115 Vac**
- **APU**
- **Right Backup Generator**
- **Flight Controls PMGs**
- **Right IDG**
- **250 Circuits 115 Vac**
- **250 Circuits 115 Vac**
- **Backup Converter**
- **115 Vac**
- **115 Vac**
- **RAT**
- **TRU TRU TRU TRU**
- **700 Circuits**
- **28 Vdc and Battery Systems**
- **Battery Charger**
## More Electric Platforms

**Power Electronics (Si, SiC, Future):**
- Semiconductor switches
- Capacitors
- Circuitry
- Other components

**Energy Storage:**
- Batteries
  - Maintenance free
  - Lithium rechargeable
- Supercapacitors

**Thermal Management:**
- Active vs. Passive
- Spray cooling
- "Electric" air conditioning
- Solid state thermal engine

**Power Generation/Utilization:**
- Motor types
  - Switched reluctance
  - Induction
- Starter/generators
- Cooling
- Mag bearings
- Controllers
- Electric actuation

**Power Distribution/System Integration:**
- Voltage type
- High voltages, frequency
- Quality/stability
- EMI
- Modeling
- Demonstrations
- Signal controls
  - Electric
  - Photonic

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"More Electric" is Industry Trend

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Current More Electric Aircraft

F-35 Fighter

Airbus A380

Boeing 787
More Electric Aircraft is an Evolutionary Application of Electrical power

Enabling Technologies such as power electronics, motors, advanced materials and thermal management

Electric Power (Main Generators)

- 600kW
- 1.5 MW

More Electric Engine

No Bleed-Air Network

No Hydraulic Networks

Fuel Cells

2000  2015  2030

All Electric Engine
The 787 More Electric Airplane

787 No–Bleed Systems
787 MEA Architecture

Generate, Distribute, and Consume energy in an effective and efficient manner

- Electric Engine Start
- Electric Wing Ice Protection
- Electric Driven Hydraulic Pumps
- Elimination of Pneumatic Bleed System
- Electric Air Conditioning and Cabin Pressurization Systems
- Highly Expanded Electrical Systems
Advanced Electric Architecture

• The Boeing 787 “Dreamliner”
  – The first commercial airplane to have a 230 Vac Variable frequency distribution system.
  – The first commercial airplane to have an electrically powered air conditioning system.
  – The first to utilize electro-mechanical flight control actuators.
  – Unrivalled airplane efficiency.
  – Extensive use of solid state power electronics.
787 Electrical Systems Summary

Hybrid AC and DC Primary Distribution Systems
(235Vac, 115Vac, ± 270Vdc, 28Vdc)

Remote Power Distribution System

Variable Frequency Generation at 235Vac
- 2 x 250 kVA per Engine
- 2 x 225 kVA on APU

Aft E/E Bay

Current Return Network

Forward E/E Bay

Power Conversion from 235Vac to ± 270Vdc

Electric Engine Start

Three 115Vac Ground Sources

Electric Brakes

Adjustable Speed Motors and Motor Controllers

Liquid cooling of ± 270Vdc Conversion and Motor Controllers

Reference: Aviation Week, “Massive 787 Electrical System Pressurizes Cabin” 3/27/05
Power Electronics is a Pervasive Technology in the MEA

787 has a total of 1 MW of Power Electronics Loads
MEA is Applicable to Multiple Platforms

MEA is applicable to UAVs, Commercial and Military airplanes, supersonic and subsonic, pressurized and unpressurized, high and low altitude.
More-Electric-Airplane

Vision:

The More-Electric-Airplane has the potential to take advantage of emerging technologies in power generation and distribution, power electronics, and energy storage.
Goals

• Improve power system efficiency
• Improve Weight/Volume
• Reduce Total Cost
• Enhance Safety
• Improve Thermal Efficiency
• Improve Reliability
• Improve Maintainability
• Increase Functionality
• Cost Effective Rapid Technological Insertion
• Green Systems
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• **Green Systems**
The 787 Dreamliner is cleaner, quieter and more efficient

The 787 Dreamliner delivers:

- 20%* reduction in fuel and CO₂
- 28% below 2008 industry limits for NOx
- 60%* smaller noise footprint

*Relative to the 767
The Challenge

How can we most effectively minimize aviation’s impact on the environment – specifically CO₂ emissions?
Priority technology research for fuel efficiency, emissions and noise

Researching next generation materials
Next generation composites
Result: Reduces weight, which reduces fuel use and emissions

Researching less energy-intensive electric systems
Reducing pneumatic systems
Result: Improving electrical efficiency improves fuel efficiency

Demonstrating fuel cell technology
Fuel Cell Demonstrator
Result: Reduces fuel consumption, NOx and noise

Advancing more efficient operations and air traffic management
Continuous Descent Approach (CDA)
Result: Reduces noise and saves up to 500 pounds of fuel on each flight

Designing aerodynamic improvements
Advanced wing design - raked wing tip
Result: Reduces drag which reduces fuel use and emissions
Fuel cells Support Grid-like Power Systems

- Power system flexibility & utility
- Graceful, graduated failure modes
- Reduced power extraction
- Lower wire weight
- Improved efficiency
- Greater dispatch availability
- Reduced Power Extraction
- Reduced Operational (Life Cycle) Cost
- Environment (less emissions and noise)
Future Aircraft Power Systems

– Advance Architectures
– Higher Voltage Systems
– High Temperature Power Electronics
– Adaptive and Intelligent power systems
– Power Electronics Integration
– Fuel Cell Integration
More-Electric-Airplane Challenges

• Integration of New Power Electronics Loads
  – System Power Quality
    • All electrical loads are prone to failures when exposed to one or more electrical power quality problems.
    • Electrical equipment is only guaranteed/qualified to operate properly if its input power quality is per specification
    • Examples:
      – Interactions between power electronics loads and sources (stability and resonance)
      – Harmonic distortion
      – Start-up
  – Testing and Simulation is extensively used to develop requirements, validate requirements, and verify design
How to analyze and evaluate the power system?
Interdisciplinary Technology

- Analog and Digital Electronics
- Control Theory
- Microcomputer, DSP, ASIC circuits
- Power Quality EMI
- Power System
- Computer Aided Design & Simulation
- Power Semiconductor Devices
- Converter Circuits
- Electrical Machines
- Thermal
Simulation

- Power Quality
  - In-rush
  - Harmonic Distortion
  - Modulation
  - Power Factor
- System Stability
  - Linear and Non-linear
- System Protection
- Power Quality/Thermal/EMI/Lightning/

\[
\frac{Z_o}{Z_{in}} << 1
\]
Simulation

• Models are developed using Multiple Tools
• Challenges:
  – Number of components
  – Multiple Time Scales
  – Different types of analysis (stability, power quality, protection coordination, faults/failures, load management)
  – Model Validation
Conclusions

• More-Electric-Airplanes are the industry trend
• MEA is an enabler for advances in future airplane system design, operation and performance
• MEA is a technology enabler for energy generation, storage and conversion systems and technologies
• MEA contributes to lower operating costs and reduces fuel use, emissions and noise.
• Power Electronics, Intelligent Power Systems, and alternative sources play a significant role for future More-Electric-Airplanes
• There remains challenges with efficient large-scale simulation of more-electric-airplanes.