Future Aircraft Power Systems- Integration Challenges

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Future Aircraft Power Systems- Integration Challenges

Outline

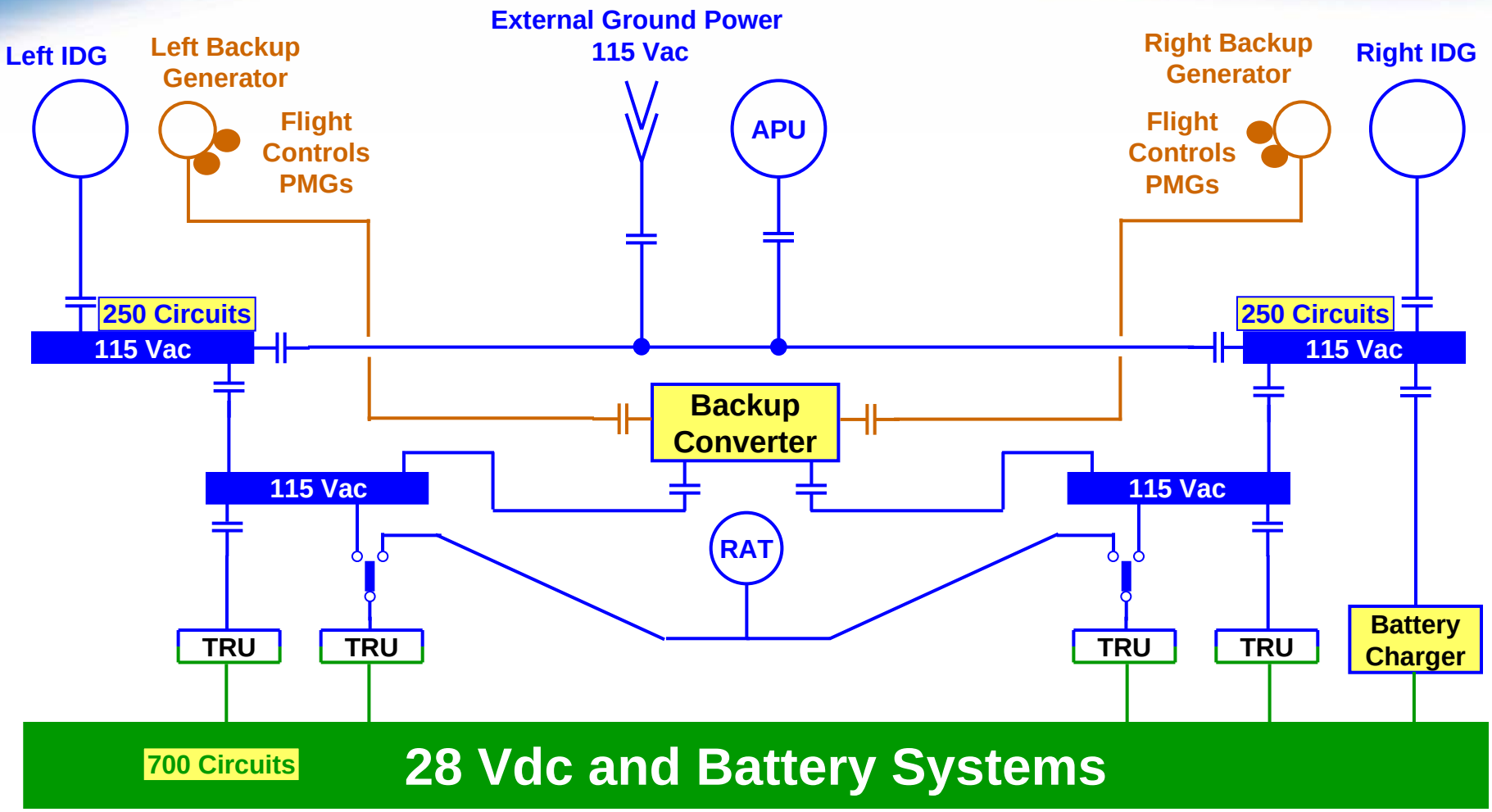
- Aircraft Electric Power Systems
  - Existing Systems
  - More-Electric-Airplanes (MEA)
    - 787 No Bleed System
    - Power Electronics
- Vision and Goals for Next Generation Electric Airplane (NGEA)
- Role of Power Electronics and System Simulation in NGEA
- Conclusions and Summary

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



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“More Electric” is Industry Trend

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

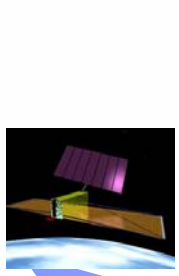
POWER GENERATION / UTILIZATION

- 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

More Electric Platforms





COMMERCIAL AIRCRAFT

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Current More Electric Aircraft

Boeing 787

Airbus A380

F-35 Fighter

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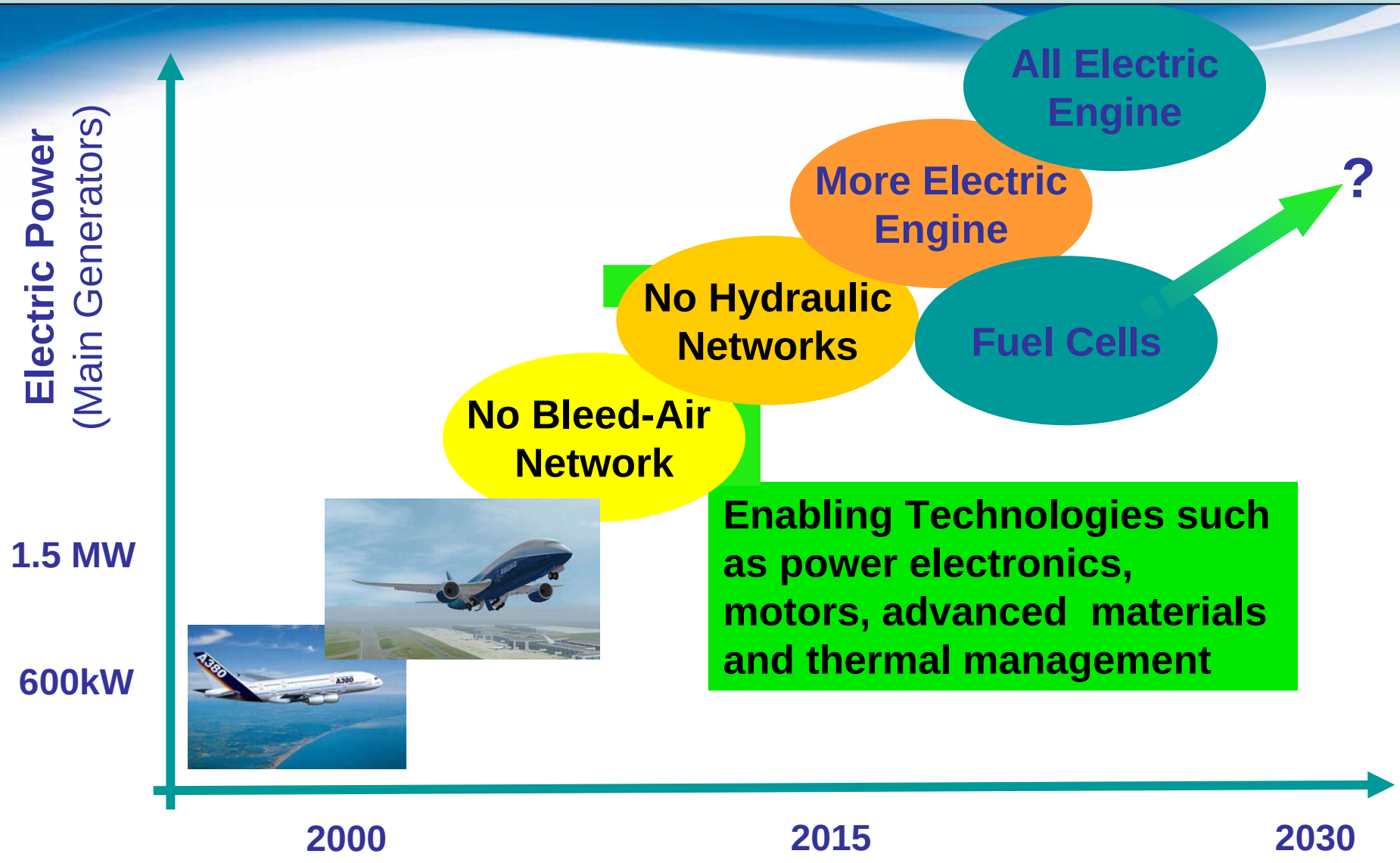
More Electric Aircraft is an Evolutionary Application of Electrical power



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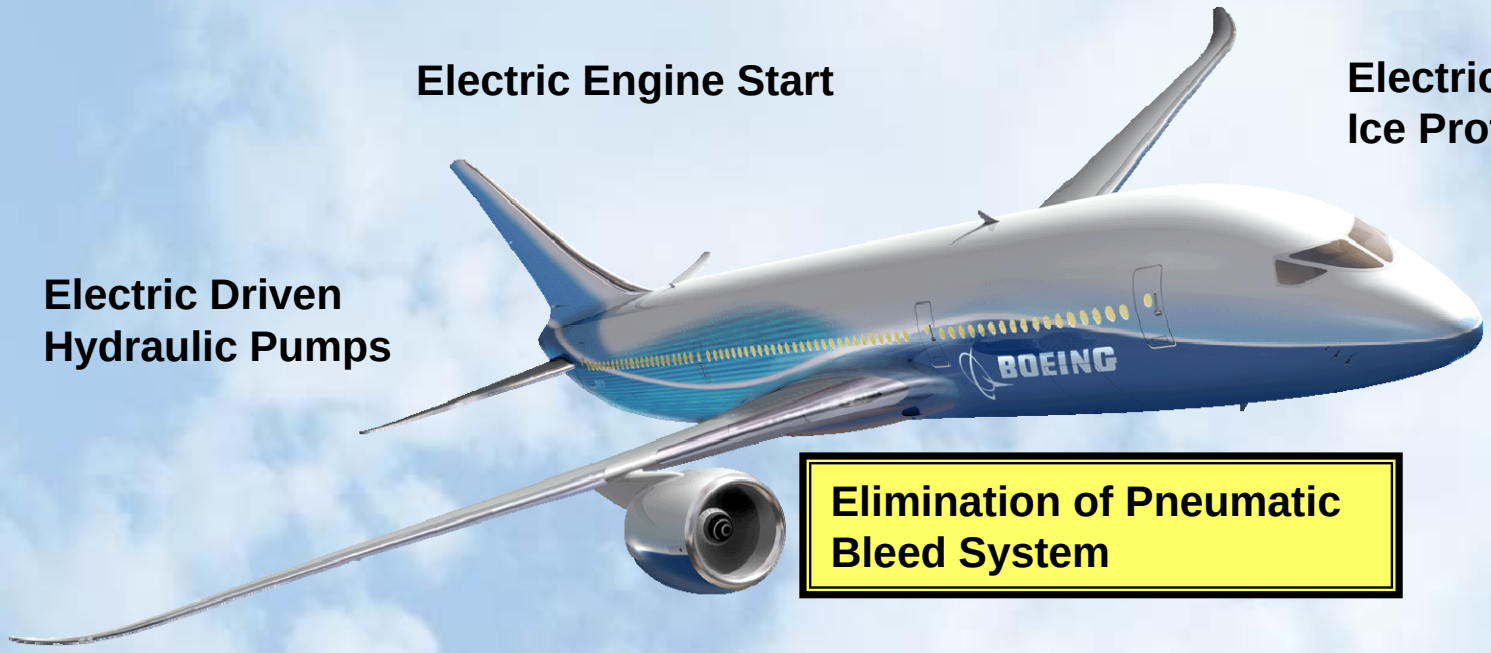
The 787 More Electric Airplane

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)

Power Conversion from 235Vac to ± 270Vdc

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

Remote Power Distribution System

Forward E/E Bay

Aft E/E Bay

Electric Engine Start

Current Return Network

Three 115Vac Ground Sources

Electric Brakes

APU Starter / Generator System

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

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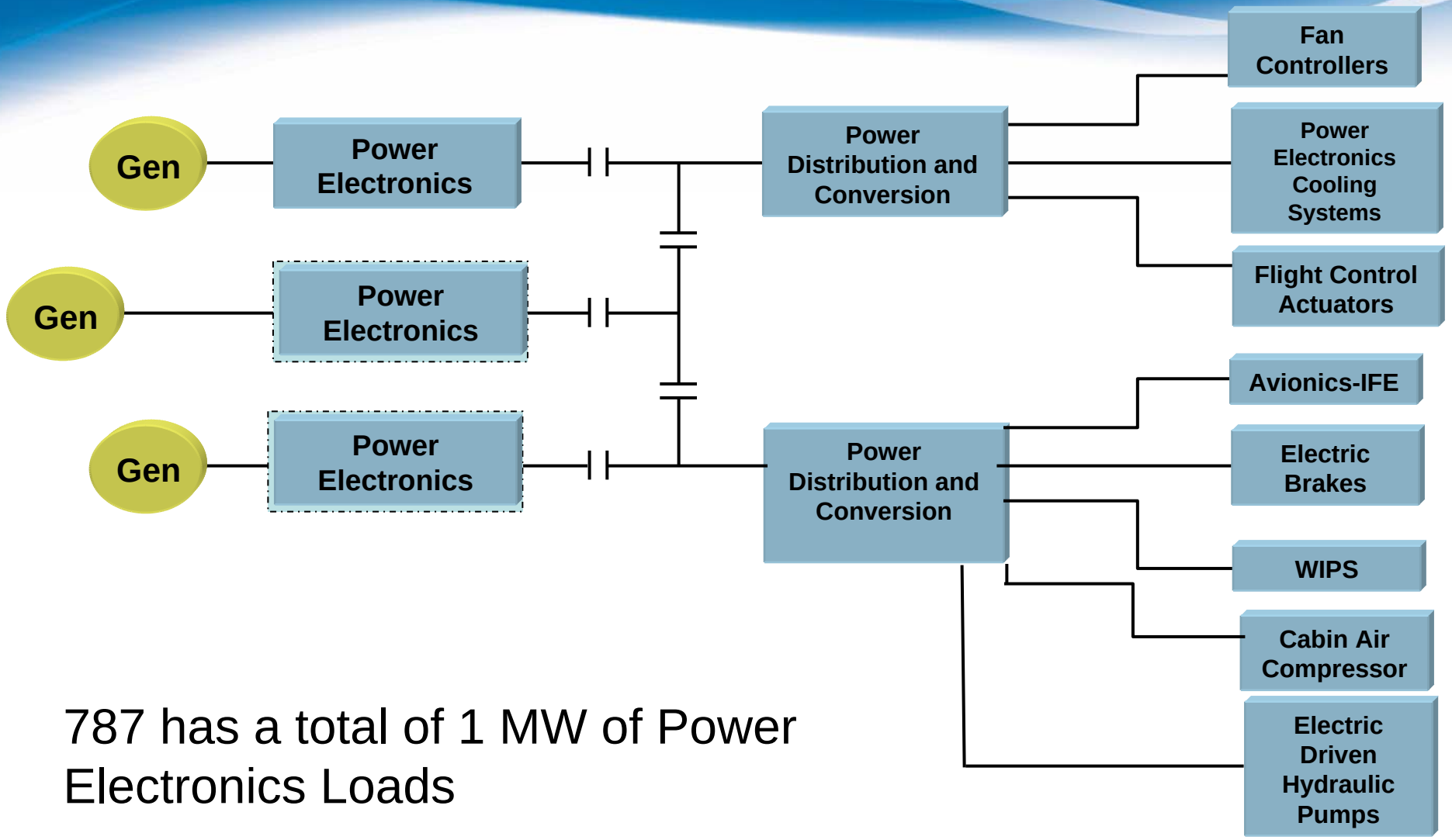
Power Electronics is a Pervasive Technology in the MEA



787 has a total of 1 MW of Power Electronics Loads

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MEA is Applicable to Multiple Platforms

SSBJ

Quiet GA

Honda Jet

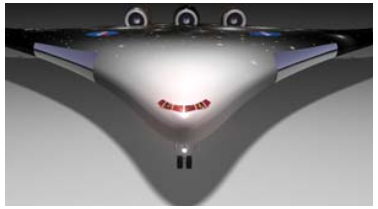
Global Hawk

PAV

Raven

Eclipse

X-45



Future Airliner

Present Airliner

BR&TE Technology Demonstrator

General Aviation

Darkstar

J-UCAS

HALE

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

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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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The 787 Dreamliner is cleaner, quieter and more efficient

The 787 Dreamliner delivers:

*Relative to the 767

20%* reduction in fuel and CO_2

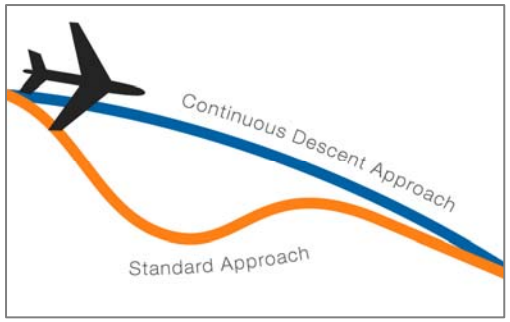
28% below 2008 industry limits for NOx

60%* smaller noise foot print

The Challenge

How can we most effectively minimize aviation's impact on the environment – specifically CO_2 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

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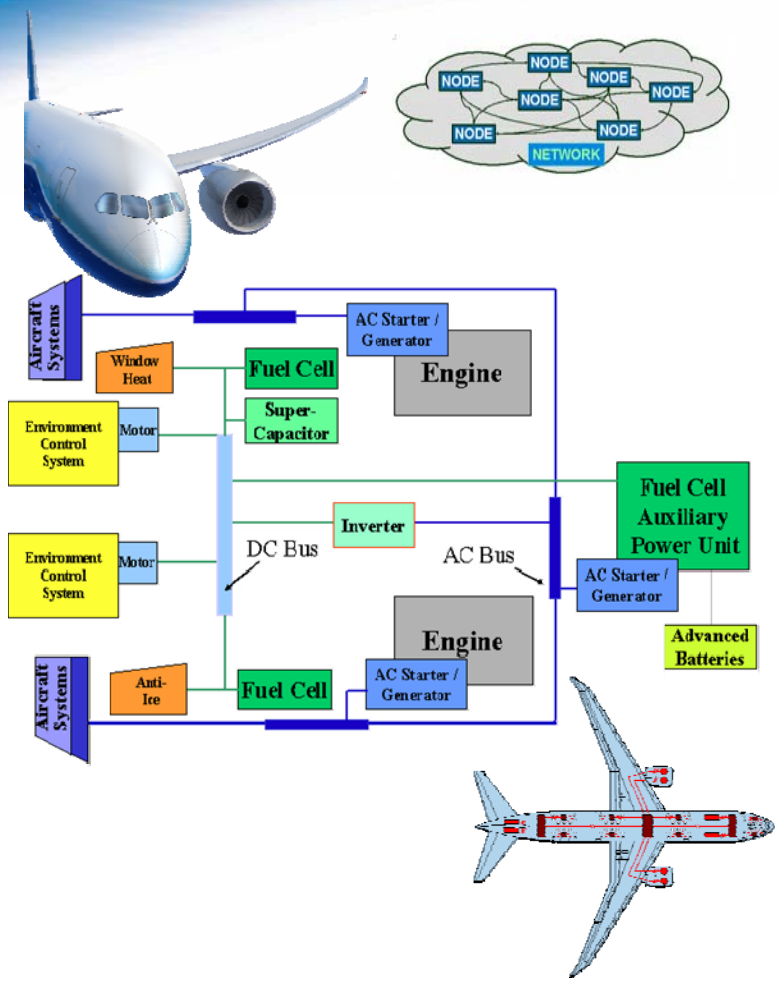
Fuel cells Support Grid-like Power Systems



- 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)

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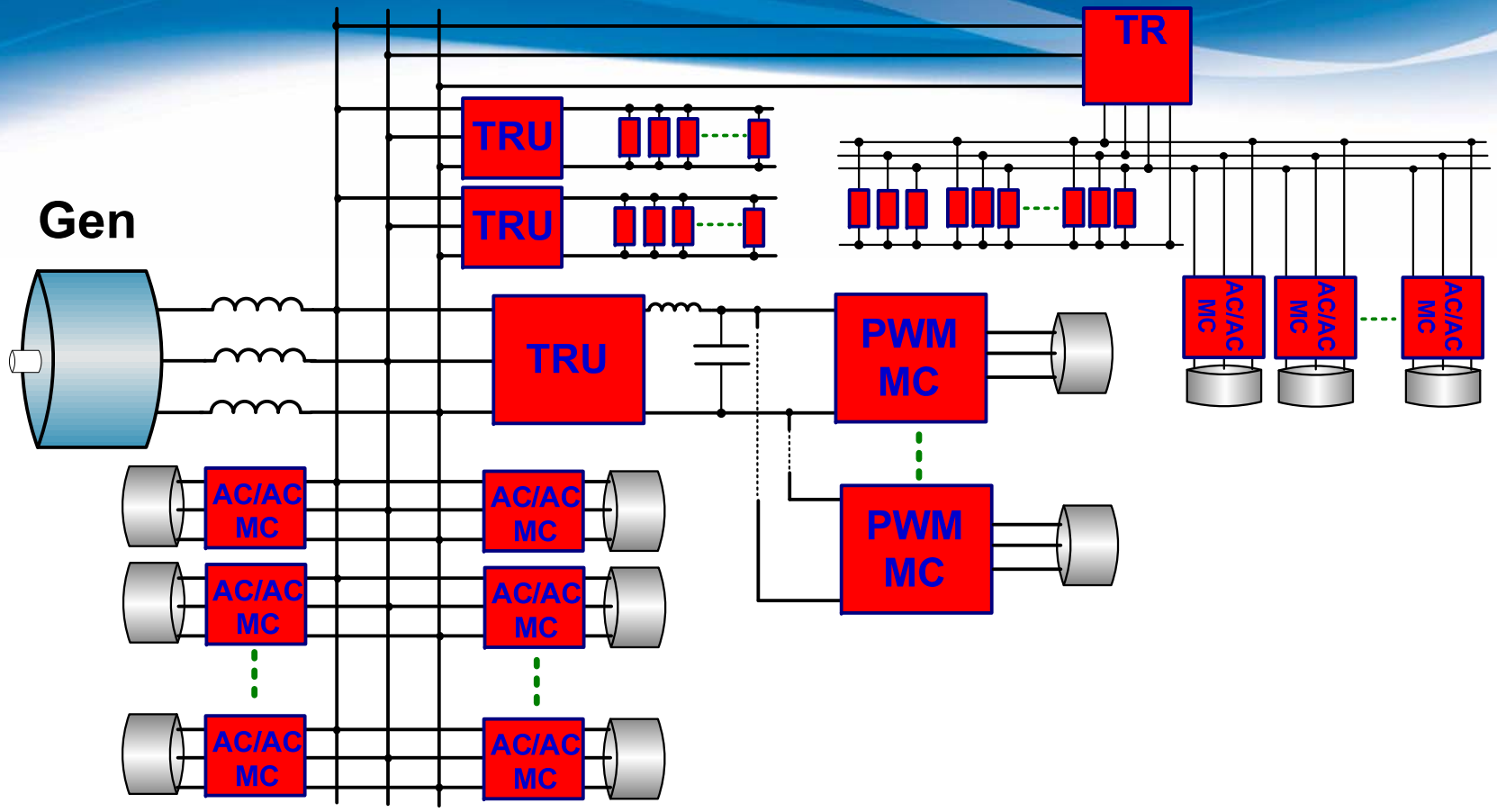
Future Aircraft Power Systems

- 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

Aircraft Power System



How to analyze and evaluate the power system?

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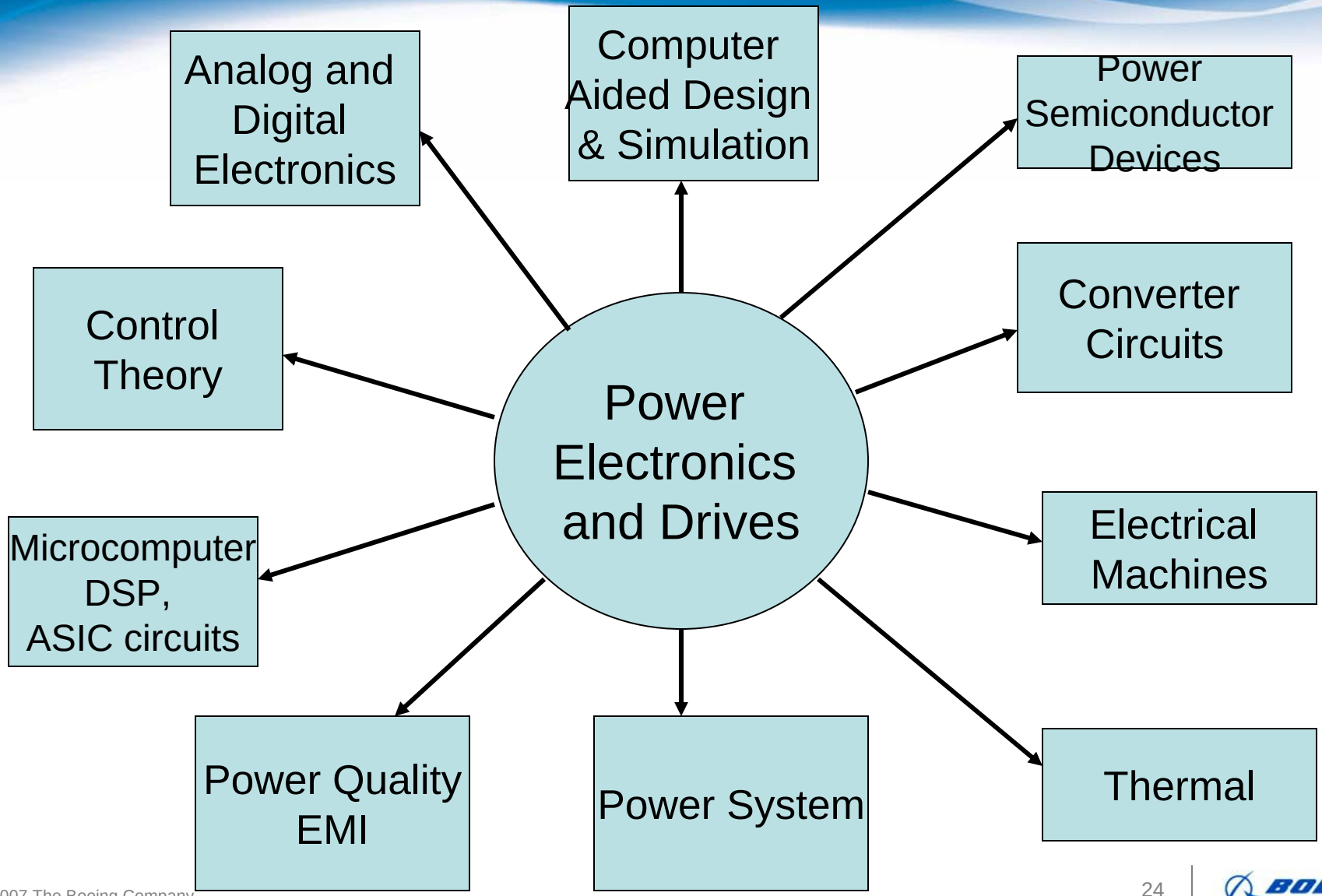
Interdisciplinary Technology



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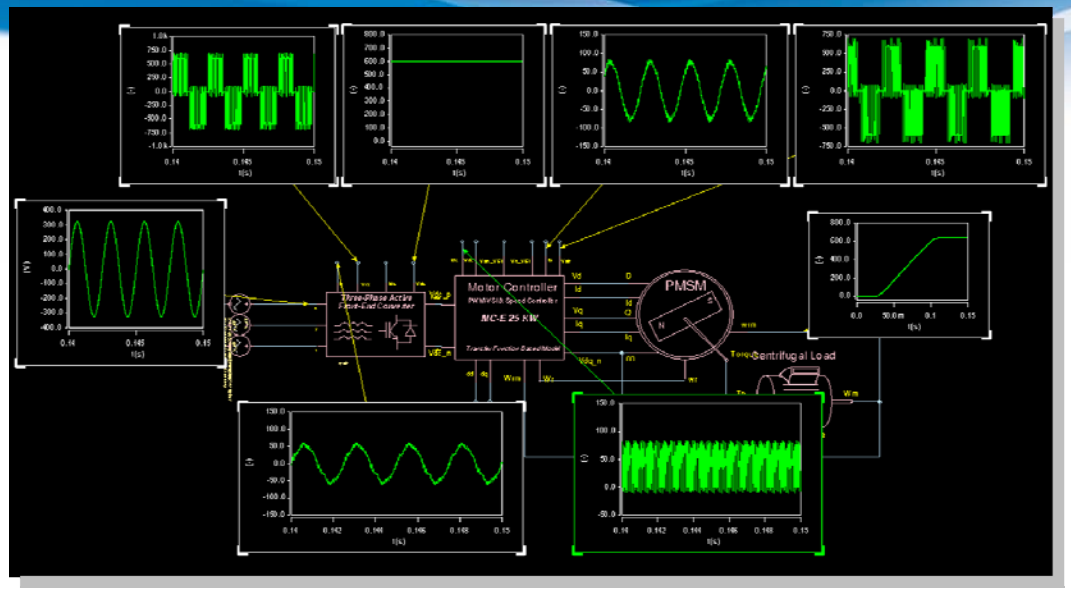
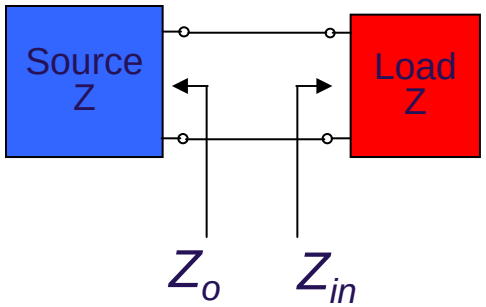
Simulation

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





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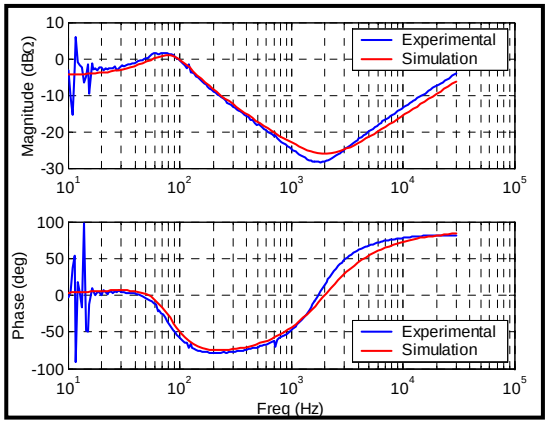

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Simulation

- 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.