Overview of CAS HEP Activities at GRC

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Convergent Aeronautics Solutions (CAS) Project

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Contents
CAS HEP activities

• High-Voltage HEP (HVHEP)

• Multifunctional Structures for High Energy Lightweight Load-bearing Storage (M-SHELLS)
High Voltage HEP activity

• PI: Ray Beach (GRC)
• Co-PI: Linda Taylor (GRC)

• Objectives
  – Demonstrate controllable, variable frequency AC system to reduce weight and enable distributed electric propulsion
  – Demonstrate materials to enable safe, high-voltage EP

• Idea/concepts
  – Variable frequency, AC power system
  – Doubly fed electric generators and propulsors (DFIM)
  – Settingless protection system
  – Zero energy fault isolation
  – Self-healing insulation
Hybrid Electric Propulsion Architecture Example

Base Architecture

NASA AATT / RR LibertyWorks (RTAPS)

System weight is dominated by the converters and SSCBs.

PI: Ray Beach (GRC); co-PI: Linda Taylor (GRC)
Convergent Technologies

High voltage
Self healing insulation

Gore flat cable

LeRC testbed
SSF 20kHz Power System

Advanced Exploration Systems (AES)
Digital control smart switchgear

High Voltage / Variable Frequency Propulsion System

Wind turbine
Doubly fed machine

787 Variable frequency power system

Ion engine PPU
Zero energy fault clearance
High-Voltage AC Benefits

- Adoption of AC leads to
  - Utilization of zero voltage crossing
  - Energy delivery every half cycle
    - Minimal fault energy
  - Ease of voltage transformation
  - Electromagnetic torque coupling between generator & motors
    - Accommodate GR between turbine & propulsor
  - Doubly fed electric machine significantly reduces power electronic processing (& associated thermal management / weight)
NASA Team Members

• ARC – Control development
• LaRC – Self-healing insulation materials development
• GRC –
  o High voltage cable system development
  o Low power and high power testbed design/build, and test
  o Software in the loop simulation
  o Smart protection system development and test

Partners

PCKrause and Associates – Modeling and simulation of DFIM control

AFRL (WPAFB) – INVENT Program models

CMU – DFIM and power system control

UT-CEM – High speed brushless DFIM concept design
M-SHELLS
Multifunctional Structures for High Energy Lightweight Load-bearing Storage (M-SHELLS)

- PI: Pay Loyselle (GRC)
- Co-PIs: Eric Olson (LaRC), Diana Santiago (GRC)

- Objective – enable hybrid electric propulsion for commercial aircraft by melding load-carrying structure with energy storage to save weight

- Idea/concepts – multifunctional material
  - Hybridize (integrate) supercapacitor & battery chemistries to achieve optimal power and energy densities
  - Utilize strong carbon materials and nanotechnology enhancements to provide integral load-carrying capability.
Multifunctional Structures for High Energy Lightweight Load-bearing Storage (M-SHELLS)

Innovative Lightweight Structural Designs

Combining Advanced Hybrid Battery/Supercapacitors into Structural Elements

PI: Pat Loyselle (GRC); co-PIs Eric Olson (LaRC) & Diana Santiago (GRC)
Multifunctional Structures for High Energy Lightweight Load-bearing Storage (M-SHELLS)

• Intent

<table>
<thead>
<tr>
<th>Properties</th>
<th>Supercapacitor</th>
<th>Battery</th>
<th>Structural Hybrid Supercapacitor</th>
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<td>High Power Density</td>
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<tr>
<td>Long Cyclic Life</td>
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<tr>
<td>Load Bearing</td>
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</tbody>
</table>

• Approach – hybrid battery/supercaps & lightweight structural integration
  o Advanced nanostructures & materials
    ✓ High surface area & electrochemical reactivity
    ✓ High strength components & integration of constituents
  o High-performance polymer & ceramic electrolytes & separators
    ✓ High ionic conductivity and structural strength
    ✓ Enables strength & stiffness / transfers stress to electrodes
Multifunctional Structures for High Energy Lightweight Load-bearing Storage (M-SHELLS)

Advanced Hybrid Battery/Supercaps (GRC/ARC)

Innovative Lightweight Structural Integration (LaRC/GRC)

Multifunctional Structural Energy Storage

System Analysis and Trade Studies (LaRC/GRC)