Antares DLR-H2 - Flying Test Bed for Development of Aircraft Fuel Cell Systems

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Short Presentation DLR

DLR is the Aerospace Research Center as well as the Space Agency of the Federal Republic of Germany

Research Areas
- Space Flight
- German Space Agency
- Aeronautics
- Transport Research
- Energy Technology
7,000 employees working in 31 research institutes and facilities
- at 8 sites
- in 7 field offices.


Fuel cell research in Hamburg and Stuttgart
DLR - Institute of Technical Thermodynamics
Electrochemical Systems

Fuel cells systems
Reformer and stacks

Battery systems
Battery packs

Electrolysis

Hybrid systems
Fuel cell stack
Battery pack

DC
AC
M
Electric Load
Fuel Cell Aircraft and Airport Applications at the DLR

**Airworthy technology development platform for A320**
- for emergency power
- for multifunctional use
  → APU
- energy source for nose wheel drive

**Modular architecture development platform**
- for GPU applications
- for high torque airport applications (transport)

**Modular airworthy propulsion platform**
Antares DLR H2
- for UAV applications
- for general aviation
  (up to 6 Pax or utility)
Antares DLR-H2 – overview, build-up

High efficient airplane

Technical Challenges:
- High efficient fuel cell system
- Minimized air drag
- Optimized aeroelastics

Fuel cell system
Hydrogen storage
Hydrogen storage system

- Tank: Dynetec W205
- Dimensions 415 mm x 2110 mm
- Weight 99.5 kg
- Volume 74 Liter, H2 capacity 4.89 kg
  at 350 bar → max. 5 h flight time
Fuel cell technology Antares DLR H2

Fuel cell system power up to 33kWnet

→ modular system 3 x 11kW
→ liquid cooled

Modular fuel cell system with cooling booster
Antares DLR H2 – LT PEM Fuel Cell Technology Gen 2
Optimized electrical network - direct hybrid

> 40% overall efficiency (from chemical energy to movement)

Storage System

Batteries

Energy Delivering System
approx. 33kW

High efficient power grid
200-450V DC at 40kW

Very high efficiency and reliability due to:
- Direct coupling of the motor electronic to the fuel cell/energy source, without DC/DC
- High reliability due to direct, parallel use of an optional battery
Aircraft application: Flight profile

Temperature!  
$\Delta T = -6 \ldots -10 \text{ K/km}$
Fuel cell system performance „on ground“ (150m) vs. „in flight“ (1200-1600m)

- summarized performance loss „in flight“ due to altitude and cooling effects ca. 5%
Concept of the direct hybrid

- Fuel cell stack: high energy density
- Battery pack: high power density

Load distribution

Hybrid system

Load
Concept of the direct hybrid

Conventional hybrid systems

- DC/DC converter for potential separation
- DC/DC converter are expensive
- DC/DC converter require cooling system

Direct hybrid system

Advantages
- No inductance
- High efficiency
- Lower cost
- Light weight
- Reliable
- Passive elements

Disadvantages
- High voltage spread
Concept of the direct hybrid

- Fuel cell
- Battery
- Battery OCV

Graphs showing the relationship between current in A and voltage in V, as well as power in kW and hybrid current in A.
Battery characteristics: State of charge (SOC)

- Battery voltages depend on SOC and current
- I-U-characteristics change while battery is discharged
- Battery current ratio reduces at lower SOC
Battery characteristics: Temperature

- Battery resistances decreases with higher temperature
- Battery current ratio decreases at lower temperature
- OCV slightly reduces at lower temperature
- Battery heats up over time due to ohmic losses
Fuel cell degradation

- Fuel cell degrades over time: voltages decreases
- Fuel cell current ratio is reduced over time
Aircraft application: Battery Temperature

- Hybrid system/battery used only at high power requests
- Different initial battery temperatures
- Higher fuel cell current at lower temperature
- Battery heats up due to ohmic losses – less influence
Aircraft application: Fuel cell degradation

- Comparison between new and degraded fuel cell at room temperature
- Fuel cell current ratio decreases over time
Conclusions and Outlook

- Hybrid characteristics influenced by
  - Battery state of charge/temperature
  - Fuel cell degradation
- Reliable design for aircraft application
  - Low cost, high efficient, light weight
  - Support fuel cell at high power request (e.g. flight start)
- Very promising results for aircraft application

- **Next step:** Integration and test with Antares DLR-H2 with improved FC Power

- **Further work:** Efficient dynamic applications
Thank you for your attention!