Integration of fuel cell system for aeronautical applications

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Integration of FCS into aircraft

Maturated-equipment for development program (TRL6)

→ Works are still to be done to mature FC technologies for aeronautic applications
AIRCRAFT REQUIREMENTS FOR FCS CERTIFICATION

- **V-type development life cycle**

  - **S/S PDR**
  - **SS CDR**
  - **PDR**
  - **S/S CDR**

**CS25** “Certification specification for large aeroplane”

**ARP4754** → Guidelines For Development Of Civil Aircraft and Systems

**ARP4761** → Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

**DO-178** → Software considerations in airborne systems and equipment certification

**DO-254** → Design assurance guidance for airborne electronic hardware

**MIL-STD-704-F** → Aircraft Electrical Power Characteristics

**AIR-1168** → Aerothermodynamic Systems Engineering and Design

**AIR-2000** → Aerospace Fluid System Standards

**AIR 6464 / EUROCAE ED-219** “Hydrogen Fuel Cells Aircraft analysis Fuel cell Safety Guidelines”

**FCS certification**

**ED14/DO-160G** → Environmental Conditions and test Procedures for Airborne Equipment

**FCS component qualification**

**FCS qualification**

**S/S to be validate:**
- Stack
- thermal management S/S
- Reactive alimentation S/S
- C/C
- mechanical, electrical interfaces
AIRCRAFT REQUIREMENTS FOR FCS CERTIFICATION

Design for safety: “how making a safe O₂/H₂/e- system for aircraft?”

O₂ standard known for aeronautic → CS 25
H₂ standard to be found for H₂ storage sub-system. → SAE AIR 6464
→ EN 12245 (DOT-CFFC) targeted for HP H₂(O₂) bottles (High TRL)

Examples of guidelines
- Robust to single failure + uncontrolled fire on aircraft level is extremely improbable
- HP H₂/O₂ storages shall be treated similarly regarding safety analysis
- Bottle burst to be extremely improbable by combining qualification and design

Examples of risk mitigation
- Energetic source segregation, FCS ventilation
- Fire resistance proofness (TPRD + venting line)
- Functions of control and security have to be separated
Cathode alimentation

- Mission/cycle: long mission (compressor); short mission (O₂ tank)
- Location: air cabin, atmosphere
- Life time → fuel cell stack size, reactive purity (filtering)

Operational conditions (DO-160)

- Mechanical solicitations (vibration, shocks)
  - Shock absorber: mechanical design compliance
- Thermal environment [-55°C ; +85°C]
  - Ground survival conditions
- Pressure [0.1 ; 1.088] bar abs
  - Ground conditions
  - On-board conditions

Impact on structure design, alimentation design of FCS and component (gas pressure regulator, air compressor, gasket and coolant)

Altitude

41000ft

8000ft

ground

inboard

0.75 bar

8000ft

0.75 bar

< 0.2 bar

0.6 - 1 bar
FUEL CELL SYSTEM LOCATION OPTIONS

Fuel cell system location onto an aircraft

➔ The localization of FCS on airplane would be mainly influenced by the relative proximity between FC hardware and public

➔ Different options:
  - FCS near to the load
  - FCS in tail cone
  - FCS in fairing

➔ The issues that influence the choice
  - Availability space
  - Safety
  - Tubing, wire mass & volume
  - Rejection of waste
  - FC waste heat
Fuel cell system location onto an aircraft

- Thermal management
  - Waste heat from depleted-air and cooling loop
  - Thermal power to evacuate depends on FCS electric performance (stack design) & operational condition (H2 purity, temperature, pressure)
- Design of cooling loop
  - Air cabin: limitation by ECS
  - Exterior air: external temperature variation with altitude, no control of air flow rate
  - Specific Equipment: power regulation depends on mission profile
- Specific exchanger design vs localization
- Compatibility coolant vs operational temperature
GENERAL REQUIREMENTS FOR FCS INTEGRATION

- Optimizations of FCS design and location vs application

- Equipment integration (design) into aircraft = certification specification
  - Safety assessment early in development phase
  - Operational environment
  - Integration requirements

- Automotive-based fuel cell system solutions could not be adapted to aeronautical environment

- Specific development
  - Energetic source segregation
  - H₂ fuel cell standards under evolution
  - System and component development needed
SAFRAN’s fuel cell activities
ROADMAP SAFRAN – HYDROGEN POWER UNIT

Sub-systems

- Stack FC PEM-HT 5 kW
- H2 Storage Type IV – 350 bar
- Air Compressor
- GGH2 (solid)

Systems and products

- Ground demo PEM-HT 5 kW
- H2 Storage 350 bar
- PEM-HT 2.5 kW
- PEM-HT 12 kW
- PEM-HT 50 kW
- GGH2 solids

Environmental-Navigability

- EUROCAE – aeronautical certification
- AFNOR – H2 and FC standardization
- Military directives – logistic – Airport installations

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COMPETENCIES @ SAFRAN ON FCS
SAFRAN DEVELOPS SPECIFIC FC EQUIPMENTS

- **HT-PEMFC stack coupling with GGH₂ (solid-based)**
  - HT-PEMFC flexible to H₂ impurities, thermal management
  - Solid GGH₂ = more safe than HP bottle, manipulation
  - HT-PEMFC + GGH₂ = compact system

- **Metallic HT-PEMFC stack (500cm²)**
  - SAFRAN’s design proprietary
  - 5kW H₂/air 160°C (2kg/kW)
  - Ageing tests under investigation
  - TRL5 (2015)
KEY MISSIONS, KEY TECHNOLOGIES, KEY TALENTS
**FUEL CELL EXPERIENCES IN SAFRAN**

→ **Synergy with Space activities & competences:**
- Design & Integration of complex systems (hydraulics-thermal-mechanics)
- Handling quantities of hydrogen & oxygen
- Availability of wide & secured test area (130 ha)

→ **Fuel cell experiences:**
  - System design & tests: PEMFC & SOFC (electric & MFFC)
  - Power Range: from 300 W to 70 kW
  - Reactants: (H\(_2\)/O\(_2\)) direct or (reformat H\(_2\)/Air), with gasoline fuel processing, ethanol kerosene, LPG, NG…

→ **Hydrogen production experiences (Fuel Processing and GGH2):**
  - Hydrocarbon Fuel Processor: NG, LPG and low sulfur kerosene
  - Solid Hydrogen – hydrolysis and thermolysis