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FUEL CELL POWER SYSTEM DESIGN FOR GENERAL AVIATION AIRCRAFT

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Abstract – **The application of PEM fuel cell technology to the aircraft propulsion and/or to auxiliary energy supply has a great interest for the advantages in terms of pollution emissions, noise reduction and fuel consumptions.**

In this paper the sizing procedure for a PEM fuel cell system, designed for aviation applications, is presented. The main requirement of the proposed procedure regards the specific energy that has to allow to the fuel cell system to reach better performance with respect to a battery system.

In order to guarantee fixed climate conditions in which the power system has to work, a containment chamber has been designed to ensure that inside the microclimatic conditions are compliant with the specifics of the off-the-self-components.

This study has been conducted in the framework of Long Endurance Demonstrator (LED) project.

Index Terms – PEM Fuel Cell, aviation, electrical motor, Specific energy

I. INTRODUCTION

Many research groups have developed fuel cell-powered aircrafts to demonstrate the possibilities of fuel cells as the new power source alternative to existing batteries in the field of the electric power supply systems [1,2,3]. The main problem that has to be overcome is the energy to mass ratio of the power system that has to be better than that of batteries.

In 2013, CIRA (Italian Research Aerospace Centre) started a research project whose goal was the design of a power system for the electrical motor, to be installed on a general aviation aircraft in the class of AERMACCHI SF 260.

According to the project, LED should guarantee at least 10% endothermic engine maximum power, assumed equal to 220 kW (300hp). The high level requirements are summarized as follows:

REQ1 LED is a fully electric power system;
REQ2 LED is a system maximum power of 25 kW
REQ3 LED has to supply power for 6 hrs
REQ4 LED operates at an altitude of 3000 m;
REQ5 LED maximum weight must be less than 400 kg

II. DESIGN OF AN ELECTRICAL POWER SYSTEM

A. Battery vs. Fuel cells

The design of an electrical power system must start from the energetic mission profile. Thus, in the choice of the power system it is possible to affirm, in first analysis, that fuel cells are recommended for high energy-consuming missions, while, batteries are more suitable when the mission is characterized by low-energy/high power. Moreover, the specific energy requirement of a fuel cell system must be of 0.35-0.4 kWh/kg, if the system aims to be more competitive than commercial LiPo batteries characterized by a specific energy of 0.2 kWh/kg. Thus, the analysis on a PEM fuel cell system for aviation applications has to be defined in terms of power requirements and mission duration, in order to evaluate if, once assigned a specific mission, the fuel cell power system is better than a battery system.

B. System off-the-self components

A proposed power supply system, designed to operate on an aircraft, must be realized with the components listed in the table 1. Starting from these components, a sizing procedure has been carried out to find the number of fuel cells stacks, model A1000 (the system component that most affects the overall performance), that maximizes the system specific energy for an assigned mission (25 kW for 6 hr); in fact, for a given electric load, the weight of the overall system depends on both the energetic mission profile and on the operating conditions of the power unit (full or partial load of the FC stack). As a consequence:

- the operating current depends on the FC stacks number;
- the H_2 mass flow rate that has to be stored to complete the mission (H2 storage) depends on the operating current;
- the air mass flow rate and, as a consequence, the size and the number of compressors, depend on the H_2 consumption;

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- the operating current influences the cooling requirements and thus the size and the weight of the heat exchangers.

Table 1. Components of a fuel cell power system

Component	Model	Weight [kg]	Power / Energy	Specific power [W/kg]
Fuel Cell (power supply unit)	Horizon A1000	2.5	1 kW	0.4
H2 Tank (storage unit)	TUFFSHELL	21.9 (1.3 H_2)	44 kWh	-
Air Compressors (for oxidant feeding)	Airsquared, P16H36N3.25R	6.35	0.16 kW	-
Batteries (auxiliary unit)	Thunder Power 8Ah_4s4p	0.6	2 kW	3.3
Heat exchanger (fuel cell cooling unit)	Titan AIR, H-1-20A-600	30	30 kW	1

The specific energy has been defined as a function of the power, the mission duration and the number of fuel cell stacks:

$$\rho_E = \rho_E(W_{ob}, t_{miss}, N_{STACK})$$

Moreover, the fuel cell performance has been calculated by a numerical model, properly developed by using the Aspen Plus code.

For a mission of 25 kW, with a duration of 6 hr, the specific energy vs. stack number has been plotted in Figure 1.

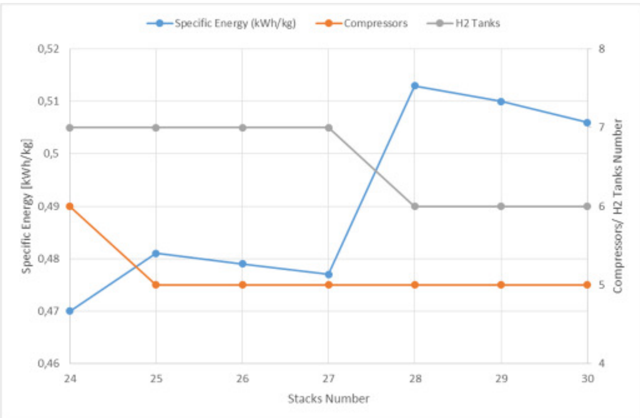

Figure 1. Specific energy, number of hydrogen tanks and number of compressors vs. stacks number

In figure 1, the number of H_2 tanks (blue line) and the number of air compressors (green line) are reported too.

It can be noted that increasing the stacks number from 24 to 25, the specific energy increases because the lowest H_2 consumption (the fuel cell works at lower load with a higher efficiency) implies a lower number of air compressors (from 6 to 5). However, even if the increasing of the stacks number from 25 to 27, causes a further reduction of the mass of H_2 (weight), it is not compensated by the increasing of overall stacks (A1000) weight. As a consequence, the specific energy decreases. Finally, by increasing again the stacks number (27 to 28), not only the H_2 consumption decreases but also the number of hydrogen tanks (from 7 to 6). This decreasing of the H_2 tanks permits a drastic weight saving (22 kg) with a great increment of the system specific energy (0.51 kWh/kg).

It is important to highlight that the H_2 tank have the greatest influence in terms of weight percentage (table 2).

Table 2. Weight percentage with respect to the system weight

Components	Weight percentage
H_2 Tank	47 %
Fuel Cells	24 %
Compressors	11 %
Heat exchanger	8 %
H_2	2 %
Batteries	1 %

C. High level system design

Finally, in order to guarantee fixed climate conditions in accordance with the operation conditions of the selected components (the external conditions are t=-5 C°, P=0.74 bar), it has been chosen to place the power system in a containment chamber as shown in Figure 3.

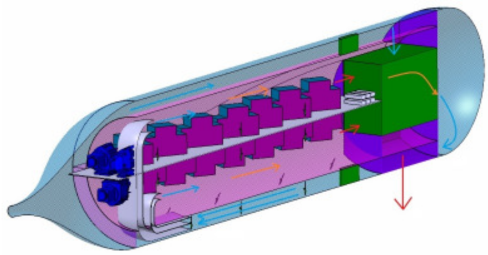

Figure 3. The containment chamber in which the power system is placed

D. Conclusions

In this paper the design of a fuel cell power system, suitable for aeronautical applications, has been reported. In order to increase the specific energy of the whole system, the number of system components has been defined by means of an optimization process. The calculated specific energy results to be equal to 0.51 kWh/kg, with a system that consists of: 28 stacks, 5 air compressors, 6 hydrogen tanks, 6 batteries and 1 heat exchanger. The total weight is 282 kg.

References

[1] T. Kim, S. Kwon, Design and development of a fuel cell-powered small unmanned aircraft, Int J of Hydrogen Energy, 2012; 37:615-22

[2] O. Erdinc, M. Uzunoglu, Recent trends in PEM fuel cell-powered hybrid systems: Investigation of application areas, design architectures and energy management approaches, Renewable and Sustainable Energy Reviews, 2010; 14: 2874–84

[3] G. Romeo, F. Borello, G. Correa, E. Cestino, ENFICA-FC: Design of transport aircraft powered by fuel cell & flight test of zero emission 2-seater aircraft powered by fuel cells fueled by hydrogen, Int J of Hydrogen Energy, 2013;38: 469-79

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