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MANAGEMENT OF ELECTRIC POWER SOURCES FOR SMALL AIRCRAFT

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Abstract: *The paper describes a possible solution of electric propulsion for small plane with a hybrid power supply. The energy source consists of the battery and fuel cell system requires the electronic management of this resource. The article shows the physical-mathematical model of management of hybrid power source for electric propulsion of aircraft.*

Keywords: *aircraft, electric propulsion, battery, fuel cell, hybrid power supply, management.*

1. INTRODUCTION

Aircraft manufacturers are looking for possibilities to produce cleaner engines for aircraft. For small aircraft there is one of the options to change gasoline engines by electric motors. One of promising technology is electric powered of aircraft with hybrid power supply. The hybrid power supply electronic control system requires cooperation of the elements according to the needs of the aircraft flight operations.

2. ELECTRIC PROPULSION FOR SMALL AIRCRAFT

Propeller of the small aircraft would be powered by an electric motor through a corresponding reduction in the maximum speed of propeller. The electric motor draws energy from the lithium-ion battery and fuel cell.

Operation of the fuel cell requires water tank and the tank with pure hydrogen, which is fuel for a fuel cell. Figure 1 shows the arrangement of elements of electric power in the trunk of a small aircraft.

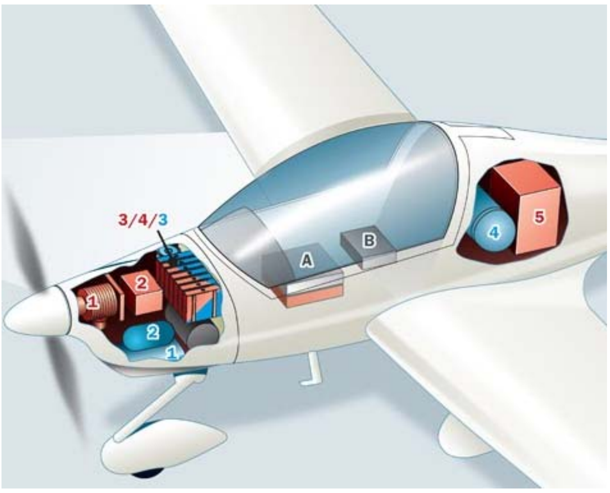

Fig. 1 The arrangement of elements of electric power in the trunk of small aircraft [1].

Blue- Fuel cell systems: 1- radiators, 2- water reservoirs, 3- PEM fuel cell, 4- hydrogen tank,
red- energy storage system and propulsion system:
1- electric motor, 2- electric motor controller,
3- battery, 4- other energy back-up system,
5- alternate battery location
A- Power management and distribution system, B- Motor controller / inverter

Fuel cells and batteries are both galvanic cells and therefore have many similarities. Both devices generate electrical energy by converting chemical energy from a high energy state to lower energy state using an electrochemical reaction. Fuel cells differ from batteries in the nature of their anode and cathode. Fuel cells also differ from batteries in the fundamental method in which the chemical reactants are stored. In a battery, the anode and cathode form an integral part of the battery structure and are consumed during use. In a fuel cell, the chemical reactants are supplied from an external source so that its materials of construction are never consumed and do not need to be recharged. A fuel cell continues to operate as long as reactants are supplied and the reaction products are removed.

The fuel cell produces electricity through an electrochemical reaction of fuel (pure hydrogen) and oxidant (oxygen from the air). This reaction produces the water as the output product. The fuel cell produces no harmful emission and is relatively quiet during operation. Electric-powered aircraft is generally very quiet. Fuel cell with the proton Exchange membrane PEM operates at a low temperature around 100 °C and working at full power shortly after starting to work.

Figures 2,3 shows the operation of fuel cell with PEM membrane.

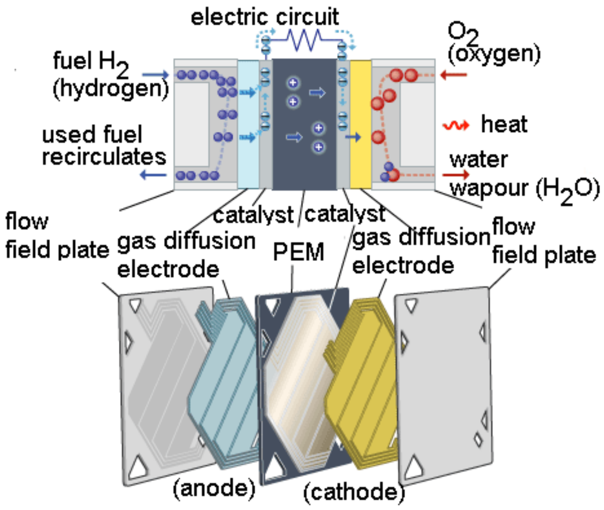

Fig. 2 The operation of fuel cell with PEM membrane [2].

In steady mode of flight is expected to use energy of the fuel cell. For extreme operating modes, eg. start of the aircraft and other difficult modes will be necessary to use electric traction power of fuel cell together with the energy of lithium-ion batteries.

Fig. 3 Fuel cell system with PEM membrane for mobile applications [3].

3. CONTROL OF HYBRID ENERGY SYSTEM

Hybrid energy management system is based on knowledge of the future conditions, as provided by scheduled flying time and flying conditions. Therefore, they are not suitable for real-time control, but they still have an acknowledged importance as a basis of comparison for the evaluation of the quality of real-time control strategies. In this approach, often referred as “local optimization”.

Model is based on Lithium-Ion battery. Battery pack is to size on voltage - 400 volts and their capacity is 120Ah. Battery will put performance about 50 kW in the continuous terms (Fig. 4).

The model of fuel cell for simulation is a 650 cells, 400 Volts - direct current, with maximal peak power - 50 kW Proton Exchange Membrane (PEM) fuel cell stack. Weight of fuel cell engine system with battery pack is 270 kg and depends on hydrogen storage in hydrogen tank.

The model of hybrid energy source for aircraft is based on local optimization of dynamics loads with primary energy source – PEM fuel cell. Batteries are used to assist PEM fuel cell in the critical parts of dynamic loads during flying with peak power energy demand. The fuel cell and its power is design for charging battery pack, when battery power is on low level. This feature is provided by inverter (Fig. 4).

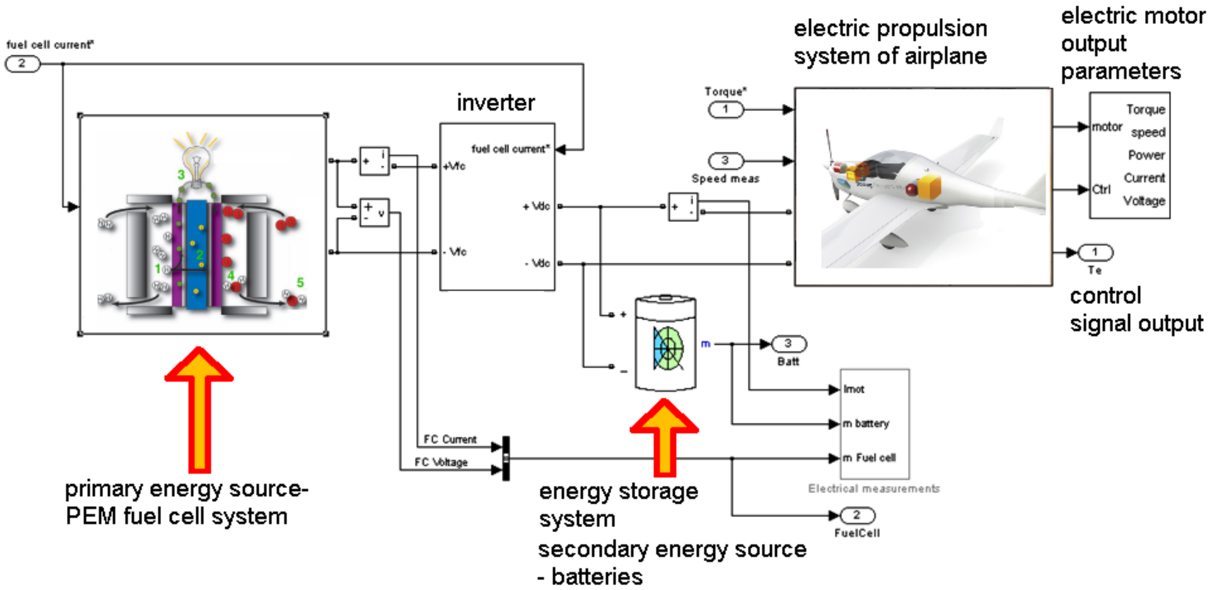

Fig. 4 Hybrid energy storage system (PEM fuel cell –battery) with aircraft propulsion system and control signal output in the simulation software Matlab/Simulink.

4. CONCLUSIONS & ACKNOWLEDGMENT

Fuel cell stack can operate only if provided with pressurized air and hydrogen and flushed with coolant. Practical fuel cell systems require additional equipment to regulate the gas and fluid streams, provide lubrication, operate auxiliary equipment, manage the electrical output and control the process. Some systems include reformers for fuel processing. All of this equipment introduces losses and reduces the total efficiency of the system from its theoretical ideal.

For a fuel cell power plant operating on pure hydrogen, an overall system efficiency breakdown at the output of the propeller is roughly 30 to 40 %. Batteries have electrochemical efficiencies comparable to fuel cells.

More difficult to quantify is the effect of overall system weight. Fuel cell systems including fuel storage are heavier than small internal combustion engine systems. Batteries as a means of power storage are heavier than fuel cells although this is offset somewhat by the elimination of other components.

Work presented energy management model of fuel cell vehicle model with battery storage system which can predict the effect of sizing parameters on the system efficiency characteristics, overall efficiency of fuel cell system.

The combined optimization results show that the optimality lies in:

- increasing degree of hybridization and
- employing corresponding control strategy of hybrid energy system in military applications.

If fuel cell and battery applications go into production in the near future in aircraft systems, their degree of hybridization and design of energy management strategy will significantly impact on the operational time, combat deployment time, vehicle equipment costs of fuel cells, batteries and aircraft weight.

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