

STUDYING THE POSSIBILITY OF INCREASING THE FLIGHT AUTONOMY OF A ROTARY-WING MUAV

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Abstract: *In the last few years, many researchers wrestle with the challenge to increase the flight autonomy of mUAVs. All these efforts were conclude in some results in term of fixed wing mUAV, where the flight autonomy has increased significantly, but for the rotary wing mUAV, the improvements are still pending. This paper approaches the idea of increasing autonomy for a quad rotor mUAV, by implementing a hydrogen PEM fuel cell alongside two lithium batteries. The idea behind this concept is to charge a battery from the PEM fuel cell, while using another battery to power the system. To test different configurations, simulations of the charging and discharging process were realized using Simulink and represent the main subject of this paper. The theoretical mUAV model used in the simulation, makes use of state of the art components, available on the market, to achieve great efficiency.*

Keywords: *flight autonomy, PEM cell, rotary wing, quadcopter, battery.*

1. INTRODUCTION

The UAV domain is in a continuous expansion from the point of view of both the manufacturing process and the missions that can be accomplished by those. A great interest was built in the military and civilian around the unmanned aircraft thanks to a great number of successful military missions performed by drones.

Advances in technology and the use of intelligent materials allow for more and more challenging and interesting UAV projects to emerge.

At this time, multi-rotor MUAVs are continuously researched and developed. Manufacturers keep introducing new hardware such as cameras, gimbals, sensors, tanks and sprays for agriculture and also new software functions, including subject capabilities, preset path, automatic return, automatic landing, autonomous flight, mapping, obstacle detection, flight management, battery management.

The development and implementation of all these features implies an increasing energy consumption. In this paper a method of increasing flight autonomy is approached, and as a reference model was chosen a rotary-wing UAV, in this case a quadcopter.

The method consists in implementing a hybrid power system which is made up of two batteries, alternately charged during flight by a hydrogen fuel cell.

To demonstrate this method, a Matlab - Simulink model was designed, in which two batteries are charged by aid of a constant voltage source (21V), representing the PEM (Proton Exchange Membrane) fuel cell, and between these two components is connected a high rate battery charger.

Simulating a possible implementation of this system will notice an increase in flight autonomy for the particular quadcopter case.

2. SYSTEM DESCRIPTION

Quadcopter has received considerable attention from researchers as the complex phenomena of the quadcopter has generated several areas of interest. The basic dynamical model of the quadcopter is the starting point for all of the studies but more complex aerodynamic properties has been introduced as well.[1,2]

As a reference model we used a Tarot F650 Ironman quadcopter (fig. 1.) which is equipped with four LD Power Motors M2810-720KV with 12x5.5” propellers, single battery powered, with a total mass approximated to 2.2kg and a total power onboard consumption measured in different operating modes as it is depicted in the following table:

Table 1:measurements of a power consumption of a Tarot F650 Ironman

Mode	Power(W)	Current(A)	Electric Charge(Ah)
Stand-by	5.8-5.9	0.38	15×10^{-3}
Idle	14.4	1	32×10^{-3}
50%	210	15	14×10^{-2}
100%	700	50	48×10^{-2}

The reference hydrogen subsystem is composed of a fuel cell stack, a hydrogen tank and auxiliary components.

Fuel cells are inherently modular and therefore lend themselves to a wide range of applications, from large stationary power plants to small portable power packs.[3]

The fuel cell stack has the following electrical characteristics: 200W rated output power of 21V nominal voltage, and 9.52A output current. It weighs about 600g and measures 130mm in length, 85mm in width and 68mm in height.



FIG. 1. Tarot F650 Ironman quadcopter

The output of a PEM Fuel Cell is an electric energy, with water and heat as the only by-products. Efficiency can be high due to the absence of a Carnot cycle. From the electrical point of view, the cell can be seen as a voltage source where the output impedance presents a highly nonlinear dependence to operating conditions such as temperature, electric current, partial pressure and humidity levels of the incoming gases. [4].

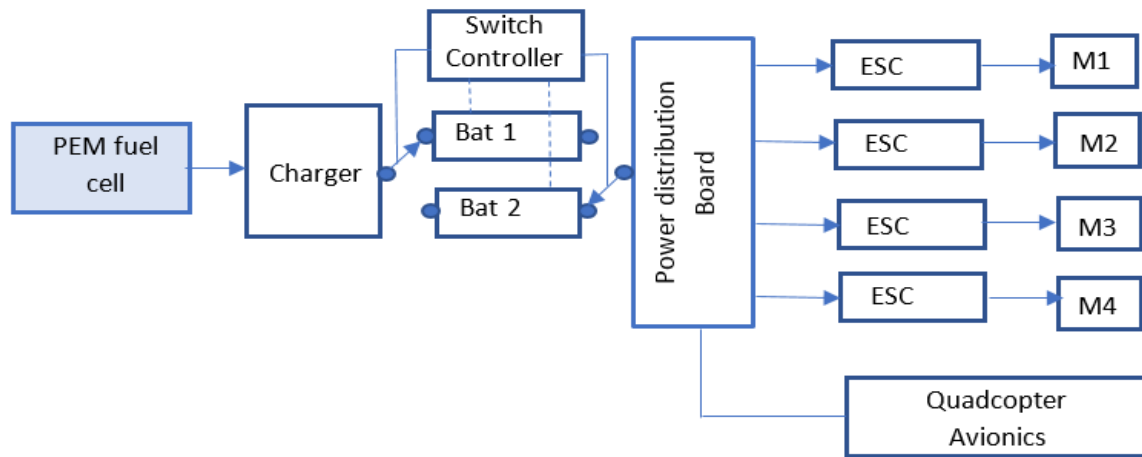


FIG. 2. Block diagram of a hybrid power system

At the time of take-off, it is assumed that the batteries are already charged 100% and the onboard consumers are powered by a single battery, the fuel cell and the charger are in stand-by.

When the first battery reaches 10%, estimating that this will happen after approximately 13 minutes, the switch controller switches the load on to the 2nd battery, and at the same time the fuel cell and the charger start charging the first battery at an initial charge rate About 16 A.

The second battery will also reach 10%, which is the minimum preset value at which switching between batteries is performed. Flight time with the 2nd battery reaches 13 minutes. In the 13-minute operation of a battery, the charger managed to charge the first battery, bringing it to a value of 35%, which means another 5 minutes of extra flight.

After 3 switching between batteries, you can reach a 30-minute flight time, which means 5 minutes longer than a flight using 2 parallel-connected batteries.

3. SIMULATION

In the Simulink model, the fuel cell stack is represented as a constant voltage source connected to a DC-DC buck converter to which we have implemented a feedback controller to allow CC/CV(constant current/ constant voltage) charging. The batteries are connected to the charger via individual switches operated by a controller. The same controller switches the load (esc, motors, autopilot, auxiliary devices) between the batteries, allowing one battery to be charged and the other discharged in parallel.

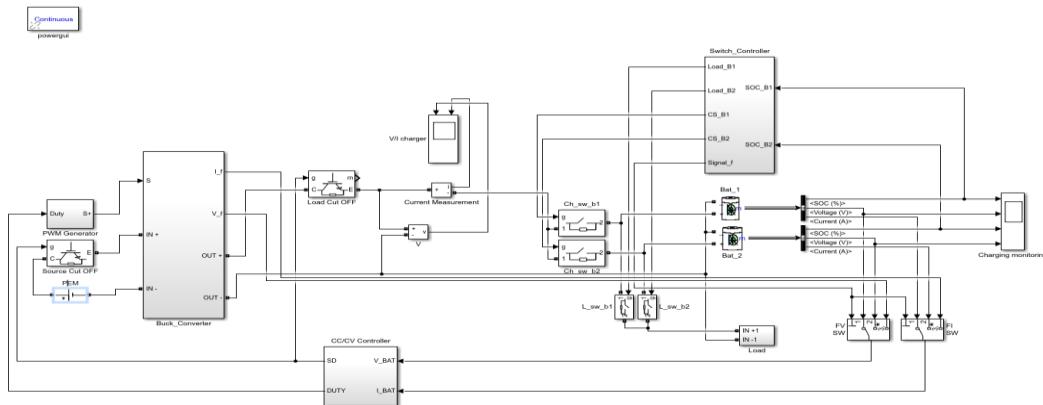


FIG. 3. Model Simulation in Simulink – MatLab

The designed model implements two separate circuits, one charging circuit and one for discharge. The charging circuit starts with a PEM fuel cell, implemented as a constant voltage source (21V), which feeds directly to a Buck DC-DC converter with a feedback controller for output regulation.

The buck converter steps down with high efficiency, the voltage of 21 V to 12.6 V, regulated by the feedback controller, through a PWM signal.

The feedback controller ensures the CC / CV charging mode so that until the battery reaches the maximum voltage of 12.6V, it is charged with constant current. After reaching the maximum voltage, the controller switches to CV mode and gradually decreases the battery power while keeping the voltage at 12.6V.

The two batteries are charged in an alternative way. This process of switching is ensured by the switch controller, which is based on an editable threshold representing the minimum state of charge accepted, disconnects the battery and connects the other. The same controller connects the load to the battery disconnected from the charging circuit and switches between the signals fed to the feedback controller.

4. RESULTS

Figure 4 shows the simulation result of the hybrid power system. In the first graph you can see the battery status number 1 represented in percentages and reaching the 10% threshold. Graph 2 accompanies graph number 1 and represents the battery number 1 voltage during the process of discharging and then the process of charging.

In graphs 3 and 4 the same features are represented, but for battery number 2. By comparing the two batteries represented in figure 4, it is noticeable that while the first battery is being charged, the second one is discharged by feeding the consumers on board of the mUAV and vice versa.

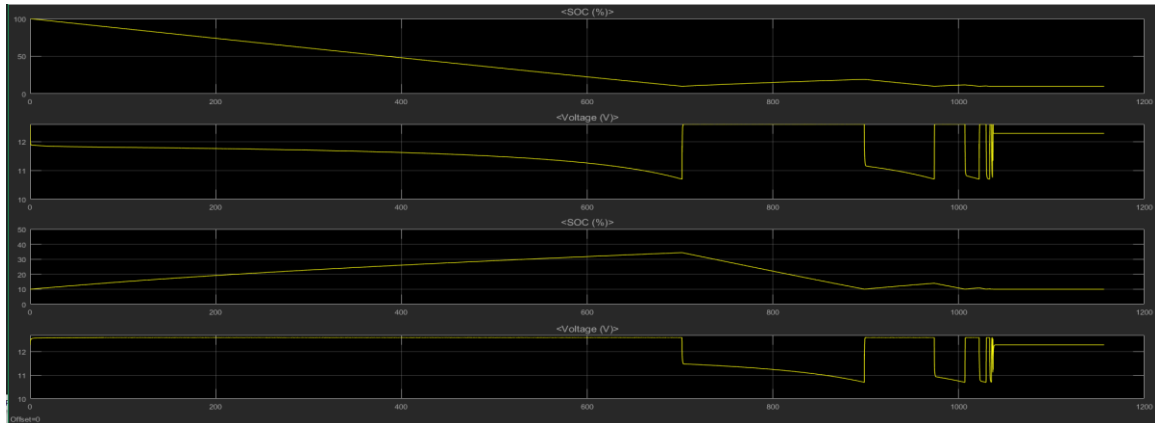


FIG. 4. Graphical representation of the evolution of batteries

Following the implementation of this hybrid power system, we have estimated the following flight times according to different power system configurations, as shown in the following table:

Table 2: Estimated flight times on different configurations of power systems

Power system	Estimated flight time	MTOW
One battery	17 min	2.2 kg
Two batteries	25 min	2.7 kg
Hybrid system	33 min	3.5 kg

5. CONCLUSION

Hoping for a future development of fuel cell technology by decreasing weight and improving performance. This hybrid power system can become an alternative solution for increasing flight autonomy for both rotary-wing mUAVs and fixed-wing mUAV.

Even if the implementation of this system can reach several thousand euros, the security and intervention structures (Firefighters Department, Police etc.) can take advantage of it, especially as when a droning operation is used, each minute with which the autonomy is extended flight can be decisive in saving human lives.

In this paper we have demonstrated that there are alternative sources of power supply for MUAVs others than LiPo batteries. It is also possible to consider creating a power system consisting exclusively PEM fuel cell stack.

7. FUTURE WORK

As future improvements to the system implemented in this paper, we thought about the following:

Integration of a method of supplying the consumers and using the PEM fuel cell in parallel with the first battery, starting with the take-off time until the first battery is discharged. This can lead to an increase in the duration of the first battery discharge from 13 minutes to approximately 20 minutes.

Implement a failsafe function that, if both batteries are fully downloaded, can feed the system directly from the PEM fuel cell.

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