Evaluation of fuel cell/battery passive hybrid power systems for unmanned vehicles

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Introduction

Unmanned vehicles offer multiple possibilities in industrial, scientific and security applications, due to their ability to provide in real time high quality data, at a lower cost than other techniques. Among the different issues to take into account in the design, development and operation of unmanned plat-forms, on board energy storage is one of the most relevant, due to its influence on the performance and capabilities of the vehicle [1]. In several applications, electric propulsion is the only available option. In these cases, it is necessary to have suitable systems for electrical energy storage, in order to provide high energy density and power in mass and volume, time life (charging and discharging cycles) and safe operating condition, among other requirements. At present, most electric unmanned vehicles use lead-acid or lithium ion batteries. Despite the rapid progress of these technologies, the use of hybrid configurations, combining different energy storage technologies, is seen as a promising option to overcome the existing gaps for power systems in unmanned vehicles.

The main advantages of these hybrid power systems, compared to battery-based systems, would be the possibility of achieving higher energy densities; redundancy in power supply, reducing the possibility of failure; and improvement in system performance. Hybrid power systems with fuel cells and batteries are usually available in two configurations: active, with control elements (typical configuration with DC/DC converters); or passive, with a direct coupling between the system components.

Hybrid power systems in unmanned vehicles

In particular, the integration of fuel cells and batteries is playing an increasing role in unmanned mobile platforms, with a number of demonstration projects of these technologies in different applications, such as unmanned ground vehicles (UGVs), air vehicles (UAVs), submarines (UUVs) and surface boats (USVs) [2,3]. The main potential benefits of these hybrid power systems, in comparison with pure battery power systems, are that they can achieve a higher specific energy and energy density, while provide redundancy in power supply and reduce the possibility of failure.

Usually, hybrid power systems with fuel cells and batteries can be arranged in topologies with active control systems (typical configuration with DC/DC converters) or passive (with direct coupling among components system) [4, 5]. Figure 1 shows examples of both configurations, applied to a UAV with PEM fuel cell and Li ion batteries, in a conventional hybrid system (a) and a hybrid direct scheme (b).

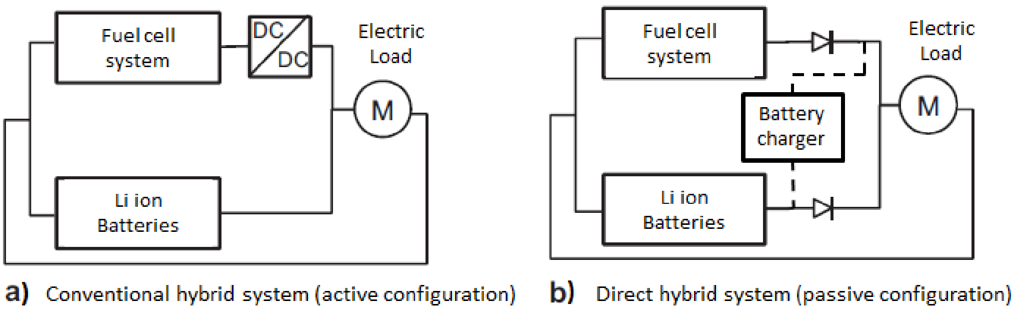

Figure 1: Different topologies of hybrid power systems with fuel cells

The choice of the most suitable configuration will depend on the requirements of the vehicle, in terms of power and energy, and its possible constraints, in terms of weight and volume, as well as the characteristics of the fuel cell system and batteries. The active configuration allows a decoupling of sizing and operating conditions in batteries and fuel cell, thanks to the DC/DC converters, allowing also a more precise control of the power system. The main disadvantages of indirect hybrids (active) are the more complex system topology, reduced efficiency due to losses at the voltage, system cost, and higher weight and volume. The passive configurations, with direct connection to DC bus, offer the advantages of lower losses, reduced cost and simpler architecture. However, active power control is not possible, and a careful design and integration of fuel cells and batteries is required to ensure a similar voltage range operation and proper charging conditions of the batteries from fuel cell if this option is considered [6]. There are also several possibilities in passive configuration, depending on if the fuel cell is able to charge the batteries without limitations, if there are some kind of regulation in this process, or even if there is not possible to charge the batteries from the fuel cells.

Testing and characterization of passive hybrid systems

In the framework of the project "Improving efficiency and operational range in low-power unmanned vehicles through the use of hybrid fuel-cell power systems (IUFCV)" [7,8,9], whose objective is the evaluation of hybrid power systems, based on batteries and fuel cells, in real applications of unmanned ground and submarine vehicles, INTA's Energy Laboratory has carried out the development, integration, testing and evaluation of two different configurations for passive hybrid power systems, suitable for their application in the unmanned ground vehicles considered in the project. The results and experimental data obtained will be used to model the system, as well as to design and size the definitive hybrid power systems that would be installed in the vehicles.

The evaluated passive hybrid power system integrates a PEM fuel cell stack from HES, model AEROSTAK 200 W, and six 6 LiPo cells (16 Ah theoretical capacity, 3.7 V nominal voltage per cell and 240 A continuous current) connected in series, obtaining a nominal voltage in the battery pack of 22.2 V. In spite of the nominal power rating of the fuel cell stack was 200 W, a maximum power of 160 W (20 V, 8 A) was obtained during the characterization tests prior to its integration with the batteries. The hybrid system was tested in two configurations: direct coupling between the fuel cell stack and the batteries (no limits to the charge of the batteries from the fuel cell), and without the possibility of charging the batteries.

The results obtained with the direct recharge option are more favorable from the point of view of stability in the fuel cell and total system voltage, which can result in greater durability of the power system. However, to ensure proper operation under these conditions, a careful joint design, selection and integration of the batteries and the fuel cell is required.

Acknowledgements

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