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Characterisation of a hybrid, fuel-cell-based propulsion system for small unmanned aircraft

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HIGHLIGHTS

- An experimental characterisation is presented for the hybrid AeroStack fuel-cell system.
- The electrical efficiency of the fuel cell was found to be over 50% for a large range of output power.
- The polarisation curve exhibits hysteresis effect during dynamic load changes.
- The systems' battery ensures a fast response and protects the fuel cell from starvation.
- The fuel cell recharges the battery with a peak current of 1 A.

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ABSTRACT

Advanced hybrid powerplants combining a fuel cell and battery can enable significantly higher endurance for small, electrically powered unmanned aircraft systems, compared with batteries alone. However, detailed investigations of the static and dynamic performance of such systems are required to address integration challenges. This article describes a series of tests used to characterise the Horizon Energy Systems' AeroStack hybrid, fuel-cell-based powertrain. The results demonstrate that a significant difference can exist between the dynamic performance of the fuel-cell system and its static polarisation curve, confirming the need for detailed measurements. The results also confirm that the AeroStack's lithium-polymer battery plays a crucial role in its response to dynamic load changes and protects the fuel cell from membrane dehydration and fuel starvation. At low static loads, the AeroStack fuel cell recharges the battery with currents up to 1 A, which leads to further differences with the polarisation curve.

1. Introduction

Small, electrically powered unmanned aircraft systems (UAS) are currently used for a variety of reconnaissance and remote-sensing missions [1–3]. Electric propulsion is typically preferred over the use of small internal-combustion engines because of its comparatively high efficiency, low cost, and high reliability [1,2,4–6], as well as low infrared and noise levels. The energy density of commercially available batteries, however, limits the achievable endurance of battery-powered UAS; and this has motivated the development of advanced fuel-cell-based powerplant systems [2,6–8]. Several research groups around the world have designed and flight-tested fuel-cell-powered demonstrator aircraft [2,4–16]. Their research systematically reports the lack of publicly available detailed performance specifications [6–8] and demonstrates that airworthy fuel-cell-based systems require a different design strategy than automotive and stationary applications [4,17].

Aircraft typically require a large power range for different flight phases, and a fast response is required to balance the load variations [6]. However, fuel cells are generally limited in power density and can suffer from a slow dynamic response [18–24]. A hybrid system, in which a fuel cell is combined with a secondary, short-term boost capacity, such as that provided by batteries or ultracapacitors, is thus required for operationally viable systems [6,15]. These hybrid systems combine the high power density of the secondary system, ideal for short-duration peak power, with the high energy density of the fuel cell, which enables long endurance [19–21,24–28]. In a hybrid system, the advantages of each of the subsystems are exploited, which can lead to a lighter, cheaper system with improved efficiency [25–27]. Hybrid systems, however, include dynamic subsystems and passive or active power-

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