Systems Engineering for Autonomous Systems
Defence Technology Centre

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Very Long Endurance Propulsion Systems – PPEM014

Very long endurance uninhabited aerial vehicles (UAVs) are ideally suited to provide surveillance, remote sensing and communication relay capabilities for both military and civilian applications. The primary requirement for these UAVs are low power, lightweight with high efficiency propulsion and power systems. Propulsion system concepts offering a step change in fuel consumption will be required to realise the project target endurance of 1 week. PPEM002 studied a High Altitude Long Endurance (HALE) UAV that typically cruises at an altitude of between 15km and 20km, loitering above areas of interest for prolonged periods. An all-electric power system architecture was proposed with the primary power being supplied by a hybrid gas turbine (GT) solid oxide fuel cell (SOFC) system using hydrogen with PV array assistance. The propulsion system proposed used air cooled permanent magnet drive systems. PPEM014 seeks to investigate liquid Hydrogen (LH2) storage and delivery and the ability to use fuel cooling to further improve the efficiency of the propulsion system. Consideration will also be given to a Polymer Electrolyte Membrane (PEM) fuel cell at lower altitudes where the ambient air density makes this technology more favourable.

Aim

To investigate the potential benefits provided by employing a fuel cooled propulsion and electrical distribution system for long endurance UAVs. To investigate a PEM fuel cell at lower altitudes where ambient air pressure is more preferential for this technology.

Approach

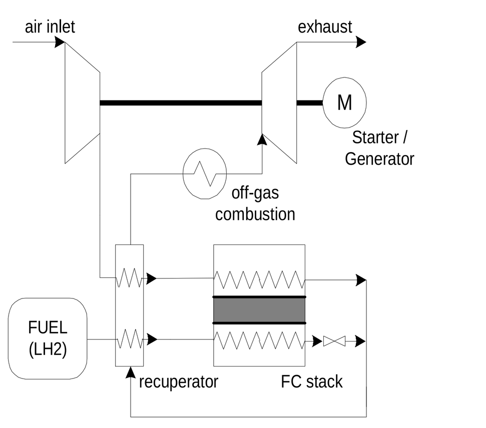
Novel propulsion system designs utilising fuel cooling will be investigated along with an improved understanding of LH2 storage and delivery. A PEMFC system design will be undertaken at lower altitudes. These results will be compared with the baseline PPEM002 findings. Some PPEM002 completion work (I.e. air-cooled converter) will be required to validate the baseline model.

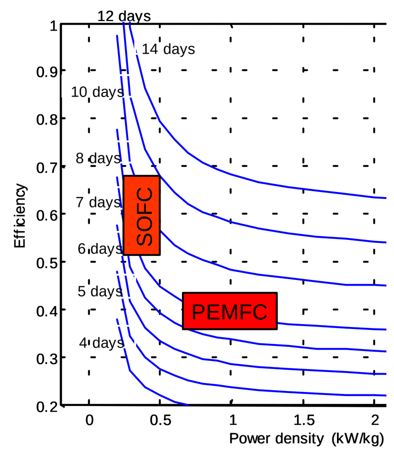
Outcomes

PPEM002 has established a LH2 baseline air-cooled propulsion and power system. System modelling has been completed. A hybrid GT/ SOFC and a Photovoltaic (PV) assembly has been proposed. A demonstrator air-cooled PM machine has been built.

Fuel Cell System

PPEM002 research focused upon a hybrid gas turbine / solid oxide fuel cell system using pure hydrogen fuel, stored in the liquid phase. Significant compression is required at altitude in order to increase the pressure of the incoming air for efficient operation of the stack. The normalized air mass flow is large at cruise altitude as the ambient pressure is low and air is required to cool the stack in addition to providing oxygen for the oxidation.



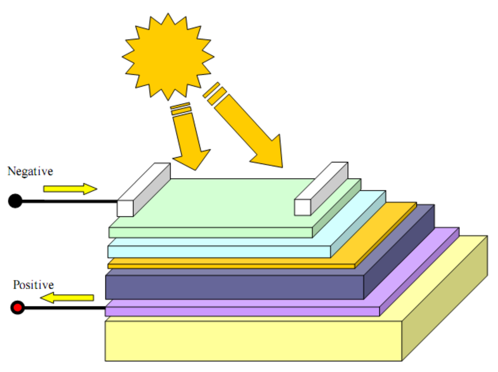


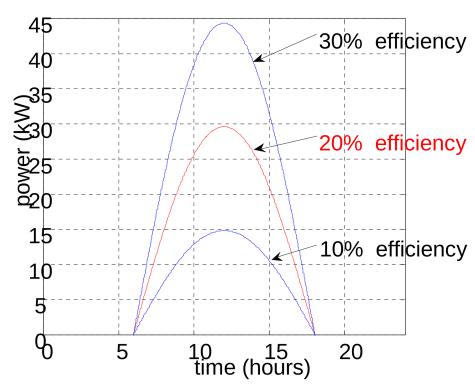
Hybrid GT/SOFC Fuel Cell System

PPEM014 will consider Polymer Electrolyte Membrane Fuel Cell (PEMFC) systems at lower altitudes. The preference of fuel cell technologies is predominately based on the fuel cell auxiliary system requirements, particularly air pressure. This work will establish the preference at lower altitudes to aid system designs for any very long endurance UAV.

Thermo-Electric Device

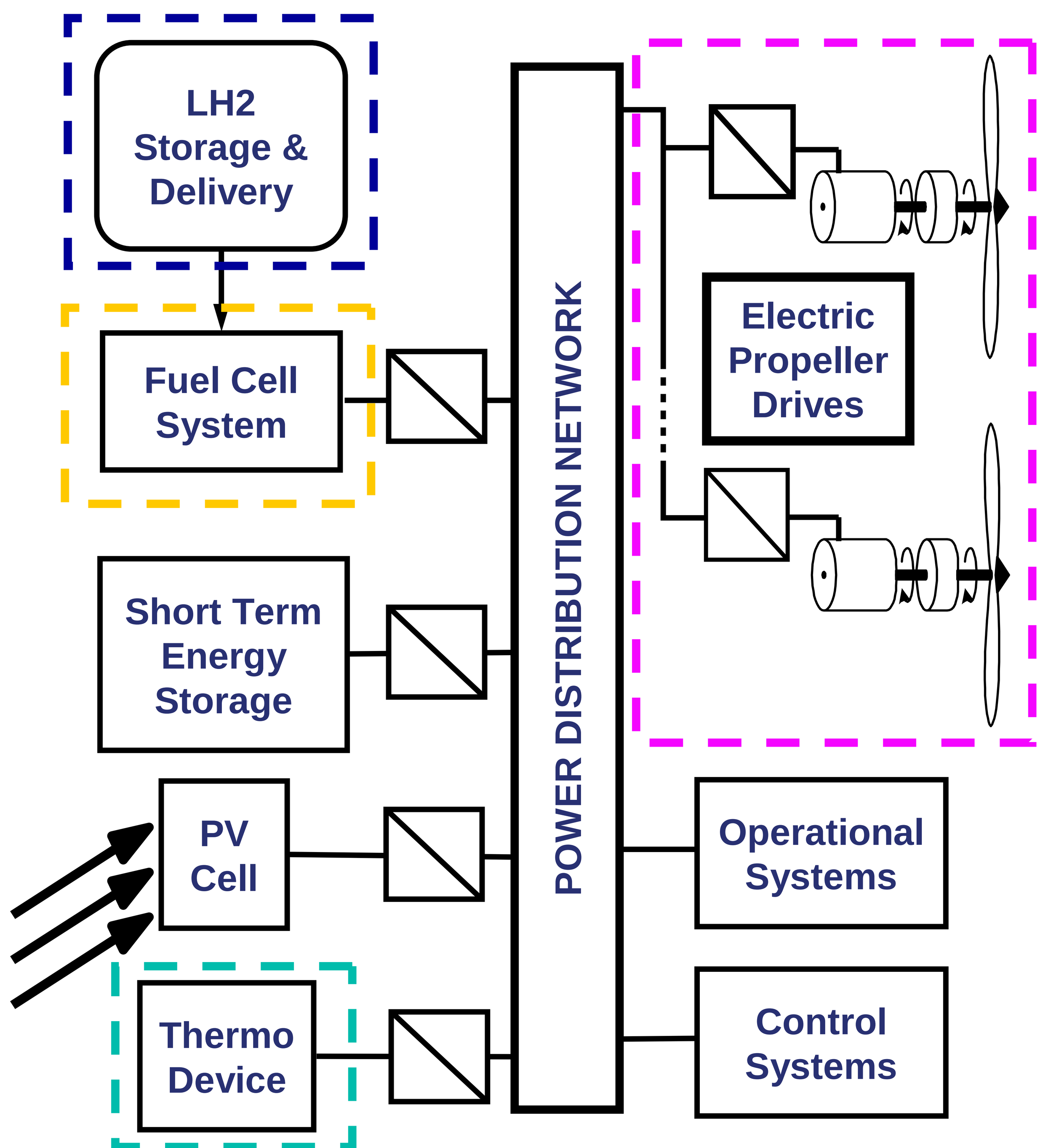
PPEM002 investigated a Photovoltaic (PV) system to enable an extension to endurance. A thin film PV wing surface was proposed that increased endurance by 10%.





Thin Film PV Array

PPEM014 will investigate a thermo-electric device that generates a voltage in two different semiconductors in the presence of a temperature difference via the Peltier-Seebeck effect. By using LH2 (at nominally 22K) a temperature difference to the ambient environment can be permanently achieved. PPEM014 will consider the potential benefits of employing thermo-electric devices.

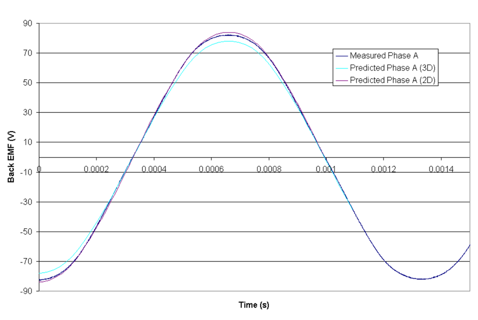


UAV Power System Architecture

NASA Helios

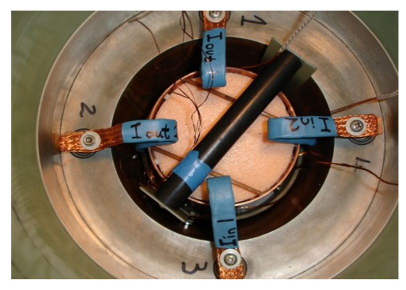
Electric Propeller Drives

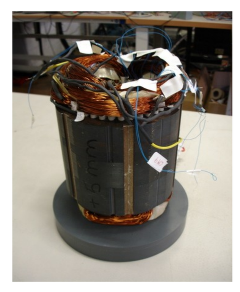
The University of Sheffield as part of PPEM 002 established a preferred configuration of eight propeller drives (nominally 15kW) with high speed, air cooled, permanent magnet electrical machines using a single stage gearbox. A machine was designed, built and tested against this criterion.



Prototype Machine

PPEM014 will consider the use of fuel cooling. This will enable the adoption of more torque dense and efficient motor designs and the consideration of superconducting options. This work will be undertaken by the university of Manchester.





Low Temperature Tests

The University of Sheffield will complete the baseline HALE electrical study by undertaking the detailed design of an air-cooled converter using state-of-the-art devices. The University of Manchester will consider the use of fuel-cooled converters potentially enabling the use of high efficiency cryogenically cooled power electronic devices. A detailed design study will be undertaken.

LH2 Storage & Delivery

Research will initially focus on LH2 storage and thence consider LH2 delivery around the UAV. PPEM002 work has already demonstrated that the thermal insulation requirements to prevent the risk of icing inhibit sufficient boil-off gas from being created. Thus for the baseline air-cooled solution pre-heating systems are required. By distributing the LH2 it is hoped that improvements in reliability and a reduction in pre-heating requirements can be achieved.

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