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Title

Modelling of the cathode air supply for a pressurized hydrogen fuel cell system in airborne applications

Authors

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Abstract

The use of hydrogen for propulsion in aircrafts promises to reduce the climate impact by up to 90% [1] and is seen as a suitable aviation fuel for short and intermediate distances [2]. Using PEM fuel cells in hybrid-electric planes has attracted much attention in the last years [3,4], however, in order to obtain high power and efficiency while operating PEM fuel cells at high altitudes, pressurizing the cathode inlet air is necessary.

In previously presented work, a cathode air supply system was designed and tested. It consists of an electrically driven centrifugal compressor, a temperature management unit, a humidification unit and a throttle valve at the outlet. The automatic control utilizes a decentralized control strategy with pilot control for cathode pressure and mass flow regulation, manipulating compressor speed and control valve opening. The functionality of the system was demonstrated, stable and unstable modes of operation in steady state and transient operation were identified, but the transient behavior could not be predicted [5].

Consequently, a transient model of the cathode air supply system was developed. As a basis, a model of a compressor-volume-throttle system with spool dynamics is utilized [6,7]. This model type consists of three differential equations and is able predict mass flow and system pressure. Temperature and relative humidity are added in an additional step.

Identifying the appropriate set of parameter values in the model is necessary to quantitively predict the transient behavior of the real system, for the specific hardware chosen. The parameters of the model were identified from hardware measurements.

The manipulated parameters in the model are the compressor drive torque τ_t and throttle gain k_t. In the real system these parameters cannot be controlled directly. τ_t is subject to the motor-inverter-unit of the compression system and its internal control law. k_t is a function of the valve opening angle and the differential pressure over the valve. For both motor-inverter-unit and throttle valve, transfer functions need to be identified and implemented into the model.

The model is being validated at on-ground and in-flight ambient conditions. It can be used in the development of an automatic control system, and is low in computational effort.

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