Modeling and Simulation of a Fault-Tolerant Electromechanical Actuation System for Helicopter Swashplates in Modelica

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A general trend in aviation is to replace hydraulic subsystems like primary flight control actuators by electromechanical devices. However, substituting a hydraulic actuator by an electromechanical actuator (EMA) has the disadvantage of reduced component reliability. This accompanies two major challenges. First, in order to meet aircraft safety regulations higher degrees of redundancy are needed for the utilization of EMAs. Moreover, in the case a redundant actuator jams mechanically, it must be disconnected from the swashplate to maintain controllability of the remaining actuators and the ability to position the entire swashplate.

The system under investigation is therefore specified to provide fail-operative behavior for major mechanical failures and dual-fail-operative behavior for combinations of any other failures. This requires certain degrees of redundancy of all system parts and meaningful mapping of the components in order to allow for failures while maintaining function and performance. A special control approach is applied to cope with the redundant actuators. Furthermore, suitable means for failure detection, failure isolation and system reconfiguration are needed.

In specific failure cases the system must be reconfigured in order to maintain the specified performance level to meet aircraft safety regulations. The assessment of the system's reaction upon such kind of scenarios is however a complicated task and must be supported by modeling and simulation.

Therefore, modeling and simulation of such a fault-tolerant electromechanical system in Modelica is described in this paper. The most relevant Modelica features regarding the introduced system are discussed, such as base classes, inheritance, and parameterization. Finally, sample simulation results are shown and discussed.