Abstract

This thesis presents the development of a medium-scale, single-rotor rotorcraft unmanned aerial vehicles (RUAVs) nonlinear dynamic model to be used for model-based design of fault-tolerant control. This model includes the swashplate actuator dynamics and the engine propulsion model. Most rotorcraft controller design treat these two system components as linear first-order systems. The inclusion of actuator dynamics allows us to simulate the actuator faults with increased fidelity, which enables the development of robust integrated flight-propulsion controllers (IFPCs) that are seamlessly transferable to the true platform. IFPC is proposed for the RUAV in order to handle the deliberate variations in rotor speed and for its exploitation as a redundant thrust control input in the case of a single swashplate actuator fault. The presented RUAV model is first controlled by using proportional-integral-derivative (PID) controllers in six degrees-of-freedom (DOF). To obtain the best controller gains, computational intelligent optimisation techniques are used, these are: (i) ant-based: ant colony and antlion optimisation algorithms; (ii) flight-based: cuckoo search and firefly optimisation algorithms; and these are compared to (iii) particle swarm optimisation and genetic algorithm. The performance of the PID controllers are used for benchmarking the rest of the control strategies investigated. For fault tolerance, we present the passive fault-tolerant control (PFTC) based on sliding mode controller (SMC). Conventional SMC and super-twisting SMC are compared in terms of robustness to handle loss-of-effectiveness (LOE) faults in one of the three swashplate actuators and the deviation of the rotor speed from nominal. These controllers are also optimised using the same computational intelligent algorithms as in the PID case. The SMC-based controllers proved robust to actuator LOE faults. However, they fail to recover the rotorcraft from total actuator failure. For this problem, an active fault-tolerant control (AFTC) scheme based on dynamic neural networks (DNN) is employed. RUAV system identification using DNN is combined with feedback linearisation (FBL). Multi-objective optimisation algorithms are used to find the controller and FBL gains. DNN is also used for fault detection and diagnosis (FDD) for the AFTC. This applied indirect DNNFBL control strategy proved to be more suitable for IFPC and was able to recover from severe actuator faults and rejected rotor speed variations. The effectiveness of the proposed control strategies is evaluated in hardware-in-the-loop simulations (HILS) using an experimental swashplate rig of three electromechanical actuators. The experimental results validated the developed and simulated control strategies.