Towards Robust Automatic Operation of Rigid Wing Kite Power Systems

Sebastian Rapp, Roland Schmehl
Delft University of Technology

A key enabler of success in the field of airborne wind energy (AWE) is the ability to operate the AWE system in a reliable manner throughout every phase of flight. In this contribution a modular path following flight control architecture will be presented that allows to control a rigid wing AWE system during all phases of the flight, including vertical takeoff, power generation and vertical landing. It is a first step towards a flight control architecture with increased reliability and robustness in nominal as well as in adverse conditions compared to existing approaches.

The cascaded control structure consists of two separate outer loop controllers connected with a switching logic which is controlled by a high-level state machine. The flight path controller for vertical takeoff and landing (VTOL) guides the system along a predefined flight path up to the operational altitude or lands the system. To guide the kite along the path during VTOL mode common thrust vectoring is used. For improved control effectiveness the control surfaces of the wing are used along with the thrusters using a pseudo-inverse control allocation method to generate the required moments. This allows to exploit the complementary control effectiveness of thrusters as well as control surfaces with respect to the current flight condition.

For the power generation mode the second outer loop controller is activated. A novel path following controller for AWE systems has been developed that can be applied to soft was well as rigid wing kites. Different flight patterns can be generated consisting of circle and great circle segments. This allows to solve the path following control problem on a sphere similarly to straight line and orbit following control problems of untethered aerial vehicles. Since during power generation mode the thrusters are not in operation, only the lift vector is controlled using the orientation of the kite with respect to a tether reference frame. This allows to generate the required centripetal force to guide the kite along the curved paths on the tangential plane. In this way the model dependency of the controller is reduced to a minimum, while at the same time the control method is intuitive from a flight physical point of view. To enhance the disturbance compensation capabilities the baseline controller is enhanced with an adaptive part, which allows to recover a defined reference behavior in case of large disturbances or failures.

So far simulation results using a generic rigid wing kite model demonstrate the feasibility of the proposed control approach. Due to the modularity of the control architecture, the low computational demand and the reduced model dependency the proposed flight control architecture can be easily tested on different platforms in the future.