Model-Based Development and Verification of Ampyx Power's Airborne Wind Energy System

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The systematic processes used by Ampyx Power to evaluate conceptual design choices, perform detailed algorithmic design, and conduct simulated-based verification during the development of its Airborne Wind Energy system are presented. Ampyx Power is currently simultaneously working on different parts of the development cycle for a rigid wind AWES: 1) Flight test and evaluation of a small-scale prototype (AP-2), 2) Detailed design and manufacture of a medium-scale prototype (AP-3), and 3) Conceptual design of a large-scale commercial prototype (AP-4). Each of these phases requires a different approach so as to properly balance process rigour taking into account efficiency, accuracy of output, and risk.

A detailed description of the methods and lessons learned used by Ampyx Power during the development of its AWES are presented. The main development framework utilises MATLAB/Simulink with a set of customised tools developed specifically for AWES. The approaches used by Ampyx Power are presented together with representative examples of the output of the processes for the AP-2, AP-3 and AP-4 projects. For context, the aviation-industry design guidelines SAE ARP 4754A for complex systems, and DO-178C/DO-331 for software incorporating model-based design elements are used to provide a methodological approach to design and development, with the ultimate aim to deliver a certifiable product that meets stringent safety standards. Ampyx Power believes that this currently provides the best context for development of AWES, with some specific tailoring, so as to meet the high reliability and safety requirements that a commercial AWES should be capable of meeting.

Ampyx Power employs physics-based modelling of the rigid-wing aircraft, with a major focus on the aerodynamic and actuator modelling, which drive the stability and control performance of the system. Combinations of CFD, nonlinear lifting line, and a vortex-lattice method are used to derive the static and dynamic aerodynamic coefficients for the bare airframe. Detailed models of the electromechanical actuators, characterised by extensive experimental testing, are employed. In-house sensor characterisation is performed to derive models for all sensor components. The control systems for the on-ground and in-air computers are implemented as design models and incorporated into the simulation test harness that simulates the complete airborne wind energy system. The design models are converted into embedded C code via Simulink Embedded Coder. The algorithms and ultimately the generated source code are verified by a three-tier testing strategy: 1) Functional, robustness, and requirements-based testing of the design models against requirements, 2) host-based source-code tests against the design models, and 3) Hardware-in-the-loop tests of the integrated software on the target processor.