FAST, EXACT FULLY COUPLED ODE SYSTEMS IN TIME INTEGRATION SCHEMES

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ABSTRACT

During the last few decades engineers have been designing wind turbines of increasing size seeking lower values of cost of energy (CoE). A great amount of research has been done recently seeking alleviation of aerodynamic loads on the rotor and support structure and thus reducing material costs and CoE. At the same time, Finite Element Method (FEM) tools have been introduced more and more as part of the design process for structures, drive system and mechanisms of these machines. Coupling FE models with in-house modelling tools is a powerful means to enhance designs despite risking computation trouble. The present work explains a computation method to couple ODE systems to time integration schemes with the aim to run fully coupled simulations.

The method is applied to a comprehensive rotor aerodynamic model, including inflow and loads unsteadiness and dynamic stall, to a finite element based Multibody model of a wind turbine. All these unsteady aerodynamic phenomena behave ultimately as a set of interacting dynamic systems and are included in a proprietary in-house model of rotor aerodynamics.

The methodology presented here is based on an exact closed form solution of an Ordinary Differential Equation (ODE) system with a linear-with-time source term and it aims to provide a robust and systematic way to couple in-house models in discretized time integration schemes. The presented method minimises computation trouble avoiding nested iterative procedures while getting exact results and therefore resulting in limited CPU-time and unharmed numerical behaviour.

A fully alternative formulation is given for a Pitt-Peters aerodynamic inflow model by applying the exact solution of an ODE to the three states' system symbolically diagonalised beforehand into three independent equations. Results show machine error accuracy for systems with up to 10Hz bandwidth integrated with time-steps 100Hz.

The method is validated in simple ODE cases and is finally used to build an holistic aeroelastic model of a wind turbine with a view to compute loads, however it seems promising for real-time requirement computations such as simulators and for any in-house model coupling of multiphysics' problems in time integration schemes.

The method is recently published by the author in the article ‘Exact method for coupled non-linear state-space simulation and its application to a flexible multibody wind turbine aeroelastic code’ at the ASD Journal.