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Wind turbine simulations using Xcompact3D toward exascale computing

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The wind farm simulation capabilities Xcompact3D [1] have been applied for wind turbine simulations employing the actuator line model (ALM). Xcompact3D is based on higher-order compact finite-difference discretization schemes and uses an efficient 2D domain decomposition algorithm that allows the code to scale up to O(10^5) computational cores, an important characteristic for the upcoming exascale computing systems. The ALM of Xcompact3D has gone through a rigorous verification and validation procedure [2].

While studying the efficiency and the scalability of Xcompact3D, the most prominent factor limiting the efficiency was found to be not the underlying fluid dynamics solver but instead the turbine modelling used to represent the wind turbines. In the ALM, the turbine forces are added as a body force in the momentum equations, relying on the local determination of the lift and drag forces on some locations along the blade followed by force projection method to project the forces on the grid.

The efficiency of the parallel execution of Xcompact3D has been accessed using the Hawk supercomputer, the flagship system of the High-Performance Computing Center Stuttgart (HLRS) at the University of Stuttgart (USTUTT). Hawk is a HPE Apollo system with 5632 compute nodes, each one with dual AMD EPYC Rome 7742 processors (128 cores/node). A scalable LES simulation based on the NREL 5 MW wind turbine was used as test case.

The results show that the computational overhead of the ALM becomes a significant bottleneck when the simulations are performed on many processors, counting for up to 40% of the computational time. Different strategies have been used to alleviated this overhead, in order to make larger wind turbine and wind farm simulations more efficient in the upcoming exascale machines.

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