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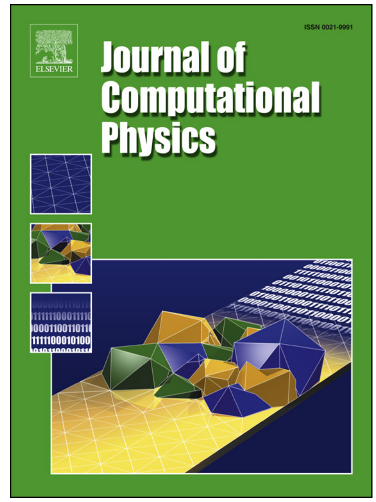


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# A Parabolic Velocity-Decomposition Method for Wind Turbines

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**An economical parabolized Navier-Stokes approximation for steady incompressible flow is combined with a compatible wind turbine model to simulate wind turbine flows, both upstream of the turbine and in downstream wake regions. The inviscid parabolizing approximation is based on a Helmholtz decomposition of the secondary velocity vector and physical order-of-magnitude estimates, rather than an axial pressure gradient approximation. The wind turbine is modeled by distributed source-term forces incorporating time-averaged aerodynamic forces generated by a blade-element momentum turbine model. A solution algorithm is given whose dependent variables are streamwise velocity, streamwise vorticity, and pressure, with secondary velocity determined by two-dimensional scalar and vector potentials. In addition to laminar and turbulent boundary-layer test cases, solutions for a streamwise vortex convection test problem are assessed by mesh refinement and comparison with Navier-Stokes solutions using the same grid. Computed results for a single turbine and a three-turbine array are presented using the NREL offshore 5-MW baseline wind turbine. These are also compared with an unsteady Reynolds-averaged Navier-Stokes solution computed with full rotor resolution. On balance, the agreement in turbine wake predictions for these test cases is very encouraging given the substantial differences in physical modeling fidelity and computer resources required.**

## Nomenclature

| | | |
|---|---|---|
| *PNS* | = | Parabolized Navier-Stokes |
| *AL* | = | Actuator Line |
| *L* | = | Reference length, length scale in the *x*-direction |
| *D* | = | Turbine diameter |
| *u* | = | *x*-direction velocity |
| $\nu$ | = | Kinematic viscosity |
| $\rho$ | = | Reference density |
| *Re* | = | Reynolds number, $uL/\nu$ |
| *p* | = | Pressure |
| *v*, *w* | = | Velocities in *y* and *z* directions (transverse plane) |
| $\epsilon$ | = | Projection width, distance over which forces are distributed |
| $\vec{b}$ | = | Body force per unit volume: $b_x\hat{i}+b_y\hat{j}+b_z\hat{k}$ |
| *h* | = | Distance between boundary node and first point off the boundary |

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