

Wind Energy Research

Faculty: Ganesh Rajagopalan Aerospace Engineering, Iowa State University
 Research Partners: DOE, SANDIA, NREL, DNR, IEC, Sukra Helitek, Inc.
 Goal: Numerical modeling wind energy potential analysis and optimization

Blade Modeling

Reynolds-averaged Navier-Stokes equations:

Continuity

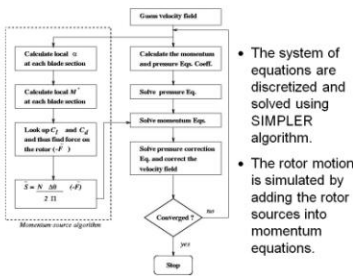
$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{u}) = 0$$

Momentum

$$\frac{\partial (\rho u_i)}{\partial t} + \nabla \cdot (\rho \vec{u} u_i - \mu \nabla u_i) = -\frac{\partial p}{\partial x_i} + V_i + S_i$$

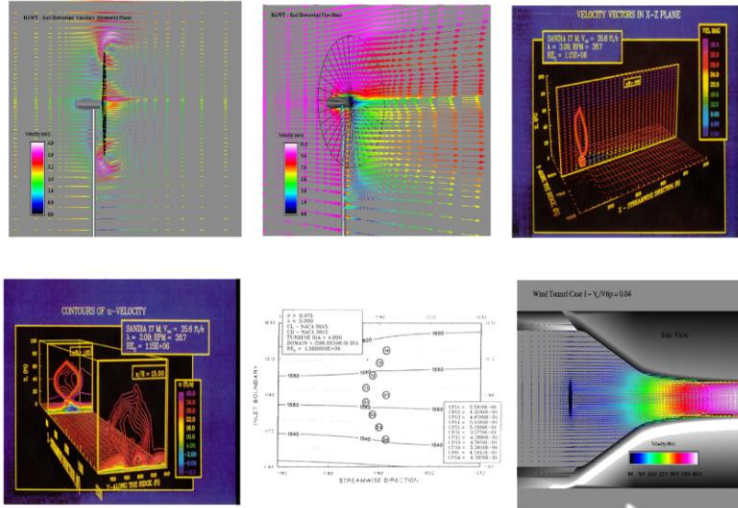
Rotor Source

$$S_i = S_i^r(C_r, C_d, \alpha, \vec{V}_{tip}, \theta, x, y, z, t, c, \rho, B)$$

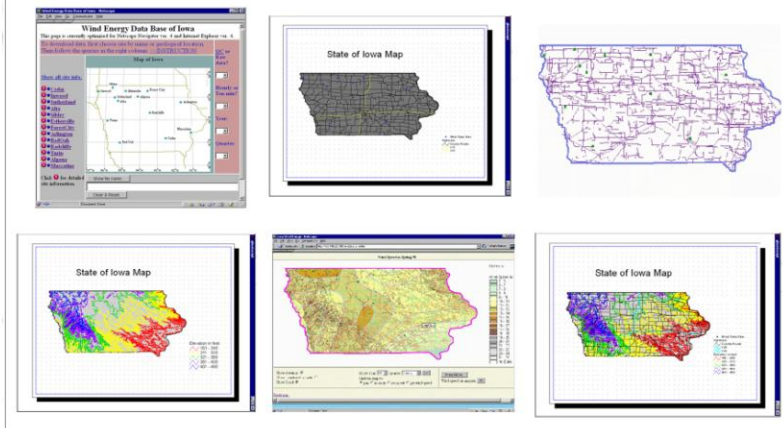


- The system of equations are discretized and solved using SIMPLER algorithm.
- The rotor motion is simulated by adding the rotor sources into momentum equations.

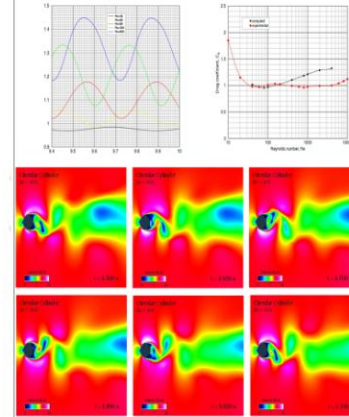
HAWT, VAWT, Simulation and Optimization



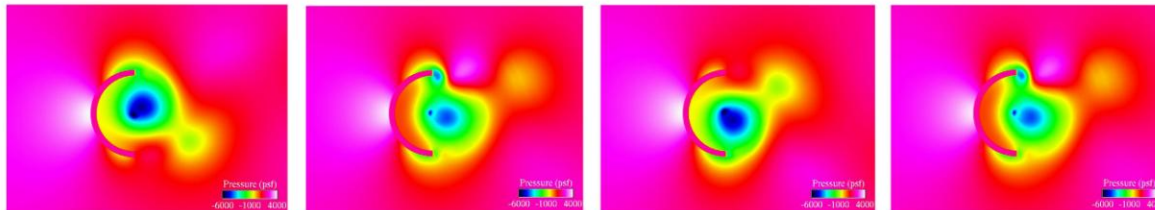
Energy Potential Of Iowa and Project Planning



Tower Shadow



Unsteady Flow Over a Cup Anemometer



Further Reading

Rajagopalan, R. G., Berg, D. E., Klimas, P. C., "Development of a Three-Dimensional Model for the Darrieus Rotor and Its Wake," *Journal of Propulsion and Power*, Vol. 11, No. 2, March-April, 1995.
 Rajagopalan, R. G., Fanucci, J. B., "Finite Difference Model for Vertical Axis Wind Turbines," *Journal of Propulsion and Power*, Vol. 1, No. 6, November-December, 1985
 Govindaraju, S. P., Rajagopalan, R. G., "Prospects of Improving Wind Pump Performance by Load Matching," Proceedings, Paper 85, National Energy Convention, India, 1979

R. GANESH RAJAGOPALAN

Professor of Aerospace Engineering, Dr. R. Ganesh Rajagopalan, is a member of the computational Fluid Dynamics Center at Iowa State University, and leader of the wind energy research group in the College of Engineering.

Actively involved in research since 1976, Dr. Rajagopalan has researched many aspects of wind energy such as rotor aerodynamics and wind energy conversion systems. His research has been supported by DOE through its national labs, SANDIA and NREL as well as by local agencies such as Iowa DNR and IEC. Working with the government and wind turbine industries, Dr. Rajagopalan successfully stimulated the aerodynamic influence of terrain and other turbines.

Prior to coming to the United States, Dr. Rajagopalan worked as a scientist for the Wind Energy Group of National Aeronautical Laboratory, in Bangalore, India. While there, he successfully investigated the performance of sail-type, horizontal-axis wind mills and developed numerical methods to design and optimize horizontal-axis wind turbines with blade pitch speed control.

At the present time, Dr. Rajagopalan is using CFD techniques to study the flow field and operational characteristics of rotating machines such as helicopter rotors, wind turbines, propellers, and ducted fans. His primary focus has been on developing computationally efficient methodology for rotor research. This methodology can be used for day-to-day design-related optimization as well as for advanced research topics such as computational simulation and optimization of wind power parks.

WIND ENERGY PUBLICATIONS

Rajagopalan, R. G., Berg, D. E., Klimas, P. C., "Development of a Three-Dimensional Model for the Darrieus Rotor and Its Wake," Journal of Propulsion and Power, Vol. 11, No. 2, March-April, 1995.

Rajagopalan, R. G., Rickerl, T. L., Klimas, P. C., "Aerodynamic Interference of Vertical Axis Wind Turbines," Journal of Propulsion and Power, Vol. 6, No. 5, September-October, 1990.

Allet, A., Lamarche, L., Paraschivoiu, T., and Rajagopalan, R. G., "A Quasi 3-D Viscous Aerodynamic Model for the Vertical-Axis Wind Turbine," Preprint, European Community Wind Energy Conference and Exhibition, Herring Congress Centre, Denmark, June 6-10, 1988.

Rajagopalan, R. G., Masson, C., Paraschivoiu, I., "Comparisons of Two Numerical Methods for Studying the Aerodynamic Characteristics of the VAWT," Numerical Methods in Laminar and Turbulent Flow, 5:1725-1738, C. Taylor, W. G. Habashi, and M. M. Hafez, Editors, Pineridge Press, 1987.

Rajagopalan, R. G., Fanucci, J. B., "Finite Difference Model for Vertical Axis Wind Turbines," Journal of Propulsion and Power, Vol. 1, No. 6, November-December, 1985.

Rajagopalan, R.G., "Inviscid Upwind Finite Difference Model for Two-Dimensional Vertical Axis Wind Turbines," Ph.D. Dissertation. West Virginia University, Morgantown, West Virginia, 1984.

Govindaraju, S. P., Rajagopalan, R. G., "Prospects of Improving Wind Pump Performance by Load Matching," Proceedings, Paper 85, National Energy Convention, India, 1979.

Rajagopalan, R.G., "Energy Potential of Wind," MS Thesis, Indian Institute of Science, Bangalore, India, 1978.