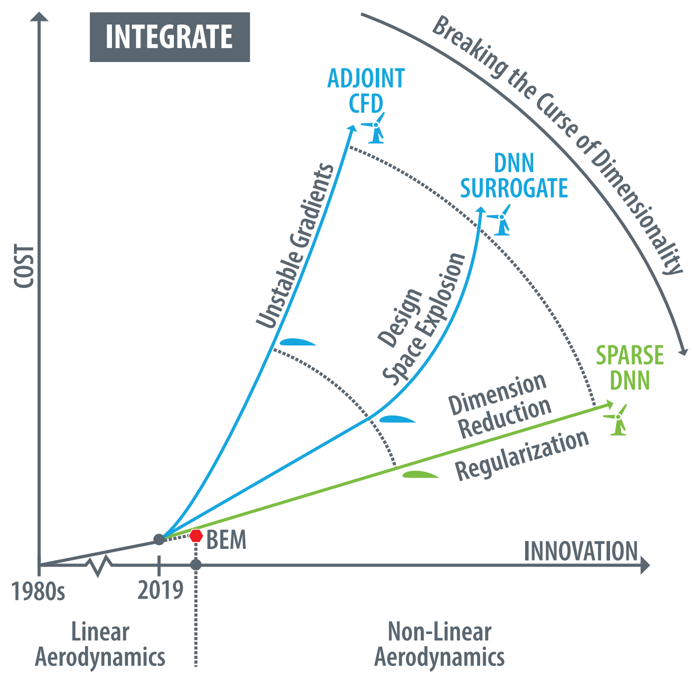
Enabling Innovation in Wind Turbine Design Using Artificial Intelligence

The Inverse Network Transformations for Efficient Generation of Robust Airfoil and Turbine Enhancements (INTEGRATE) project is developing a new inverse-design capability for wind turbine rotors using invertible neural networks. This artificial intelligence (AI)-based technology can capture complex nonlinear aerodynamic effects 100 times faster than alternative design approaches.



Innovation potential versus cost for competing technology pathways. Illustration by Brittany Conrad, NREL.

Next-Generation Aerodynamic Tools

The National Renewable Energy Laboratory (NREL), in partnership with the University of Maryland, is developing the next generation of aerodynamic tools for 2D airfoil and 3D wind turbine blade design.

Researchers are leveraging a specialized invertible neural network (INN) architecture that learns complex relationships between airfoil or blade shapes and their associated aerodynamic and structural properties.

This INN architecture will accelerate designs by providing a cost-effective alternative to current industrial aerodynamic design processes, including:

- Blade element momentum (BEM) theory models: limited effectiveness for design of offshore rotors with large, flexible blades where nonlinear aerodynamic effects dominate
- Direct design using computational fluid dynamics (CFD): cost-prohibitive
- Inverse-design models based on deep neural networks (DNNs): attractive alternative to CFD for 2D design problems, but quickly overwhelmed by the increased number of design variables in 3D problems

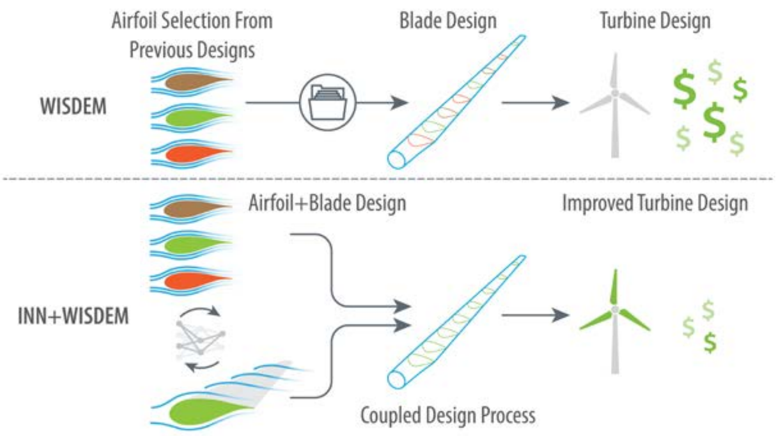
The Approach

INTEGRATE's specialized INN architecture—along with the novel dimension-reduction methods and airfoil/blade shape representations developed by collaborators at the National Institute of Standards and Technology (NIST)—learns complex relationships between airfoil or blade shapes and their associated aerodynamic and structural properties. The INN is trained on data obtained using the University of Maryland's Mercury Framework, which has with robust automated mesh generation capabilities and advanced turbulence and transition models validated for wind energy applications.

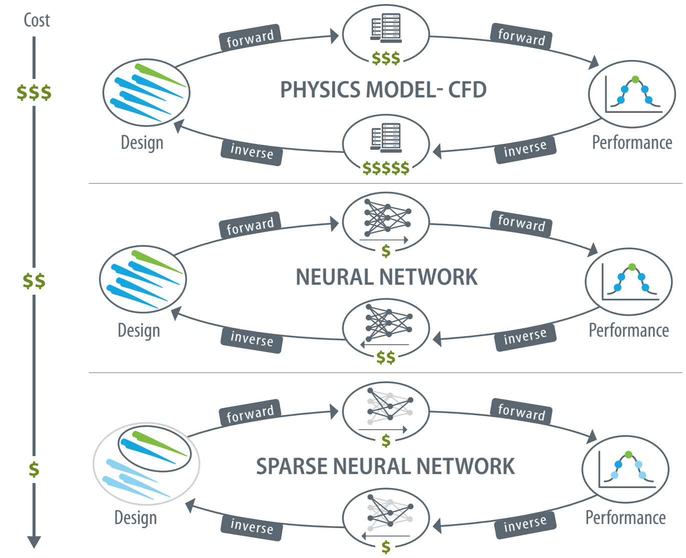
Technology Transfer Demonstration: INN-Airfoil + WISDEM®

As part of a technology transfer demonstration, researchers have integrated the inverse-design tool for 2D airfoils (INN-Airfoil) into the Wind-Plant Integrated System Design and Engineering Model (WISDEM), a multidisciplinary design and optimization framework for assessing the cost of energy. The traditional approach to wind turbine design involves creating a 3D blade from a preselected set of 2D airfoils. However, the multidisciplinary nature of design means that the most aerodynamically efficient airfoils may not be the best choice for all types of design constraints for wind turbines.

The integration of INN-Airfoil into WISDEM allows for the design of airfoils and blades that meet the dynamic design constraints of cost of energy, annual energy production, and capital costs. Through preliminary studies, researchers have shown that the coupled INN-Airfoil + WISDEM approach reduces the cost of energy by around 1% compared to the conventional design approach.



Coupled INN-Airfoil + WINDSEM approach.
Illustration by Besiki Kazaishvili, NREL.



Aerodynamic design of wind turbine rotors using inversion of deep neural networks. Illustration by Julia Laser, NREL.

Impacts

- Get new designs with desired performance on your laptop in under one second
- Accelerate time to market by improving early design iterations with more certainty
- Increase design space exploration for improved performance and robustness
- Capture complex nonlinear aerodynamics in design 100 times faster than comparable approaches
- Increase annual energy production by up to 6% compared to traditional design approaches.

Contact

Ganesh Vijayakumar
ganesh.vijayakumar@nrel.gov

Ryan King
ryan.king@nrel.gov

Read INTEGRATE publications:
https://openei.org/wiki/INTEGRATE

NREL Transforming ENERGY

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

NREL/FS-5000-82756 • May 2022