U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad (MIRACL) Research: *Controls*

The 4-year MIRACL project, which is funded by the U.S. Department of Energy's Wind Energy Technologies Office, aims to increase deployment of wind in distributed applications by advancing wind-hybrid distributed energy systems to provide flexibility, security, and resilience to distribution systems and microgrids. *Photo courtesy of David Nevala Photography for CROPP Cooperative*

Advanced Turbine Control for Distributed Wind Deployments

The Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad (MIRACL) research initiative is funded by the U.S. Department of Energy's Wind Energy Technologies Office and led by researchers at the National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (Sandia). The initiative's controls research seeks to expand the benefits from distributed wind energy assets beyond solely providing low-cost power directly to consumers. To make these turbines operate more effectively, there is a need for more advanced ways to control them—allowing power companies, businesses, and energy consumers to take advantage of some of the unique technical characteristics of wind energy.

Wind turbine controls operate the electrical and mechanical systems of a wind turbine, using a network of sensors connected to a central processing system. The sensors collect data about the conditions surrounding the turbine such as temperature, wind speed, and voltage on the electric grid. The central processing system receives the data, identifies what action should be taken based on predefined settings or algorithms, and sends signals to the turbine's mechanical and electrical systems to respond accordingly—such as changing the speed of the rotor or the power coming from the inverter.

The team uses advanced power system simulation laboratories and wind turbine validation facilities to research, develop, and demonstrate advanced control strategies for the distributed wind systems of the future. The advanced control systems developed through MIRACL will optimize existing wind turbine hardware to reduce downtime and increase overall power system stability in the absence of, or in support of, conventional generation sources.

Distributed Wind in Microgrids

A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect to and disconnect from the grid to enable it to operate in both grid-connected or island mode.

Wind turbines deployed in microgrids must, therefore, be able to operate in both grid-connected and islanded modes—which requires more complex turbine control systems and grid-integration processes. MIRACL control systems research focuses on reducing this complexity to improve turbine operation and enable easier integration with the microgrid and other sources of power generation.

Advanced Controls Focus Areas

Distributed wind systems cover a wide range of technology integration—from simple

MIRACL controls-specific research aims to develop and demonstrate the grid support functions of wind turbines in grid-connected and islanded microgrids as well as improve the control and communications compatibility of wind turbines with other distributed energy resources.

One key objective of MIRACL is to expand understanding and documentation of active control capabilities of different distributed wind technologies, which will help address wind integration challenges on weak and isolated energy networks.

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distributed wind deployments providing power (watts) and energy (watt-hours) to providing grid support through advanced controls and using the unique mechanical characteristics of a wind turbine connected through an inverter. To ensure that distributed wind systems operate effectively in these situations, MIRACL researchers will focus on three specific areas:

- Grid services from advanced controls in systems with high contributions of wind
- Turbine availability through fault-tolerant controllers
- Distributed wind grid integration and wind-hybrid integration.

Grid Services Controls

Many distributed wind turbines were originally deployed to solely provide energy (watt-hours) to their connected distribution systems. As contributions from distributed energy resources increase, wind turbine support for grid stability increases in importance. As a generation source with unique characteristics employing mechanical and solid-state technologies, wind generation is well-positioned to provide these grid services to advance reliability and economics of the system.

Some of the major grid services to be investigated and demonstrated for distributed wind to provide to grid-connected, islanded, and isolated power systems are:

- Active and reactive power control
- Inertial response
- Primary and secondary frequency response
- Voltage support
- Black-start support.

Fault-Tolerant Controllers

In many wind turbine controllers, if a fault occurs or threat is detected in the turbine system, the turbine will shut down to protect itself. Although acceptable in transmission-scale wind deployments, this rapid shutdown could have a significant impact in many distributed wind applications because of the large contribution that the wind turbine plays in overall system stability. NREL and Sandia are investigating other control methodologies that could result in power reduction instead of total system shutdown for certain turbine system faults.

Distributed Wind Integration

Research is underway to improve how wind turbines integrate with distribution grids and how they can become more plug-and-play with other generation sources and energy storage.

The major wind integration functions to be investigated and demonstrated for distributed wind to provide to grid-connected, islanded, and isolated power systems are:

- AC and DC-coupled wind-storage systems
- AC and DC-coupled hybrid wind-solar photovoltaic systems
- Load management. ■

MIRACL controls-specific research is led by NREL and Sandia with funding from the DOE Office of Energy Efficiency and Renewable Energy's Wind Energy Technologies Office. For more information, visit: nrel.gov/wind/miracl.html

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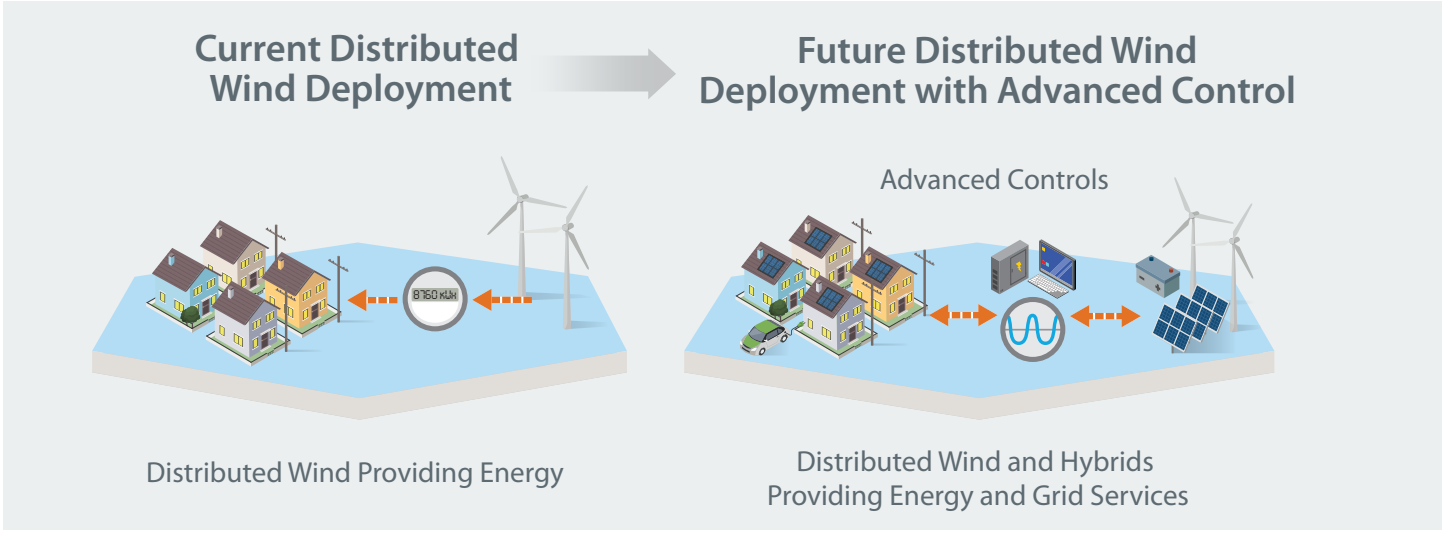

Traditional distributed wind deployments, shown on the left, supply energy in kilowatt-hours to distribution systems such as homes and businesses. The graphic on the right illustrates how MIRACL research will demonstrate advanced wind turbine controls that benefit distribution grids of the future. The sine wave in the center represents how wind, using advanced controls (such as inverters and human-machine interfaces), can support grid frequency for distribution systems. *Illustration by Fred Zietz, NREL*

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