NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Virtual Oscillator Control Maintains Grid Operations with High Inverter Penetrations

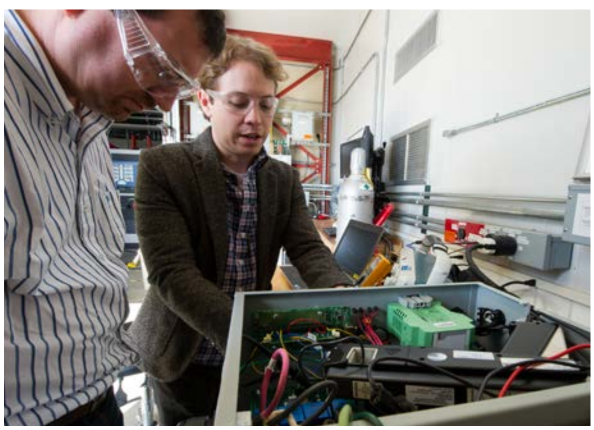
Highlights in Research & Development

A new control strategy helps the grid run normally with lower percentages of spinning, synchronized power sources.

Today's power grids rely on massive generators rotating at the right speed to produce power at a certain frequency—60 cycles per second in the United States. These generators give the entire power grid inertia, enabling it to absorb disturbances with minimal deviations in frequency. Under such high-inertia grid conditions, inverters are designed to lock onto the grid's frequency and follow it.

However, as the world shifts to more inverter-based, distributed energy sources, the grid could lack mechanical inertia, and stability of such a vast number of inverters is uncertain. To address this issue, NREL, the University of Minnesota, and the University of California Santa Barbara are examining virtual oscillator control (VOC) as a new strategy for inverters to help ensure stability of the grid.

VOC leverages the tendency of coupled oscillators to oscillate in unison. Inverters electrically coupled this way would tend to converge to the same frequency, resulting in a stable grid. Any change in voltage or frequency will induce an inverter response that maintains them within the nominal range. VOC also offers faster response times, because the inverter controls are streamlined.



NREL engineers Nathan Ainsworth (left) and Brian Johnson work on an NREL-designed, custom inverter. Photo by Dennis Schroeder, NREL/31589

NREL has demonstrated VOC on a small microgrid, but to make sure VOC would function correctly across large-scale grids, NREL has developed a comprehensive modeling framework and is preparing a larger-scale experiment that will couple five custom-built residential-scale inverters and loads with a larger simulated grid. The power-hardware-in-the-loop capability at the U.S. Department of Energy's Energy Systems Integration Facility on NREL's campus will be used to allow the inverters and loads to interact with the emulated grid and additional emulated inverters, creating a wide range of test scenarios from which to examine grid stability.

Technical Contact: Brian Johnson, Brian.Johnson@nrel.gov

References: Brian B. Johnson, Sairaj V. Dhople, Abdullah O. Hamadeh, and Philip T. Krein, "Synchronization of Parallel Single-Phase Inverters with Virtual Oscillator Control," *IEEE Transactions on Power Electronics* 29, no. 11 (2014): 6124–6138.

Brian B. Johnson, Mohit Sinha, Nathan G. Ainsworth, Florian Dörfler, and Sairaj V. Dhople, "Synthesizing Virtual Oscillators to Control Islanded Inverters," *IEEE Transactions on Power Electronics* 31, no. 8 (2016): 6002–6015.

Key Research Results

Achievement

VOC makes each inverter behave electronically like a spring, "bouncing back" to its normal operating range when disturbed. Coupling these inverters electrically could result in a new way to stabilize power grids.

Key Result

VOC has been demonstrated in a microgrid using several small inverters. In addition, five custom-designed inverters have been built and will be tested with grid simulations at NREL using power hardware-in-the-loop technology.

Potential Impact

VOC may provide a simple method to keep microgrids stable—a topic of growing interest as resilience to energy disruptions gains prominence. VOC may also provide a means to transition power grids from today's inertia-dominated systems to systems that do not rely on rotating machinery.

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.

15013 Denver West Parkway
Golden, CO 80401
303-275-3000 | www.nrel.gov

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