Droop control inverter

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The example illustrate the operation of an inverter-based microgrid disconnected from the main grid (islanded mode), using the droop control technique. The U.S. Department of Energy defines a microgrid as a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously.

Droop control is a well-established technique to control an autonomous grid. In fact, the Active Power/ Frequency (P/F) and Reactive Power/Voltage (Q/V) droop control mimics the operation of synchronous generators in a transmission system. With the droop control technique, PLL are not required to achieve system-wide synchronization because all inverters reach the same frequency. In addition, power sharing among each inverter can be achieved since each inverter gives power in proportion to its capacity.

The microgrid consists of three parallel inverters subsystems, with power ratings of 500 kW, 300 kW and 200 kW respectively, connected to the PCC (Point-of-Common-Coupling) bus. A dynamic load model is used to dynamically change the microgrid total load. The Microgrid Supervisory Control system, when enabled, modifies the inverters P/F and Q/V droop set points in order to bring back the microgrid frequency and voltage at their nominal values (60 Hz and 600 Volts respectively).

Each inverter subsystem contains a three-phase two-level power converter, an LC filter, a 480/600V transformer as well as an ideal DC source to represent the DC link of a typical renewable energy generation system (such as PV array, wind turbine, battery energy storage system). Each subsystem also includes a control system and a PWM generator feeding the inverter.

Measurements: Based on the frequency value given by the Droop control, the measurement subsystem computes the active and reactive power generated by the inverter. It also computes the d-q components of the three-phase voltages and currents at the microgrid PCC bus.

Voltage Regulators: Reference voltage Vref given by the Droop Control is fed to the Voltage Regulators. The regulators process the measured d-q voltages and reference voltage Vref to generate the reference currents Id_ref and the Iq_ref.

Current Regulators: The Id_ref and the Iq_ref reference currents are fed to the Current Regulators. The regulators process the measured and reference currents to produce the required d-q voltages (VdVq_conv) for the inverter. Note that the regulators dynamics benefits from a feed-forward calculation.

At 1 s, the total microgrid load is increased from 450kW/100kvar to 850kW/200kvar. At 3 s, droop control is enabled on all inverters. We can see that the microgrid load is now shared equally among the three inverters. At 5 s, the supervisory control is enabled. The frequency is then being slowly increased to 60Hz and the line voltage to 600V.

To demonstrate the impact of the inverters PWM carrier's initial phase on the PCC bus voltage harmonic content, first open the FFT Analyzer App to perform an FFT analysis of the PCC phase A bus voltage.

In the App, set the Structure with time parameter to PCC, the Signal parameter to V_PCC, and the Dimension parameter to 1 to analyze the PCC phase A bus voltage. Set the Zoom on parameter to FFT window, the Start time parameter to 7.9, and the Max frequency parameter to 7000. Click Compute FFT. In the FFT plot, the maximum harmonic occurs around the switching frequency (2700 Hz) and is close to 2%.

Now, double-click on the Inverter 2 (300 kW) subsystem and change the Carrier initial phase parameter to -90 degrees. Rerun the simulation and again, perform an FFT analysis on the PCC phase A voltage. You should see that this new carrier phase setting significantly reduces the harmonic content around the switching frequency (2700 Hz). This is due to the fact that Inverter 1 carrier phase is set to +90, so switching harmonics are then partially canceled.

NREL report: Research Roadmap on Grid-Forming Inverters Yashen Lin, Joseph H. Eto, Brian B. Johnson, Jack D. Flicker, Robert H. Lasseter, Hugo N. Villegas Pico, Gab-Su Seo, Brian J. Pierre, and Abraham Ellis