Design and Implementation of Microgrid Lab-Scale Hardware/Software Demonstration

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Abstract

To facilitate education and research in smart grid control methods, hardware AC and DC MicroGrid demonstration units have been designed and constructed.

The AC demonstration system incorporates a variety of energy generation and storage devices, including wind, solar, compressed air energy storage, batteries, and simulated conventional generators, connected via purpose-built networked grid-tie inverters capable of adjusting power factor and sharing load. Modular loads, varying in magnitude, granularity, and load angle, are designed to represent residential, commercial, and industrial customers. A switched capacitor bank is provided for load angle correction. A table top electrical, sensing, and actuation infrastructure routes electrical power between sources and loads and I/O between the electrical infrastructure and the system's controllers. One of the system's four PLCs is devoted to scenario generation- controlling the simulated environment, including solar irradiance, wind speed, and simulating contingencies such as malfunctioning relays and ground faults.

A DC MicroGrid, which can operate in a standalone capacity or as a component of the AC system, has also been designed and constructed. The DC MicroGrid unit is a cabinet housing an electrical infrastructure, resistive loads, solar panels and illuminating lamps, and a battery bank. The electrical infrastructure includes expansion ports, allowing the unit to be used with additional loads or devices including the AC MicroGrid demonstrator.

A National Instruments data acquisition module is used for scenario generation. Both MicroGrid demonstrators will support the application of novel network-based distributed control methods including software agent-based supervisory control in conjunction with ladder-logic driven reactive control. A platform enabling the rapid transition between software models of the demonstrators and the hardware, without modification to the controller or control code, has been used to develop and validate control programs for the DC MicroGrid hardware.

This system is a great test-bed for research in the areas of smart grid, AC, DC, and hybrid microgrid, distributed generation, power systems stability, and agent based control. It is also intended as practical equipment for use by undergraduate students as part of laboratory courses in power systems and automation.

AC MicroGrid

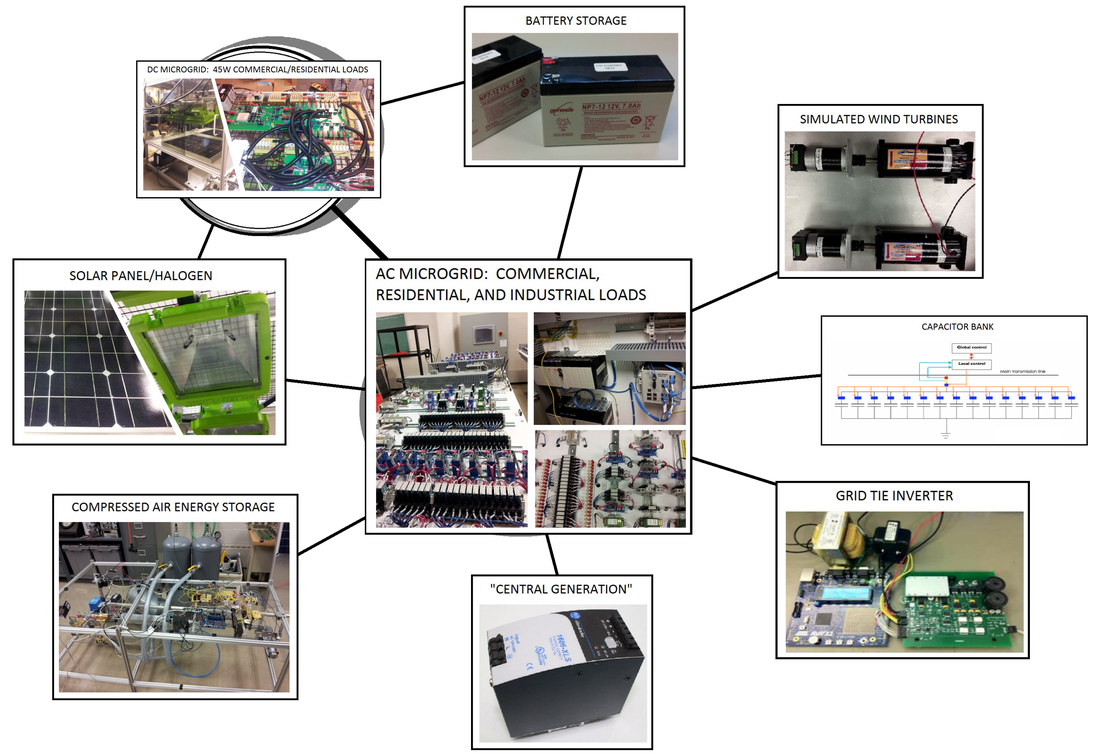
The AC MicroGrid is a network of resistive and inductive loads, power generation sources, and storage modules linked by a switchable, sensor-equipped distribution line carrying 60Hz 18VAC power. Energy sources interface using a custom-built grid-tie inverter.

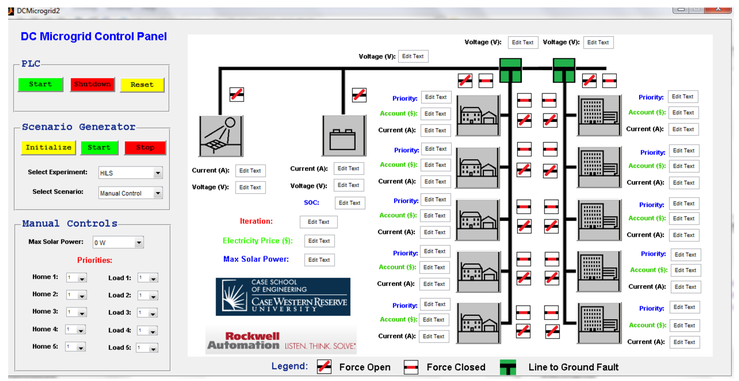
- Approximately 300W of Residential, Commercial, and Industrial loads
- Residential and Commercial Loads are purely resistive
- Industrial loads are represented by RL circuits
- Switched capacitor network for power factor correction
- Numerous attachment points for additional loads and sources.
- Distributed sensor network for control and data logging
- Separate control and scenario generation PLCS
- 3 control PLCs read sensor values and implement user's control strategy
- 1 scenario generation PLC simulates environment, creates contingencies
- Scenarios can be preprogrammed using a touch-screen interface
- Ethernet communication with subsystems
- ARM core processors expand control strategies beyond what is possible with ladder logic alone using software agents.

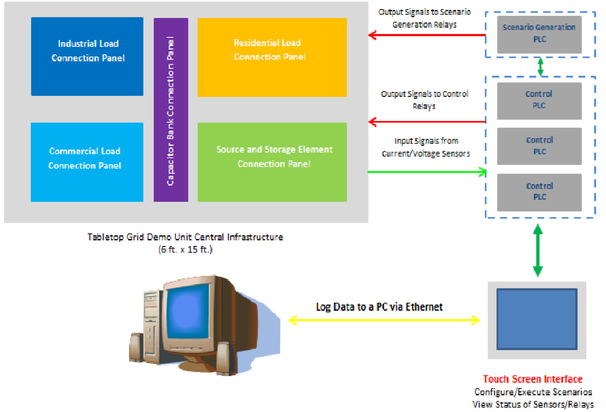
DC MicroGrid

The DC MicroGrid is a network of resistive loads, battery storage system, a solar generation system, and a switchable, sensor-equipped 12VDC distribution line mounted in a cabinet. Intended in part as a step toward learning to operate the AC MicroGrid, the DC MicroGrid will be capable of operating in a standalone configuration or in conjunction with the AC Microgrid.

- Approximately 45W of Residential and Commercial loads
- Solar panel can be exposed to varying levels of irradiance from 4 halogen lamps
- 7 Ah Lead-Acid battery storage system
- Expansion board for additional source connections
- Loads connected through adjustable 12V DC-DC converters
- 1 Control PLC reads sensor values, operates control and scenario generation relays
- Scenarios can be read from a spreadsheet or injected using the HMI (shown to the right)
- PLC chassis includes an ARM processor module for the implementation of agent-based distributed control







System Layout