Grid Security: Distributed Controls Test Bed

Research Capabilities and Facilities at the Distributed Energy Control and Communication (DECC) Lab

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ORNL DECC Lab Facilities

The DECC Lab over the last six years has become a test bed for testing high-penetration distributed energy resources (DERs) on an actual electrical distribution system which makes the DECC Lab unique. The DECC Lab is connected to the ORNL Campus distribution system via ORNL's 3000 substation and 2.4 kV/480V step-down transformers. The DECC Lab includes one 50 kW photovoltaic (PV) system, one 100 kW and one 30 kW microturbine, 250 to 20 kVA smart inverters with simulated PV generation, 300 kVA synchronous machine that can be operated as a conventional distributed generator (such as a diesel engine), and 24 kW energy storage system. The DECC Lab includes various types of loads including 1068 kVA of RL load banks, induction motor loads ranging from 7.5 hp to 75 hp, a 250 hp synchronous motor, 100 and 45 kW resistive load banks, and a 36 kW programmable RLC load bank which can be programmed for a year's worth of load settings. The DECC Lab has been enhanced to provide three voltage testing levels (480 V to 120 V) including three-phase and single-phase voltages, multiple distributed and renewable energy resources, multiple smart inverters, energy storage, and controllable motor and RL loads and ultimately will provide a demonstration and testing platform for the application of the state-of-the-art technologies in, and not limited to, DERs, power electronics, smart inverter control, relay protection, communications and distribution management systems that can advance the development of the smart grid, microgrid, and advanced distribution systems' operation. Figure 1 shows the DECC research and test platform for advanced distribution system operation. With the addition to be completed in FY13, it will be a reconfigurable test bed for testing and operating smart topologies in different system configuration, such as radial and loop and in different operating modes such as on-grid and islanding and transition between these modes of operation. Figure 2 shows some of the test systems in place at the DECC Lab.

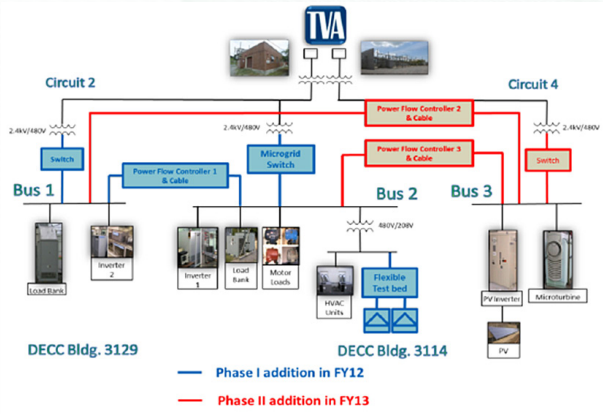
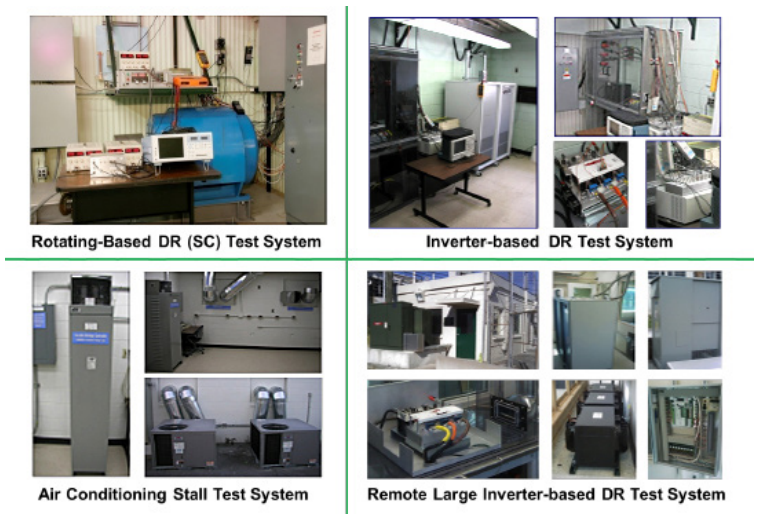


Figure 1. ORNL's DECC research and test platform for advanced distribution system operation.

Figure 2. DECC Lab test systems.



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The major accomplishments in the Power and Energy Systems Group at ORNL in the areas of smart inverter controls, voltage/var regulation, smart grid/microgrid design, control and protection are as follows.

- Adaptive proportional-integral (PI) inverter feedback controls for distributed energy resources have been developed and tested, including local voltage regulation, decoupled active power and reactive power (PQ), decoupled frequency and voltage control (f and V). The adaptive control is independent of the power system parameters (which are unavailable or inaccurate for most cases), improves steady-state stability, has faster transient response, and configures the PI gains in real time based on system operating conditions.
- Multiple inverter control and coordination has been developed including voltage control coordination of multiple inverters via a strategy that chooses the voltage reference for each inverter, and uses P-f and Q-V droop controls.
- Smart inverter controls for PV inverters have been developed including decoupled active power control and reactive power control of the PV inverter and maximum power point tracking and voltage/var control, which can be achieved simultaneously and independently.
- Smart inverter controls for microgrid operation have been developed including three inverter control modes, fixed PQ control, P-f and Q-V droop control, and closed-loop feedback frequency and voltage control methods for distributed energy resources to be able to operate in microgrids.
- Microgrid control, protection, and communications have been developed and simulated, including a complete microgrid central hierarchical control strategy. The control hierarchy will be implemented in the DECC test platform later this year. New protection schemes and adaptive control using communications have been developed and will also be tested in the coming fiscal year.

In the next two years, the DECC Lab will be established as a fully functional microgrid. The DECC Lab will provide testing of both on-grid and islanding operational modes, autonomous on-grid and islanding transition modes, and adaptive protection systems effective at all operational conditions. The microgrid will provide an optimal energy management system to improve system efficiency and maximize renewable energy production, energy storage utilization, and dynamic load control and demand response. The DECC Lab inverter testing is only limited by the number and capacities of the transformers currently in place at the Lab. The DECC Lab has the capability to expand to allow for the testing of much larger inverter systems and a greater penetration of inverter-based DERs.

Besides serving as the test bed for the research activities conducted by ORNL researchers, this flexible, reconfigurable platform is a unique test environment for both manufacturers and utilities. Experiments and testing at the DECC Lab can be carried out unDERs many conditions that are not possible for the power industry to test or conduct on their own power systems. The DECC Lab will provide a full range of operational conditions and different system configurations for this full range of testing and be able to provide extreme condition testing such as faults, different types of controllable and programmable loads, and plug-and-play control and communications. Following are some examples of the testing that can be carried out at the DECC Lab.

- Benchmarking and testing of power system components, such as, but not limited to, distributed energy resources and their interfaces, energy storage, protection relays, plug-in electric vehicles, demand/frequency responsive loads, smart meters, PMUs, etc.
- Testing and assessment of distribution systems, substations, smart grids, microgrids and/or inverter controller and energy management systems.
- Testing and assessment or power system controls, communications, cyber security products and/or strategies.

ORNL researchers have extensive capabilities in power system modeling, simulation, testing, control design, and system analysis, including bulk transmission system, distribution system, flexible AC transmission system, distributed energy resources and their interfaces, energy storage, electric vehicles, demand response, etc.