OAK RIDGE NATIONAL LABORATORY FACT SHEET
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Distributed Energy Communications and Control

DECC: Supplying Reactive Power Locally and Dynamically.

Overview

The nation's electric system is under great stress, due in part, from a lack of reactive power reserves. Reactive power is the crucial component of electric power (voltage times current) which regulates voltages and plays a key role in electric power grid operation. It is created by capacitors (source) and inductors (sink) as they stabilize voltage and current, respectively. It must be supplied to most types of power (magnetic) equipment (i.e., motors and transformers) for proper operation. During summer peak load demand, air conditioning motor loads can stall during a low voltage event, such as a fault, and draw significant levels of reactive power placing an additional burden on an already strained grid. Without sufficient reserves, the power system could experience a voltage collapse and result in a wide area blackout. Distributed energy (DE) technologies can supply reactive power locally to ensure a robust electric power delivery system.

Reactive power is best applied locally; its transmission from remote sources can cause power lines to experience voltage drops and decreased capacity to carry active power.

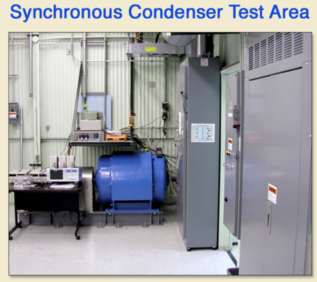
DECC Laboratory

DECC is a unique laboratory that can test multiple DE systems in a real-world distribution system and demonstrate the ability of these technologies to provide dynamic reactive power locally. It provides the link between testing and simulation needed to ensure accuracy of experimental results and to simulate the integration of multiple technologies on the electric grid. Renewable energy technologies, many being inverter-based, like photovoltaics (PV), can be accommodated along with traditional DE. At present, the laboratory consists of three systems: a 300-kVar synchronous condenser, a 150A (or 125kVar) inverter supplied with DC, and a 30kW micro-turbine generator. This year, there are plans to add a second inverter-based system at a second feeder location, a PV-based inverter system and a charging station for testing plug-in hybrid electric vehicles. A 100kW micro-turbine which has some power factor correction capability is onsite and there are plans to connect it to DECC in the near future. We estimate that DECC has the capability to test up to 1MVA of DE at the same time.

Inverter Test Area

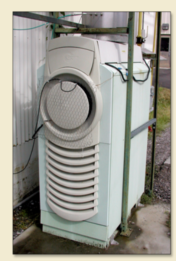
Power Electronics based DE with Voltage Control

Synchronous Condenser Test Area



Generator-based DE with Voltage Control

Microturbine Generator



DE without Voltage Control

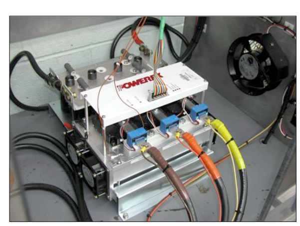
The DECC Laboratory offers multiple DE types (rotating and inverter-based) for testing on a "live" distribution system.

DECC is unique in that ORNL owns and operates the campus distribution system and can configure the system to provide optimum testing opportunities. For example, DE systems at DECC which are on two different circuits can be reconfigured to be fed from one substation source. Also, capacitance at the substation can be relaxed or a 250 hp motor started to test a more severe voltage regulation case.

Benefits of Regulating Voltage from DE

Adding dynamic reactive power supply capability and controls into distributed energy (DE) systems requires only a nominal cost increase, and can provide significant savings in the following:

- Reduced distribution system losses
- Improved customer power quality
- Increased distribution system capacity
- Increased voltage stability and overall power system reliability
- Reduced transmission congestion (subsequently reduced customer prices)



The three-phase inverter can be controlled to regulate active and non-active power (including reactive power) to regulate voltage, power factor and voltage unbalance.

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Research & Development at DECC

ORNL, in partnership with industry and academia, is performing R&D in the following areas:

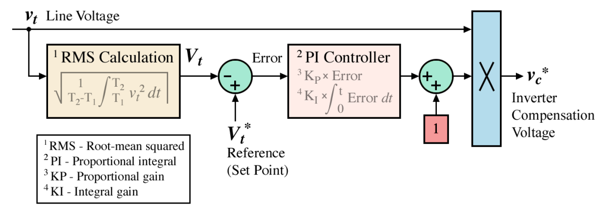
- Develop adaptive independent control methods for local dynamic voltage regulation from DE
- Test adaptive methods in a "live" distribution system to fully demonstrate voltage regulation benefits
- Recommend tariffs for utilities to encourage customers to provide local voltage regulation service
- Define engineering guidelines for the placement and for setting regulation control for reactive power producing DE
- Analyze the impact of air conditioning (A/C) and other nonlinear inductive loads on the distribution system.*
- Identify how advancements in information, renewable and DE and plug-in hybrid electric vehicles will both enhance and increase the complexity of the electric grid.**

**High efficiency A/C motor loads are more susceptible to stalls (motor stops turning) caused by low voltage transients which can cause the motor to draw high reactive current (6-10 times rated). Providing dynamic reactive support at the load may be an effective solution.*

***Ensuring safe and reliable operations will be necessary as well as identifying additional functionality and improving asset utilization from these systems. ORNL's innovative control concepts will be tested for multiple applications.*

Advanced Controls for DE

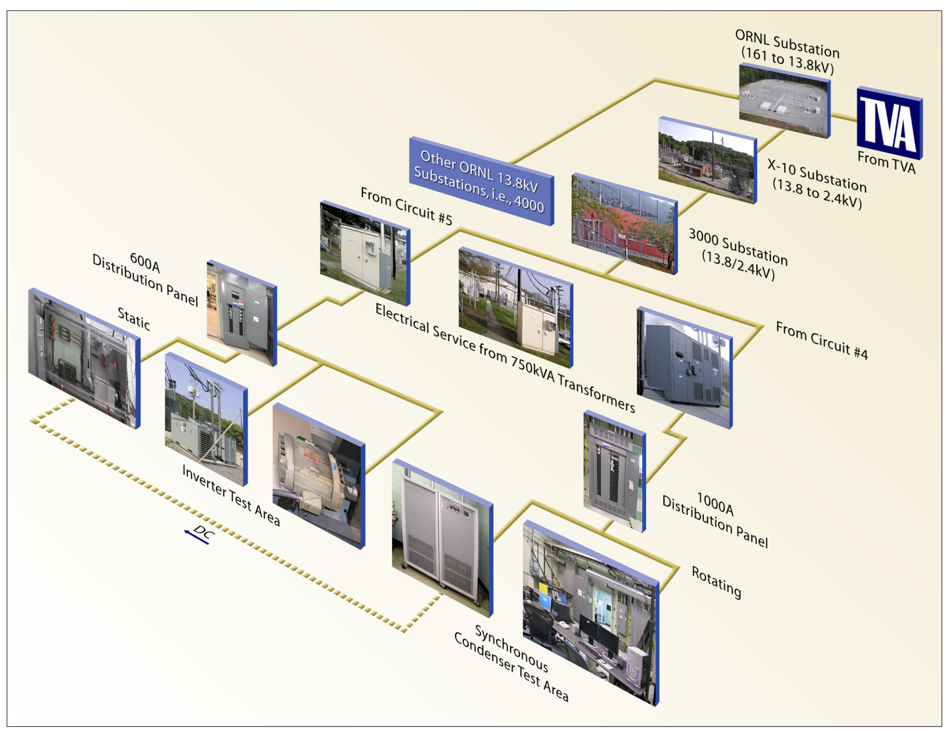
Advanced controls, currently based on proportional-integral feedback control, are utilized and being enhanced at DECC to adjust reactive power output from the DE systems to regulate local voltage and power factor. The dynamic control of local voltage is important for improving power quality to local and nearby loads and reducing line losses because the injection of reactive power offsets the demand by local loads reducing the delivery current from the utility. This ability by DE systems also relieves transmission and distribution line capacities and increases the margin to voltage collapse. The inverter-based DE can be controlled as a reactive power generator or sink depending upon the reactive power that is needed, such as it can generate reactive power to boost voltage when voltage is low. Conventionally, shunt feeder capacitors and line regulators are used to control distribution voltages, but they are slow and are not continuous (fixed step sizes). Also, reactive power from capacitor banks drops off with the square of the voltage, so they provide diminishing value at low voltage when they are most needed. Reactive-power producing DE systems with the proper controls can improve voltage stability on the grid.



The proportional-integral feedback control represented here is used to provide real-time reactive power control.

Partnerships

Our industry partners view DE providing local voltage regulation as the wave of the future. The use of DE is growing, and local voltage regulation is a necessary ancillary service for ensuring power quality for more demanding loads, such as computers and electronics-based loads, which are increasing in volumes on the power system. Southern California Edison, one of our utility partners, is looking toward implementation of this technology on their "Distribution System of the Future." They envision providing for more than 30% of the reactive power needs of the distribution circuit using local DE.



The DECC laboratory is interfaced with an actual power delivery system, the ORNL distribution system, which is supplied by the TVA transmission system.

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