Supply of Reactive Power from Distributed Energy Resources

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Reactive Power

- Reactive Power is a phenomenon of AC Power and doesn’t do real work.

- “Power” refers to energy quantities flowing in the power system.
  - Instantaneously, the product of voltage & current
  - Normally, “Power” refers to real power

- Real Power only when voltage & current are in phase
  - Measured in Watts (joule per sec) or Kilowatts (kW)

- Reactive Power (along with Real Power) when voltage & current are not in phase
  - Measured in VAR (volt-ampere-reactive) or KiloVars (kVars)
Why Is Reactive Power Needed?

1) Utility Restructuring Has Reduced Voltage Margins
2) Little system-wide reactive power planning
   Many utilities have crash programs now to install more reactive resources
1) New generators - less reactive support capability.
   Merchant Generators - no system responsibility
2) System planners rely more on capacitor banks.
   Least effective when needed most - during voltage sag
3) Increased energy transfers –
   More current = more reactive power losses
Project Description

1) Establish a reactive power laboratory with both generator & inverter-based DE technologies
2) Test individual and multiple reactive power producing DE.
3) Use the ORNL campus distribution system to demonstrate that several reactive power producing DE devices can operate in close electrical proximity
4) Regulate voltage or net power factor without extensive communications & control and without increasing available fault current.
5) Use a mathematical programming platform and real-time controller to implement various control algorithms & strategies for feedback control.
6) Use commercial power system analysis software to model the performance of the DE in controlling voltage & net power factor and evaluating local control methods.
7) Demonstrate that DE inverter designs with local control can be developed and packaged to economically supply adequate reactive power levels to satisfy utility and user needs.
Reactive Power Laboratory

- **Overview**: First of its kind laboratory for testing reactive power injection from DE.
- **Testing Areas**: Provides testing capability of rotating (generator) and static (converter) based DE. Also, capability to test vendor provided reactive power producing DE, such as a microturbine or reciprocating genset.
- **Distribution Interface**: Interfaces at two different electrical locations on the ORNL distribution system. Provides capability to test multiple reactive power producing DE and also interaction.
- **Substation**: Capability to relax compensation at the substation by switching out capacitor banks.
- **Power System**: Interfaces with the TVA Grid through the ORNL distribution system. Ownership gives us ability to vary load and reconfigure for testing different scenarios.
Project Timeline

- **Task 1** Sept 05
  Build reactive power laboratory & test dynamic/variable reactive power injection and local voltage regulation from synchronous condenser

- **Task 2** Oct 05
  Complete economic evaluation of DE resources for reactive power supply

- **Task 3** April 06
  Install & test inverters, conduct transient testing and local voltage regulation

- **Task 4** Sept 06
  Operate inverters in parallel with synchronous condenser, evaluate capability to regulate local system voltage, and compare with model results

- **Task 5** Sept 07
  Install other DE resources and modify inverter controls to regulate voltage while supplying controlled levels of reactive power and limiting fault current, characterize their performance with alternate local control schemes.
Project Team

- Bowman Power
- Capstone Turbine
- General Electric
- Rolls Royce
- SmartSynch
- Lenoir Cities Utilities Board
- Southern California Edison
- Tennessee Valley Authority
- EPRI-Solutions
Objectives

1) Evaluate economic & engineering feasibility of supplying reactive power locally from DE to regulate local voltage and control power factor to improve the efficiency and reliability of the utility distribution system.

2) Determine if reactive power can be supplied from local DE sources with independent voltage control so that an expensive hierarchical control & communications system is not required.

3) Address key barriers to the local supply of reactive power so that it may be supplied without requiring the local utility to either modify the existing distribution system or perform engineering analysis of the circuit.
Task Definition

1) Our goal is to develop methods for the incorporation of DE into distribution systems to provide voltage regulation and dynamic reactive reserves.

Specifically, the focus is for DE to provide these reactive power services without the installation of extensive communication and control systems.

2) The goal is that the controller supplied with each individual DE will be adequate for it to operate in harmony with other DE sources to regulate voltage, control the power factor presented by the distribution system, and provide other power quality services.
Milestones Completed

1) A unique & first-of-its kind R&D laboratory for evaluating reactive power from DE has been established at ORNL.

2) A 300kVar Synchronous Condenser (250hp synchronous motor unloaded and overexcited) is operational for evaluating local control of rotating-based DE with an actual distribution system.

3) A test of the synchronous condenser was performed during the summer with the device providing a maximum of 311kVar of reactive power.

4) The capability of testing 3-phase inverters for producing reactive power from DE has been established at the Reactive Power Laboratory.
5) A commercial power system analysis software of the ORNL campus distribution system utilizing input data from the tests is being used to model the voltage and current changes on the distribution system.

6) A Mathematical and Real-Time Control Hardware & Software are being used to have been established for a versatile programming environment for developing and testing various control algorithms and schemes.

7) An economic evaluation of DE resources for Reactive Power Supply has been completed.
Milestones Planned

1) Develop automated feedback control schemes for both the synchronous condenser & inverters for varying reactive power output based on local voltage.

2) Develop & test methods for rapid fault current limiting.

3) Operate multiple DE in parallel to evaluate interaction, prove control concept and develop engineering guidelines for DE application in providing voltage regulation & net power factor regulation.

4) Move the concept from the laboratory to the field environment by working with our partners to implement the concept to a much larger extent, such as Southern California Edison’s and their distribution circuit of the future.
How Can DER Provide Reactive Power?

- Oversized DER synchronous generators, a 500 KVA generator on a 200 Hp machine (The generator is inexpensive compared to the machine)
- Controls respond to LOCAL conditions
- Power electronic converters inside the DER,
Transmission System Trend

PV Over the Years

Voltage

Increased Power Transfer

P

60's 70's 80's 90's 2000