University of Wisconsin-Madison

Micro-sources with Storage Bringing High Value to Customers

Goals

The Wisconsin Power Electronics Research Center (WisPERC) of the University of Wisconsin-Madison is developing a hardware demonstration of the feasibility and value of distributed resources as a solution to the sensitive load problem. Current efforts focus on research and development of micro-source distributed generation (MSDG) using commercial microturbine, fuel cell, or photovoltaic systems combined with energy storage to provide high quality, uninterrupted, efficient, environmentally friendly, and cost-competitive power.

In particular, this WisPERC project emphasizes systems of distributed resources that can switch from grid connection to island operation while maintaining critical loads and offering customer benefits such as deferred distribution cost, local voltage control and reliability, coordinated demand side management, and premium power. Recent achievements in the first phase of the project include:

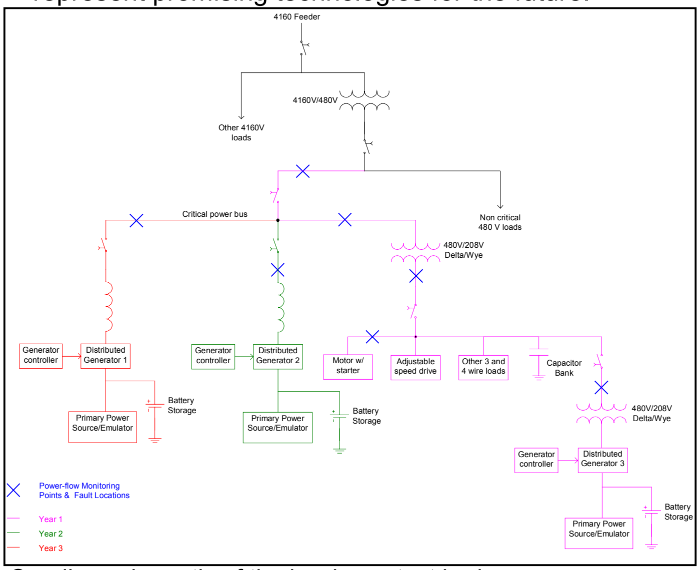
- Investigation of energy storage requirements for distributed generation systems resulting in a design procedure, functional model, and simulation for deep-cycle lead-acid batteries to manage sudden changes in load demand
- Modeling and emulation of a 75-kW microturbine, including generator interaction within an islanded microgrid and generator response to load changes under a variety of loading profiles to move toward improved control methodologies and protection schemes
- Modification of a commercial motor drive system inverter to supply utility-grade AC power and evaluation of the modified inverter in island mode over a complex range of varying power factor, balanced and unbalanced, linear and non-linear loads
- Development of a hardware test bed to implement control strategies and experimentally verify theoretical analyses and computer simulations.

Current Results

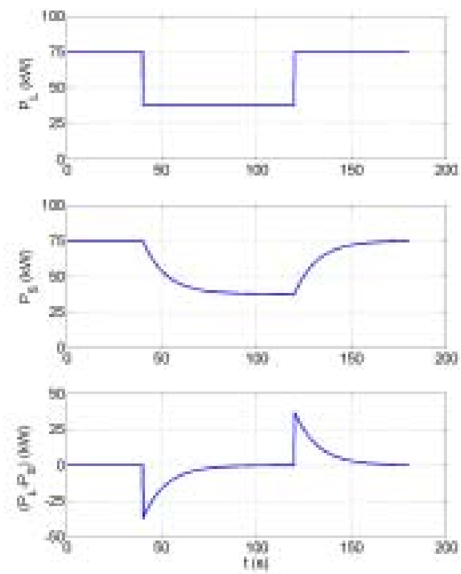
Battery Storage Requirements

MSDG systems, under transient conditions in power demand, require a short-term source of energy to meet the stringent demands of premium power systems. Therefore, during island-mode operations, auxiliary energy storage equipment is required.

Investigation results indicate that lead-acid batteries with deep discharge, good charge acceptance, and low internal resistance are the most cost-effective means for energy storage. Flywheels and ultracapacitors also represent promising technologies for the future.



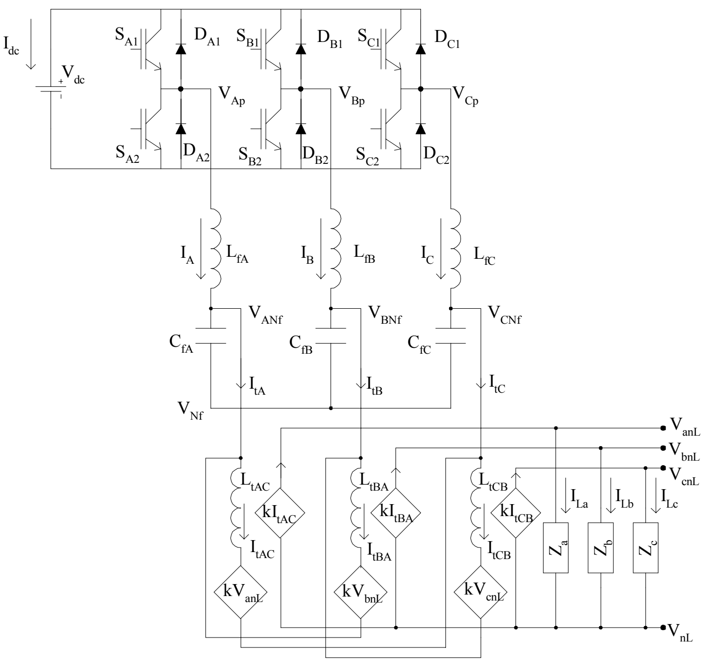
One-line schematic of the hardware test bed



As shown by the difference between load (P_L) and generator output (P_S) for step changes in load, auxiliary energy systems are required in stand-alone MSDG applications

Motor Drive Inverter Conversion for MSDG Applications

In an effort to enhance the economic benefits of MSDG systems, WisPERC has conducted research aimed at modifying a low-cost, off-the-shelf inverter designed to drive induction motors into an inverter that provides utility-grade three-phase AC voltage. This approach is designed to save engineering effort by using commercial components with minimal modifications.



Schematic of an inverter-based island micro-source distributed generation system

WisPERC accomplished this task by retrofitting an Allen-Bradley motor drive with a transformer and second order LC filter.

Nonetheless, the performance of the inverter system under a complex set of load conditions, including unbalanced operating conditions, has been sub-optimal. In the future, control strategies for overcoming these problems and a seamless grid interface while operating multiple inverter units will be demonstrated through the expansion of the hardware system to incorporate multiple inverters and interconnection switchgear.

Experimental Test Bed

To physically study and benchmark MSDG components, verify the operation of the proposed models and simulations, and implement various control strategies, WisPERC is developing a hardware test bed. Experimental results from the test bed will be used to further refine the control algorithms and iterate on the best possible approach to realize the performance objectives.

A conceptual one-line schematic of the hardware test bed is illustrated on the front. The system has been designed to provide the maximum amount of flexibility and variety of loads to study the operation of the systems under various operating scenarios.

The test bed is being commissioned in various phases over the period of the project. In its complete version, the experimental system will feature:

- A directly interfaced DG system
- A transformer-coupled DG system
- The possibility of island operation
- The possibility of satellite operation
- Induction motor loads
- Adjustable-speed drive loads
- Four wire systems
- Single-phase loads
- AC-side capacitor banks.

Investigations of various concepts of protection within the laboratory-scale microgrid will also be conducted. The laboratory will facilitate flexible interconnections in a systematic and safe manner.

Distribution and Interconnection R&D (Formerly Distributed Power Program)

DOE's Distribution and Interconnection R&D supports the development of technologies and policies that enable distributed generation (e.g., photovoltaic systems, wind turbines, fuel cells, and microturbines), storage, and direct load control technologies to be integrated into the electric system. Through a collaboration of national laboratories and industry partners, DOE's Distribution and Interconnection R&D pursues activities in: (1) strategic research, (2) technical standards, (3) distribution system technology, (4) interconnection technology, and (5) mitigation of regulatory and institutional barriers.

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Additional Distributed Power Information
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