5.11 MicroGrid Protection and Control (T-18)

Summary	The key research focus is the coordination of protection and control within a MicroGrid.
Research Need	Integration of large numbers of microsources require a system approach to insure stable and reliable power at the customer site, one such approach is the MicroGrid paradigm.
Research Stem	T&D Technologies
Academic Team Members	Robert Lasseter (Wisconsin-lead: Lasseter@engr.wisc.edu, 608-262-0186) Mladen Kezunovic (Texas A&M)
Industry Team Members	Jerry C Thompson and Mike Agee (Duke Power) Dale Krummen (AEP)
Funding Period	June 1, 2002 to June 30, 2005
Budget	Lasseter: $40,000; Kezunovic: $10,000. Total: $50,000 per year for three years (2002-2004).

Project Description:

Background: The MicroGrid concept assumes a cluster of loads and microsources operating as a single controllable system that provides both power and heat to its local area. This concept provides a new paradigm for defining the operation of distributed generation. To the utility the MicroGrid can be thought of as a controlled cell of the power system. For example this cell could be controlled as a single dispatchable load, which can respond in seconds to meet the needs of the transmission system. To the customer the MicroGrid can be designed to meet their special needs; such as, enhance local reliability, reduce feeder losses, support local voltages, provide increased efficiency through use waste heat, voltage sag correction or provide uninterruptible power supply functions to name a few.

The microsources of special interest for MicroGrids are small (<100 kW) units with power electronic interfaces. These sources, (typically microturbines, PV panels, and fuel cells) are placed at customers' sites. They are low cost, low voltage and have high reliable with few emissions. Power electronics provide the control and flexibility required by the MicroGrid concept. Correctly designed power electronics and controls insure that the MicroGrid can meet its customers as well as the utilities needs. The above characteristics can be achieved using a system architecture with three critical components;

- Local microsource controllers
- System optimizer
- Distributed protection

Figure 1 illustrates the basic MicroGrid architecture. In this example the electrical system is assumed to be radial with three feeders A, B and C and a collection of loads. The radial system is connected to the distribution system through a separation device, usually a static switch. The feeder voltages at the loads are usually 480 volts or less. Feeder A indicates the presents of several microsources with one providing both power and heat. Each feeder has circuits breakers and power flow controllers. Consider the power flow controller near the heat load in feeder A. This controller regulates feeder power flow at a level prescribed by the Energy Manager. As loads down stream change the local microsources increase or decreases their power output to hold the power flow constant. In this figure feeders A and C are assumed to have critical loads and include microsources, while feed B is assumed to have non-critical loads which can be shed when necessary. For example when there are power quality problems on the distribution system the MicroGrid can island by using the separation device shown in the figure. The non-critical feeder can also be dropped using the breaker at B.

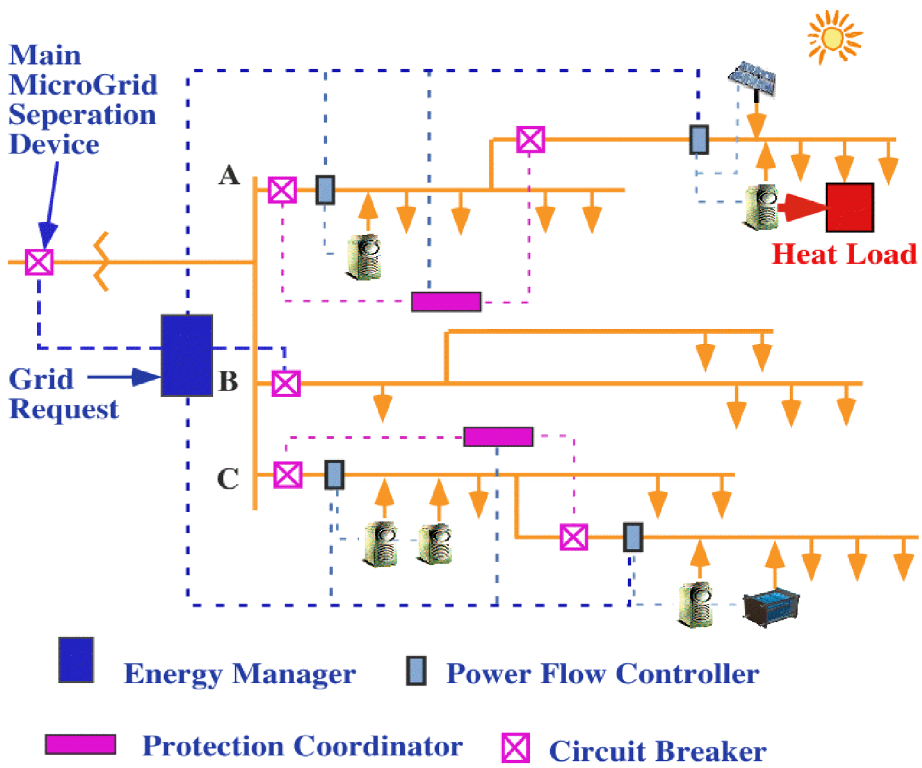

Figure 1. MicroGrid Architecture

Microsource controller is an important component of the MicroGrid infrastructure. This controller responds in milliseconds and uses local information to control the microsource during all events. A key element is that communications among microsources are unnecessary for basic operation. Each inverter is able to respond to load changes in a predetermined manner without communication of data from other sources or locations, which enables "plug and play" capabilities. "Plug and play" implies that a microsource can be added to the MicroGrid without changes to the control and protection of units that are already part of the system. The basic inputs to this controller are steady state set points for output power, P, and local bus voltage, V.

Integration of large numbers of microsources, implied in the MicroGrid concept, is not possible with basic P-Q controls. Voltage regulation is necessary for local reliability and stability. Without local voltage control, systems with high penetration of microsources can experience voltage and/or reactive power oscillations. Voltage control requires care to insure that there are not large circulating reactive currents between sources. The issues are identical to those encountered in the control of large synchronous generators. In the power grid the impedance between generators is usually large enough to greatly reducing the possibility of circulating currents. In a MicroGrid, which is typically radial, the problem of large circulating reactive currents is immense. With small errors in voltage set points the circulating current can exceed the ratings of the microsources. This situation requires a voltage vs. reactive current droop controller. Basically, as the reactive current generated by the microsource becomes more capacitive the local voltage set point is reduced. Conversely as the current becomes more inductive the voltage set point is increased.

MicroGrids can provide premium power through the ability to smoothly move from dispatched power mode (while connected to the utility grid) to load tracking (while in island mode). In the island mode such problems as slight errors in frequencies generation at each converter and the need to change power-operating points to match load changes imply a need for a complex communication system. This is not so. These issues can be addressed using power vs. frequency droop functions at each microsource without an explicit communication network.

When grid connected, the loads in the MicroGrid receive power both from the grid and from the microsources depending on the customer's situation. With loss of the grid due to voltage drops, faults, blackouts etc. the MicroGrid smoothly transfer to island operation. With separation from the grid the voltage phase angles at each microsource in the MicroGrid change resulting in an apparent reduction in local frequency. This frequency reduction coupled with a power increase allows for each microsource to provide it's proportional share of load without new power dispatch from the Energy Manager. In fact in island operation the Energy Manager is not used except for reconnection to the grid.

System optimization is provided by the Energy Manager. The Energy Manager uses information on local electrical and heat needs, power quality requirements, electricity and gas costs, wholesale/retail service needs, special grid needs, demand-side management requests, congestion levels, etc. to determine the amount of power that the MicroGrid should draw from the distribution system. Some key functions of the Energy Manager are;

- Provide the individual power and voltage set point for each power flow/microsource controller
- Insure that heat and electrical loads are met
- Insure that the MicroGrid satisfies operational contracts with the transmission system
- Minimizes emissions and system losses
- Maximize the operational efficiency of the microsources.
- Provides logic and control for islanding and reconnecting the MicroGrid during events.

Protection must respond to both system and MicroGrid faults. If the fault is on the utility grid, the desired response may be to isolate the MicroGrid from the main utility as rapidly as necessary to protect the MicroGrid loads. The speed of isolation is dependent on the specific customer's loads on the MicroGrid. In some cases sag compensation can be used without separation from the distribution system to protect critical loads. If the fault is within the MicroGrid, the protection coordinator isolates the smallest possible section of the radial feeder to eliminate the fault.

Research Focus: The focus of this work is on protection and control of the MicroGrid from internal faults. Most conventional distribution protection is based on short-circuit current sensing. Power electronic based microsources can not normally provide the levels of short circuit required. Microsources may only be capable of supplying twice load current or less to a fault. Some overcurrent sensing devices will not even respond to this level of overcurrent, and those that do respond will take many seconds to respond, rather than the fraction of a second that is required. This work will look at less traditional protection methods coupled with the microsource controls to create an effective MicroGrid control and protection system.

Potential Industry Benefits: This concept provides a new paradigm for defining the operation of distributed generation that brings benefits to both the utility and customer. To the utility the MicroGrid can be thought of as a controlled cell of the power system, for example a dispatchable load. To the customer a MicroGrid can be designed to provide the quality of power his loads require.

Expected Outcomes: Practical control & protection options for MicroGrids.

Technical Approach: Both simulation and hardware tools are to be used on this project. An EMTP test bed of a MicroGrid including the details of the power electronics and microsources will provide a platform for proof-of-principle of protection concepts. A reduced MicroGrid hardware test bed created with help of NREL funds at Wisconsin will provide test of control & protection concepts at 480 volts and load current up to 100 amps. Loads available include motors.

Overcurrent protection may not work at all forcing more complex and costly solutions. The unique nature of the MicroGrid design and operation requires a fresh look into the fundamentals of relaying. One approach that is quite powerful is to develop a real-time fault location technique that will identify the exact location of the fault much more accurately that the classical relaying is capable of doing under any circumstances. Low cost approach such a CT based zero sequence detection, and differential current and/or voltage methods also show promise and will be investigated.

Work Plan:

June 02	Create a simulation test bed using the EMTP	June 03
August 02	Investigate the effects of power electronic sources on short circuit currents in the MicroGrid	May 03
April 03	Develop and test protection and control strategies using the test bed simulator.	June 04
March 04	Implement protection systems on Wisconsin Electric Machines and Power Electronics Consortium's hardware MicroGrid test bed	May 05

Related Work: This work is closely coordinated with DOE/NREL/CERTS work on MicroGrids and distributed generation. The lead investigator does complementary work for the above organizations.

How this Work Differs from Related Work: Currently MicroGrids research does not look at coordinated protection and control from a fundamental approach.

5.11.1 Project Status

Status as Reported for the May 2002 IAB Meeting

Work progress since the report for the December 2001 IAB meeting
This is a new PSERC project. Work is just beginning.

Description of work activities and anticipated project outcomes/deliverables by each project team member during next reporting period.
Lasseter and student will create a simulation test bed using the EMTP.

Students working on the project during the next reporting period
Chirdpong Delertpiboon, mcdeelert@students.wisc.edu

5.11.2 Project-Related Documents

Work on this project is just beginning

Click here to return to the Project Overviews