The CERTS MicroGrid Concept[1]

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Introduction

Evolutionary changes in the regulatory and operational climate of traditional electric utilities and the emergence of smaller generating systems such as microturbines have opened new opportunities for on-site power generation by electricity users. In this context, distributed energy resources (DER) - small power generators typically located at users' sites where the energy (both electric and thermal) they generate is utilized - have emerged as a promising option to meet growing customer needs for electric power, with an emphasis on reliability and power quality. The portfolio of DER includes generators, energy storage, load control, and, for certain classes of systems, advanced power electronic interfaces between the generators and the bulk power provider. This paper briefly describes a concept that significantly enhances the application potential of smaller DER to meet the needs of both customers and some utilities by organizing these resources into MicroGrids.

> ***The Consortium for Electric Reliability Technology Solutions (CERTS) MicroGrid concept assumes an aggregation of loads and microsources operating as a single system providing both power and heat. The majority of the microsources must be power electronic based to provide the required flexibility to ensure operation as a single, aggregate system. This control flexibility allows the CERTS MicroGrid to present itself to the bulk power system as a single controlled unit that meets local needs for reliability and security***.

The CERTS MicroGrid represents an entirely new approach to integrating DER. Traditional approaches for integrating DER focus on the impacts on grid performance of one, two or a relatively small number of microsources. An example of the traditional approach to DER is found in the Institute of Electrical and Electronics Engineers (IEEE) Draft Standard P1547 for Distributed Resources Interconnected with Electric Power Systems. This standard focuses on ensuring that interconnected generators will shut down automatically if problems arise on the grid. By contrast, the CERTS MicroGrid would be designed to seamlessly separate or island from the grid and reconnect to the grid once the problems are resolved.

A critical feature of the CERTS MicroGrid derives from its presentation to the surrounding distribution grid as a single, self-controlled entity; that is, it appears to the grid as indistinguishable from other currently legitimate customer sites. Maintaining this profile relies on the flexibility of advanced power electronics that control the interface between microsources, both generation and energy storage, and their surrounding AC system. In other words, the CERTS MicroGrid concept eliminates dominant existing concerns and the consequent approaches for integrating DER. Current attention tends to focus on assessing how many DER can be *tolerated* before their collective electrical impact begins to create problems, such as excessive current flows following faults and voltage fluctuations. The MicroGrid architecture ensures that its electrical impact on its bulk power provider at least qualifies it as a *good citizen*; that is, it complies with grid rules and does no harm beyond what would be acceptable from an existing customer.

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[1] The MicroGrid concept described in this paper was developed by CERTS. CERTS was formed in 1999 to research, develop, and disseminate new methods, tools, and technologies to protect and enhance the reliability of the U.S. electric power system in the transition to a competitive electricity market structure. Its members include some U.S. DOE National Laboratories and several universities prominently engaged in power engineering and policy research. The MicroGrid program was funded by the Assistant Secretary of Energy Efficiency and Renewable Energy, Office of Power Technologies of the U.S. Department of Energy. The California Energy Commission also supported development of this program through its PIER Program.
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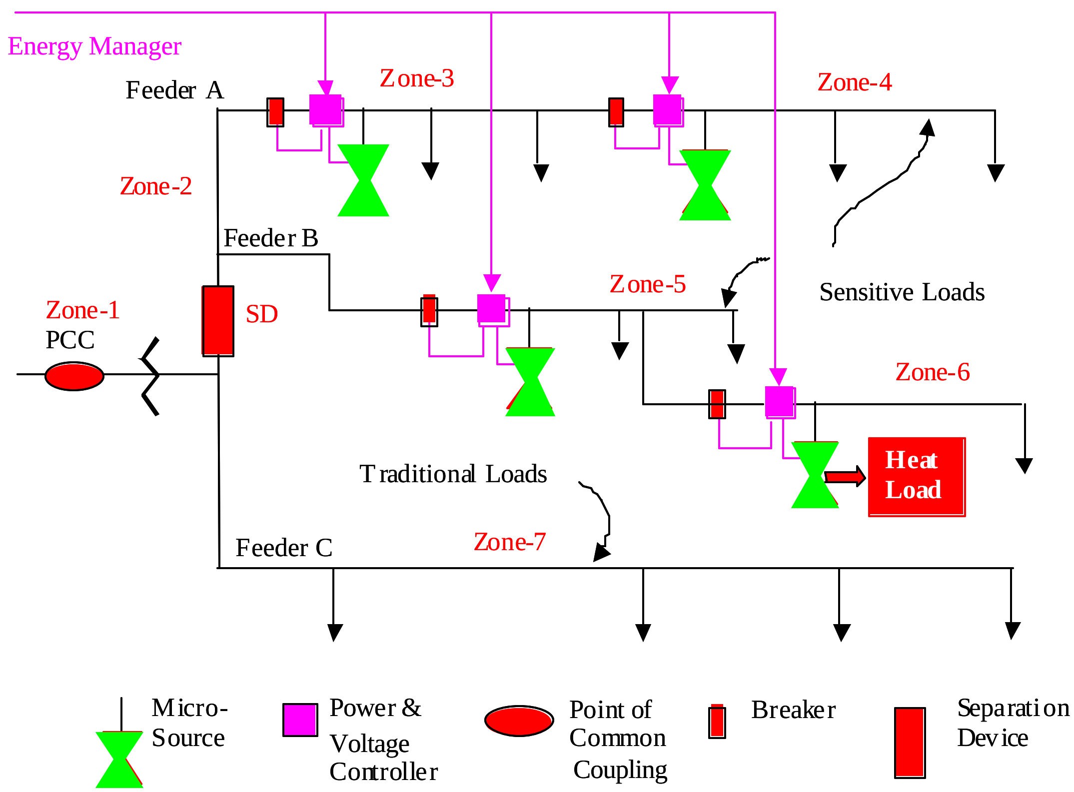
The MicroGrid Structure

As mentioned earlier, the MicroGrid structure assumes an aggregation of loads and small capacity generation and storage sources, or microsources, operating as a single system providing both power and heat. The majority of the microsources must be power electronic based to provide the required flexibility to ensure controlled operation as a single, aggregate system. This control flexibility allows the MicroGrid to present itself to the bulk power system as a single controlled unit, have plug-and-play simplicity for each microsource, and meet the customers' local needs. These needs include increased local reliability and security.

The Figure below illustrates the basic MicroGrid architecture. The electrical system is assumed to be radial with three feeders – A, B, and C – and a collection of loads. The microsources are either microturbines or fuel cells, interfaced to the system through power electronics. The Point of Common Coupling (PCC) is on the primary side of the transformer and defines the separation between the grid and the MicroGrid. At this point, the MicroGrid must meet the prevailing interface requirements, as defined in draft standard IEEE P1547.



MicroGrid Architecture

The sources on Feeder A & B allow full exploration of situations where the microsources are placed away from the common feeder bus to reduce line losses, support voltage, and/or use its waste heat. Multiple microsources on a radial feeder increase the problem of power flow control and voltage support along the feeder when compared to all sources being placed at the feeder's common bus; but this placement is key to the plug-and-play concept. The feeders are usually 480 volts or smaller. Each feeder has several circuit breakers and power and voltage flow controllers. The power and voltage controller near each microsource provides the control signals to the source, which regulates feeder power flow and bus voltage at levels prescribed by the Energy Manager. As downstream loads change, the local microsource's power is increased or decreased to hold the total power flow at the dispatched level.

To illustrate a wide range of options, the figure illustrates two feeders with microsources and one without any generation. During disturbances on the bulk power system, Feeders A & B can island, using the separation device (SD) to minimize disturbance to the sensitive loads. Of course islanding does not make sense if there is not enough local generation to meet the demands of the sensitive loads. The traditional loads on Feeder C are left to ride through the disturbance. This eliminates nuisance trips of the traditional load when the MicroGrid islands to protect critical loads.

The MicroGrid assumes three critical functions that are unique to this architecture:

- **Microsource Controller** — The Power and Voltage Controller coupled with the microsource provides fast response to disturbances and load changes without relying on communications. The important feature of each Microsource Controller is that it responds in milliseconds and uses locally measured voltages and currents to control the microsource during all system or grid events. Fast communication among microsources is not necessary for MicroGrid operation; each inverter is able to respond to load changes in a predetermined manner, without data from other sources or locations. This arrangement enables microsources to “plug and play” – that is, microsources can be added to the MicroGrid without changes to the control and protection of units that are already part of the system.
- **Energy Manager —** The MicroGrid provides operational control through the dispatch of power and voltage set points to each Microsource Controller. The time response of this function is measured in minutes and this function could be as simple as having a technician enter these set points by hand at each controller to a state-of-the-art communication system.
- **Protection —** Protection of a MicroGrid in which the sources are interfaced using power electronics requires unique solutions to provide the required functionality. The protection coordinator must respond to both system and MicroGrid faults. For a fault on the grid, the desired response might be to isolate the critical load portion of the MicroGrid from the grid as rapidly as is necessary to protect these loads. This provides the same function as an uninterruptible power supply, at a potentially lower incremental cost.

Role of Storage

Energy storage plays an important role in enhancing the benefits of the MicroGrid. Small quantities of energy storage could augment the ramp rates of small microturbines and allow them to follow rapid fluctuations in load requirements. This storage could reside on the dc bus in parallel to one or all of the microturbines that comprise a MicroGrid.

Larger storage could play a more conventional role by allowing the MicroGrid to capture excess local energy production and store it for use either during peak times or when the energy tariff indicates favorable dispatch. By the nature of this function, this storage would have a conventional pcs interface with the rest of the MicroGrid on the ac bus and be under the control of the Energy Manager.

Development Plans

The California Energy Commission (CEC) is sponsoring a workshop to present the CERTS MicroGrid concept to a wide audience in May 2002. Following that, the CEC is planning a phased testing of the essential control and protection hardware at a test laboratory. Field demonstrations of the MicroGrid are planned once these concepts are validated through the laboratory testing.

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