Off-Grid Thermoelectric Refrigerator

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Introduction

Microgrids are localized energy grids that use distributed energy resources for power generation.[3] They can be operated in conjunction with a main utility grid or in isolation from a utility grid. When intentionally islanding a microgrid, the effects on power, voltage, and frequency should be considered to seamlessly separate the microgrid from the utility grid.[3] Microgrid islanding is currently widely researched and tested, and has been successfully implemented in several locations.

Microgrid Components

There are four main parts of a microgrid, as shown in *Figure 1*. A low voltage distribution network transfers electricity from the generators to the load. These generators are termed distributed energy systems (DES), and can be in the form of solar photovoltaics, wind turbines, fuel cells, or diesel generators. The DES must be connected to the rest of the microgrid via converters. The converters are an essential part of the microgrid system because they transform the electricity waveform generated from DES to the electricity waveform necessary for the load. They can convert between direct current (DC) waveforms and alternating current (AC) waveforms to obtain a certain voltage and frequency required at the load input. There are two main types of converters used to transfer power from the generator to the distribution lines. For solar photovoltaic and other direct current generators, a DC/DC/AC converter is used. For wind turbines, and other alternating current generators, an AC/DC/AC converter is used.[3] This is assuming that the load requires AC power, which is generally the case, such as for a home. The third part of a microgrid is energy storage units, which are usually battery storage systems that can be coupled with capacitors, provide a means to match electricity supply and demand. The fourth component is the load, which can be either controllable or uncontrollable, and consumes the power generated. An example of a load in a microgrid would be a house or an electric vehicle charging system.[3]

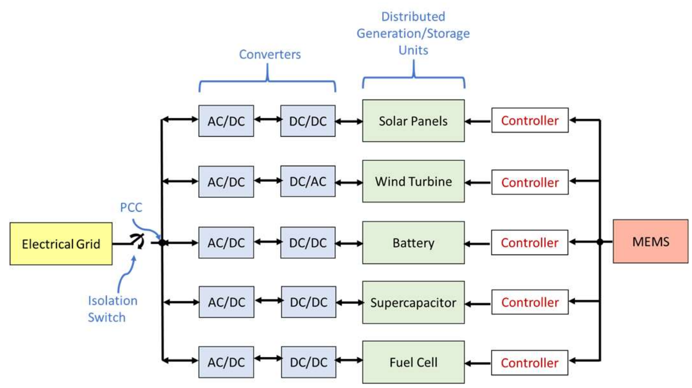

Figure 1. The block diagram above shows three of the four parts of a microgrid: the distribution network (represented by lines/arrows), the distributed generation units, and the energy storage units. The fourth part, controllable and uncontrollable loads, would be connected somewhere between the PCC (Point of Common Coupling) and the converters.[3]

Islanding a Microgrid

The microgrid energy management system (MEMS) is responsible for controlling the microgrid when it is in islanding mode.[5] It inputs data from signal measurements in the microgrid and uses hardware and software to make sure all the signals are maintained at appropriate values. For example, the MEMS needs to monitor and control voltage and frequency, balance the instantaneous and reactive power between the generator and the load, and protect the microgrid internally to prevent faults.[3] When the microgrid is islanded, a relay at the point of common coupling (PCC)—the interface between the microgrid and utility grid—is tripped, causing a circuit breaker to open, as shown in *Figure 2*.[2]

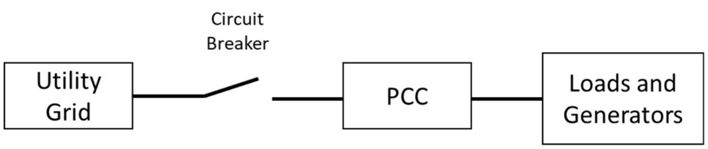

Figure 2. The block diagram above represents a microgrid that has been islanded from the utility grid. The circuit breaker has been tripped to disconnect the microgrid from the utilities grid. This disconnection occurs at the point of common coupling (PCC) which is connected to the loads and generators of the microgrid.

The main motivation for autonomous operation of a microgrid is to isolate it from the utility grid when the utility grid is disrupted.[4] As a guideline, when a characteristic at the PCC exceeds a reasonable threshold value, the microgrid is intentionally islanded. These characteristics include voltage unbalance, frequency deviation, over current, and a change in impedance.[2]

Microgrid Islanding Standards

In order to ease the development of microgrids, the Institute for Electrical and Electronic Engineers (IEEE) has created several standards related to microgrid controllers and testing procedures. The goal of the IEEE microgrid controller standards is to provide guidelines that will enable a transition from operation of a microgrid attached to the utility grid to operation of a microgrid autonomously. The control functions allow the microgrid to manage itself when islanded, connect and disconnect from the utility grid, and manage itself when operating in conjunction with the utility grid.[5] According to the standard, it should take no more than two seconds for the transition from grid-connected mode to island mode.[2] Recent technological developments allow for accurate testing of the islanding procedure. Microgrid system modeling software and hardware, programmable AC power supplies for grid simulation, programable DC power supplies for battery storage simulation, and control algorithms have been developed as part of the testing process.[4]

Practical Application of Microgrid Islanding

There have been several instances of successful microgrid islanding. One such example was at the University of California, Irvine. The UCI campus includes a twenty-megawatt microgrid, which was islanded from the Southern California Edison grid in 2018. The microgrid contains distributed energy resources, such as solar panels. Before the test, a controller was developed and tested using system modeling. During a seventy-five-minute test, the UCI microgrid was subjected to varying loads and was able to transition smoothly from one condition to another. The purpose of the UCI microgrid is to provide a sustainable means to increase grid resiliency in the area.[1]

Conclusion

There are many benefits to microgrids, many of which are only achieved if the microgrid has islanding capabilities. In addition to increasing grid resiliency, microgrids allow for electrification in remote areas and have positive environmental impacts due to their use of renewable energy generators.[4] The Forest Green Team senior design project is a very small-scale version of a microgrid. The team is designing an off-grid thermoelectric refrigerator. Similarly to a microgrid, the refrigerator system contains a generator (PV panels), an energy storage system (lithium ion battery), distribution system (the cabling between the battery and kitchenette), and a load (the refrigerator). Such a system operates autonomously from the utility grid, and thus can be considered to always be in islanded mode. In order to maximize energy efficiency, a control system and maximum power point controller help regulate the power flow from the PV panels to the battery and load. These controllers act similarly to the MEMS in a microgrid. Therefore, the off-grid thermoelectric refrigerator is a reasonable small-scale representation of an islanded microgrid. As a result, the Forest Green Team senior design project is helpful for understanding microgrid basics.

References

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