What are microgrids?

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WHAT ARE MICROGRIDS?

Microgrids are small electric grids that can operate independently from the main grid. They can be isolated (also called *islanded mode*) or connected to the main grid. Some microgrids can flexibly operate in both islanded and grid-connected modes, depending on some conditions or for safety reasons. Some microgrids are installed in islands or agricultural remote areas. We see many examples of this in Chile, the United States, Canada, and Greece. New technologies have been developed to deploy microgrids, with Japan and Denmark being the most advanced countries in this area.

Microgrids involve power electronics equipment, generators, and consumption loads. Several control and communication layers are necessary to coordinate these different elements. Microgrids may also contain energy storage systems to balance generation and consumption, especially when operating in islanded mode. By using microgrids, generation can be done near the consumption loads, so we can avoid the large losses due to electrical transmission present in conventional electric grids. Microgrids also enable the introduction of small renewable energy generators, being cost effective in this small-scale version of electric grids. As we can imagine, our houses could use microgrids to store electricity when is not needed, for instance, using, during the night, the electricity generated from the sun during the day. This would make us independent from the main grid, which would then serve as an electricity backup.

The microgrid concept was born as a new electrical paradigm. Some years ago, renewable energy sources, especially wind and solar, were introduced into the grid as distributed generation (DG) systems. Nevertheless, when a blackout occurred, renewable sources were forced to stop generating to avoid damaging equipment or injuring technicians while restoring the grid. This operation form, called *anti-islanding protection*, received many complaints from users who installed photovoltaic panels on their rooves because during blackouts, even with maximum solar power generation, home electricity was shut down. At the same time, uninterruptible power supply (UPS) systems were developed to support, by means of energy storage, some critical loads when disruptions or power quality problems appeared in the grid. Nowadays, these two concepts (DG and UPS) have been merged into one so they can effectively support

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the operation of a microgrid. In this way, we do not have to stop generation when a fault occurs in the main grid; it is enough to simply disconnect the microgrid from the main grid and supply the loads from renewable sources and/or energy storage systems.

Thinking in residential applications, storage and management of not only electrical but also thermal energy is necessary. For instance, using electricity coming from photovoltaic sources to heat water is less efficient than using solar thermal panels or reusing the heat dissipated by other generators (e.g., microcombined heat and power systems). For instance, if we use hydrogen to generate electricity by means of a fuel cell, efficiency is around 45%, while if using thermal energy as well, we can increase it up to 95%. As a result, it makes no sense to conceive a microgrid considering electrical energy only, but electrical and thermal energies have to be considered globally.

Looking at our possible microgrid at home, we may discover that most of our consumption loads are dc, e.g., laptops, cell phones, LED lights, displays, etc. So, why is the electrical grid conceived in ac? The main reason is that the grid was designed more than a century ago, basically to support loads such as induction motors and other ac appliances. Furthermore, to transport electricity with minimum losses, we have to increase the voltage to reduce the current, which was only possible using ac transformers. After a century, the loads at home changed a lot but the electrical grid has not. This means that every time we plug in one of these new loads to the grid, it is necessary to convert ac to dc. You can easily see the huge losses of this conversion process by observing the heat dissipated at the transformer of your laptop. On the other hand, generation also changed from big synchronous generators connected to nuclear, coil, or hydropower plants to small solar panels, fuel cells, or batteries, which are essentially dc sources. Even small wind or gas turbines are more efficient because they use only one converter (ac/dc) instead of two (ac/dc and dc/ac). This is pointing to a close future in which microgrids and distribution systems in homes and buildings will be done in dc. With home microgrids, which are now ac but may be dc in the future, electric vehicles will also play an important appliance role at home. It is expected that during the night, when electricity is cheaper, the electric vehicle energy storage will be charging, i.e., filling the battery set and/or generating hydrogen for the fuel-cell system.

In conclusion, microgrids represent a change of energy paradigm, which is based on the electricity consumer being responsible for generating part of the energy to be consumed and for storing some amount of it, thus becoming a *prosumer*. The concept of prosumer has two common meanings: professional consumer and producer consumer, which can be summarized in a smart production/consumption entity. In this sense, microgrids would be seen as prosumers in future electrical distribution systems.

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