New framework guarantees stability of microgrids that supply local power in developing countries

November 9 2017, by Jennifer Chu

Many rural communities are turning to microgrids, small-scale power systems that supply local energy, typically in the form of solar power, to localized consumers, such as individual households or small villages. Credit: MIT News

Today, more than 1.3 billion people are living without regular access to power, including more than 300 million in India and 600 million in sub-Saharan Africa. In these and other developing countries, access to a main power grid, particularly in rural regions, is remote and often unreliable.

Increasingly, many rural and some urban communities are turning to microgrids as an alternative source of electricity. Microgrids are small-scale power systems that supply local energy, typically in the form of solar power, to localized consumers, such as individual households or small villages.

However, the smaller a power system, the more vulnerable it is to outages. Small disturbances, such as plugging in a certain appliance or one too many phone chargers, can cause a microgrid to destabilize and short out.

For this reason, engineers have typically designed microgrids in simple, centralized configurations with thick cables and large capacitors. This limits the amount of power that any appliance can draw from a network—a conservative measure that increases a microgrid's reliability but comes with a significant cost.

Now engineers at MIT have developed a method for guaranteeing the stability of any microgrid that runs on direct current, or DC—an architecture that was originally proposed as part of the MIT Tata Center's uLink project. The researchers found they can ensure a microgrid's stability by installing capacitors, which are devices that even out spikes and dips in voltage, of a particular size, or capacitance.

The team calculated the minimum capacitance on a particular load that is required to maintain a microgrid's stability, given the total load, or power a community consumes. Importantly, this calculation does not rely on a network's particular configuration of transmission lines and power sources. This means that microgrid designers do not have to start from scratch in designing power systems for each new community.

Instead, the researchers say this microgrid design process can be performed once to develop, for instance, power system "kits": sets of modular power sources, loads, and lines that can be produced in bulk. As long as the load units include capacitors of the appropriate size, the system is guaranteed to be stable, no matter how the individual components are connected.

The researchers say such a modular design may be easily reconfigured for changing needs, such as additional households joining a community's existing microgrid.

"What we propose is this concept of ad hoc microgrids: microgrids that can be created without any preplanning and can operate without any oversight. You can take different components, interconnect them in any way that's suitable for you, and it is guaranteed to work," says Konstantin Turitsyn, associate professor of mechanical engineering at MIT. "In the end, it is a step toward lower-cost microgrids that can provide some guaranteed level of reliability and security."

The team's results appear online in the *IEEE journal Control Systems Letters*, with graduate student Kathleen Cavanagh and Julia Belk '17.

Returning to normal operations

Cavanagh says the team's work sought to meet one central challenge in microgrid design: "What if we don't know the network in advance and don't know which village a microgrid will be deployed to? Can we design components in such a way that, no matter how people interconnect them, they will still work?"

The researchers looked for ways to constrain the dimensions of a microgrid's main components—transmission lines, power sources, and loads, or power-consuming elements—in a way that guarantees a system's overall stability without depending on the particular layout of the network.

To do so, they looked to Brayton-Moser potential theory—a general mathematical theory developed in the 1960s that characterizes the dynamics of the flow of energy within a system comprising various physical and interconnected components, such as in nonlinear circuits.

"Here we applied this theory to systems whose main goal is transfer of power, rather than to perform any logical operations," Turitsyn says.

The team applied the theory to a simple yet realistic representation of a microgrid. This enabled the researchers to look at the disturbances caused when there was a variation in the loading, such as when a cell phone was plugged into its charger or a fan was turned off. They showed that the worst-case configuration is a simple network comprising a source connected to a load. The identification of this simple configuration allowed them to remove any dependence on a specific network configuration or topology.

"This theory was useful to prove that, for high-enough capacitance, a microgrid's voltage will not go to critically low levels, and the system will bounce back and continue normal operations," Turitsyn says.

Blueprint for power

From their calculations, the team developed a framework that relates a microgrid's overall power requirements, the length of its transmission lines, and its power demands, to the specific capacitor size required to keep the system stable.

"Ensuring that this simple network is stable guarantees that all other networks with the same line length or smaller are also stable," Turitsyn says. "That was the key insight that allowed us to develop statements that don't depend on the network configuration."

"This means you don't have to oversize your capacitors by a factor of 10, because we give explicit conditions where it would remain stable, even in worst-case scenarios," Cavanagh says.

In the end, the team's framework provides a cheaper, flexible blueprint for designing and adapting microgrids, for any community configuration. For instance, microgrid operators can use the framework to determine the size of a given capacitor that will stabilize a certain load. Inversely, a community that has been delivered hardware to set up a microgrid can use the group's framework to determine the maximum length the transmission lines should be, as well as the type of appliances that the components can safely maintain.

"In some situations, for given voltage levels, we cannot guarantee stability with respect to a given load change, and maybe a consumer can decide it's ok to use this big of a fan, but not a bigger one," Turitsyn says. "So it could not only be about a capacitor, but also could constrain the maximal accepted amount of power that individuals can use."

Going forward, the researchers hope to take a similar approach to AC, or alternating current, microgrids, which are mostly used in developed countries such as the United States.

"In the future we want to extend this work to AC microgrids, so that we don't have situations like after Hurricane Maria, where in Puerto Rico now the expectation is that it will be several more months before power is completely restored," Turitsyn says. "In these situations, the ability to deploy solar-based microgrids without a lot of preplanning, and with flexibility in connections, would be an important step forward."

This story is republished courtesy of MIT News (web.mit.edu/newsoffice/), a popular site that covers news about MIT research, innovation and teaching.

Provided by Massachusetts Institute of Technology

Citation: New framework guarantees stability of microgrids that supply local power in developing countries (2017, November 9) retrieved 23 April 2024 from https://techxplore.com/news/2017-11-framework-stability-microgrids-local-power.html