A look at developing technology for Solar & MicroGrids –Robert Hebner IEEE

At 18 cents for rooftop-generated solar it is not yet, on average, competitive with grid-delivered electricity at 12.5 cents per Kw hour. But many governments, for example state governments, subsidize the purchase of solar-power systems to make them competitive. Meanwhile, many utilities are experimenting with alternative-ownership options. One is community solar, in which individual consumers buy a small number of panels in a relatively large, utility-scale system. They then get *monthly credits* for the electricity generated without having panels on their roofs. Another experiment, being run by CPS Energy, in San Antonio, uses rooftop solar, *but CPS Energy owns the equipment and pays the homeowner for the use of the roof.*

One challenge with distributed solar is storage. Most solar-panel owners are using the grid as the functional equivalent of storage: They sell excess power to the grid when they can and buy back from the grid to compensate for shortfalls. This is usually the simplest and cheapest way to even out differences in production and consumption. Nevertheless, many people-most notably, Elon Musk-are betting the economics will soon favor batteries. Musk's electric-car company, Tesla*, sells a battery for home use called Powerwa1l 2, which costs $5,500 and offers 14 kWh of storag*e, enough to run an average home overnight. However, adding the costs of battery storage to a solar installation to go off grid makes the costs of power significantly higher than those of ordinary electricity from the grid.

Comparing the options for expanding the use of solar power *is not straightforward*, however, because much depends on how the grid will evolve. For example, right now, the grid could not handle a changeover to 100 percent solar (even in areas where it would make sense, like the southwestern United States or the North African desert). The grid we have today was designed around sources whose output generally varies little from day to day. But the U.S**. DOE**, under its ENERGISE program, is striving to develop, **by 2030,** *the control, protection, and other technologies needed to enable an entirely solar-powered grid.*

The grid will evolve in other ways and quickly. One of the most important trends, already well under way, is the increasing use of microgrids. A microgrid is a group of connected power sources and loads. It can be as small as an individual house (often dubbed a nanogrid) or as large as a military base or college campus. Microgrids can operate indefinitely on their own and can quickly isolate themselves if a disturbance destabilizes the larger grids to which they are normally connected.

This is an important feature during both natural and man-made disasters. Consider what happened when Hurricane Ike hit the Houston-Galveston area of Texas in 2008: Blackouts were widespread, but 95 percent of the outages were caused by damage to less than 5 percent of the grid. The grid effectively distributed the effects of what was only modest equipment damage. This isolating capability of microgrids also promises enhanced cybersecurity. That's because microgrids can help keep localized intrusions local, making the grid a much less appealing target for hackers.

When disaster strikes, whatever its cause, *microgrids can limit the consequences*. If it is not physically damaged, a microgrid can operate as long as it has access to a source of power, whether that's natural gas, the sun, or wind.

In the long term, with the timing depending as much on economics and regulation as technology, it is quite possible that the grid will evolve into a series of adjoining microgrids. Utilities have proposed to build such microgrid "clusters" in, among other places, Chicago, Pittsburgh, and Taiwan, a tropical island where grids are prone to storm damage. These adjoining microgrids would share power with one another and with the legacy grid to minimize energy cost and to maximize availability.

In an era of adjoining microgrids that are privately owned and operated, what will become of the utility company? There are at least two possibilities. It might simply supply power to the microgrids that need it, rather than doing that for individual customers. Or it might manage microgrids and their connections with one another and to the legacy grid. Across the United States, the concept of a utility is already being reinvented in some places as more competition is introduced. Microgrids are going to accelerate that trend.

The spread of distributed generation and the rise of microgrids will also be shaped by two other factors: the expansion of the Internet of Things and the growing influence of big data. The Internet of Things is a boon for distributed generation because it is giving rise to industries that are mass-producing sensors, micro controllers, software, and other gear that will be easily and cheaply adaptable for use in future, data-driven grids and microgrids. How will these things be used? Imagine a residential solar-power system of the near future. It will have "customer equipment"-solar panels, a smart inverter, and a storage battery and systems to manage loads dynamically. From time to time, the power output of that installation will be lower than usual, because of, say, a heavily overcast day.

But it would be easy to design a control system, based on readily available Io'I' components, that could communicate with similar systems in surrounding houses. These systems would work together, for example, to turn air conditioners on or off ahead of or behind schedule, or alter their thermostats by half a degree, to accommodate intermittent, unexpected shortfalls in capacity. What would enable this plan to work is the fact that most modern homes are well insulated, so it takes time before the internal temperature changes enough to trigger the HVAC system. The reason why homes would be grouped together in this scheme is that it would make the task easier: In the group, some homeowners would be willing to sacrifice a lot of comfort, some less. But the power needs of the group of houses would be relatively predictable and manageable, from the utility's standpoint.

Most consumers do not want to make frequent and detailed decisions on energy use. So imagine a device-let's call it an energy thermostat-that permits you to set a range of comfortable temperatures, rather than entering a single one. The wider you set the range, the less you'll pay for power. The grid or microgrid operator would use the range-yours and everybody else's-to dynamically match supply and demand on a minute-by-minute basis. On a hot afternoon, with demand at its peak, the temperature in your home would be at the top of the range.

Electric utilities will also begin making greater and much more effective use of big data. Utilities have been using data since the very beginning: When Thomas Edison opened the Pearl Street power station, in New York City in 1882, it had indicator lights to show when the load had increased or decreased enough to warrant adjustments to the dynamo producing the DC power. But that system clearly was not scalable. If a utility had to readjust its generators every time a customer came online, the industry would have died out long ago.

Having a large number of loads makes the aggregate demand predictable-and manageable. This happy condition obviously depends on there being little correlation of usage from house to house and business to business. But just suppose that at 3:00 p.m. on a hot summer day, every- one in a medium-size city turned off their air conditioners at the very same second, waited 15 minutes, and then turned them all back on again at exactly the same time. That would almost certainly cause a massive blackout.

With big-data tools, it may no longer be necessary to depend on consumers' actions being only loosely similar. It should be possible to understand how to adjust production and consumption to enhance system behavior. For example, with the energy-thermostat concept outlined above, the system operator needs to have not only the appropriate controllers but also access to real-time data to determine the risk of system failure when load-management actions are taken.

Utilities in many areas have embarked on this path using various customer incentives to permit, say, time-of-day pricing or some other form of load management by the utility rather than by the consumer. But we are now taking just baby steps. Big-data tools will soon let us take larger strides and may well one day let us run. It may be possible to use real-time operational data to optimize the performance of large sections of the grid and to predict future performance.

Although my main goal is to describe a hopeful vision that many of us in the utility business have for the electric grid, I would be remiss if it did not point out some of the challenges. These include financial ones, regulatory ones, and technical ones. And they come in all shapes and sizes.

One of the most fundamental is slow growth. To pay for costly system upgrades, utilities in the past would have relied heavily on growth in demand, and therefore sales. But improvements in efficiency, which consumers seek (and rightly so), have slowed growth in demand to the extent that it is now increasing at a rate lower than that of the growth in gross domestic product. And the figures are sobering: In 2014, the U.S. DOE predicted that in the period from 2012 to 2040, the demand for electricity will grow by **only 0.9 percent per year**. So, utilities cannot expect to fund the required system changes in the same ways as they have in the past, through growth.

Other shifts in the industry will only exacerbate these money woes. For example, in the past utilities could count on key pieces of equipment lasting a long time. But smart grids depend on electronic components, such as smart meters, controlled by software, which have shorter lifetimes and require much more frequent upgrades.

The biggest unknown is how swiftly the regulatory process can adapt. If it can't move quickly enough to keep up with the technology, expect agonizingly slow change. And what if governments try to prop up outmoded technologies with subsidies? That could drag out the process further. On the other hand, some would argue that regulators should slow the rate of change. Though the arguments for that are worthy of political discussion, I'm certainly not in that camp. Historically, regulations have been driven mainly by legal and economic considerations rather than by technical ones.

But now, with the pace of technology outrunning other factors, regulators in the United States and Europe are reacting to this new state of affairs in many different ways. My view is that the **staffing of regulatory agencies will need to become more technically savvy** if we are to navigate these turbulent waters while continuing to provide electric power with the lowest cost and highest reliability.

I'm confident that in the end, we'll have electrical grids that are less costly, more sustainable, and more user friendly than the ones that came before. The United States' National Academy of Engineering recently selected electrification as the top engineering accomplishment of the 20th century. But electrification now needs to be reengineered to meet the needs and opportunities of the 21st century. This is our chance to show that we are as good as our forebears of two, three, or four generations ago at technology, regulation, public policy, finance, and the management of change in general. And to leave to posterity a legacy as fine and enduring as the one that was left to us.

April of 2017 excerpts of text from IEEE spectrum – Title changed -