DC Microgrids and the Virtues of Local Electricity


It’s time to revisit Thomas Edison’s strategy for providing people with electricity

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Photo: IEEE History Center

Hotel Power: Generating and distributing DC power through a local grid is an old idea that began with Thomas Edison and persisted in some spots for many decades. The photo above shows the DC control board at the New Yorker Hotel in Manhattan, New York City, where steam boilers generated 2200 kilowatts of DC power, a system that remained in use through the 1960s.

It's been more than a century since Thomas Edison lost the great technological battle he waged against George Westinghouse and Nikola Tesla, the now-famous “War of Currents.” The idea Edison hoped to defend was that the world should run off direct current (DC) electricity. But his position just couldn’t stand up to the pounding it took from the logic of Westinghouse and Tesla’s competing scheme, which was to produce and distribute alternating current
With an AC system, the fledgling electricity industry would easily be able to shift voltages from one level to another, allowing power to be carried long distances at high voltages, which would minimize transmission losses. When the electricity arrived at its destination, it could then be converted to the low voltages appropriate for use in homes and businesses. Lacking that ability, Edison’s DC system would have required the installation of an electric generator in every neighborhood so that the low-voltage current-carrying wires wouldn’t have to be more than a few blocks long.

Generations of electrical engineers have learned about Edison’s efforts to exaggerate the dangers of AC in an attempt to make people wary of it. But Edison had some great insights about electric power too. For example, he considered its sustainability long before this became a popular issue. “We are like tenant farmers chopping down the fence around our house for fuel, when we should be using Nature’s inexhaustible sources of energy—sun, wind, and tide,” he remarked in a 1931 conversation with Henry Ford and Harvey Firestone. “I hope we don’t have to wait until oil and coal run out before we tackle that.”

Illustration: Rajendra Singh & Krishna Shenai

**Keep It Close:** Keeping the source of power close to the end user reduces transmission losses and does away with the need to convert the electricity to high voltage.

Many people have attempted to tackle sustainability problems by turning to various forms of renewable energy. But some of those sources—hydroelectric generating stations, wind farms, and solar-thermal power plants, for example—require large installations in places that are often far from population centers. That in turn demands the long-haul transmission and distribution of electricity to consumers. This is not difficult to accomplish, but it wastes energy. In the United States, transmission and distribution losses amount to about 7 percent.

For that reason alone, it’s worth revisiting Edison’s vision of local electricity generation. We and other champions of this idea refer to a system of local power generation and distribution in the form of direct current as a DC microgrid. The modern conception is quite similar to what Edison had in mind, but with the added benefit that the local DC grid is able to operate either in parallel with the surrounding AC grid or in isolation from it.

DC microgrids, with their much smaller footprints, avoid most transmission and distribution losses. They also eliminate the waste of energy associated with the conversion of AC to DC, which is required for so many of the electrical loads found these days: LED lights, variable-speed motors, computers, televisions, and countless other forms of consumer electronics—loads that account for a steadily increasing fraction of the electricity consumed. (Some estimates suggest that most of the electricity used in commercial buildings already goes to serve such loads.) In a time of increased concern about energy efficiency and carbon-dioxide emissions, DC microgrids obviously have a
great deal to offer. Yet traditional AC distribution systems are still all most people ever think about when you use the term “power grid.”

**The only places you can count** on finding local grids carrying DC now are within data and telecommunications centers or, on a much smaller scale, within automobiles, ships, and airplanes. But we expect to see more DC microgrids sprouting up soon, at least in certain settings.

For example, future army outposts in war zones will probably use them to reduce energy consumption and to deploy wind turbines and photovoltaic panels more easily. Replacing the usual diesel generators with renewable sources of power would be especially valuable in hostile territory, where fuel costs can be enormously high, both in dollars and in lives lost protecting supply lines.

DC microgrids may also prove irresistible for certain energy-intensive manufacturing operations. These include paper and pulp production and the smelting of aluminum, which now wastes more than 6 percent of the total energy consumed in the conversion of AC to DC current.

DC microgrids hold great promise, too, for ordinary residential and commercial buildings, where they could service the many electrical loads that use DC. These include LED lighting and, increasingly, charging stations for electric vehicles, whose hefty batteries demand (or produce) DC. Heating, ventilation, and air-conditioning (HVAC) equipment and various household appliances are also well suited to powering with DC. That’s because the most energy-efficient types of HVAC equipment and appliances incorporate variable-speed motor drives, for which AC power from the regional grid must be converted to DC internally. So it would be straightforward—and more efficient—to power such motors directly from a local DC source.

Developments on the generation side only strengthen the case for DC microgrids. Consider how often you see photovoltaic panels mounted on the roofs of houses or commercial buildings nowadays. These panels produce DC power. And even if all that power is used within the building where it is generated, the electricity flowing from those panels is typically converted to AC using an inverter, which wastes about 10 percent of the energy right off the bat. The AC is then sent to various loads, some of which convert the electricity back to DC, in the process squandering about a third of the energy fed to them. Being able to distribute and use DC within a building would prevent the substantial losses that result from having to make the round trip from DC to AC and back to DC again.

Events like 2012’s Hurricane Sandy also highlight the advantages of local power generation, storage, and distribution. That one storm caused more than US $50 billion in damages and left many residents of the U.S. Northeast without power for days, weeks, in some cases even months. DC microgrids fed by batteries, generators, fuel cells, photovoltaic panels, or small wind turbines would surely have proved much more resilient in the face of this natural disaster. They would have been less prone to the most common form of damage—the downing of power lines—and the DC electrical equipment itself would probably have exposed far fewer critical points of failure.

Other reasons to expect a proliferation of DC microgrids come from the developing world, where about 3 billion people still burn wood, charcoal, or animal dung to meet their day-to-day energy needs. These people are, of course, eager to see electrification reach their communities, but it’s far from clear what form that electrification should take.
Round Trip: Today, locally produced DC power (say, from photovoltaic panels) is typically converted to AC using inverters. Much of the time, though, the power supply in the end user’s equipment just converts the AC fed to it back to DC.

With the decreasing cost of electricity generated by photovoltaics and wind turbines, DC microgrids may be the most efficacious way to provide electrical energy to those who have none. Just as cellphone use in the developing world exploded without the prior installation of landlines, DC microgrids could leapfrog over the traditional system of centralized AC generation. The market for microgrids in the developing world could be huge, and the benefits they would bring to what are now grossly underserved regions are monumental.

Clearly, DC microgrids hold extraordinary promise for a wide variety of situations. Why then are they still so few and far between?

Some of the blame, at least in developed countries, can be placed on antiquated building codes that make it difficult to set up the infrastructure needed for generating and distributing DC power locally, perhaps within a single building. And even if property owners can overcome this hurdle, they will still struggle to find advice on how to construct such a system.

One of the few resources now available is the EMerge Alliance, an organization of more than 100 member companies interested in fostering the development of DC microgrids for commercial buildings. Alliance members are working to speed the adoption of this approach to improving energy efficiency, in part by setting relevant standards.
The EMerge standard for occupied spaces specifies that power be distributed at 24 volts DC, with current limited to about 4 amperes on each circuit. This combination is considered intrinsically safe with respect to shock and fire hazards, allowing electricians to install relatively simple wiring (without grounding or metal junction boxes, for example) and still meet the United States’ National Electrical Code.

The EMerge Alliance is also promoting a standard for data and telecom centers. It calls for DC to be created and distributed at 380 V, which saves energy by eliminating the AC-to-DC conversions in each individual piece of electronic equipment plugged into the building’s power grid.

Setting technical standards for DC microgrids, while challenging in its own way, is not the only problem by far. Another barrier comes from the regulatory environment that people or companies face when they want to share the power they generate, even if they just want to send it to others in their immediate vicinity.

Distributing power from rooftop solar panels to several apartments in one building, for example, might be very easy from a technical standpoint, but someone interested in doing that must navigate through some rocky legal shoals. Would selling power to those apartment dwellers violate the monopoly granted to the local electric utility? What if you need to supplement the power you’re providing by drawing some energy from the AC grid and converting it to DC? Would your purchase of electricity from the utility then be considered a wholesale transaction (which in the United States would be governed by federal law rather than by the rules of a state utility commission)?

Such questions are hard to answer, and it will surely take a long while yet for federal and state authorities to sort out the many legal sticking points that DC microgrids raise. The same is true for other countries, each of which will face struggles of their own developing public policies that can accommodate these unconventional grids. But it’s important to do that if we want to move forward.

**For more than a century**, AC power grids have provided the foundation for industrialized societies. The adoption of AC allowed voltages to be shifted using simple transformers, allowing electricity to be carried over long distances even with the earliest systems. Edison’s competing DC approach wouldn’t have permitted that. And because electricity was initially used mostly to power induction motors and incandescent lights, AC served well.

Things are different now. For one, we have solid-state DC-to-DC power converters with efficiencies that are already about 95 percent. (When we begin to use the new wide-bandgap semiconductors in this equipment, efficiencies should rise even further.) So there is no longer any worry about how to shift DC voltage levels or carry voltage over long distances. Indeed, high-voltage DC transmission lines are often used to link separate AC grids, in part because they obviate the need for intergrid synchronization.

Another fundamental change that has come about since Tesla and Edison’s day involves the kinds of things we plug into our outlets. Most of the loads now are essentially DC, so supplying them from a DC source would simplify their power circuitry and save energy overall.

These developments make you wonder why DC hasn’t replaced AC entirely for power grids big and small. In addition to providing energy savings, such a move would mean that it would no longer be necessary for electronic-equipment manufacturers to accommodate the different AC voltage and frequency standards found around the world.

The prime reason AC continues to reign supreme is just that it would be enormously difficult to replace it entirely with DC equipment. So we continue to use it, even though the original justification for doing so no longer exists. This situation is all too common. We no longer have to worry about typewriter hammers sticking together, for example, yet we still use QWERTY keyboards, which are even older than our AC power grids.
But sometimes a shift to new technologies is inevitable, even when the transition promises to be expensive or otherwise disruptive. And for power grids, we have the luxury of being able to start small. So it's high time for the world to embrace DC microgrids, an old-yet-new model for providing people with electricity.

**About the Authors**

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