The grid can handle more renewable energy, but it needs some help

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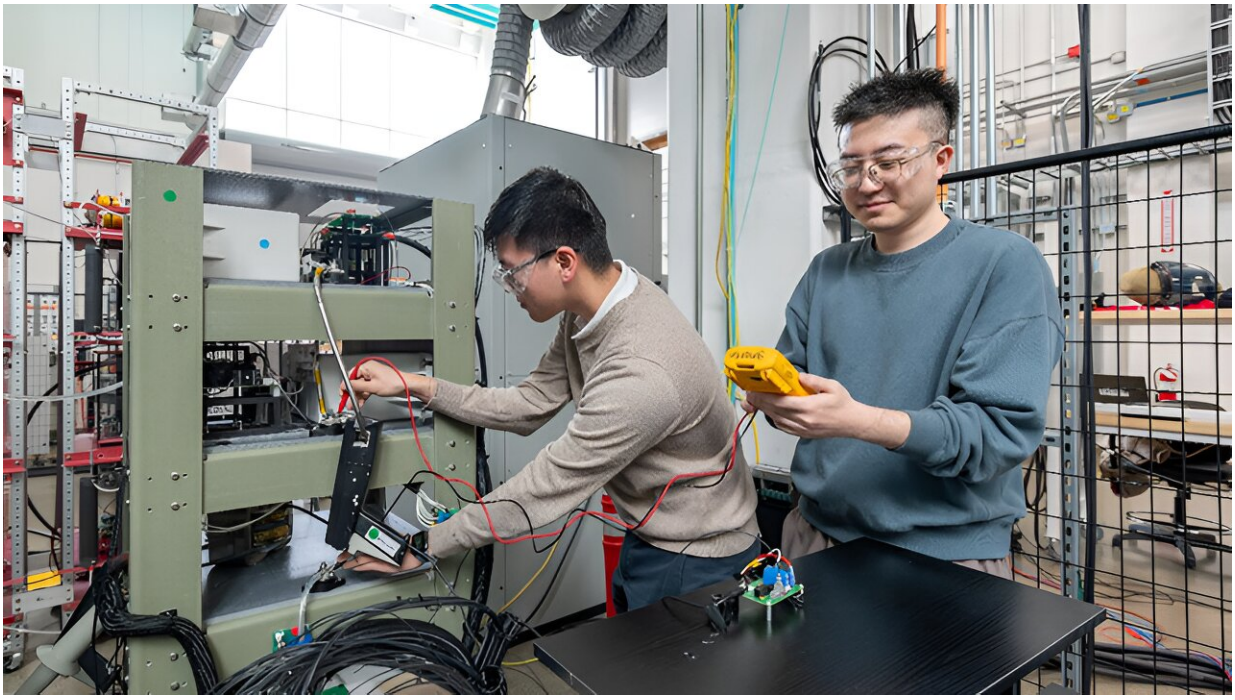

A new kind of grid technology, called medium-voltage silicon carbide converters, could help the U.S. grid smoothly transition to renewable energy. Credit: Josh Bauer, NREL

The grid needs to change. To electrify everything from vehicles to heating systems to stovetops, the U.S. grid must expand by about 57% and get more flexible, too. Solar and wind energy are the renewables most likely to dominate a future clean energy grid. But they are found

primarily in remote areas, far from the hubs that need their power.

And that is a problem. Today's transmission system simply is not designed to ingest all that remote power. Bursts of power on an especially sunny day in the desert could cause grid faults—little blips that can propagate and cause outages—or overload power lines.

But what if we could better control where and how solar energy—or all our energy—flows within the distribution system so we can balance out all that power? That is what a team of experts from the National Renewable Energy Laboratory (NREL), Florida State University, and Ohio State University are working to do.

Over the last four years, the team built a testbed to study and hone an entirely new kind of grid technology, one that could help grid operators better regulate how and where electricity flows. The device, called a back-to-back medium-voltage converter, could do that with a fraction of the weight and cost of the technology it could replace.

"This is a whole new type of equipment that opens up a whole new way for a utility to manage their distribution systems," said Barry Mather, a researcher at NREL. "Much higher levels of distributed energy resources could be put onto a circuit if you had this extra device within the system."

Mather is leading this project, which was funded in part by the U.S. Department of Energy and is known as the Grid Application Development, Testbed, and Analysis for Medium-Voltage Silicon Carbide project, or GADTAMS. GADTAMS wrapped up in December 2023. But the project's successes, which include a first-of-its-kind prototype and fully functional testbed to study and improve these novel grid technologies, could help the U.S. grid evolve.

The benefits of medium-voltage power converters

Medium-voltage electricity is what's pumping through the power lines outside your window—unless you live in Europe.

"The U.S. grid is … Well, it's a little bit unique," Mather said. "We have what's called medium-voltage distribution that ends up pretty close to our customers."

Today, grid devices called transformers convert that medium-voltage electricity into a higher voltage—so it can zoom across high-speed power lines—or a lower voltage—so it can safely enter our homes.

Say a tree limb falls on a power line, cutting off electricity to a neighborhood. Today, a utility worker can open and close switches in a transformer to move power from a nearby line into the disrupted one and restore at least some power while workers remove the tree.

That's great. But we can do better.

Replace a transformer with a back-to-back converter and power can be redirected automatically, reducing outage times. Plus, transformers are cumbersome, a bit costly, and, because of shaky supply chains, some can take up to two years to arrive. Back-to-back converters are about one-fifth the size and one-tenth the weight of those transformer-based low-voltage systems.

"If we can do direct medium-voltage conversion," Mather said, "then we can effectively get rid of that transformer altogether."

Power sharing is not just beneficial in emergencies. Many of today's rooftop solar panels must first convert their energy to low voltages and then to a medium voltage. With medium-voltage converters, that energy

can skip an unnecessary hurdle.

"It's kind of like arbitrage of power across the distribution system," Mather said. "It allows you to mitigate a lot of the impacts of distributed resources, specifically solar."

In short, medium-voltage converters could help utilities safely control how and where electricity moves through local grids. And that could help make a future clean energy grid both resilient and reliable.

The first testbed to safely study medium-voltage technology

Medium-voltage converters are still a relatively new technology. That means they must undergo extensive testing to ensure they are efficient, affordable, and safe enough to introduce to the U.S. power grid.

But it is not easy to build or study medium-voltage devices.

"The checklist for startup, operation, and shutdown procedures had to be written and rewritten," said Ramanathan Thiagarajan, a research engineer at NREL (who goes by "Ram").

In NREL's Energy Systems Integration Facility, the team painstakingly constructed a replica of the kind of power system that could benefit from their medium-voltage converters. Safety—for the crew but also the prototype—was the team's top priority.

The whole testbed, which takes up a space about the size of a city bus, is enclosed in a black fence about as tall as the average man (but shorter than LeBron James). Inside, insulated wires snake from converters—which look a bit like bookcases—to gray metal cabinets or

sit in neat coils along the shelves.

The team's academic partners built one prototype: a 10-kilovolt silicon-carbide-based power converter that is designed to work back to back with its twin. When the researchers were ready to plug the prototype into their grid replica, they nudged the voltage up bit by tiny bit until they reached the medium-voltage range. The prototype was too precious (and expensive) to risk damaging with a surge of too-potent electricity.

"We did get up to the 5-kilovolt range," Mather said. "It's not a massive number, but that's higher than anybody else has operated at."

And it worked. The team could then see how well their system-controlled electricity flow and whether they needed to make any changes. Next, they plan to open their testbed to more research on how medium-voltage devices could help the grid adapt or rely on hydrogen as another source of clean energy. The NREL team also hopes to reach even higher voltages in an entirely new facility dedicated to medium-voltage power electronics.

"Medium-voltage power conversion in general looks like its day is rapidly approaching," Mather said. "We're going to see more and more applications and more and more people interested in this.

"We're super happy to have this testbed now—not just for this GADTAMS project but for the future as well," Mather continued. "It's basically a home for medium-voltage power electronics development."

Provided by National Renewable Energy Laboratory