

Advanced conductors could double power flows on the grid

Widespread reconductoring of the US transmission system could ease bottlenecks that are preventing renewable energy sources from hooking up to power grids.

Following 15 years of stagnating electricity consumption in the US, demand is now on the rise, driven by a proliferation of power-hungry data cen-

ters and by the increasing adoption of electric vehicles and heat pumps. As those technologies become more widely adopted and industrial processes are

electrified over the coming decade, the US will need to increase its electricity-generation capacity by more than the amount currently available in Texas, according to Jeffrey Brown, managing director of the nonprofit EFI Foundation.

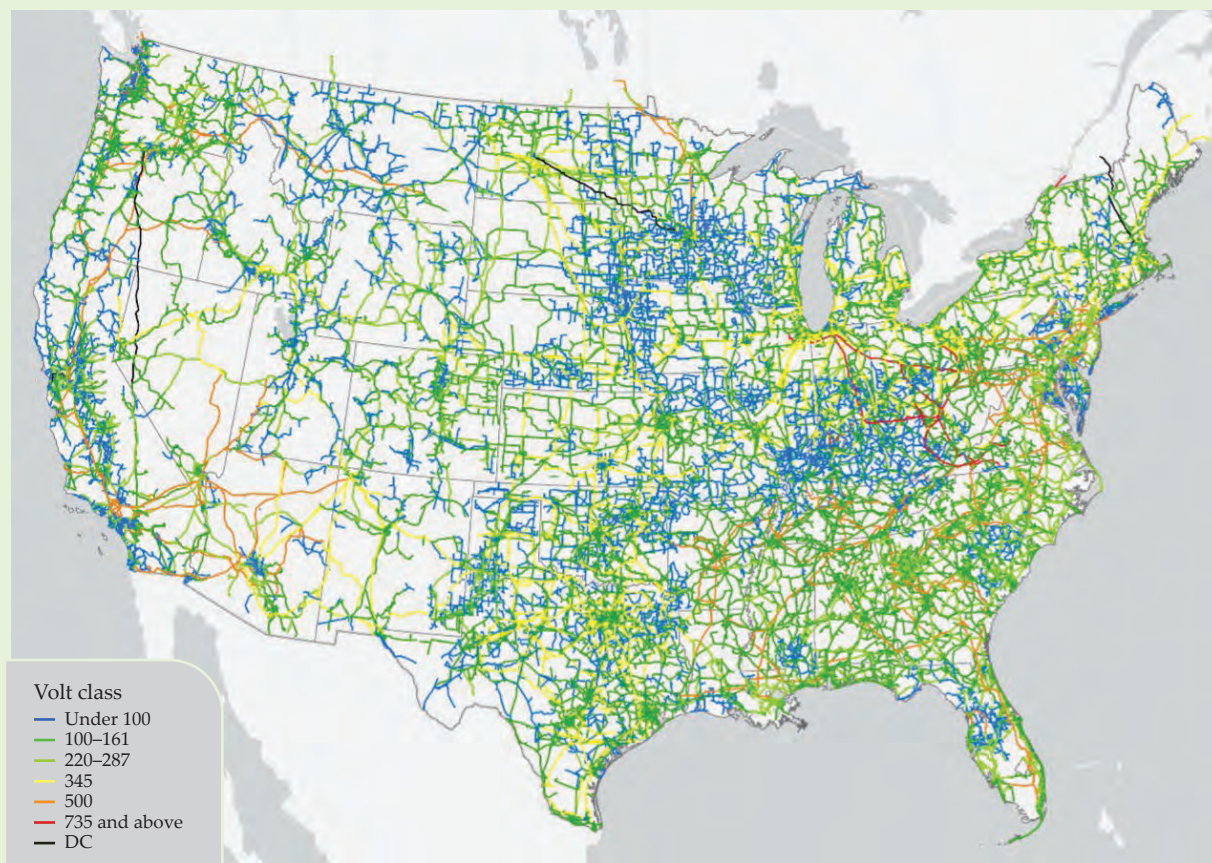
An assessment by Lawrence Berkeley National Laboratory released in April

TS CONDUCTOR

THE ARIZONA UTILITY SRP is shown carrying out a reconductoring of a 230 kV double-circuit transmission line with composite-core conductors made by TS Conductor. The circuit on the right side of the tower is live. As lineworkers string the new conductor, it is anchored to heavy concrete blocks on the ground using the gray clamps shown. The blocks are then moved to the next section for reuse.



US TRANSMISSION LINES



IDAHO NATIONAL LABORATORY

THE VAST MAJORITY of US transmission lines are 235 kV or below. Their capacity could double if they were refitted with advanced conductors, researchers say.

identified 2600 GW of proposed wind, solar, and energy storage projects that are awaiting connection to the grid. Their capacity is more than double that of the entire nation's 1250 GW installed power generation. Renewable energy and batteries make up 95% of the queue, and 1200 GW were proposed since passage in August 2022 of the Inflation Reduction Act, which included a range of tax incentives and other provisions to encourage clean-energy production. History indicates that nearly three-quarters of those interconnection requests will eventually be withdrawn, the assessment says.

The consulting firm Grid Strategies published a report last year saying that transmission congestion costs exceeded \$20 billion nationwide in 2022, a 56% increase from 2021. The primary cause, it says, is the failure of transmission expansion to keep up with the growth of low-cost wind and solar energy.

The growth of data centers is already

straining the grid in some locations, notably northern Virginia, which is home to 150 hyperscale centers, more than one-third of the world's total, according to the Virginia Economic Development Partnership. Hyperscale centers are generally considered to comprise 5000 servers or more, and they are typically operated by tech giants such as Google, Amazon, Meta, and Microsoft. Dominion Energy, the utility that services most of them, experienced load growth of 500 MW annually from 2019 to 2022, says Grid Strategies.

The Department of Energy's 2023 National Transmission Needs Study finds that to rapidly electrify the US economy and decarbonize the grid, intraregional transmission must double and interregional transmission capacity must increase by a factor of six by 2040.

Building new transmission lines, however, can take 10 or more years. The process involves acquiring new rights of way, determining how to allocate the costs to

the utilities that will benefit, acquiring permits from regulators, and building the towers and associated infrastructure.

On 25 April DOE announced a final transmission-permitting reform rule that commits the agency to coordinate and complete within two years—about half the current timeline—all the interagency reviews required for approval of new transmission corridors. At the same time, the agency announced a \$331 million investment, from the 2021 Infrastructure Investment and Jobs Act, in the construction of a new 459 km transmission line that will carry 2000 MW of wind energy from Idaho to southern Nevada and southern California.

A quick doubling

Even before new transmission corridors are built, the capacity of today's grid could quickly be doubled if cables were replaced with advanced conductors on a wide scale, says an April report by researchers at the

University of California, Berkeley, and GridLab. Although advanced conductors may be two or three times as costly as conventional ones, upgrading existing lines with them could be accomplished at one-quarter to one-half the cost of building new lines, and the jobs could be completed in 18–36 months, without a need to obtain permits, the researchers found.

Of the approximately 1.3 million kilometers of existing transmission lines in the US, only 1% are reconducted or rebuilt each year, the report says. And even though advanced-conductor alternatives have been available for more than two decades, many rewiring projects in the US are still completed with conventional conductors, which don't appreciably increase capacity.

Most transmission lines in the US today deploy a more than century-old type of cable known as aluminum-conductor steel-reinforced (ACSR). Those conductors are designed to operate continuously at temperatures of up to 93 °C and at higher temperatures for brief periods during emergency conditions. As line temperature increases in concert with the current carried, the ACSR steel core expands, increasing the sag between towers.

The 2003 blackout in parts of the midwestern and northeastern US and Ontario, Canada, resulted in 11 deaths and cost the economy an estimated \$6 billion. A federal commission identified the initial trigger of the event as an Ohio transmission line sagging and contacting a tree. In the aftermath, the North American Electric Reliability Corp issued a requirement that lines be surveyed and clearances be maintained.

Advanced conductors have composite cores, made of material such as carbon fiber and ceramics, that are stronger than steel and thermally expand at far lower rates—carbon fiber has one-tenth the thermal expansion of steel, says Gary Sibilant, a senior program manager at the Electric Power Research Institute. That allows much higher operating temperatures and current flow.

The smaller diameter of advanced conductor cores allows more aluminum to be packed into a cable of the same diameter as an ACSR cable. Advanced conductors also lose less power during transmission, so generating stations can produce less power to satisfy the load. Those advantages add up to cables with twice the current-carrying capacity of ACSR ones.

Advanced conductors have been underutilized for a variety of reasons, according to the Berkeley–GridLab report. They include workforce shortages, cost, lack of space needed to perform the reconducting, uncertainty over permitting requirements, age and condition of existing structures, and concerns that the increased capacity will require transformer upgrades at substations.

Many other nations in Europe, South America, and Asia are reconducting, some to a greater extent than in the US. Globally, more than 144 000 km of advanced conductors have been deployed since 2003, the Berkeley–GridLab report says.

Elia Transmission Belgium, which operates the country's national grid, has been reconducting since 2009. Kristof Sleurs, the company's head of grid development, says the utility expects to reconduct its entire transmission backbone of 380 kV lines over the next decade. In combination with other grid-enhancing technologies, such as dynamic line rating—calculating actual conductor conditions in order to match current capacity to real-time conditions—and flow-directing tools, reconducting should accommodate most of Belgium's transmission needs for the next decade, he says. Still, new circuits, including high-voltage DC lines, must be built for electricity generated by new offshore wind farms to be carried, he adds.

Thermal constraints

Opinions differ on the extent to which advanced conductors could be deployed in the US. According to a 2023 report by Idaho National Laboratory, around 20% of the US transmission system is ripe for advanced conductors. But the Berkeley–GridLab report says that all but around 2% of the nation's transmission lines could benefit. An accompanying report by GridLab and Energy Innovation says wide-scale advanced conductors could help quadruple the capacity of the new transmission lines that are projected to be built by 2035. That should enable a 90% clean electricity system and could save \$85 billion in energy system costs, it says.

An April report from DOE says advanced reconducting is most economically viable on lines that are approaching end of life or in places where the increase in capacity is so significant that it warrants early replacement. Capacity benefits are most applicable to lines

with lengths less than 48 km and voltages less than 500 kV, the report says. For reducing line losses, however, advanced reconducting is more broadly applicable, it adds. Supporting structures and poles must have sufficient remaining life and structural integrity to be candidates, the report notes.

Sibilant says lines carrying 138–230 kV are thermally constrained and would benefit the most from advanced conductors. They consist of a single line for each of the three AC phases carried, and they make up the bulk of the nation's grid (see the figure on page 22). Transmission at 345 kV or greater is not thermally constrained, because it uses two or more conductors—and much more aluminum—for each phase, Sibilant says.

Jason Huang, CEO of TS Conductor, which manufactures carbon-fiber-core cable, says that savings from reduced line losses could be monetized to finance the cost of reconducting without any cost to utilities. He notes that advanced conductors also allow for transmission lines with longer spans and fewer towers. At \$250 000 or more per tower, those savings can add up, he says.

Still, many utilities remain hesitant to install composite-core conductors over perceptions that they are fragile and easy to damage. Some advanced conductors can't be bent as easily as those with steel cores, notes Sibilant, and those require different handling procedures. Composite-core conductors are also considerably more expensive; they cost as much as four times the price of ACSR cables, according to the Idaho National Laboratory report. But given that the conductor material is less than 5% of the total cost of a new transmission line, the premium for a more expensive conductor is easily justified, the report adds.

Upgrading the voltage of transmission lines could also increase their capacity, says Sibilant. High-voltage DC provides the greatest capacity, but that requires expensive conversion equipment at both ends of the line. DC is used for transmission over very long distances, such as those involved in bringing hydroelectric power from northern Quebec to the US and bringing offshore wind power to land, for which line-loss savings justify the additional expense.

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