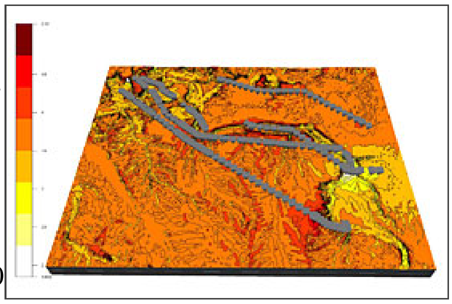
INL research on how wind cooling affects high-voltage power lines aims to increase transmission capacity at very little extra cost.

INL wind researchers test cool way to stretch capacity of existing power lines

By Sandra Chung, *INL Research Communications Fellow*

In the continental United States, some 500 power companies operate a massive, complex network of more than 160,000 miles of high-voltage transmission lines. The capacity of that network has been largely unchanged for the last two decades and now must expand to accommodate new power plants and renewable energy projects. Adding new transmission capacity is extremely expensive. A new high-voltage line typically takes 7 to 10 years to plan, permit and erect — and costs upward of $1 million per mile. The difference in time and cost between using existing transmission lines or new ones can make or break a new wind or solar farm and significantly impact growth of carbon-free energy sources.

Some Idaho National Laboratory wind power researchers think we can move more electricity through the transmission lines we already have without breaking the bank. In areas where wind farms are being developed, there is potential to take advantage of wind cooling on transmission lines concurrent with wind power generation. The key is to pay close attention to the weather. The more electric current a line carries, the hotter it gets. After a certain point, the line operator can't add any additional current without overheating and damaging the line. But just as a wisp of wind can make a sultry summer day much more bearable, a breeze can ease the journey for electricity traveling through hot power lines. An increase in wind speed of 5 mph blowing at a right angle to a high-voltage line can cool the line enough to increase the amount of current it can safely carry between 30 and 50 percent, says INL wind power expert Gary Seifert.



INL researchers use data from the weather stations to create a 3-D mean wind speed map. The scale shows wind speeds in meters per second.

The amount of wind cooling a line receives varies with the wind's speed and its direction relative to the line. So INL researchers are working with Idaho Power Company in a windy part of southern Idaho to translate detailed wind and temperature information into dynamic line ratings — real-time estimates of how much current each 500-meter segment of high-voltage line can safely carry at the same time that wind power is being generated. Idaho Power and the Department of Energy's Office of Energy Efficiency and Renewable Energy are funding the wind cooling research, which could help make electricity cheaper and accelerate renewable energy projects.

"If we can increase transmission capacity in many power lines with very little cost, we give these projects the ability to grow without putting in new transmission lines," Seifert says. "We can leapfrog some of the transmission limitations to renewable power."

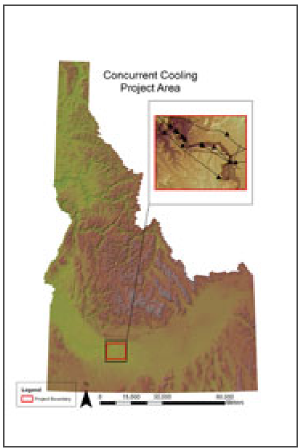
Power utilities operate transmission lines based on static ratings, which set a conservative limit on the amount of current the lines can safely carry without overheating. Static ratings assume there's little or no wind blowing, so in moderately windy places, a line's static rating is often much lower than its real transmission capacity. Those windy places are often next to wind power farms. Using dynamic line ratings to manage high-voltage lines in such places could help increase the overall efficiency of power transmission and lower the cost of power to customers.

A long-term record of dynamic line ratings could also help utilities identify portions of transmission lines that act as bottlenecks, says INL wind power researcher Kurt Myers. Upgrading these bottleneck stretches could significantly increase the transmission capacity of the entire line at a fraction of the cost of replacing the whole line or putting up a new one.

Windy with a chance of upgrades

The INL research team worked with Idaho Power Company to install 15 small weather stations that monitor the temperature and wind along more than 100 miles of high-voltage transmission lines. But the weather stations can't make measurements at each and every point along the lines. Instead of installing hundreds more wind and temperature sensors, the researchers are using a sophisticated computational fluid dynamics software package to analyze air flow and fill in the gaps between the weather stations.

Modeling the weather is a complex task that requires a lot of computing power. The INL research team started with a weather simulation program called WindSim, which meteorologists, wind power developers and researchers



INL researchers and Idaho Power installed 15 weather stations along transmission lines in a windy part of Idaho.

typically use to model climate over uneven terrain. By working with WindSim's developers, the INL team modified the software to boost the simulation speed and add several new data capabilities, says INL engineer Jake Gentle.

Gentle and his INL colleagues also developed a new tool that can take WindSim's weather model results and estimate how much the weather should affect a power line's real transmission capacity. This will help determine the relationship between wind energy generation and resulting concurrent cooling of the transmission lines carrying that wind power to homes and businesses.

In its first seven months collecting and analyzing weather data in the study area, the INL research team has already captured some compelling results. The researchers' software tools helped them identify several portions of high-voltage line that, when the wind is blowing hard enough to make wind power, could carry as much as 50 percent more current than its static rating allowed, Myers says.

On the other hand, around one-tenth of the length of the high-voltage line in the study area seems to get hardly any wind at all, Seifert says. No wind means no cooling boost in transmission capacity. Such hot stretches limit the amount of current the entire line can carry, in the same way that weak links limit the strength of an entire chain. Upgrading the hottest stretches with a higher-capacity cable could bump up the entire line's transmission capacity by 30 to 50 percent, Myers says.

On high-voltage lines that carry heavy transmission loads, a capacity increase of 10 percent is a big deal, Myers says. For a new wind farm, it could be the difference between being able to use existing transmission lines now versus having to sink several years and millions of dollars into new ones while waiting many years for them to be developed.

Improved forecasting

Each weather station measures and records wind speed peaks and averages, wind direction averages, temperature and operating battery voltage.

The INL research team is still working to make the weather simulation software run faster and generate more accurate results on extreme terrain. Sharp features like a cliff face or ravine can profoundly affect nearby wind and temperature conditions and throw off the weather model's results. Trekking out in the field to take weather and line temperature measurements on the spot will help the researchers validate and refine their weather model, Myers says.

Meanwhile, the INL team is working with Idaho Power Company engineers and plans to start training some Idaho power line operators to use the weather station data and software tools to generate transmission capacity estimates. The ability to reliably make such estimates on a large scale with high spatial resolution could bring power utilities a step closer to using a transmission system dynamic concurrent cooling process.

Such a system may be many years away — as it would require more sophisticated technology and management than the current static rating system, not to mention major changes in utility regulations and procedures, Myers says. In the near future, the researchers' weather monitors and wind cooling tools could help line operators in emergency situations by giving them the ability to monitor line conditions in real time. "It's a little bit of peace of mind for operators," Myers says.

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