Neural network-based forecasting for renewable energy transmission

September 5 2014, by Christine Rüth

Everything was simpler in the past. Power plants were distributed throughout countries and their output was adjusted according to energy demand. Power plants used calendars and weather forecasts, among other means, to predict the power needs of regions and large production plants.

Today, the situation is more complicated. Depending on the weather, wind farms and solar parks produce varying amounts of electricity, and conventional power plants must make up for fluctuations. The greater the share of fluctuating renewable energy sources, the more difficult it becomes to manage power supply—an issue that affects power suppliers and grid operators alike.

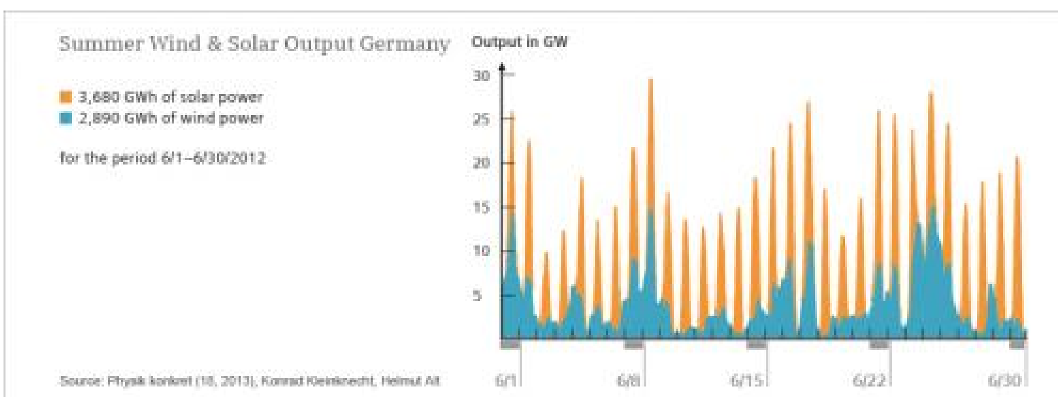
To ensure the grid remains stable, it must always be supplied with as much electricity as is taken from it. If a power station or a major consumer breaks down, the energy supply is either increased or decreased, as the case may be, to prevent power outages. Every power plant is required to supply certain amounts of positive and negative controlling power. However, it will become increasingly difficult to keep the grid in balance in the future—especially in Germany, which is in the midst of an energy transition and plans to greatly boost the share of renewables in its power mix.

How should this new situation be handled? How can power companies keep the grid stable, provide a secure supply of energy, and still remain profitable? Dr. Ralph Grothmann, a researcher at Siemens Corporate Technology (CT), says the answer is to improve planning through better forecasting. "If you knew how much solar and wind energy would be available in the days ahead and also had regional demand forecasts, you could manage conventional power stations with great foresight, plan sufficient energy supply to counterbalance transmission losses, and buy energy at favorable terms on the power exchange," he says.

With this vision in mind, Grothmann and his colleague Dr. Hans Georg Zimmermann have developed forecasting software known as the Simulation Environment for Neural Networks. SENN uses artificial neural networks (i.e. computational models) that are similar to the ones in the human brain. These networks can be trained to recognize interrelationships so that they can make forecasts. "The cool thing about neural networks is that you don't have to fully analyze and understand a problem in order to make a forecast," Grothmann explains.

For example, if you wished to depict a solar park with an analytical model, you would need to calculate how much electricity a solar panel produces on the basis of the incident solar radiation and other environmental factors, such as temperature, wind speed, and humidity. If some of the panels happened to block the sunlight from reaching others, this would need to be taken into account. Only then could the model use the weather forecast to predict the solar park's output at its precise location.

Training with Data. Neural networks are handled very differently. They are trained using past data—in this case, weather forecasts and the solar park's electricity output for these times. The weather data doesn't have to come from the solar park's location; it can be supplied by a nearby weather station. The program's task is to predict how much solar power will be produced on the basis of the weather data. At first, the software doesn't know what effect the various parameters will have, so its forecast will deviate significantly from the solar park's actual output. During the training phase the program repeats this process thousands of times to minimize the difference between a forecast and actual values. As this happens, SENN changes the weighting of individual parameters to become more and more precise.



Originally developed over 20 years ago, SENN is currently used, for instance, to forecast raw material prices and the price of electricity over 20 day periods. It can accurately predict the best purchasing day two thirds of the time. Siemens has used SENN since 2005 to buy electricity at times when prices are lowest.

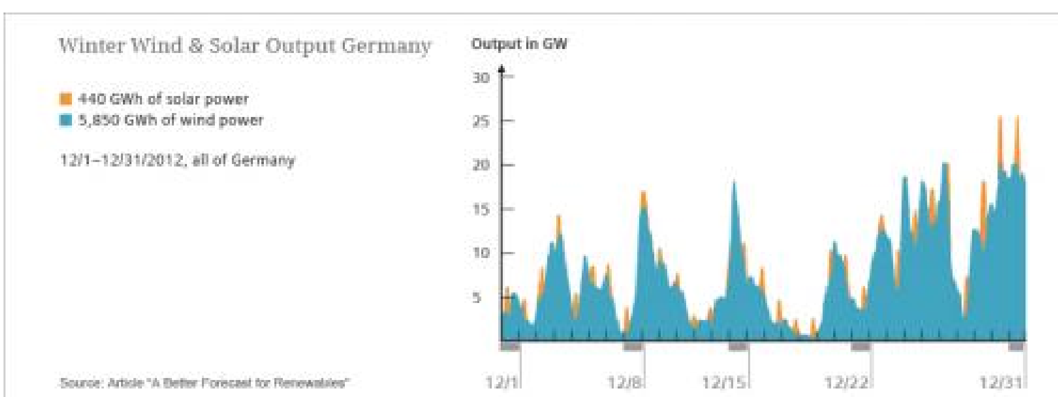
With the boom in renewable energy sources, Siemens recognized that SENN forecasts would have great potential for the energy industry. For example, forecasts of the amount of electricity that will be fed into the grid by renewables allow network operators to plan the use of additional power stations or the need for balancing energy. Operators of wind farms and solar parks can use the forecasts to schedule maintenance work during times when energy systems are expected to produce a lower yield, to sell the expected amounts of electricity at more favorable terms, and to plan future income.

A SENN model is now being tested on data from a large offshore wind farm in Denmark. The model uses forecasts for wind speed, temperature, and humidity to predict the farm's electricity output for the next three days to within 7.2 percent. For example, if the system forecasts an output of 100, the actual value would be between 92.8 and 107.2. "The accuracy of the forecast depends mainly on the quality of the data," says Grothmann. "All in all, we can predict the weather fairly accurately three days in advance."

Siemens Energy offers SENN production forecasts as part of its monitoring and control solutions for power facilities that use renewables. For instance, SENN is being used in South Africa at two solar parks, each with 50 megawatts of output. The software enables the power companies to meet the network operators' forecasting need regarding the amount of electricity that will be fed into the grid. SENN can predict the solar parks' electricity production for every hour of sunshine in the next five days to within about seven percent.

A second model for solar parks is now being planned. It will advise operators about ways to handle grimy solar panels. Dust can reduce panels' power production by up to 15 percent, but cleaning them costs money too. "If an operator knows that enough rain is on the way to wash away the dust, it won't have to send in a cleaning crew," Grothmann explains. The new software will resolve this issue by using environmental factors such as aridity, wind, and rain to forecast how much dust will cover the panels.

Forecasting Demand. Demand forecasts are the second major application of SENN in the energy market. They enable major consumers to buy electricity at favorable terms or schedule operations so as to avoid periods of peak demand during which they may have to pay stiff fines. Energy suppliers can use regional forecasts to plan electricity purchases and power plant operations. For instance, Swiss network operator Swissgrid uses SENN to plan electricity purchases in such a way that transmission losses are taken into account as huge amounts of power flow from Germany or France to Italy. Because Swissgrid has to offset such losses, it purchases electricity on the spot market up to 36 hours in advance, for about €48 million per year.

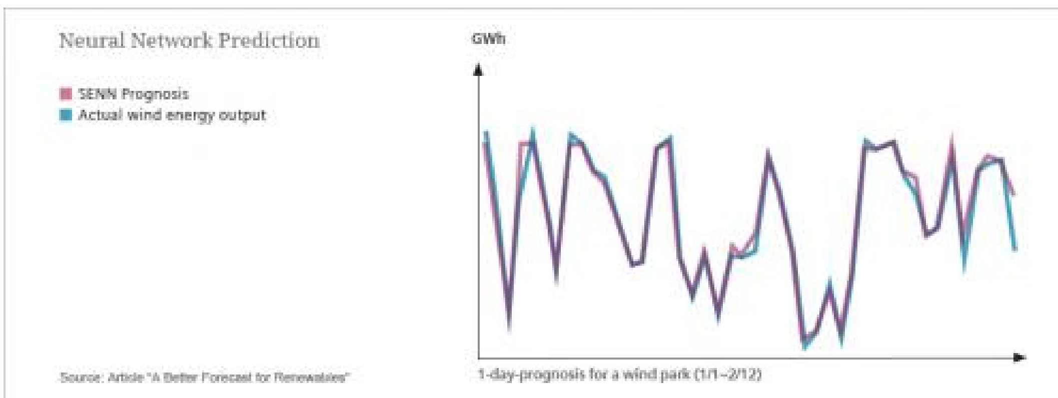


Swissgrid used to estimate demand on the basis of calendar and weather data and information supplied by network operators in neighboring countries. But SENN has reduced the forecasting error from 11 to 10 percent, enabling Swissgrid to save hundreds of thousands of francs per year.

SENN generates very accurate demand forecasts with an error rate of only three percent. On this basis, it can directly predict the transmission losses. To do this, it monitors the hourly development of demand in the region to which the electricity is to be transmitted. It also examines current power flows, the amount of energy being generated from renewable sources, weather forecasts, and the water levels in pumped-storage electrical power stations.

Although sunshine and wind are unreliable, software from Siemens is learning to forecast the resulting electricity yield.

Thinking Holistically. Individual forecasts are a first step toward a future energy market in which almost all factors—production, demand, price, and transmission—are in flux. All of these quantities in the system are interdependent; as a result, they should be examined holistically. For instance, if wind facilities increase energy production, conventional power stations would need to produce less power, which might reduce the price of electricity. Depending on demand, the wind energy would be transmitted either northward or southward. This, in turn, would change the need for balancing energy to offset transmission losses. "The better the interaction of these parameters can be predicted, the more efficient the entire system will be," says Grothmann.



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This is an area where the SENN neural network shines. Because it doesn't use analytical relationships but instead learns to recognize interrelationships from the behavior of all parameters, its forecasts already encompass the interdependencies. "One of the ways in which we use SENN is to determine the price of electricity from a wide variety of interacting parameters, such as the development of the price of electricity and other raw materials, the development of demand, and the cost of CO2 emission permits. This makes our software unique," says Grothmann.

Today, an energy supplier with several power plants could already use SENN to purchase natural gas cheaply and optimally adjust electricity output to forecasts for the price of CO_2 permits and electricity. In the future, a network operator could provide the energy supplier with forecasts regarding demand and the anticipated need for balancing energy. These predictions would, in turn, be based on the production and demand forecasts supplied by other partners. All of this would make the rather dizzying volatility of energy markets easier to handle, because all of the players could adjust their activities in advance to accommodate developments affecting other market participants.

Provided by Siemens