



Intelligent network technology helps to integrate renewable energy sources such as wind and solar power into the grid. It can also smooth fluctuations in supply and demand by using automatic network control processes and financial incentives. Siemens is the leading developer of solutions for sustainable power networks.



New offshore wind farms (left) will provide a wealth of clean power. High-voltage direct-current transmission insures low-loss transmission over long distances (picture shows a transformer).

2020 and to increase the share of renewable resources in energy production from six percent in 2005 to 20 percent by 2020. In other words, the use of wind power is set to increase. Moreover, if and when a new global agreement on climate change comes into force, the emissions reduction target for 2020 will increase to 30 percent.

The installed capacity of German wind farms is forecast to rise from today's figure of 23 gigawatts to 50 gigawatts by 2030. In addition, progressive liberalization of the electricity market will lead to widespread energy trading throughout Europe and increasingly unpredictable load flows. In 2007, a total of 1,273 terawatt-hours — two and a half times Germany's annual power requirements — were traded at the EEX in Leipzig, Europe's largest energy exchange. And that figure is set to increase in 2008.

**Sustainable Power Networks.** In response to these challenges, the European Union has unveiled its smart grid concept, which is designed to transform the current electricity network into a sustainable power system, with a major emphasis on protecting the atmosphere and ensuring security of supply. In particular, the grid must be capable of automatically regulating fluctuations in incoming power supply. This will involve the use of devices to temporarily store excess energy as well as flexible load control systems that activate or deactivate power-hungry devices for a short time. Likewise, blackout prevention systems such as Siemens' Flexible AC Transmission System (FACTS) will rapidly adjust voltages, buffer grid fluctuations, control the flow of current, and increase the transmission capacity of longer power lines.

"In the long term, the only way to ensure trouble-free transmission of large amounts of surplus electricity — from offshore wind farms,

Low transmission levels improve efficiency, which benefits the environment. In China, for instance, Siemens is currently building the world's most efficient HVDC system. From 2010 onward, it will link hydroelectric power plants in southern China with the country's coastal industrial centers 1,400 kilometers away. Without the use of HVDC, it would be impossible to transmit the 5,000 MW of hydroelectricity that the system is designed to carry over such a distance.

The system's transmission efficiency is expected to cut CO<sub>2</sub> emissions by around 30 million tons per year. Furthermore, HVDC acts as a firewall, separating individual national grids from one another and thus preventing a cascade of blackouts.

A further development in this area is the introduction of HVDC PLUS (High-Voltage Direct-Current Power Link Universal System). According to Weinhold, a member of the project team in this field, HVDC PLUS will enhance the sustainability of integrated power systems because it allows for compact power converter stations that can be installed on site and can thus be used to link offshore wind farms and oil rigs to the mainland.

**Superconducting Current Limiters.** Modern grid systems also require the use of power electronics with semiconductor components featuring a large current-carrying capacity and a high reverse voltage. "The circuit breakers have to be able to switch large loads reliably and deal with the very high currents that arise during a short circuit," says Dr. Roland Kircher from the Power and Sensor Systems Division of Siemens Corporate Technology (CT). To this end, scientists at CT are using simulation programs and complex physical models to develop components with new materials and contact geometries. The aim is to ensure that the arc

## Tomorrow's Power Grids — Getting Smarter and Safer

It's a summer's evening in 2016, half an hour after the final of the European Soccer Championship. A rapidly freshening westerly hits offshore wind farms in the North Sea and onshore wind farms in Denmark, northern Germany, and the UK, funneling twice as much as the expected 20,000 megawatts (MW) of power into Europe's interconnected network grid. This huge input of power, which is equivalent to the amount generated by 20 nuclear power plants, takes operators completely by surprise. Within

a matter of seconds, there is a major overload, chiefly impacting the high-voltage transmission lines and substations that form bottlenecks between various countries in the European grid. The grid fails, at first locally, and then throughout the entire network. Night falls prematurely across all of Europe...

Experts have long feared such a scenario. On November 4, 2006, a partial blackout plunged half of Europe into darkness. What's more, the planned construction of large wind

parks in coming years, especially in the North Sea, will mean that almost 40-year-old networks will have to cope with huge power surges during storms. Then the only way to avoid major grid failure will be to rapidly ramp down output at conventional power plants.

"Europe's interconnected grid needs to become smarter so it can handle surges in power caused mainly by the fluctuations associated with wind and solar energy," explains Dr. Michael Weinhold, Chief Technology Officer at

the Siemens Energy Sector. "We have to make power transmission failsafe between the various control zones within the German and European grids even when they are operating at higher loads."

Time is running short, however, not least because of a package of proposals to fight climate change presented by the European Commission on January 23, 2008. The proposals are designed to cut greenhouse gases emissions by least 20 percent relative to 1990 by

for example — is to enhance the extra-high voltage system," predicts Dr. Wolfgang Woyke, a grid expert at power company E.ON. "One solution here is to exploit high-voltage direct-current transmission (HVDC)." This can be used to transport large amounts of electricity at low losses over distances of more than 1,000 kilometers. Siemens is a leader in the development of HVDC technology and is involved in major projects in this area around the world (*Pictures of the Future*, Spring 2006, p. 20).

produced during switching is rapidly extinguished, thus protecting the device in question.

"In the future, superconducting current limiters could provide an alternative to conventional switches," says Kircher. "These components have practically no electrical resistance at temperatures of around minus 196 degrees Celsius." But if the current in the grid rises above a particular critical value, the response is immediate and the current limiter's resistance

rockets in less than a millisecond, thus limiting the current and minimizing the risk of a blackout. Following such an event, the current limiter returns to a superconducting state and is again fully functional. In 2007, CT successfully tested a self-reactivating high-breaking-capacity fuse, which used these types of superconductors and was rated for currents of up to 300 amps and voltages of up to 7,500 volts.

**Storing Power in Cars.** Innovative approaches like this will soon be in demand. After all, the pressure on the power grid could rise further due to measures designed to promote the use of battery-powered cars equipped with ei-

ther a plug-in hybrid drive system or an electric motor (see p. 22). Such vehicles not only draw power from the grid but could also feed it back in. It would therefore be possible to use the batteries of such cars to buffer power generat-

**In the future, electric and hybrid cars could serve as a gigantic battery to store surplus electricity.**

## The Future of Power Networks



**In a study entitled *Electric Power Transmission and Distribution: The Backbone of a Sustainable Energy System***, the Siemens Energy Sector has taken a detailed look at the social, technological, and consumer-driven developments that will shape the markets for power transmission and distribution over the next 15 to 20 years. In addition to projecting the impact of global trends such as climate protection, diminishing resources, and growing urbanization, the researchers also predict the advent of more efficient power transmission technology.

The study employed the “Pictures of the Future” methodology used by Siemens for strategic planning. Specifically, experts from Energy Transmission and Distribution as well as Corporate Technology conducted over 100 interviews with external specialists and identified new market trends and key technologies, whose impact on regional markets was subsequently investigated. On this basis, they came up with detailed scenarios for various fields, which were developed into new business ideas.

The study determined that grid optimization will be driven by three overriding objectives: sustainability, security of supply, and efficiency. For the period until 2020, researchers forecast a growing proportion of decentralized generation, with more and more electricity being produced either by small power plants serving individual towns and communities or by buildings fitted with generating systems such as photovoltaic panels. Similarly, an increasing share of our electricity will come from CO<sub>2</sub>-free energy resources. And thanks to the use of intelligent network technology, it will be possible to feed power generated by decentralized renewable energy sources into existing networks and to transmit the electricity from remote power plants such as offshore wind farms to major centers of consumption with minimal transmission losses. High voltage direct current transmission technology will be used to connect power plants into large generating networks. Likewise, so-called microgrids will link smaller municipal power plants to the grid, and generating facilities of varying sizes will join forces to function as a virtual power plant.

Additional trends include increased use of IC technology, featuring a mix of sensors and sophisticated data-processing systems to measure, monitor, manage, and enhance power generation, transmission, and consumption. Energy storage systems will also play a major role in guaranteeing a secure supply. At the same time, the development of enhanced power electronics and new materials will do much to increase the efficiency of power transmission and distribution — an area in which the use of environmentally compatible products and solutions is increasingly becoming the rule.

ed by wind farms. There is huge potential here. If the 45 million cars currently on German roads were all hybrids, the maximum combined charging capacity would be around 270 GW. That’s enough to temporarily store surplus electricity from the grid, which could then be released when required. What’s more, the system could be controlled by state-of-the-art power electronics. This would create millions of “prosumers” — producers and consumers of electricity, who would feed power into the grid and also use it economically.

**Intelligent Grid Infrastructure.** Naturally, such a constellation will require development of flexible billing rates as a means of influencing energy consumption — and thus making it easier to control power movements in the grid. In other words, electricity will be cheap during times of surplus generation and more expensive when supplies are stretched.

This will allow attentive customers to tailor their consumption accordingly and save money. “We need an intelligent grid infrastructure featuring information and communications technology that is capable of remotely controlling energy-hungry devices such as refrigerators and washing machines,” says E.ON grid expert Woyke. An integral part of an intelligent network concept will be the use of financial incentives, involving so-called smart meters equipped with communications capability.

“In the future, we will be able to send a message to consumers saying, for example, that power currently costs only five cents a unit. This will enable customers to adjust their electricity consumption correspondingly,” says Frank Borchardt, head of Smart Metering at E.ON Energie. “We might even see intelligent home automation systems that switch on appliances when the price of power falls below a certain level. That way, consumption can be spread more evenly around the clock and power grids used much more efficiently.” Siemens has already fitted 1,000 households in Austria with smart meters (see p. 82), and according to current plans, hundreds of thousands should follow over the next few years.

■ Harald Hassenmüller