

SMART ELECTRICAL GRID AND METERING

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INTRODUCTION

The electrical grid system could on a wide scale basis be operated as an energy storage system, since the wind blowing at some location can produce energy that can be used at another distant location where it is not blowing at some time. The solar energy produced at some clear-sky location can be transmitted to a cloud-covered one.

The current USA power grid has its roots in early grid projects in the late 1800s. Since then, the power grid grew substantially in a piecemeal fashion. By 1940, 10 percent of the USA energy consumption was supplied by the power grid. Currently, about 40 percent of USA energy consumption is supplied through the electrical grid system. With advances in electric automobile technology displacing petroleum as a transportation fuel, this figure is expected to rise.

The reliability of the USA electrical grid is showing signs of degradation in the face of increasing demand. The North American power grid is interconnected in such a way that a small technical or human error can cause cascading failures. Over the last 20 years, power outages have increased by 125 percent. One of the most complex systems ever built, it has proven increasingly prone to failing from causes ranging from hotter than usual weather to trees falling over power lines.

In 2007, an energy bill was passed that addressed the need to modernize the USA power grid. Designated as the “smart grid,” it would bring real intelligence to power distribution.

With the thrust toward alternative energy technologies, new transmission lines will also be needed. Solar power resources predominate in an East-West corridor in the sunny south USA away from the populated industrial centers. Wind power is most readily available in a north-south corridor in the USA’s Midwest. New nuclear power plants will be sited in thinly populated areas. This necessitates a major upgrade of the North American power grid.

SMART GRID CONFIGURATION

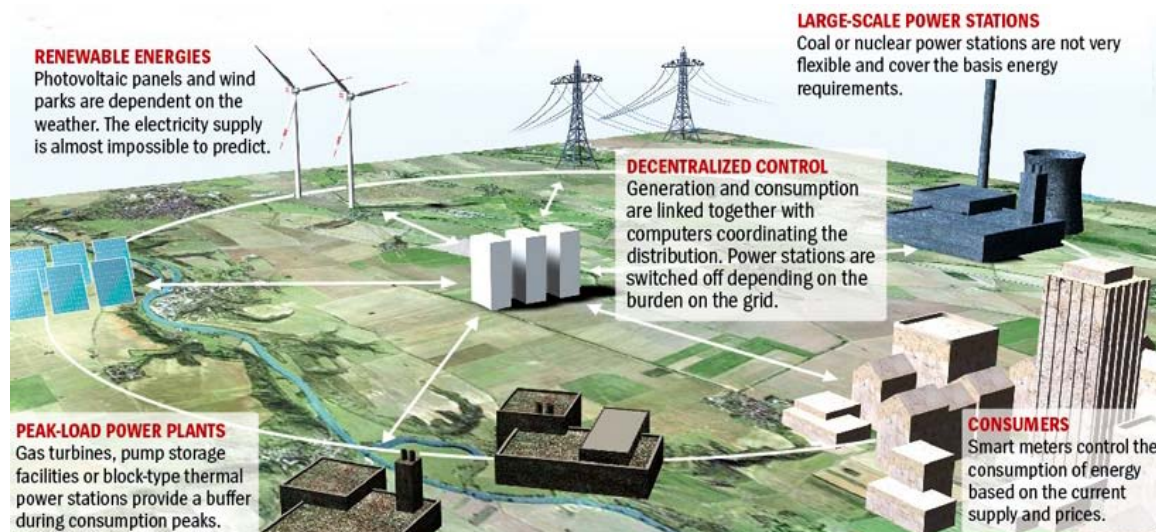


Figure 1. Smart Electric Grid Configuration in Europe. Source: Der Spiegel.

On a macro scale, the electrical grids in the industrialized nations must grow larger as well as flexible and smarter using modern information technology to perfectly coordinate energy distribution, making them more efficient and reliable.

The global electricity industry is spending billions on building new, transnational power lines to harness electricity from renewable energy sources. The Smart Grid system is meant to make the distribution of electricity more reliable and efficient. As an example, the European power grid is 6,875 miles or 11,000 kilometers in length. Only when the electrical consumption and supply are perfectly balanced does the grid remain stable.

A new variable affects the equation: everything can be planned, except for the wind availability. It fluctuates between gentle breezes and powerful storms. New wind turbines and solar panels are added every day.

In Europe, the grid operators are required by law to give priority to the clean forms of energy when feeding electricity into the grid. The problem is that the sun and the wind are very unpredictable. The fluctuations complicate their work with the grids reaching their maximum loads more frequently.

Germany plans a massive expansion in renewable energy and expects it to make up 30 percent of total power production by 2020. Giant offshore wind power projects are being implemented in the North and the Baltic Seas.

The Mediterranean countries intend to utilize the massive potential of solar energy with the Desertec project in the deserts of North Africa and export the electricity using High Voltage DC (HVDC) cables under the Mediterranean to Europe.

A vision of wind power from the north and solar energy from the south is being realized for the European and African continents.

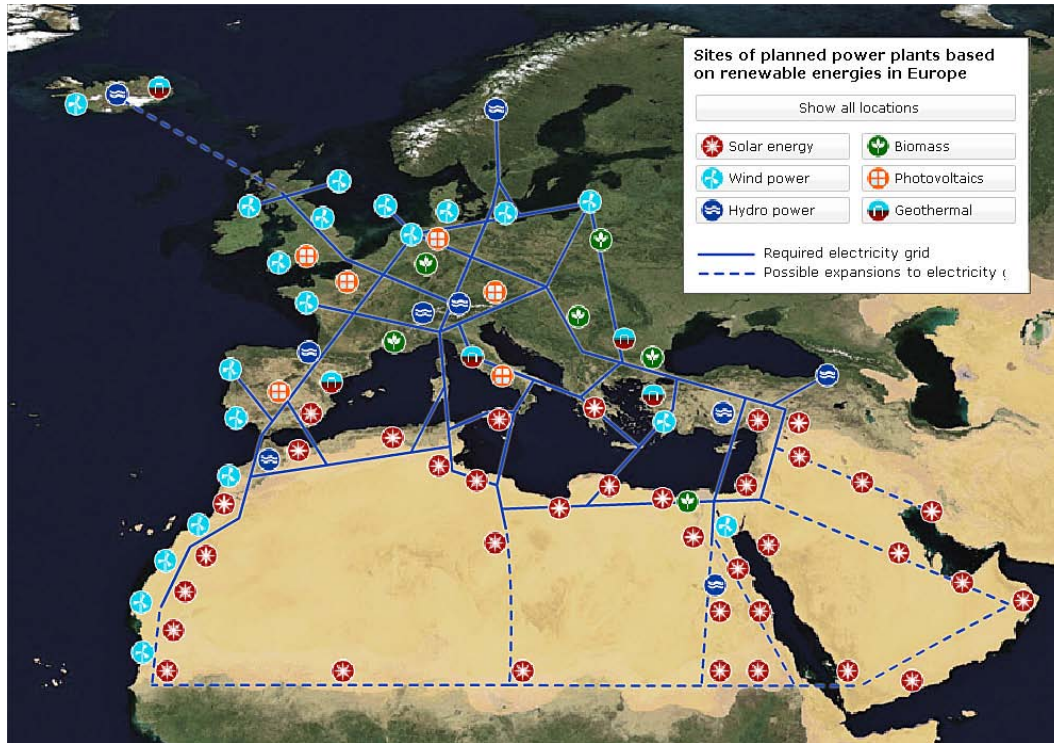


Figure 2. Grid connections planned as part of the Desertec and Mediterranean Union projects.

What is missing is a modern power grid that will transport green electricity to consumers in the center of Europe and is capable of integrating fluctuating loads into the existing system.

Without such a system the situation could turn disastrous with an elevated number of critical grid situations could arising in the coming years leading to bottlenecks within the network.

Such a bottleneck occurred to millions of households after 10 pm on November 4, 2006. The engineers with the network operator E.on had shut down an important transmission line during the transit of a cruise ship, and had incorrectly assessed the consequences. The rest of the grid became overloaded, causing one line after the next to shut down automatically. A blackout occurred and the electricity consumers were in the dark for about one-and-a-half hours.

Such blackouts are expected to become more frequent as a result of the fluctuations in the levels of electricity being fed into the grid from wind turbines. If the transformation of the system proceeds as planned in the next 10 years, wind turbines generating a total of 42 gigawatts (GWs) will be installed in Germany. Photovoltaic systems will be generating about 21 GWs. This is more than is needed on some weekends, when demand can drop to less than 30 GWs. If the sun is shining and the wind is blowing at the same time, the grid would be thrown off balance.

Ironically, the European electric utilities are paying others to take the excess electricity off their hands during nighttime wind gusts. The operators of an Austrian pumped storage hydroelectric power plant benefit from the available free energy to pump

water into lakes at higher altitudes. Once prices have recovered, they release the water from the lakes, which drives generators that produce electricity that is then sold. Such a unique situation makes it clear how urgent it is that the providers modernize the infrastructure and grid management.

The electrical utility companies are embarking on a radical change in their history. Power highways that will cost billions to build are needed to connect renewable energy sources in the north and south to the markets in-between. Massive power lines will be installed across Europe and North Africa, some through desert sand and some on the sea floor.

The power companies are incorporating a multitude of small and very small energy sources. Homeowners are taking advantage of the net-metering rules effectively turning into producers of electricity as they install solar panels on their roofs and cogeneration plants in their basements.

There are many hurdles to be overcome, including technical problems that are proving to be a serious challenge for engineers, but the political world is supportive.

SMART METERING



Figure 3. Smart meter, Germany. Source: Yello Strom subsidiary of EnBW energy company.

On a micro scale, some consumers are getting a glimpse of the new world of intelligent grids. The old black electricity meters, with their rotating metal disks, have been replaced by digital meters. These smart meters record all data in real time, which allows consumers to determine which of their household devices consume large amounts of electricity.

To save on their electrical usage, people have installed power strips in their homes and turn off their lights when they leave a room and take shorter showers.

With the help of the smart meters, electricity service providers hope to be able to handle fluctuations in the grid more effectively. They are betting on a classic market mechanism: When they have a lot of electricity available, they reduce prices, making it more attractive for customers to consume more electricity.

The vision is that the smart meters will eventually switch on washing machines during off-peak hours, when electricity is cheapest. Or they will remotely reset the temperature in the freezer from minus 18 degrees Celsius to minus 24, so that the freezer can then be shut off for a while later on, when electricity rates are higher. Household devices would communicate with one another, so that they can be controlled more efficiently.

Such ideas represent a complete departure from the existing electrical business philosophy. Providers base their energy production levels solely on consumption. They would offer the amount of electricity that consumers and industry need at any given time. They charge a largely uniform price for that electricity, regardless of fluctuations in the load on the grid.

In the future, consumption could be adjusted to conform to the fluctuating supply, and prices will fluctuate accordingly. The providers are currently developing variable pricing models much like the phone market. In the future, customers could change electricity providers or they could buy entire packets of kilowatt hours at preferred prices, which would essentially amount to a pre-paid electricity system.

On the other hand, whoever still wants to use as much electricity as he happens to need at a given time will have to pay a premium for the convenience.

TECHNICAL CONSIDERATIONS

In Germany it will cost the industry an estimated \$50 billion or €40 billion to modernize and expand the grid by 2020. The estimated cost of producing solar electric power in the Mediterranean region and transmitting it to northern Europe is even higher at about €400 billion. As in the days of the California Gold Rush, the equipment makers are the ones who will rake in the profits first. The smart grid is expected to be several times the size of the Internet. The companies that will benefit most are the suppliers of the hardware, companies like Siemens and ABB, which manufacture and install the necessary generators, distribution stations and high-voltage lines.

To connect offshore wind farms with the terrestrial grid ABB's engineers had to address that task 125 kilometers off Germany's North Sea coast, on the Borwin 1 platform. In rough weather, they laid a thick cable through the region's tidal flats. A special ship was used to drive the heavy copper cable with each meter weighing 84 pounds or 38 kilograms into place on the sea floor. The cable leads to a transformer station in the East Frisian town of Diele.

ABB employed a special technology known as High Voltage Direct Current (HVDC) transmission for the €300-million project. The method is considered to be ideal for transporting current across long distances. On an HVDC line, only 3 percent of the electrical energy is lost for every 1,000 kilometers of transmission. By comparison, the distribution loss on a heavily used alternating current line is almost twice as high for only 100 kilometers.

The high-tech lines are part of a network plan recently unveiled by the European Network of Transmission System Operators for Electricity (ENTSO-E). Under the plan, more than 42,000 kilometers of high-voltage lines will be built or replaced throughout Europe by 2020. The hope is that the larger the grid, the more opportunities there will be to balance supply and demand.