Desertec, Smart Grids and Smart Buildings – Vision or Reality?

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Abstract
In the coming years, renewable energy sources such as wind and solar will play an increasingly important role in the energy mix. Transporting this energy, which is typically generated far from population centers, to where it is needed requires low-loss electricity highways up to 2,000 km in length. This is a prerequisite for implementing the vision of “electricity from the desert” that is at the core of the Desertec project. An additional step toward this new energy age includes optimizing the energy system through smart grids, which efficiently coordinate energy supply and demand. To ensure the best energy supply possible, power grids cannot end at national boundaries. This article describes how all these aspects – from Desertec to smart grids and smart buildings – are interrelated and who can profit from them.

Desertec: electricity from the desert
By 2050, electricity generated by solar-thermal power plants and wind farms in Africa and the Middle East is expected to cover approximately 15 percent [1] of Europe’s power demand [Figure 1]. That is the goal of the Desertec Industrial Initiative in which Siemens is a founding member and technology partner. Plans call for an installed power plant capacity of 100 GW and a generated energy supply of 700 TWh per year. The space needed for the power plants would amount to 2,500 km².

From vision to reality
Continuing population growth and increasing industrialization lead to a rapid rise in worldwide energy demand. At the same time, climate change continues unabated. The Desertec concept could offer solutions in two perspectives: First, the required electricity could be produced in the desert in large amounts. Second, power would be generated in an environmentally friendly manner, which would have a positive effect on CO₂ emissions. The generated power would then be transported to the regions where it is needed with minimal losses by means of high-voltage direct current transmission (HVDC) technology.

But before this vision can become reality, a variety of basic conditions have to be established for the project. For example, international electricity trade has to be promoted and suitable incentives for investments have to be created. Another criterion that must not be overlooked is the political situation in Africa and the Middle East. The political situation must be stable to make it possible to attract the investments in power plants and transmission technology which, according to the Deutsches Zentrum für Luft- und Raumfahrt (DLR), amount to approximately 400 billion [2].

The glass industry would benefit from these investments as well. As a supplier of solutions ranging from components for solar-thermal power generation to turnkey solar-thermal power plants, Siemens estimates a demand of 190 tons of glass per megawatt of solar-thermal capacity. A 500 MW solar-thermal power plant would therefore require approximately 95,000 tons of glass. The technological implementation of a project such as Desertec is not just a vision for the future: The technology needed for solar-thermal power plants, such as steam turbine generators, receivers, and power plant instrumentation and controls, is already part of Siemens’ portfolio [Figure 2]. In addition, as a leading technology company, Siemens offers solutions for power generation by wind farms and large-scale photovoltaic facilities as well as low-loss solutions for high-voltage direct current transmission for Desertec.
Desertec and the super grid

Transporting electricity produced in an environmentally friendly manner to where it is needed requires transmission across long distances. This can be achieved with minimal loss with HVDC technology (Figure 3). However, today’s power grid is insufficient to support visions such as Desertec, especially since the supply of power from the desert does not stop at national boundaries. This is where the idea of a super grid comes into play: It could connect the European power grids, as yet not completely networked, from the north to the south, thereby facilitating the transmission of power between countries, and even beyond Europe.

A super grid completely networks the existing structures and integrates new connections. This does not mean creating additional point-to-point transmission lines between two countries. Instead, the goal is to create an entire network.

How smart do grids of the future have to be?

The more complex a grid becomes and the more producers feed into it, the higher the requirements the grid must meet in order to ensure a reliable supply of energy. To achieve this, the grids of the future have to become more intelligent – they have to become “smart grids” (Figure 4).

Smart grids will support an intelligently controlled balance between energy consumption and generation. For this to become reality, today’s static grids must become a dynamic infrastructure, allowing flexible, transparent, and rapid interaction between all parties involved in the energy market. This encompasses the entire energy conversion chain – from energy producers to consumers.

Basic requirements for a smart grid include integrated communications technology to capture state information at grid nodes and to automate the grid using protection and control technology. This would allow for remote control and monitoring of equipment as well as measuring grid state variables such as voltage, current, and line frequency. Open communication standards and a new grid intelligence are essential to achieve full interoperability of the automation components used.

Smart grids for energy-intensive industries

In the past, power generation was determined by the load. But this will no longer work with an increasing amount of power fed into the grid from renewable sources. Renewable energy sources fluctuate and make planning difficult because they feed a highly variable amount of electricity into the grid. This can result in more electricity being demanded than generated – and vice versa. That is why we need to start controlling consumption in such a way that the load curves adapt to the amount being produced. This can be achieved through financial incentives offered by energy suppliers.

Aurubis, Europe’s largest copper producer, shows how energy-intensive industries can benefit from this aspect. With enormous energy consumption during production, Aurubis temporarily shuts down its consumption-intensive electrolysis operation (a load of 10-20 MW) when it can achieve attractive prices because of high demand. When there is a peak in demand, Aurubis can either sell power on favorable terms to the European Energy Exchange in Leipzig, or if the grid operator has to balance load peaks in the grid and would like to save the expensive operating reserve required to stabilize the grid, it pays Aurubis for temporarily disconnecting its load. Flexible load management thus offers opportunities to optimize power supply costs for both consumers and producers. In the future, it will be possible to automate coordination between producers and consumers via load management; this demand response will connect or disconnect electrical consumers as needed.

Masdar City: the ecologically optimized city

Surplus energy can be used in other ways as well. Buildings will play a major role in smart grids because 40 percent of all energy worldwide is consumed by buildings for heating, ventilation, air conditioning, lighting, and household appliances. In the future, intelligent building controls shall reduce the burden on the power and heating grid and feed electricity generated by buildings into the grid. After completion in 2016, Masdar City will show how an ecologically optimized city could work (Figure 5). This city for up to 50,000 people is currently under construction in the desert of the United...
Arab Emirates, near Abu Dhabi. Masdar City will meet its energy needs with maximum efficiency from renewable energy sources within the city as well as from conventional energy sources farther away. Within Masdar City, power is generated primarily by solar-thermal power plants and photovoltaic facilities.

Masdar City is designed to be carbon neutral. While at night electricity from outside will be fed into the grid, mainly to power air conditioning and lighting systems, during the day enough CO₂-free power is produced that overall, more energy is generated than consumed. This surplus will be fed into the surrounding grid during the day. Conventional producers located farther away will be throttled back accordingly to reduce their CO₂ emissions.

A crucial aspect for all of Masdar City is maximum efficiency. In order to cut back on air conditioning and hence save energy, the buildings in Masdar City stand close together so they can shade each other while still allowing enough daylight to enter their interior. In addition, they are built on concrete stilts to allow for air circulation, which in turn lowers temperatures to bearable levels.

Buildings as prosumers

Realistically, a master-planned project like Masdar City cannot be compared to traditional cities that have evolved over time. However, intelligent building technologies are in demand everywhere (Figure 6). More and more buildings are turning into smart buildings, especially in industrialized countries. Equipped with intelligent energy management technology, these buildings are able to go from straight energy consumers to active participants in the power market who supply electricity they generate themselves – and hence become “prosumers.” More and more buildings have photovoltaic systems on the roof or on the facade. In addition, small combined heat and power (CHP) plants are installed more frequently. Smart meters are required to optimize the
integration of these power producers into the power grid. In the future, these devices will not only measure electricity consumption but will also be able to communicate with devices and appliances in buildings and with electric utility companies.

When power demand in the external grid is high, the CHP plant feeds surplus electricity not needed to supply the building into the grid and simultaneously stores the additional waste heat. The heat is either transferred to a local thermal energy storage unit or absorbed by the building's thermal capacity. For later required heating purposes, it can be released back into the building. Hot water heaters with properly insulated tanks can be used for this purpose.

Another alternative are storage units based on phase change materials. The surplus heat is used to melt salt, for example. When the demand for heat increases, the stored energy is released and the salt solidifies again. The combinations of small CHP plants with storage options currently in use are able to reach an overall efficiency of approximately 90 percent.

There is another aspect to smart grids and smart buildings beyond the storage options already mentioned: the use of electric vehicles as variable storage units for electric power. Considering that industrial companies typically have company parking lots or parking garages, electric vehicles offer an enormous potential for energy storage.

While parked, these vehicles could be “fueled” with surplus electricity from renewable sources and, when demand in the grid is high, return some of it to the grid. This process could be controlled using an intelligent building management system, which would open up potentially lucrative business models.

The amount of energy saved through intelligent networking of producers and consumers still depends on each individual case – in general, experts expect savings of 20 to 25 percent. For example, the potential energy savings in shopping centers is as high as 50 percent while in office buildings it is between 20 and 30 percent.

Vision or reality?

By 2050, the world population will grow to more than nine billion – two billion more than today. As the population grows so do cities and their infrastructures, and hence the demand for energy. The most important question in this context is how to ensure a safe, efficient, and environmentally friendly supply of energy for the future.

The good news is that the technologies – whether for smart buildings, smart grids, or Desertec – already exist. With its environmental portfolio that makes up about a third of total revenue, Siemens can play a crucial role – from renewable energy to electromobility. Using advanced technology from Siemens, customers were able to reduce their CO₂ emissions by 270 million tons over the course of only one year.

Finally, all stakeholders involved need to work together to continuously improve the prerequisites and framework for the use of intelligent, innovative technologies – in order to create sustainable solutions for the future.

Sources/references

Figure 6. Buildings are responsible for 40 percent of energy consumption worldwide and 21 percent of greenhouse gas emissions. In most buildings, intelligent technological solutions can bring energy savings of up to 30 percent – which pays off financially.