Plugging in

Taking a trip behind the electrical outlet

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Nothing is more self-evident for the members of a modern society than plugging a hair dryer or computer into an outlet and expecting it to run. It took less than a century for the most versatile form of energy – electricity – to become the fully accepted and incorporated standard all over the world.

Behind that simple plug in the wall extends a breathtaking infrastructure. Join us on a short journey through this fascinating world – from the plug all the way back to the energy source – on a path that has been paved by ABB from the very first inventions to the full-fledged grid of today.

Just behind the outlet, crucial elements are providing full safety for the user of electricity: These elements are the fuses and contactors. They come in various forms for different applications in residential buildings or factories 1. While in the early years of electrification, these modules were just electromechanical devices, they have since become “intelligent”, in line with the progressing information technology. Modern building blocks in house installations can communicate with each other or with higher-level automation systems and can take over control functions to optimize the use of electrical power in manifold applications.

Circuit breakers, also close to the plug and still on a low voltage level, can switch on and off large currents to supply a whole area or a large factory with energy. They also provide a safety function in case of a short circuit somewhere in the grid.

The more energy is needed, for example to supply a huge shopping center with lighting, heating, cooling or climate systems, the higher the chosen voltage level for distribution. To go to medium-voltage distribution, transformers and circuit breakers combined with measuring devices are needed; these are then put together in medium-voltage substations. Cables transport the electricity from those substations to the users.

If you don’t see those substations (which are sometimes small containers along the street) it is for good reason: The development of compact and integrated functions in smaller units is

ongoing. Ever-increasing automation and control of these substations contributes to the trend toward self-controlled systems.

There are two means of electrical power generation. In one method, local units such as diesel generators, wind mills, fuel cells and small power plants generate power for a close-by user. With the other established method, large central power plants run on hydro fuel, coal, oil and gas, or nuclear fuel to generate between several hundred megawatts and some gigawatts of electricity.

The large central power station requires transport of electrical power over significant distances and subsequent distribution into several channels to reach large factories, supermarkets or whole cities, for example. Transport over long distances is preferably done at a high voltage level to reduce the loss of energy in the lines. Power substations are required to convert the voltage from some ten kilovolts at the generator output to the high level of several hundred kilovolts for transport, and then back to the lower voltage level for wider distribution at the end of the line. Large transformers and powerful circuit breakers are the heart of these substations, built either as air-insulated systems on the "field" or more compactly as gas-insulated packages.

1 Devices close to the plug to provide safe electrical power

2 Control of a power plant to optimize production

It goes without saying that substations are highly automated. They are the nodes of an automation system that cover large areas, often whole countries and sometimes cross-border interconnections. With increased linking of national grids, the stability of a huge collection of power plants and consumers must be guaranteed – this requires wide-area monitoring and management.

Both methods of transporting energy over long distances, with alternating current (AC) or direct current (DC), have their optimal applications. Progress is made in both flexible AC transmission systems (FACTS) and HVDC light.

The infrastructure behind the plug is indeed fantastic – let's not take it for granted!

Local generation (that is, closer to the consumer) is a challenge addressed by the new concept known as "smart grids". With smart grids, the world is not simply separated into generators and consumers; here a consumer can also be a generator, providing the grid with the surplus energy of his local generation device. The management of such a system is a complex task that engineers have just started to work with. In fact, smart grids and wide area networks are tightly interlinked, which adds significantly to the complexity.

In the value chain of electrical power, the generation itself is essential, of course. Power generation is also the place where valuable energy is lost in the conversion from thermal to

3 Obtaining the primary energy for electrical power generation

mechanical to electrical energy. While basic physical principals limit the conversion efficiency, it is still optimal power plant management that determines how close one can get to these physical limits. Coal-fired steam power plants, for example, need coal to heat a boiler and generate very hot steam at high pressure. The high-pressure steam enters a steam turbine, which then drives the electrical generator. While the generator does not "know" how the steam was produced, it is essential for the operator of the plant to know and to do it in the most economical way 2.

The value chain goes even further back to the place where the coal or the oil and gas are exploited. The efficiency of the production of this primary energy has a great influence on the price of electricity and on its long-term availability 3.

The infrastructure behind the plug is indeed fantastic. Before the energy can be taken from the plug, it must be converted from primary energy to steam or directly to electricity in solar cells or wind mills. It has to be transformed into high voltage and back to low voltage with an optimally managed flow in smart grids or large interconnections, all the while ensuring the utmost safety and reliability for the countless ways in which it will be used – let's not take it for granted!

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