High voltage power lines and transmission tower. Photo: Stewart Tilger/Corbis

The future belongs to hybrid grids

In the future, electricity supply will come from a combination of large-scale (central) and small scale (decentralized) generation. New technologies will ensure the optimal use of the electricity.

by Jos Meeuwsen

Market researchers sometimes have heated discussions about how electricity production will develop. Advocates of sustainable energy firmly believe in the far-reaching decentralization of electricity generation. More traditionally oriented market players foresee an increase in large-scale central generation. Both camps are probably partly right. The liberalization of the European energy market means that all viable initiatives will have a chance to play their own role. A broad range of production options is looming over the horizon, from grey to green, small to large, conventional to ultra modern. This development can already be seen. The great challenge is to integrate this vast array of sources into the networks and put them to optimal use.

Nice characteristics

Electricity is a special energy source with a number of useful characteristics. For instance, it does not pollute at the place where it is used. It is safe. Electrical equipment is relatively maintenance free. Electrical energy can also be very efficiently converted into other forms of energy, such as motion, heat, cooling, radiation, etc. An exception is the incandescent light bulb, but its days are numbered. Electricity has one drawback, which is that it cannot (yet) be stored in large quantities. This is why it cannot be compared 1-to-1 with other "commodities" like oil and gas.

Because these positive qualities, it is not surprising that many experts expect electricity will become increasingly important, at the expense of other energy sources like oil and gas, for instance in transport. Another example is the electrically powered heat pump, which uses geological heat to heat buildings. This makes a connection to the gas network unnecessary. On the other hand, a household with a heat pump needs three times as much electricity.

What consequences will these developments have for electrical networks? This question was recently studied at the Technical University of Eindhoven ("Electricity networks of the future: Various roads to a sustainable energy system"). The researchers looked at the expected developments until 2050. The assumption was made that electricity consumption will approximately double and that half the electricity will come from sustainable sources. Three transition scenarios were formulated – 'Towards Super Grids', 'Towards Hybrid Grids' and 'Towards Local Grids' – which particularly differ in terms of the scale and methods of electricity production. The 'Towards Super Grids' scenario consists entirely of large-scale production, transport over high voltage lines and import of sustainable energy (for example in the form of hydroelectricity from Scandinavia and/or concentrated solar power from Southern Europe and/or North Africa).

> *It will be a huge job to integrate the enormous array of new energy sources into the networks of the future*

The scenario 'Towards Hybrid Grids' also includes large central power plants, but in combination with a large amount of small-scale generation, e.g. land-based wind parks, small biomass-fired power plants that produce heat as well as electricity, PV panels and gas-fired micro-cogeneration units.

In the third scenario 'Towards Local Grids', the number of local generators is the highest, but large industrial processes

A look at the future

It is Thursday 6 January 2050. At the end of the afternoon, John Smith steps into his electric car. His PDA uses the route planner to calculate the time he will arrive at home, and automatically communicates the expected arrival time to his house computer. Of course this takes in to account the current traffic situation. The house computer then measures how warm it is within the house, calculates how much energy is needed to heat the dwelling to the temperature of 21 °C John wants, and then decides which energy source can best be used to do this. This may depend on the current weather situation as well as the current electricity and gas prices. The computer routinely decides whether the micro-cogeneration unit should be started, of if the heat buffer should be used, and/or whether electricity is the best energy source at that moment. Once he gets home, John parks his car in the 'docking station' of his carport. The house computer immediately sig-nals that an extra energy appliance has been connected to the 'domestic energy port'. Because John's PDA automatically synchronises with the house computer every fifteen minutes, the computer knows that John will work at home tomorrow. The house com-puter concludes that the battery system of his car will only need to be fully charged after 36 hours. Taking into account the minimum charge level of 50% set by John for the bat-tery system and the market prognosis of the energy prices for the coming days, the house computer automatically determines what moments the battery system will be charged and/or whether it is still desirable to devote certain hours to re-supplying the public network.

and small consumers still partially use electricity from large-scale production.

Network development

How the network of the future will look largely depends on the primary energy mix. This is because development of the networks is strongly determined by developments in electricity generation. Aside from the scale, the controllability of the electricity production units is important. In any of the three scenarios, technicians will meet considerable challenges in the field of network development (network evolution), system integration and the application of new technologies.

From various projections it is clear that the combined production of all the sustainable electricity sources at the local level will not be enough to provide for the growing demand for electricity. For the sake of security of supply extensive and commonly linked networks continue to be necessary. In fact, there will be a need for extra network capacity in all three scenarios.

This need, however, is closely related to the primary energy mix. If the emphasis is on large-scale electricity production, extra investments will be needed in all areas of the network, i.e. extra high voltage (EHV), high voltage (HV), medium voltage (MV) and low voltage (LV). If the emphasis is on decentralized and small-scale production, investments will mainly be needed in medium and low voltage networks. Small-scale networks will take on more and more characteristics of the present transport networks, such as the ability to handle 'two-way traffic' and the responsibility of balancing supply and demand.

Internet

In all three scenarios the networks of the future are more flexible than present ones, especially in terms of the energy flows becoming more controllable. In the present networks the current follows the path of least impedance. In the networks of the future it will be possible to control the impedance, which will allow energy currents to be (more) evenly distributed over all available resources in the networks. It is expected that the increase in controllability will first be applied to the highest voltage networks and be followed later by the lower voltage networks.

The technology to control energy flows is already available and is being further developed and refined. However, it is not cheap. The great advantage is that it can be used to better use the existing infrastructure. The alternative – building extra transmission connections – also has disadvantages: it is expensive and time-consuming. Technical possibilities lie in the application of so-called phase angle regulating transformers and also in high value power electronics. The latter technology is known by the name of Flexible AC Transmission Systems (FACTS) and has the additional benefit of improving the stability of the entire system.

IT, smart meters and smart sensors will lead to increasingly refined asset management of infrastructure and better monitoring and control of energy currents as well as supply and demand. In the longer term this will be provided to even the lowest voltage levels of the networks. The step by step integration of energy technology, IT and power management electronics could even result in an electricity supply system that shows similarities with the internet. Everyone connected to the network can, within limits, upload and download packets of electricity. Needless to say this will mostly be done automatically. An important condition is that it becomes technically possible to store electricity in large quantities, centrally and/or decentrally.

Sun and wind

If we look at generation, it is clear that the use of synchronous generators will remain desirable. This is because of the need for sufficient short circuit power in the networks, which is primarily provided by these generators. Short circuit power and voltage quality are closely related. With insufficient short circuit power the voltage quality decreases, which is disturbing to the user, who, for example, will see the lights flickering when he starts a heavy motor. Because the contribution of modern windmills and solar panels to the short circuit power is negligible, it is unlikely that there will be any time when


If the emphasis is placed on decentralized and small-scale electricity production, investments will mainly be needed in the medium and low voltage networks and to a lesser degree in the high voltage networks. Photo: Construction Photography/Corbis

all the electricity comes only from the sun or wind. Synchronous generators remain necessary. This does not mean that they could not be powered by modern turbines that take their energy from biomass.
The application of solar and wind energy also has consequences for system integration – the balancing of supply and demand. Wind and sun are not very controllable. When there is little wind or sun there is little to no generation. And wind speeds and sunny periods are often correlated over large distances. For this reason, averaging wind and solar production for different regions does not offer enough perspective. Biomass fired power plants can be used for this.

In the scenario 'Towards Local Grids', which would involve the greatest contribution of wind and solar energy, temporary shortages of electricity production would need to be made up by keeping sufficient reserve production capacity, for example in the form of Combined Cycle Gas Turbines (CCGTs). In the scenario 'Towards Super Grids', the effects of the weather play less of a role because a much greater role is expected for electrical power plants that are fired with biomass and waste.

In all scenarios future networks will become much more flexible

Solutions to the problem of system balancing do not only lie with the supply side, however. There are also many opportunities on the demand side. The broad range of controlling possibilities and degrees of freedom makes this a multi-faceted issue. It is possible that introduction of large amounts of wind and solar energy might even mean a paradigm shift from 'the permanent adjustment of supply to demand' now to 'the enduring adjustment of demand to supply' in the near future.
A disadvantage of wind energy and solar energy in particular is the limited utilization time of these sources. This means that an enormous amount of peak capacity must be installed to generate energy volumes of any magnitude. A beneficial side effect of solar energy is that its production more or less matches the usual day-night pattern of energy use.

The further development of ways to store electricity is of great importance for the opportunities for solar and wind energy. Electricity can be stored at both the central (large scale) level and at the decentralized (small scale) level. However, storage is still expensive. For large-scale storage, one of the leading concepts is pumped hydrostorage or Compressed Air Energy Storage (CAES) in underground pits. For small-scale storage there are modern batteries (for example in electrically powered cars that are connected to the electrical network when they are not driving) or flow battery systems at the district level. If there is a lack of storage capacity it is recommended not to allow the total combined peak power of all the solar cells to exceed (too much) the variation in the daily electricity use, and at the same time that they are well spread out. In this way a natural balance is created, both in terms of time and space. Moreover, with a balanced spread, significant investments in the networks can be avoided.
As has been said, in many European markets at this time a dual trend is already visible in the direction of both more central and decentralized generation. Examples of the latter are cogeneration units in greenhouse agriculture, biogas fired cogeneration units in the agrarian and livestock sector, the increase of the installed capacity of windmills and the installation of large numbers of PV panels, for example as a result of an attractive subsidy system in Germany. It will be a huge job to integrate this enormous array of energy sources into the electrical networks and then to put them to optimal use. ■

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