The grid is key

Sebastian Lehnhoff at a site where a neighbourhood based on a modern energy concept is to be built.

The green energy transition was launched in 2011: Germany will phase out nuclear power and gradually increase the renewables in its energy mix. But the country's power grid, which is more than a century old, is only partially equipped for this. An entirely new infrastructure of "smart grids" is needed. In an interview, energy informatics expert Sebastian Lehnhoff explains where the challenges lie

Mr Lehnhoff, is there any way to achieve the energy transition in Germany by 2050?
Lehnhoff: Technologically speaking, certainly. But we would be a lot closer to our goals if renewables were already better and more flexibly integrated into the energy market and the technical infrastructure today. By this I mean business models in the photovoltaics and wind energy sectors, for example, as well as comprehensive utilization and recycling processes for storage technologies. Then there's outdated network structures. These are all major challenges. So I have my doubts about whether we will reach the CO_2 targets by 2050.

Critics are worried that the energy transition could put too much pressure on Germany's power grid, which is more than a hundred years old. Do you share this concern?
Lehnhoff: We definitely have to make changes. Up to now we've always been able to generate energy in a very controlled process using lignite, coal and gas. But as the percentage of renewables in the energy mix increases the situation is changing dramatically. Now, in addition to a handful of large, central power stations, there is a growing number of decentralised energy plants that feed energy into the grid only when the sun shines or the wind blows – but this input doesn't necessarily coincide with demand.

What problems does this create?
Lehnhoff: Well, take electric vehicles, which will continue to rise in number. We can assume that in the future every evening after the working day large numbers of these electric vehicles will head to charging points and stations to recharge. However, due to the lack of storage facilities, the energy from photovoltaic systems is no longer available at this time of the day. That leaves wind energy. So let's say the wind is particularly strong at 2 a.m. – most of the electric vehicles need to be charged at precisely that moment since that's when larger amounts of wind energy are being fed into the grid.

So how can we tackle this?
Lehnhoff: Until we have adequate energy storage systems, the only solution is intelligent energy management, which – sticking with the example above – would ensure that not all electric vehicles are recharged at the same time, but in a step-by-step process, perhaps also on an alternating basis. All with the goal of adjusting consumption to the infeed of renewable energy into the grid without overloading it.

You are currently carrying out research into precisely this sort of 'smart grid'. What is the aim here?
Lehnhoff: Ultimately it's about controlling power supply and demand far more actively than has been the case until now, and in real time. The biggest challenge is to predict as accurately as possible how much energy from renewables can be fed into the grid and then tailor the supply to consumer needs. The grid itself plays a key role here. Operating equipment such as power lines, cables and transformers will have to be fitted with ultra-modern information and communications technology. This is the only way to coordinate interactions between individual components, from digital electric meters in homes and adjustable local grid transformers to prediction and monitoring systems in the control centres of network operators.

That sounds like a revolution. What challenges do you see here?
Lehnhoff: Above all one that has been underestimated so far: large power plants are connected to high-performance transmission networks – redundant, fail-proof, highly automated and equipped with modern sensor technology. But the many small plants such as wind farms and solar panels are connected to entirely different areas of the grid – the lower voltage levels of the distribution networks. And it's here that the infrastructure is lacking. If we want the supply from renewables to be equally secure and reliable, many things will have to be reorganised.

What does that mean in practice?
Lehnhoff: In Germany approximately one thousand distribution network operators deliver electricity from the transmission network to individual households. Most of them are regional utilities, in many cases small municipal utilities. In the future these operators will share the responsibility for system security. However, the structures for this don't exist yet. For example, the digitalisation necessary for monitoring and coordinating all small-scale prosumers connected to the network has not yet taken place.

Does digitalisation entail risks as well?
Lehnhoff: Yes, and the dangers are embedded in the system. The smart grids of the future are highly complex structures, and this automatically and dramatically increases the risk of IT problems and cyberattacks. Digitalisation technologies require regular software updates – this we know from other fields. In addition, we will be dependent on automation through artificial intelligence. Compare this with the conventional and comparatively slow systems that are currently in use, a transformer for instance. These systems are typically in use for 60 to 70 years, with at most a little maintenance required every now and then, and then at some point they're scrapped. If you wanted to disrupt this system,

Germany's power grid is only partially prepared for the energy transition because renewable energy sources like sun and wind don't feed energy into the system consistently, like coal-fired or nuclear power plants do.

Lehnhoff in front of the new grid control centre, which forms part of the "Smart Grid Cyber-Resilience Laboratory". It shows a computer-simulated urban distribution network with energy generation facilities, cables, transformers and other components.

Lehnhoff's Energy Informatics research group creates simulations of innovate energy systems using the "mosaik" software. The software was developed by the Oldenburg scientists and is now a standard tool in this area of research.

you would have to actually go to the transformer and disable it on site. Now we're merging this world with the digital world.

You're working on this in a project funded by the Federal Ministry for Economic Affairs and Energy. Can you tell us more about it?
Lehnhoff: We're building a so-called Smart Grid Cyber-Resilience Laboratory, or CyResLab for short. This lab will be a unique test environment for smart grid architectures where we can test emergency procedures. We want to develop security measures for dealing with IT errors in highly interconnected systems and preventing malicious attacks. We're also testing ways to rapidly identify and respond to such incidents during continuous operation.

So how close are we to having an intelligent power grid?
Lehnhoff: In northwest Germany we're already pretty close. This is mainly thanks to projects like eTelligence or ENERA, which are funded by the Ministry for Economic Affairs and Energy (BMWi) and the energy company EWE. We were and are involved in these projects as a university and also through the OFFIS Institute for Information Technology. The goal is to roll out a smart grid in the test regions of Aurich, Friesland, Wittmund and Emden. These regions will basically get a hardware update: intelligent transformers that automatically compensate for voltage fluctuations in local networks or electricity storage units for intermediate storage of wind energy.

> „We need to do a lot of re-organising."

In another research project funded by the German Research Foundation (DFG) you're working on the so-called "black start". What is this about?
Lehnhoff: The black start is an unsolved problem in smart grids. It deals with how to restart the grid after a major power failure. Large power plants have a very old-school approach to this situation: a battery starts up a small diesel generator, which in turn starts a gas turbine. With smart grids the situation is far more complex: to get the grid operating again, you have to coordinate many different decentralised generators and consumers. For this you need modern information and communications technology that automatically measures, controls and regulates. But this technology itself needs electricity to operate. So where should the electricity go to first? This chicken-and-egg dilemma requires complex management and optimisation principles, which we are studying in this project.

In the coming years, you will have access to a unique test environment: Oldenburg is developing a new Smart City district with a modern energy concept on the site of a former military air base ...
Lehnhoff: That's right, although energy is just one aspect – this project is also about traffic, administration and quality of life. It all began with a broad-scale strategy paper "Smart City Oldenburg – a People-Centred Approach" – which the city compiled together with representatives from academia, business and public administration. In the paper we examine which of the city's tasks should be digitalised, from visits to local authorities, energy distribution and supply services to waste management and urban planning. Once the plan had been drawn up and the city convinced of its merits, we began to set up a "Living Lab Smart City" at the old air base: a place for collaboration between academia and civil society where the focus is on learning from each other in an experimental environment. The core of the whole concept is a lighthouse project, the Energetic Neighbourhood District ("Energetische Nachbarschaftsquartier" - ENaQ), which is financed by the Ministry for Economic Affairs and Energy and the Ministry of Education and Research. In this project we and other partners are specifically working on the energetic neighbourhood concept for this new district. There are currently only five other projects of this scale in all of Germany.

And how will the energy supply at the air base work?
Lehnhoff: The buildings will meet modern energy standards and will be connected to an intelligent power grid with a high-security smart-meter communications infrastructure – these are meters that can send and receive data. The plan is to also use this infrastructure for things like telemedical applications in future projects. There will also be modern cogeneration systems and various energy generators such as combined heat and power units, power-to-gas plants and solar photovoltaic systems. One energy source can be converted into another to cover overall energy requirements as efficiently as possible. The main point here is that this won't be a sealed-off astronaut colony, based on concepts that can't be transferred to the real world. The idea is that the whole neighbourhood and the surrounding area will benefit from the project by copying solutions developed here. This is why technologies with standardised interfaces are very important.

How will the future residents be involved in the project when they start moving into the new district in 2021?
Lehnhoff: They will play an active part in the energy supply system by being able to buy cheap energy from each other and sell their own surpluses at any time. Residents will have access to the necessary information via a consumer platform. To make the process easier we're taking a playful approach to the whole thing. We all know that people tend to compare their own performance with that of others. And if the neighbour's energy balance sheet looks better than their own, perhaps this will motivate them to make a bigger effort. We want to take a closer look at these social aspects too in the living lab.

How about your own "energy balance"? Do you already drive an electric vehicle?
Lehnhoff: In my private life I only use my bike nowadays, at least for getting around the city. It's not an electric bike though; I want to stay in shape. My wife and I are seriously considering buying a cargo bike – they're powered by an electric motor.

Interview: Volker Sandmann

Profile

Sebastian Lehnhoff has been Professor for Energy Information Systems at the University of Oldenburg's Department of Computing Science since 2015. He is also director of the university's OFFIS Institute for Information Technology and Chairman Executive Board Energy. His team of around 80 researchers develops information and communications technology-based concepts and prototype systems for the energy sector.
His research focuses on intelligent energy systems, also known as smart grids. The goal is to develop energy-efficient, green, cost-effective and secure power supply systems. His research interests include real-time operation for safety-critical applications in electric energy systems and co-simulation of complex energy systems. He is the coordinator of the "Future Lab Energy" and board member of the Centre for Digital Innovations Lower Saxony (Zentrum für digitale Innovationen Niedersachsen).