Journal 2015

DIALOGUE

RESPONSIBILITY

NEW START

amprion

AMPRION – A BRIEF PROFILE

Amprion GmbH is one of four transmission system operators in Germany. The company can draw on many years of experience in planning, constructing and operating the extra-high-voltage grid. Amprion employs a workforce of around 1,100.

~59 GW

the total installed capacity of the Amprion grid.

78,900 KM²

the area covered by the Amprion grid, stretching from Lower Saxony down to the Alps.

11,000 KM

the total length of power lines that make up the Amprion transmission system; it is Germany's longest EHV grid.

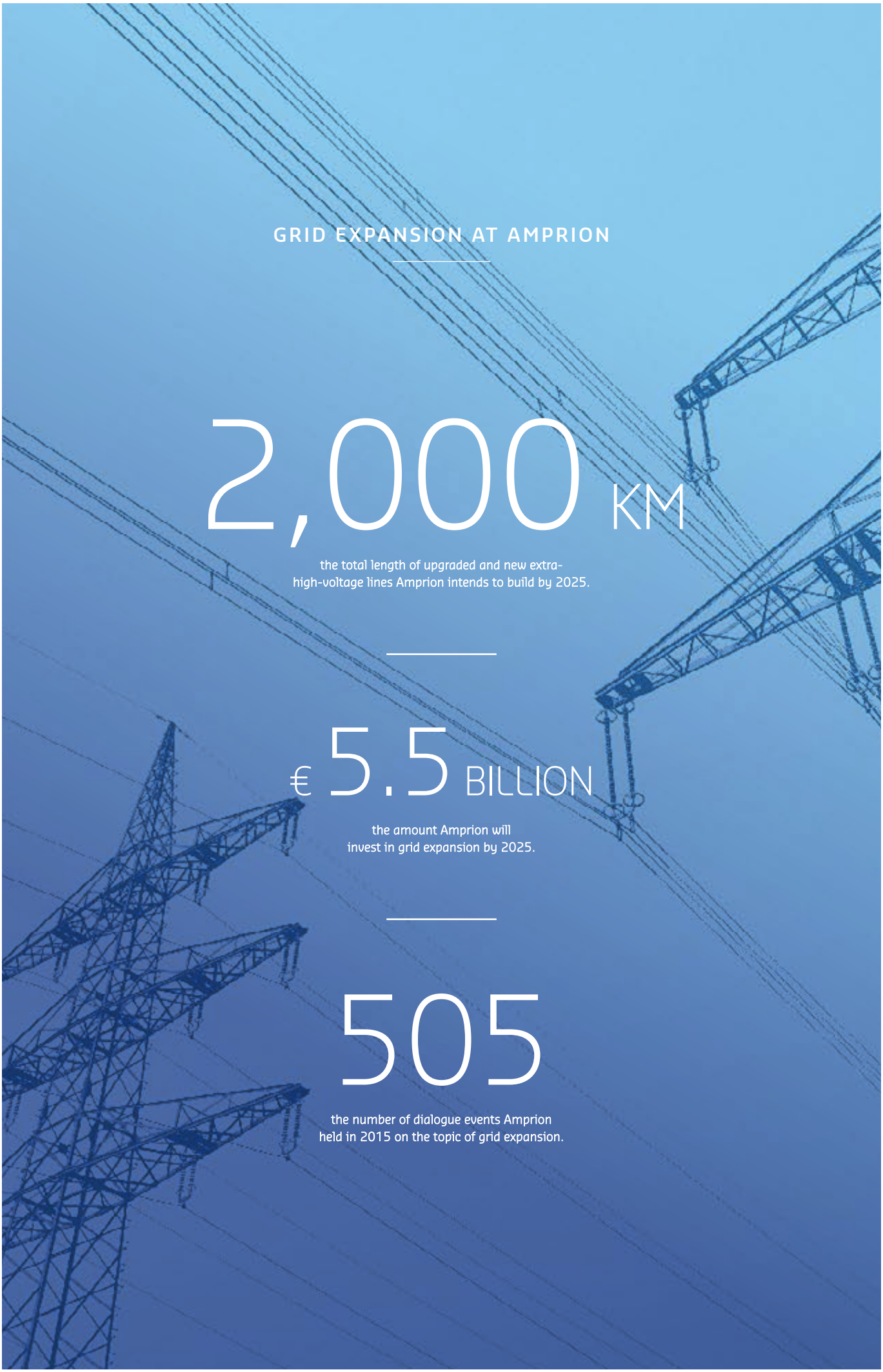
~29 M

the number of people supplied with electricity via the Amprion grid.

~170

the number of substations that connect the Amprion grid to the downstream distribution systems.


THE AMPRION GRID
Lower Saxony
The Netherlands
North Rhine-
Westphalia
DORTMUND
COLOGNE
Hesse
Thuringia
Belgium
FRANKFURT AM MAIN
Bavaria
Luxembourg
Rhineland-
Palatinate
Saarland
SAARBRÜCKEN
Baden-
Württemberg
France
STUTTGART
AUGSBURG
Overhead power line
Substation
Switzerland
Austria



GRID EXPANSION AT AMPRION

2,000 KM

the total length of upgraded and new extra-high-voltage lines Amprion intends to build by 2025.

€ 5.5 BILLION

the amount Amprion will invest in grid expansion by 2025.

505

the number of dialogue events Amprion held in 2015 on the topic of grid expansion.

JOURNAL 2015

Amprion is a transmission system operator active in Germany and Europe. Our power lines are the lifelines of the national economy. By operating and expanding our network, we are assuming our share of **RESPONSIBILITY** *[page 8]* for guaranteeing a sustainable future for the power supply. To be able to face the challenges of the energy transition, we are actively engaging in a DIALOGUE *[page 26]* with citizens, society, politics and business. We are developing innovative solutions for this NEW START *[page 38]* into the energy world of tomorrow.

CONTENTS

ACHIEVING DIVERSITY

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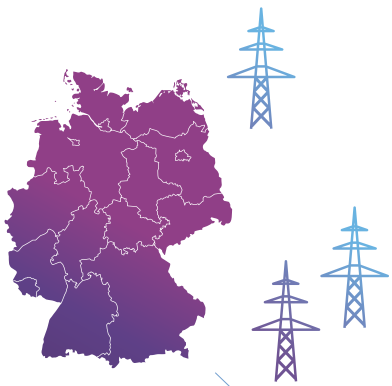
Nature conservation beneath power lines – that's the job of Amprion's biotope managers. They have now been implementing the route maintenance concept developed by Amprion for more than 20 years.

RESPONSIBILITY

DIALOGUE

NEW START



SUSTAINABLE INVESTMENT

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Grid expansion is an absolutely crucial infrastructure project when it comes to ensuring Germany's position as a location for business and investment. The amount being invested is similar to that being invested in the telephone, road and rail networks.

TRANSPARENT PLANNING

–

Amprion is continuing to develop project communication – by informing citizens at an early stage, conducting an open dialogue and offering opportunities to participate.

PROF. DR CHRISTOPH M. SCHMIDT AND DR HANS-JÜRGEN BRICK

As a transmission system operator, Amprion fulfils a statutory duty, but it also operates in the European electricity market and supports the world of politics by offering technical expertise in relation to energy matters. Lots of points of reference to exchange ideas about for Prof. Dr Christoph M. Schmidt, President of the Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI) and Chairman of the German Council of Economic Experts, and Amprion Managing Director, Dr Hans-Jürgen Brick.

SECURE POWER SUPPLY

Amprion Managing Director, Dr Hans-Jürgen Brick, and the research economist, Prof. Dr Christoph M. Schmidt, talk about the importance of security of supply – and why our energy system has to be expanded and upgraded.

PHOTOS · **MATTHIAS HASLAUER**

MANY PEOPLE REGARD ELECTRICITY AS A MATTER OF COURSE. WHAT ABOUT YOU?

SCHMIDT Yes, I too regard it as a matter of course that electricity is available whenever I want it. A secure energy supply is a prerequisite to our lifestyle and also – and I say this as an economist – for maintaining our prosperity. It guarantees our way of doing business and the way we manufacture.

BRICK This is precisely where we see our responsibility: we have a statutory duty to ensure that our transmission system is reliable 24 hours a day, 7 days a week. But we are finding that this duty, this mandate, is becoming more and more challenging. If the stability of the network is in danger, we cut in backup power plants or restrict the infeed into or the take-up of power from the grid. The more frequently we have to do this, the more expensive it becomes for our national economy.

SCHMIDT What we must not do is neglect the security of supply during this period in which we are implementing our turnaround in energy policy. By 2050, we want to have a system in Germany that is very much founded on renewable energy sources, but that operates efficiently and is technically robust at the same time. This is the social consensus. At the end of the day, all three goals fit wonderfully together. But the task of shaping the path by which we achieve this is extremely complex and challenging.

WHERE ARE THE CHALLENGES?

SCHMIDT If security of supply is so important, then we have to expand the power grids and energy storage capacities at the same time as we expand renewables. These activities should be synchronised, but this is currently not the case.

BRICK Yes, exactly. Grid expansion is lagging behind the expansion of renewable energy sources. And storage technology is a long way from what is needed. This is why we still need bridging technologies such as high-efficiency gas-fuelled power plants, but also innovative elements in the power grid. Because conventional power plants are feeding less and less electricity into the grid, Amprion has, for example, developed systems that stabilise the grid voltage by other means.

SCHMIDT In retrospect, I would say that we have made a number of mistakes in Germany. For a long time, the public at large was given the impression that the energy transition consisted solely of expanding renewables. This pushed the entire project close to the brink, rendering it almost unviable.

» We have a statutory duty to ensure that our transmission system is reliable 24 hours a day, 7 days a week. «

DR HANS-JÜRGEN BRICK

BRICK After a period of political discussion, we have now reached a situation where we once again have the planning security we need. That the energy transition also means we have to expand our power grid is now perfectly clear to most people – just as long as it doesn't affect them. That's why it is important that grid expansion is conducted in a citizen-friendly manner and that we keep close tabs on the affordability of all measures. We need this economic sustainability in order to keep Germany competitive as a business and investment location.

SCHMIDT It goes without saying that Germany must remain industrially and economically capable and productive. We want to maintain a good healthcare system for our ageing society. We want to remain an open-minded and open country that offers shelter to refugees. As an economist, I ask myself if we can't achieve the goals of the energy transition in a more macroeconomically efficient way. The Renewable Energy Sources Act (EEG) was not the ideal route to go down, because it has unilaterally promoted certain technologies by offering feed-in tariffs and has also been far too expensive macroeconomically.

WHAT WOULD YOU LIKE TO HAPPEN?

SCHMIDT In future, subsidies should be technology-neutral and structured in such a way that they pitch the different types of renewable energy source against each other, forcing them to compete on both the technological and the geographical front. The aid offered shouldn't merely promise investors good profits, but also ask such questions as: How do their facilities fit into the system? Are their locations optimal for the system? To achieve this, we could, for instance, introduce regional electricity price zones or a surcharge based on the distance the electricity has to be transmitted. Another option would be to make electricity generators contribute towards the cost of grid expansion if they build generating plants in locations a long way away from regions of high demand.

BRICK For many of the large enterprises in Amprion's grid supply area, maintaining a uniform German electricity market is important. And distance-based surcharges are only possible in the European context, otherwise they would distort competition. We need a harmonised, umbrella approach for all of Europe. Thanks to the deal reached at the UN Climate Change Conference held in Paris in December 2015, there is now greater harmonisation of the goals, leading to Germany and France working together to promote renewables.

SCHMIDT But these steps are still progressing too slowly! Europe could play an important role in limiting climate change. A joint European line of action could quite simply build on the emissions trading system. This system already exists. As we know, it does suffer from a number of teething problems, but we can make changes and refine it. I personally favour a model that stipulates a minimum price for CO_2 emissions. It's not exactly totally in line with free-market principles, but ultimately, it is closer to the free market than everything we've had to date.

BRICK We welcome all steps taken that make the system as a whole more efficient and more stable. At the moment, it's not yet running smoothly. Owing to the fact that the transmission system is gradually approaching breaking point, the grid operators are increasingly intervening in the way power plants are being operated. The cost of these "redispatch" measures reached a new, record level in Germany in 2015. The expectations people have of a new market design are therefore manifold and are currently being discussed at national and European level. In any case, the advancement and generation of renewables should be interwoven more closely with the market. The system would then harmonise better overall.

DO EUROPE'S GRID OPERATORS HARMONISE, THEN?

BRICK Fortunately, we European grid operators are already in a good place in this regard. Never before have we cooperated with one another as closely as we do now – irrespective of where we originate from and of the energy system we are connected to. We cooperate both bilaterally and regionally because we view system security and reliability as a common duty. We all know how sensitive our energy system is.

»A joint European line of action could very simply build on the emissions trading system. This system already exists. As we know, it does suffer from a number of teething problems, but we can make changes and refine it.«

PROF. DR CHRISTOPH M. SCHMIDT

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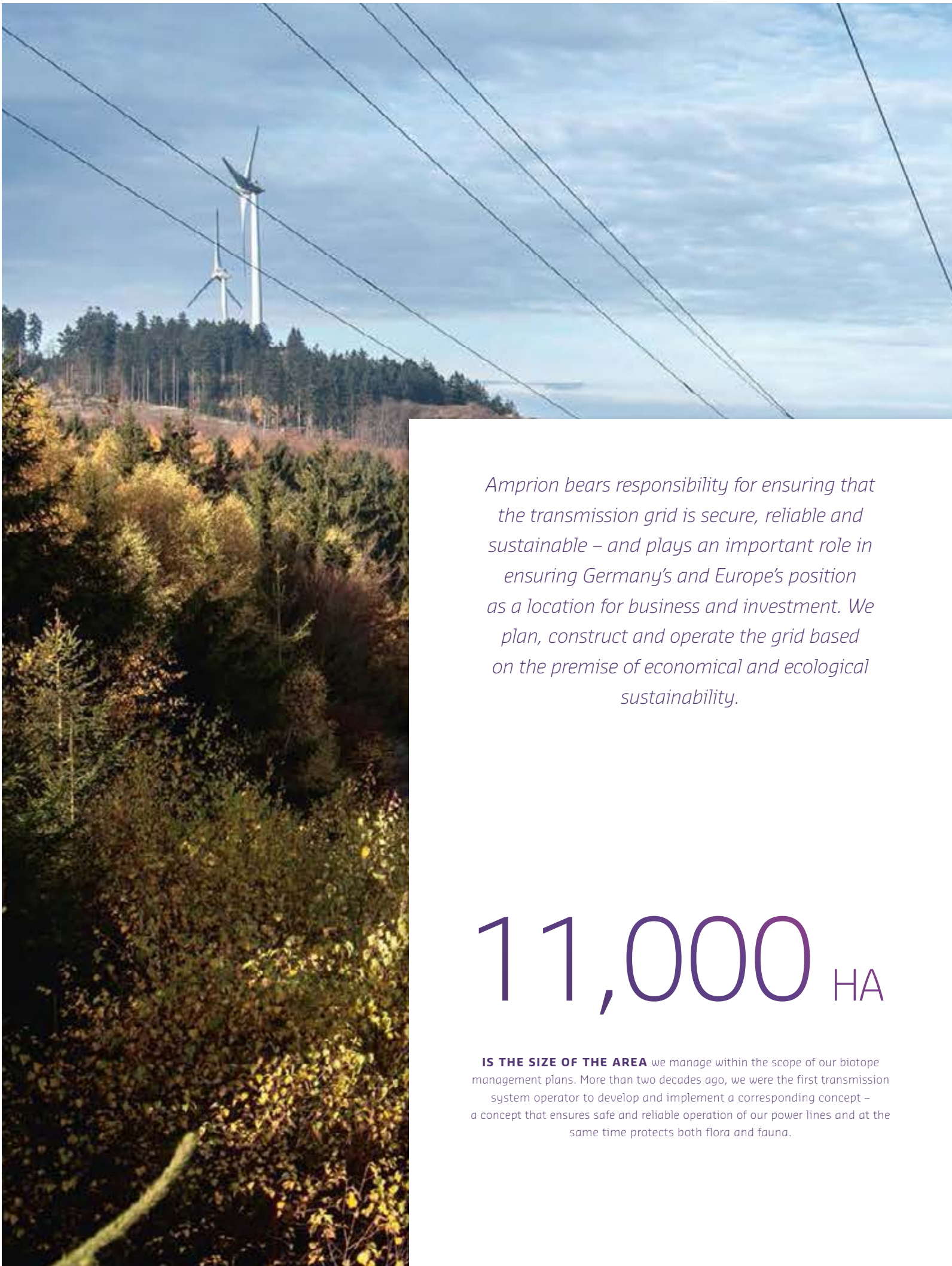
RESPONSIBILITY



Amprion bears responsibility for ensuring that the transmission grid is secure, reliable and sustainable – and plays an important role in ensuring Germany's and Europe's position as a location for business and investment. We plan, construct and operate the grid based on the premise of economical and ecological sustainability.

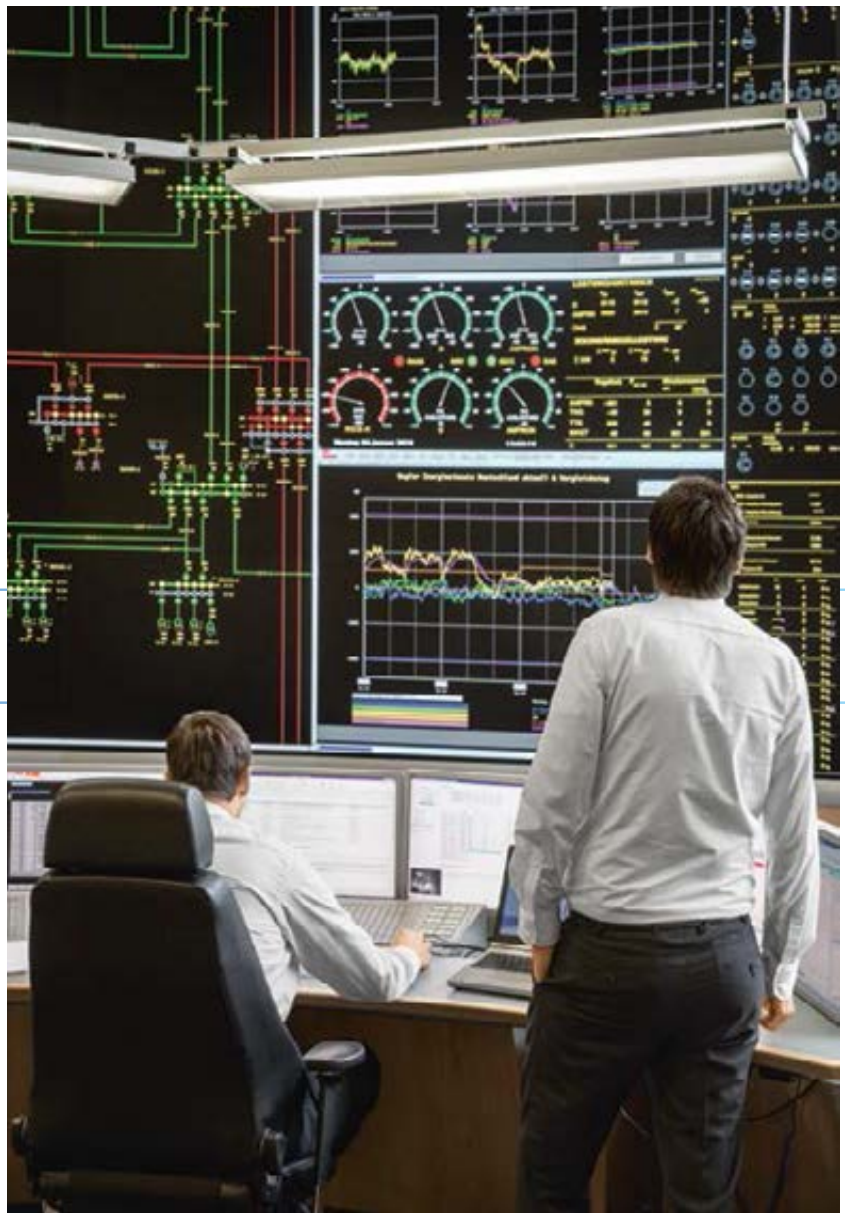
11,000 HA

IS THE SIZE OF THE AREA we manage within the scope of our biotope management plans. More than two decades ago, we were the first transmission system operator to develop and implement a corresponding concept – a concept that ensures safe and reliable operation of our power lines and at the same time protects both flora and fauna.

ALWAYS IN EQUILIBRIUM

24 hours a day, 7 days a week, system operation and control experts at Amprion ensure that power generation and power consumption remain in equilibrium. This job is becoming ever more complex owing to the growth in wind and solar energy and the trade in electricity across Europe's internal borders.

PHOTOS · **MARCUS PIETREK**



Control engineers monitor the electricity flow in the Amprion grid – around the clock.

Joachim Vanzetta, System Operation and Control Manager at Amprion, is responsible for ensuring that electricity generation and consumption in the network remain in constant equilibrium every second of the day.

We're in Brauweiler near Cologne, and it's the first Monday of 2016. The morning weather forecast promises a dull and calm day. Joachim Vanzetta looks out of the window of his office. "When the weather's like this, the wind turbines in the north simply don't turn," says the System Operation and Control Manager at Amprion. "If we had snow in the south, too, the solar farms down there would also feed very little electricity into the grid." We would then have one of those extreme situations that even a pro like Vanzetta views as a "challenge" – situations that are arising ever more frequently as a result of the energy transition. Germany wants to generate the majority of its electricity from renewable energy sources by 2040. But what happens when the wind doesn't blow and the sun doesn't shine?

On the other hand, there are days on which a stiff breeze in the north of the country and sunshine in the south mean that there's so much electricity available that these renewables alone as good as cover the country's entire hunger for energy. "These two situations are worlds apart," says Vanzetta. "We in System Operation and Control have to cope with both of these extremes."

The "system" he refers to is Amprion's 11,000 kilometres of extra-high-voltage power lines. If this system is to transmit electricity reliably, there's a simple equation that must always balance out, every second of the day, no matter what the weather conditions: generation = consumption. It's Vanzetta and his team who are responsible for ensuring this remains the case.

Keeping generation and consumption levels in equilibrium used to be a lot simpler than it is today. "The conventional power plants located all around Germany used to generate precisely as much electricity as was actually consumed," Vanzetta explains. But the electricity landscape has changed since the energy transition. Germany now relies more on renewables – and the amount they feed into the grid varies just like the weather does. On top of this, wind and solar generate electricity in those regions where the weather is most conducive – and not where it's actually needed. This situation is what Vanzetta likes to call "load-remote generation" and it has implications for Amprion's transmission system. "In the old days, we transmitted the electricity a distance of around 60 kilometres from the generator to the consumer. Today, the distances covered are

much longer, and getting longer all the time." This is why the degree to which the capacity of the "electricity highways" is utilised is increasingly rapidly. So, too, the threat of congestion and snarl-ups! Another factor is the European internal energy market. More and more power is being traded on the European electricity exchanges and "delivered" via the German grid. This can also lead to bottlenecks in the grid.

For the System Operation and Control team in Brauweiler, this means that new variables must be factored into the "generation = consumption" equation. Keeping the Amprion grid stable under these conditions requires good planning, experience, expertise and powerful systems. The effort involved is immense. A whole year in advance, Vanzetta's team of electrical engineers, energy exchange experts, weather specialists and IT professionals begins to plan each individual "electricity day" – a never-ending countdown. In this way, the Amprion experts schedule maintenance procedures for power plants, power lines and substations in advance and coordinate this "isolation scheduling" with other grid operators at home and abroad. At the same time, they also take a look at European energy trading.

Site meeting in Amprion's front office – a room with a wall of monitors packed with tables, diagrams and statistics. They are constantly on the move. Ralf Lonsdorfer, Front Office Manager, keeps an eye on every change. He and his colleagues make sure that the electricity traded on the German and European energy exchanges can be "delivered" safely and reliably via the grid. Since mid-2015, a new process known as "Central Western Flow-based Market Coupling" helps them to do this. Experts at Amprion played a major role in the development and launch of this process, together with other transmission system operators and exchanges in Germany, the Benelux countries and France. A mammoth project that Ralf Lonsdorfer has supported: "With this new process and the software based on it, we are able to compare grid capacities and traders' bids automatically." This enables us to reduce the number of critical situations in the grid considerably.

The closer the respective electricity day gets, the more the weather becomes the focus of the system controllers. After all, how much wind and solar power will be available depends totally on the weather. "When it comes to meeting the power demand in Germany, renewables take precedence. And we as a transmission system operator trade large lots of regenerative electricity on the exchange. That's how the legislators want it," explains Lonsdorfer. The better the quality of the weather forecasts, the smoother the cooperation between the power producers, exchanges and grid operators functions.

65 %

SHARE RENEWABLES ARE TO HAVE OF THE POWER GENERATION MARKET BY 2040

As the energy transition progresses, wind and solar power are in the long term to account for the largest share of the electricity consumed. In 2015, renewables accounted for roughly a third of all the electricity generated within Germany's borders.

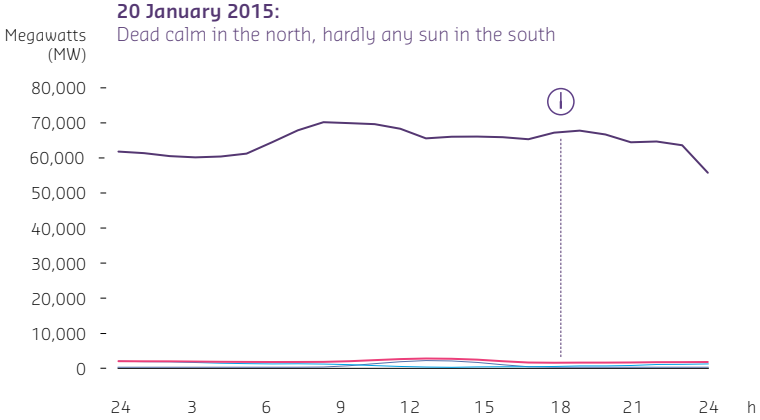
»So far, we've managed to deal with every load situation we've been faced with in the grid. But there was also a fair bit of luck involved. For the challenges are growing ever larger.«

JOACHIM VANZETTA, SYSTEM OPERATION AND CONTROL MANAGER AT AMPRION

EXTREME GRID SITUATIONS

The contribution made by wind and solar power towards meeting the power demand in Germany

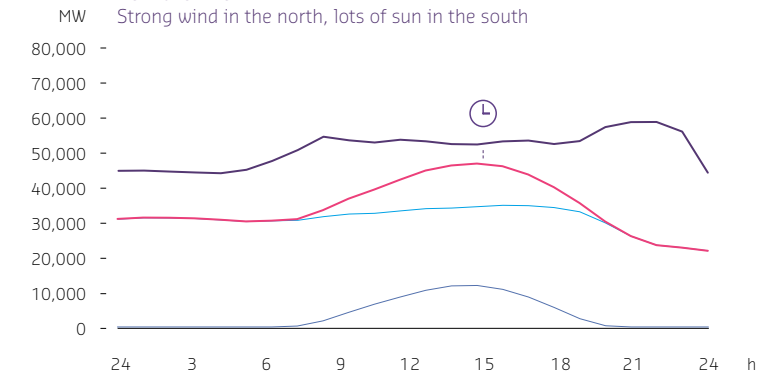
20 January 2015:
Dead calm in the north, hardly any sun in the south



0,1 %

of the grid load in Germany was accounted for by electricity generated from renewables at this moment in time.

30 March 2015:
Strong wind in the north, lots of sun in the south



90 %

of the grid load in Germany was accounted for by electricity generated from renewables at this moment in time.

- Grid load in Germany
- Total wind and solar infeed
- Wind power infeed
- Solar power infeed

Source: Amprion GmbH

GRID LOAD

The term "grid load" describes the amount of electricity the transmission system delivers to the distribution grids and to bulk consumers, such as electricity-intensive enterprises connected directly to the transmission system. This electricity is for the most part generated by the power plants connected to the grid. Electricity imports must be added to and exports subtracted from this figure.

Ralf Lonsdorfer, Front Office Manager at Amprion, coordinates cooperation with the European electricity exchanges. His goal is to avoid bottlenecks in the grid.

That's why Lonsdorfer and his colleagues in Brauweiler have become weather experts. They have developed a system that uses artificial intelligence models. This system is able to evaluate a large number of existing weather models and to predict how much wind and solar power will be generated in which regions. These models, forecasts and systems are being continuously optimised – amongst other things as part of the EWeLiNE research project that Amprion is actively promoting, along with the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), the German Meteorological Service (DWD, Deutscher Wetterdienst) and the transmission system operators 50Hertz and Tennet.

Ralf Lonsdorfer glances at the clock and in the meantime, it's turned 1 p.m. The electricity exchanges are now closed and trading for the next day is over. The front office begins to accept and examine the "schedules" for the next electricity day. These schedules stipulate how much energy will be fed into the grid by which power plants and will be taken from the transmission system by which major clients – that is, the regional distribution grid operators and large industrial enterprises – in each 15-minute block.

"If our schedule works out," Ralf Lonsdorfer explains, "and the weather doesn't get up to any antics, we have hopefully created a useful starting point for our colleagues in the control centre to follow the next day."

"Main control centre" – this is the term used to describe the heart of the system operation and control system. Control engineers sitting at three workstations monitor the current flows – 24 hours a day, 7 days a week. Their main tool: the 18-metre-wide and 6-metre-high mimic board. For laymen, the red and green lines, dots and rectangles look like a geometric pattern. For the control engineers, they show which power plants are feeding into the grid and which power lines and substations are transmitting current – and that across a monitoring area that stretches from the French Atlantic coast to the Czech Republic.

"The national power grids in Europe have long been interconnected," says Dr Christoph Schneiders, head of the Brauweiler main control centre. "If there is a problem in a neighbouring country, this can affect us, too. That's why we monitor such a large area."

Dr Christoph Schneiders, Main Control Centre Manager at Amprion – his job is to respond to unforeseen events.

Only when generation and consumption are in equilibrium does the alternating current grid operate with the ideal frequency of 50 hertz. To ensure it stays that way every second of the day, Schneiders and his colleagues play it safe. The "N-1" criterion is their absolute top priority. This stipulates that the grid must remain stable if components such as power lines, transformers or power plant blocks fail – and even at peak load. This is simulated by IT systems every 15 minutes. Based on the results, the control engineers on duty then test whether in such a case there are still sufficient other "highways" available to ensure security of supply. And it's a similar story as regards generation by wind and solar units. The control centre is constantly receiving information about how the infeed of power by renewable energy sources is actually developing and whether this current can also be transmitted.

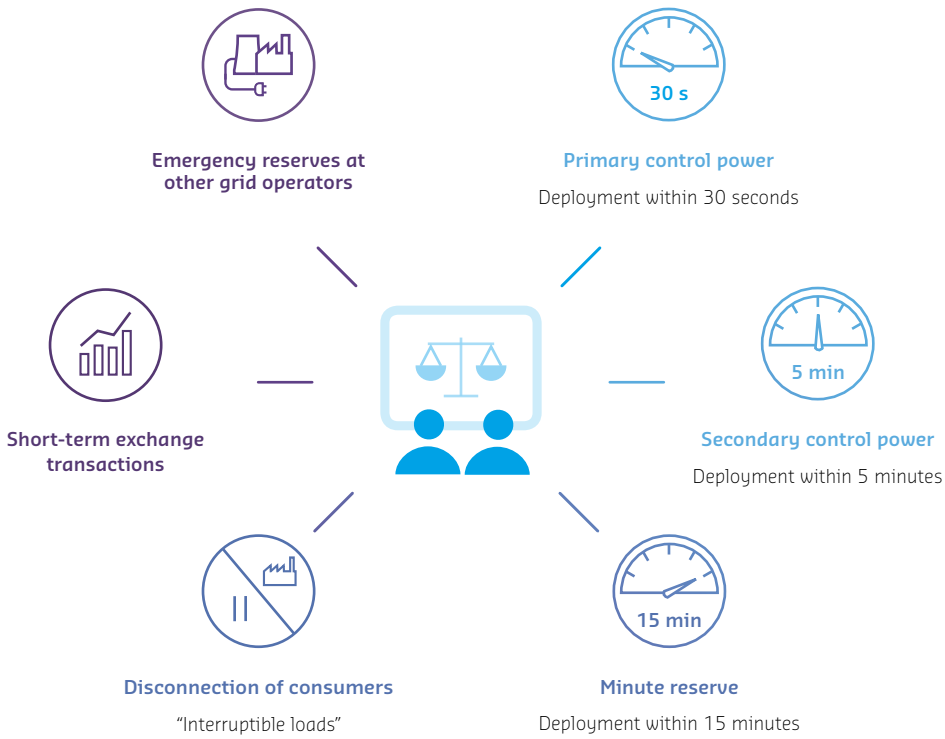
Nevertheless, even perfect planning and preparation isn't capable of completely ruling out surprises. "No matter how good my co-workers' groundwork is, it's never one hundred per cent possible to predict the amount of electricity wind and solar will feed into the grid," says Schneiders. "That's why we're constantly forced to make adjustments."

For this reason, the control engineers have a set of instruments that enable them to compensate frequency fluctuations. Three of these instruments are: primary and secondary control power and minute reserve. These refer to flexible power plants that can increase or lower their output to the grid within 30 seconds, 5 minutes or 15 minutes as required. By installing these power plants, Amprion and other transmission system operators have agreed to guarantee 24/7 readiness for action.

If these measures are not enough, the control engineers can, for instance, disconnect major power consumers from the grid for a certain period of time. However, this doesn't apply to residential customers, only to energy-intensive businesses that have willingly signed up to it and are compensated financially if and when it happens. These are what the experts in Brauweiler call "interruptible loads", with this option being clearly regulated in law. Another option available when balancing problems arise is "redispatch", which allows Schneiders and his team to actively intervene in the agreed plant schedules. Conventional power plants, but wind and solar farms, too, can be down-regulated, or infeed levels can be

SET OF INSTRUMENTS AVAILABLE FOR SYSTEM OPERATION AND CONTROL

The options available to compensate frequency fluctuations in the grid



increased at other points. However, such interventions lead to additional costs for the power plant operators, for which they also receive compensation. According to the latest statements issued by Germany's transmission system operators, redispatch costs reached a new record level in 2015 at more than a billion euros – an indicator of how often the transmission system is now operating at the very limit of its capacity.

In the meantime, it's dark outside. Joachim Vanzetta is content. The electricity day went according to plan: neither were there any unforeseen fluctuations on the renewables side, nor were there any critical bottlenecks on the supply side. "So far, we've managed to deal with every load situation we've been faced with in the grid. But there was also a fair bit of luck involved," says the System Operation and Control Manager. "But to make sure it stays that way in future, we have to take action right now." For the challenges are growing ever larger. In 2015, renewables already accounted for 30 per cent of the total amount of power generated in Germany. By 2040, the share of wind and solar power is supposed to rise to 65 per cent. The variables that make up the electricity equation will therefore fluctuate even more than they do now. The solar eclipse in March 2015 gave us a foretaste of what's to come. Thanks to meticulous preparations coordinated across Europe, the engineers succeeded in managing and mastering its impact. "What we need are even better weather forecasts, more intelligent IT systems and a continuation of the close collaboration we enjoy with our European counterparts," Vanzetta emphasises.

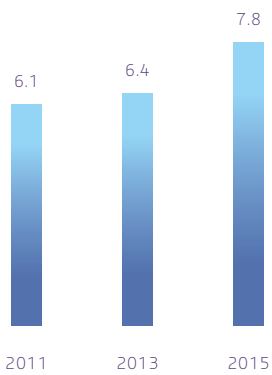
He points to the brick building that's going up across from his office. In two years' time, this will house the new main control centre that should be up and running. At its core is an innovative grid control system, which our experts in Brauweiler are currently working on together with Siemens. Vanzetta is clearly proud of this and other projects in which Amprion's System Operation and Control team is demonstrating its expertise. For him and his team, promoting new system operation and control technologies and methods is extremely important. "After all, we are responsible for one of the most important infrastructures of the national economy," he says. "One thing is clear, however: innovation isn't everything. To continue to be able to operate and control the grid reliably in future, we have to expand it quickly."

SUSTAINABLE INVESTMENT

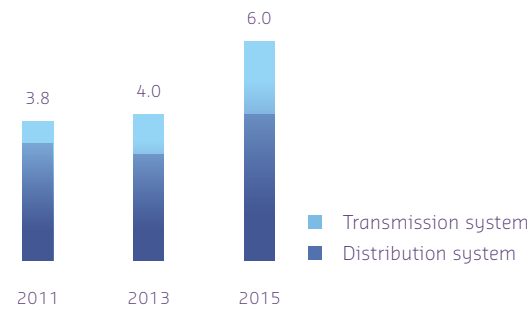
The transmission system is one of the most important infrastructures in the German economy. It is to be expanded as part of the energy transition. The level of investment necessary to do so is comparable with expenditures on the telecommunications, road and rail networks.

Investments in infrastructure in Germany (in € bn)

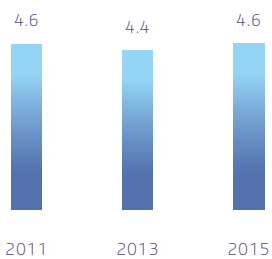
TELECOMMUNICATIONS NETWORK



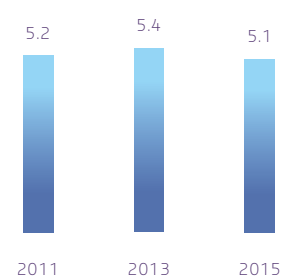
ELECTRICITY NETWORK



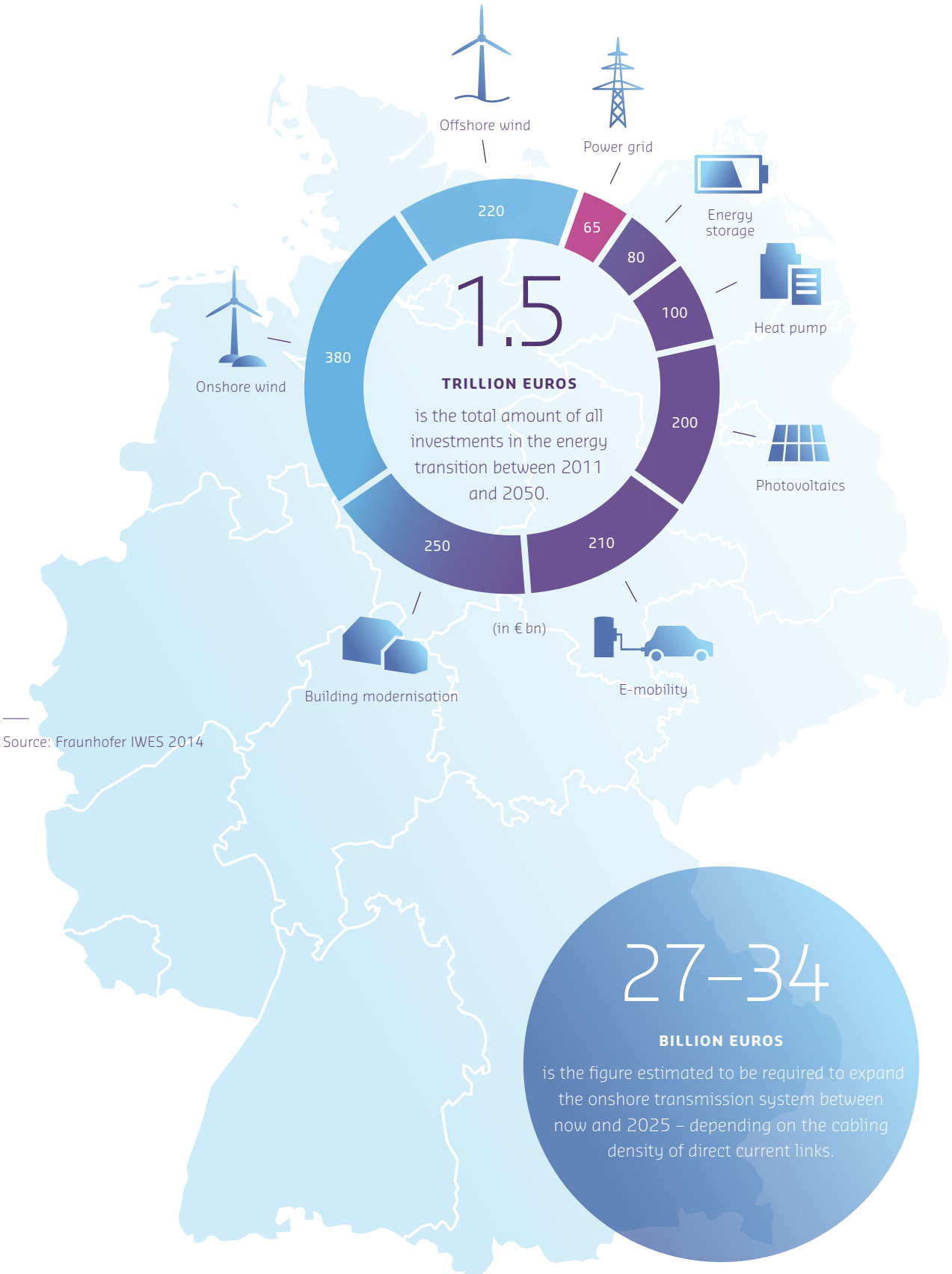
RAIL NETWORK



TRUNK ROAD NETWORK



Source: Federal Network Agency (Bundesnetzagentur)/Federal Cartel Office (Bundeskartellamt)
Energy Monitoring Report 2015 (Monitoringbericht Energie)



Source: Fraunhofer IWES 2014

27–34

BILLION EUROS

is the figure estimated to be required to expand the onshore transmission system between now and 2025 – depending on the cabling density of direct current links.

Source: Bundesnetzagentur, 2nd Draft of the Network Development Plan 2025

ACHIEVING DIVERSITY

Nature conservation beneath power lines? Biotope management makes it possible. Amprion has been implementing a corresponding concept for more than 20 years. Rare species of orchid in the Hunsrück region are also benefitting.

PHOTOS · **GÜNTHER BAYERL** TEXT · **THOMAS BECKER**

Nature conservation beneath power lines: where grasses sway in the wind at autumn time, rare species of orchid blossom in May.
To bring this about, bushes and trees are cut back every three years.
Amprion experts monitor the work performed.

Route maintenance as scheduled: Amprion has mapped all areas beneath its power lines and divided them into biotopes. This is important in order to retain the diversity of flora and fauna.

A mild autumn day in the "Wiesen am Hirtenborn" nature reserve in the Hunsrück, very close to the Rhine Gorge at Bacharach. Dried grasses sway in the wind. A few steps further and one finds young birch trees growing between sprawling raspberry bushes. An ecological treasure, right beneath a power line.

It's difficult to imagine! In May, herbs and species of orchid that are rare in this region of Germany nowadays blossom, such as the broad-leaved and the green-winged marsh orchid or the white helleborine. "What the Champions League is to football fans, that's what meadows of orchids are to conservationists," enthuses Joachim Jacobs, forest warden of the nature reserve. "What we have here is an area with more than 150 different species of plant that absolutely deserves to be protected."

If we left the bushes and trees to their own devices, the orchids in this reserve would soon disappear. What's more, the trees would grow like wildfire and pose a hazard to the power supply if they reached the height of the lines. Joachim Jacobs and Amprion biotope manager, Matthias Spielmann, want to avoid both of these possibilities. Spielmann is responsible for monitoring the growth of vegetation along the routes of the overhead power lines that cut through the region – through woods and across fields, pylon for pylon, kilometre for kilometre.

150

SPECIES OF PLANT

live in the orchid meadows in the "Wiesen am Hirtenborn" nature reserve in the Hunsrück. "An area that absolutely deserves to be protected," says warden Joachim Jacobs.

Where transmission routes cut through woods, new biotopes sprout – careful intervention makes this possible.

The 25-year-old opens a folder that bears the inscription “Biotope Management”. This contains a detailed description of the cycle of when and precisely how the vegetation along the route is to be cared for. “In the beginning, the idea was that we would mulch this area,” says Matthias Spielmann. What is mulching, then? A machine works its way through the undergrowth, shreds it and leaves behind a layer of mulch that is rich in nutrients. However, as orchids require nutrient-poor soil, biotope manager Spielmann altered the strategy to the effect that a woodsman now mows the poor grassland beneath the power lines every three years and cuts back and places branches to one side, next to the meadow. “This enables the orchids to develop.”

Work is scheduled to begin in the coming weeks – just one of thousands of maintenance measures Amprion commissions from October to February along its transmission routes throughout Germany. The first grid operator in Germany to do so, some twenty or more years ago, Amprion developed a concept designed to optimise route maintenance along ecological lines. In the meantime, all areas beneath its power lines – in all, around 11,000 hectares – have been mapped and divided into biotopes. This concept aims to manage the plants and soils along the routes in such a way that they pose no risk to the overhead power lines. “Then again, we also have a responsibility to maintain and promote the diversity of flora and fauna,” explains Amprion project manager, Dirk Uther, who helped draw up the route maintenance concept.

“In the old days, grid operators simply followed the principle of clear-cutting everything,” the expert explains. Whatever grew along the routes and beneath the overhead power lines was coppiced, that is, cut back to ground level, every 10 to 15 years. Heavy machinery dragged all of the wood and grass cuttings out of the woods, leaving behind deep furrows and barren strips of land. “This seriously disrupted the ecosystem,” says Uther. “Today, however, we coordinate all of our maintenance measures with the needs of the wildlife that lives there.”

And Amprion reaps high praise from other experts for these efforts. Together with local partners, the company won the German

Protection for the power lines: if branches lean towards the route, they are cut back. Part of the grass cuttings remains in the woods. "This enables nutrients to find their way back into the soil," says Amprion biotope manager, Matthias Spielmann.

Landscape Management Award (Deutscher Landschaftspflegepreis) in 2014 for a route maintenance project conducted in the vicinity of Wuppertal.

This award is conferred once a year by the German Association for Landscape Management (Deutscher Verband für Landschaftspflege) – making it a kind of "industry Oscar".

Spielmann, the biotope manager, and Jacobs, the forest warden, look into the distance. Behind the hill with the orchid meadow, the power line drops down into a valley. To the left and right is mixed woodland, with tall Norway spruce, oak and poplar trees – Bingen Forest. Bushes and trees grow beneath the power lines. "What we're trying to do here is ensure that the area beneath the overhead power line is permanently covered with trees – but of the kind that grow slowly, such as oak and beech," explains Günter Lips, the man at Amprion responsible for grid operations in the states of Saarland, Rhineland-Palatinate and parts of Hesse. "This means we don't have to cut them back so often."

The specialist talks about a "staggered development" for the route, where the trees at the edges are taller. Like a trough that curves gently inwards. "Overhead power lines that cut through a forest should be troughed like this if possible," he says. The principle followed for maintaining the route is: "More frequent intervention, but gentle." This means continuous pruning, cutting back, chopping, mowing and mulching.

Precisely what needs to be done along the route through Bingen Forest has been agreed earlier by biotope manager, Matthias Spielmann, with the owner of the area. In this case Joachim Jacobs, the forest warden, is in charge of part of the state-owned forest. The two of them study the map and schedule in the Biotope Management folder. The tops of some trees at the edge of the route, three pylons further on, need to be trimmed. So, let's go and do it!

The men take the car down the hill to pylon 197. A skilled forest worker and a trained tree climber are already waiting for them there. Properly secured, the tree climber clambers up a ladder and up to the crown of an oak tree. Using a handsaw, he saws away at one of the branches that is leaning towards the route. While he busily goes about his work, the pitons attached to his belt jingle and jangle.

Electricity transmission in harmony with nature: this is the basic idea behind biotope management. And this is how Amprion understands its responsibility as a sustainable business enterprise.

» We coordinate all of our route maintenance measures with the needs of the local wildlife.«

DIRK UTHER, EXPERT FOR ENVIRONMENTAL PROTECTION AT AMPRION

Brown oak leaves flutter down to the ground. Then there's a crashing sound and the first branch lies next to the tree.

A car pulls up on the road nearby. A man gets out. He has just read in the newspaper that route maintenance work is underway in Bingen Forest. "We have to do something to protect the power lines," he says, as he watches the tree climber. It turns out that the man is a beekeeper and he's just come from his hives that are located in the vicinity of the orchid meadow on the other side of the hill. He says that the meadow is "somehow sacred" to him. "After all, it's absolutely vital for my bees."

And then another crashing sound and another oak branch falls to the ground. "We leave some of the grass cuttings in the forest to rot," explains Matthias Spielmann. "This enables nutrients to find their way back into the soil." That's good for the environment, but also cost-effective at the same time. "We used to cart tons of wood and cuttings out of the woods, but there's none of that now." Despite this, the cost of ecologically optimised route maintenance is still far from cheap. Amprion spends more than a million euros on these measures in Saarland, Rhineland-Palatinate and parts of Hesse alone – nationwide it's 3.2 million euros. "We see it as an integral part of our remit and our responsibility as a sustainable business enterprise," says Günter Lips. "At the same time, by carrying out this work, we ensure that our power lines are safe and continue to operate reliably."

The working day is drawing to a close. Some distance away, a kestrel is circling above the transmission route, looking for mice. "The hawks nest on our pylons," says Matthias Spielmann as he gets into the car. It's almost knocking-off time for the biotope manager. Tomorrow, the work will continue with more mowing, chopping and mulching – pylon for pylon, kilometre for kilometre.


amprion
amprion
Merken

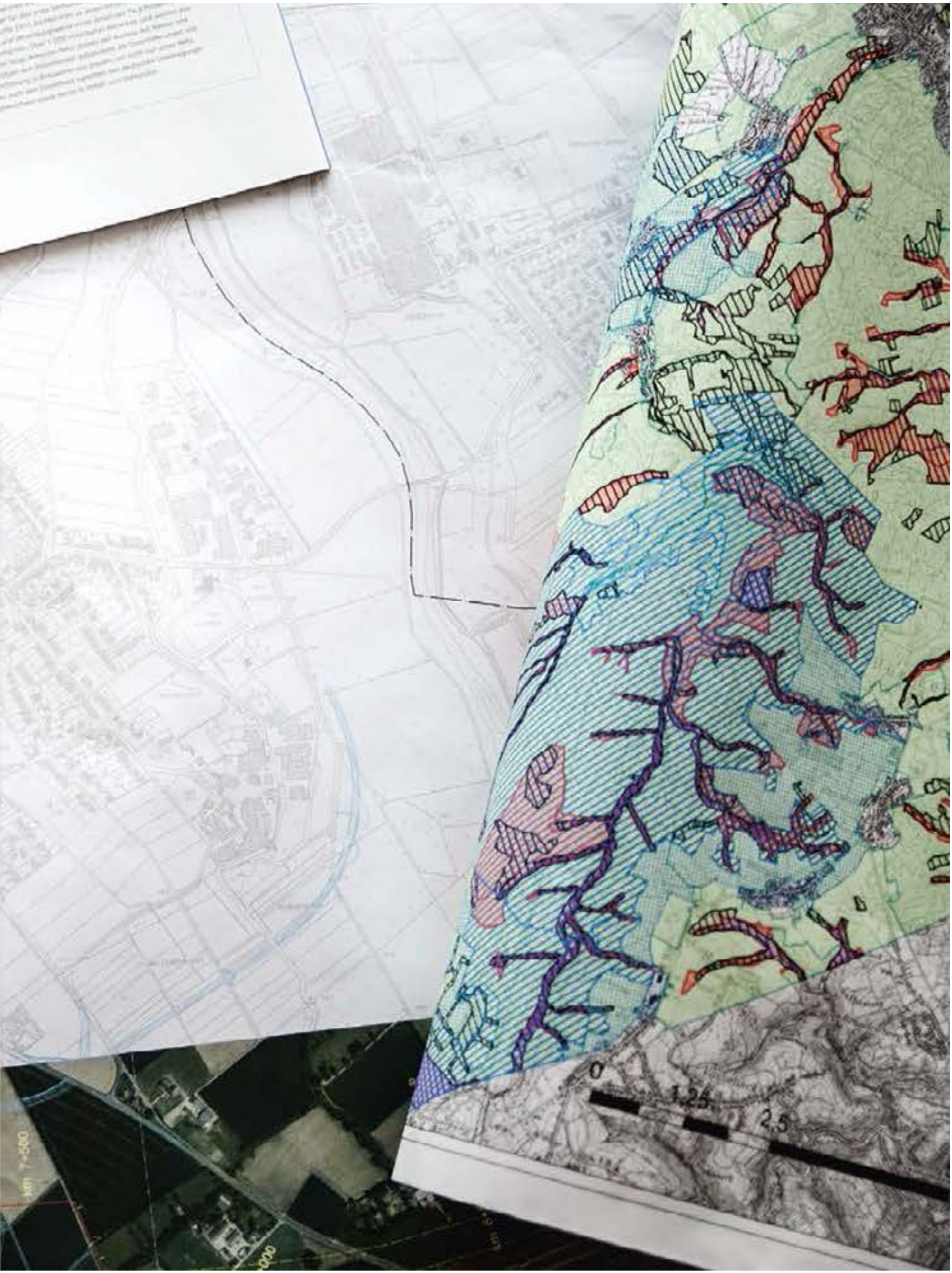
2

DIALOGUE

Amprion actively seeks to engage in dialogue with its stakeholders – with citizens, social groups and organisations, its European partners, politics and business. Only through dialogue, by talking to one another, will we be able to implement the level of grid expansion that is so essential to the success of the energy transition.

505

That's the number of **EVENTS** we organised in 2015 in order to converse with our stakeholders – about the energy transition, our company and actual projects. This dialogue helps us to advance grid expansion in as citizen-friendly a manner as possible.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GUEST ARTICLE

INCREASING OPPORTUNITIES TO PARTICIPATE

Germany needs new power lines. Local residents should be involved in the planning phase from an early stage, because people who have a say are more likely to grasp the necessity of infrastructure projects.

ILLUSTRATION · **SILKE WERZINGER**

The decision to phase out nuclear energy and the energy transition mean that Germany is faced with two enormous challenges. The goal is to reduce the share of coal and oil in the national energy mix to less than 20 per cent by 2050 by increasing the use of wind and solar power, while maintaining the security of supply. This assignment demands high levels of investment, far-reaching structural changes, a readiness to cooperate on the part of everyone involved and innovative political initiatives. It's a challenge that can only be successfully resolved if residents along the proposed routes are able to participate in planning the infrastructure projects, such as new power lines or wind farms.

In theory, nine out of ten Germans support the energy transition. At the same time, however, the prevailing attitude is that politics and business will join forces and somehow carry out and master this transition on their own – and do so while guaranteeing full security of supply and acceptable prices, but without causing any further negative impact on the environment. But when people realise that the energy transition will cost money and give rise to new concerns and challenges, enthusiasm quickly turns to disappointment and scepticism. This is reflected by, among other things, the resistance to expansion of the power transmission systems.

To enable people to grow to accept changes that will result from infrastructure projects, a number of different criteria must be taken into account. First of all, local residents need guidance in order to comprehend the aims of the respective project as well as information about the planning options and the planning process.

»Readiness to engage in dialogue isn't always enough to increase acceptance. Instead, local people should be given more opportunities to become involved.«

Moreover, the level of acceptance increases the more oneself and people closely connected to oneself benefit from the project in question. It's important, then, that local residents

PROF. DR ORTWIN RENN
is one of Germany's most eminent sociologists specialised in the fields of technology and the environment. He took up the post of Scientific Director at the Institute for Advanced Sustainability Studies (IASS) in Potsdam (Germany) in February 2016.

are clear about the pros and cons of planned power lines and wind farms. Being able to identify emotionally with a project also plays a massive role. Grid operators, businesses and local authorities should help local residents to understand the significance of a project for the development of their local and regional environment.

People tend to reject intervention in and changes to their environment if they fear that this could impact on their own personal freedoms and self-empowerment. Conversely, they are willing to get personally involved if they are certain that their own efforts towards realisation of a project can make a difference.

Information and communication activities must take these aspects into account. But opportunities and a readiness to engage in dialogue aren't always enough to increase acceptance – especially if a project is bound to impact residents' lives. Instead, local people should be given more opportunities to become involved. This presupposes that there is genuine room to manoeuvre.

Communication is designed to convey a decision made by legislators to those affected, in the hope that they also accept or at least tolerate this view. The idea of participation goes a step further. It presumes open policy-making processes and, within the scope of the legal limits, leaves it to the citizens involved to come up with new options and assess existing ones based on their own ideas. The moment people become decision makers themselves, the more likely they are to identify with the project simply as a result of their participation in the process.

Participation processes must take a specific form. It has been shown that especially in the initial phase, the key points must be made transparent for all participants. There must be clarity regarding the form in which citizens can participate towards the success of the process and the degree to which the results of their contribution are binding on the outcome. Likewise, it's absolutely essential to have a realistic perception of the possibilities and limitations of the participation process from the technical, legal and planning point of view.

If these cornerstones are in place, the chances of local residents being able to better acquaint themselves with the opportunities and risks of new infrastructure projects and to gain a greater insight into the planning projects than before are good. This doesn't mean that the acceptance of participants is a given, but it does make it easier to persuade and convince them. All in all, early inclusion and greater opportunities for citizens to participate could help the population at large to see the energy transition as a common mission for society as a whole.

Kaarst near Düsseldorf: this is where Amprion plans to build the converter at the northern end of the Ultranet link.

TRANSPARENT PLANNING

Amprion continues to develop project communication. Informing citizens from an early stage, engaging in an open dialogue and offering opportunities to participate are important components of this. The company has used pilot projects to gather valuable experience.

PHOTOS · **GÜNTHER BAYERL** · **MARCUS PIETREK** · **FRANK PETERSCHRÖDER** TEXT · **HEIMO FISCHER**

Heinz Smolibowski has read in the newspaper about Amprion's "citizens' info market". The pensioner from Sinzig is now standing in the hall of his local club, studying the maps that employees of Amprion have attached to display boards. An EHV power line nearby is to be upgraded. "I would like to know what this means," says the 69-year-old. His questions this evening are answered by, amongst others, Jonas Knoop. The 31-year-old is a project communicator at Amprion. He sees information markets like this one in Sinzig as an important element in the dialogue. "They have proven to be successful, because they enable us to start a dialogue with the local residents."

Amprion has held more than 500 information and dialogue events during the course of 2015, around 50 of which have been citizens' info markets. And there will be even more in 2016. This is because over the coming years, the company wants to upgrade and expand its transmission system by a further 2,000 kilometres – installing the majority of this new equipment along existing routes. And it isn't just info markets that play an important role. "Practical experience shows that we need to engage in a wide range of measures to inform the public about our projects and to campaign for acceptance. There is no patent method for communicating one's message that fits all projects," says Joëlle Bouillon, who is developing new formats for citizen participation at Amprion. "We see ourselves as an adaptive, learning enterprise," says the 38-year-old. "And we have a steep learning curve."

Some projects, however, require more than a targeted campaign to inform the public. That's why Bouillon and her colleagues have conducted pilot projects aimed at developing new forms of dialogue and participation. Take the example of Ultranet, the 340-kilometre-long direct current link, which is expected to carry electricity between North Rhine-Westphalia and Baden-Württemberg as of 2020. Scheduled for construction at either end of the line is a converter (see page 40). One of these facilities is to be built in Kaarst near Düsseldorf.

When Amprion's plans were made public, reservations began to grow among the population of this small town. The people were worried about the overall appearance of the landscape and some were even worried about their health. Amprion promptly organised an information evening to be held at short notice, but attracted the resentment of those opposed to the converter in the process. "The invitation went out two days before it was to be held, which was far too late," criticises Guido Otterbein, the spokesman of the local citizens' action group. This meant that there was no time to mobilise the members. He felt like he'd been steamrollered.

Amprion learned from this mistake and set up a discussion group with the town and parish councils and citizens' action committees that met regularly. Joëlle Bouillon, the project communicator, meets with council representatives and citizens interested in the converter construction project in a hotel in the neighbouring town, where up to 30 people gather. They inform themselves about the progress of

Guido Otterbein, spokesman of the citizens' action group in Kaarst, endorses the discussion group set up to help plan construction of the converter.

50

CITIZENS' INFO MARKETS

were held by Amprion in 2015.

Jonas Knoop, project communicator, and Heinz Smolibowski in conversation.

» There is no patent method for communicating one's message that fits all projects.«

JOËLLE BOUILLON,
PROJECT COMMUNICATOR AT AMPRION

the plans, ask questions and offer suggestions. In the meantime, communication between the various parties is much better, Otterbein confirms. "As regards communication skills, Amprion has taken a great leap forwards."

Even though the positions held by advocates and opponents of the converter are still far apart, there is one point on which everyone agrees: wherever projects like this are concerned, parish councils, residents and organisations must be brought on board at the earliest possible stage – even if relevant approval procedures haven't even yet begun.

The problem for Amprion often lies with the fact that at the very beginning of a grid expansion project, it is difficult to tell who really is affected. The only facts stipulated by the legislators are the starting point and destination of the planned link – no more, no less. Drawing a straight line between these two points is as good as pointless. For example, new lines are not allowed to run through either built-up areas or nature reserves. In which parishes a new route is to be built often doesn't become clear until months later, when the planning process has been underway for quite some time. "The problem is that if the people don't find out about the planning work until this point, they feel they have been presented with a fait accompli," says dialogue expert Bouillon.

This is why Amprion today contacts all councils through which a new route could pass right from the word go. What's required is sensitivity, says Joëlle Bouillon. "Face-to-face meetings are far better than any letter when it comes to canvassing for a long-term exchange of views on equal terms."

One example of good communication is the district of Bissendorf in Lower Saxony. It comprises several villages across the boundaries of which the new transmission link from Osnabrück to Wehrendorf is to pass. There were already two power lines in the district, and the new route was initially intended to follow one of them. But this would have meant having to replace all of the old pylons. This in turn threw up the question as to whether it wouldn't be better to relocate whole sections of the route – and if so, where the route should then run. Amprion and Bissendorf's mayor, Guido Halfter, resolved this question in a multiphase "route identification process" into which the public was consistently integrated. This process could act as a model for future planning projects.

It began in 2014 with three workshops, to which around 20 representatives from the local administration, administrative district and regional planning authority were invited. The working groups set up were asked to simply mark recommendations for a preferred route on a map – without laying down any requirements. In a second step, experts examined the result and clarified the situation with regard to legal restrictions. During the second and third rounds of discussion, two potential corridors materialised along which the line could run.

"We presented the result to our fellow citizens at the beginning of 2015," says Lisa Ziemer, who represented Amprion in the route identification process. The citizens of Bissendorf pointed out to the

» We have collated an enormous amount of knowledge and know-how – about the project and how route planning functions.«

GUIDO HALFTER, MAYOR OF BISSENDORF

planners that a popular riding school was located on the one route, while a moated castle, a listed building, stood on the other. "We learned a great deal about the sort of things in people's own neighbourhoods that are important to them," says Ziemer. This defused or even totally eliminated conflicts from the outset and was an important lesson for the future.

Bissendorf's mayor, Guido Halfter, backed the process from the word go. "Our citizens have collated an enormous amount of knowledge and know-how – about the project and how route planning and the approval procedures function," he explains. The council is now in a position to discuss matters with the authorising agency and with Amprion on equal terms and to develop optimal solutions for Bissendorf.

Amprion has also learned from Bissendorf – how to shape potential forms of participation even better. "Sitting down together in front of a blank piece of paper is not the best or most constructive way to kick off joint planning efforts. There are technical criteria and statutory provisions for approval processes that have to be taken into account," explains the project planner, Ziemer. That's why Amprion will in future do the necessary groundwork before initiating public route identification processes, so that only planning alternatives that can actually be implemented are discussed.

Experiences already gained with new forms of dialogue and participation are now being channelled into the communication plans for "Corridor A North" – the northern extension of Ultranet. This link is to run from the Rhineland to East Frisia and should go into operation in 2025. With respect to communication, this project represents a first. The people who lived in any of those areas through which the route could potentially run are to be informed of and involved in the process from a very early stage.

Amprion is calling the package of measures that is to be worked up during the coming months the "transparent planning office". "Pilot projects such as Kaarst and Bissendorf have taught us how regular dialogue or a joint route identification process best functions. As a result, we now have a number of sophisticated information, dialogue and participation formats at our disposal," says Jonas Knoop. One decision already taken is that we will open a local office manned by a permanent member of staff who will answer questions about the route at regular citizens' consultation meetings and take on board all suggestions made. In addition to this, Amprion will keep local residents informed about the progress and status of the planning process by posting the latest news on the corporate website and holding citizens' info markets. Another essential component of this strategy are face-to-face meetings. These will enable district administrators and mayors, for instance, to regularly voice the feelings and any proposals put forward by their colleagues on the local and parish councils. As Jonas Knoop and his Amprion colleagues sincerely hope, these measures will allow all parties involved to develop a mutual understanding and trust.

COMMUNICATION FORMATS

Amprion has a number of different formats at its disposal from which it can develop a tailor-made communication concept for each and every one of its projects.

INFORMATION

Project brochures and leaflets

provide information about why projects are necessary, how they are planned and the approval process.

Amprion's website

brings together and publicises all information about the company and its expansion projects.

www.amprion.net

Newsletter

regularly reports on the progress and status of the larger expansion projects.

DIALOGUE

Citizens' info markets

offer local citizens information on the project in their area and the chance to talk to Amprion employees.

Citizens' consultation meetings

are meetings held with Amprion employees to discuss concrete route planning activities.

Discussion groups

bring all parties together round one table – the citizens' action groups, the councils and the authorising agency.

"direktzu Amprion"

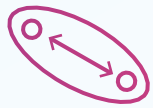
is an online platform that enables people to ask questions about the company, grid expansion and projects.

www.direktzu.de/amprion

CITIZEN PARTICIPATION

Site selection processes

such as the one underway with respect to the Ultranet converter, help the various interested parties to jointly define the criteria according to which the location for a large-scale facility is to be selected.



Route identification processes

like the one in Bissendorf, serve to jointly develop a route that is both technically feasible and as citizen-friendly as possible.

Mediation processes

bring together different interest groups in order to reach a consensus on the path of a power line or the location of an installation or building.

QUESTION TIME

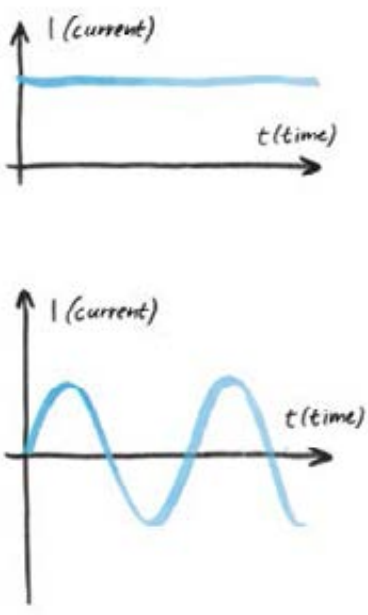
The German government is increasingly turning to underground cables as the solution to the problem posed by grid expansion. From now on, priority is to be given to using underground cable to construct the major direct current links. The cable technology to be employed to carry alternating current is currently undergoing trials in pilot projects. Why this distinction is necessary and important is explained here by Amprion's Dr Christoph Gehlen, who is responsible for transmission line technologies.

ILLUSTRATION · **SILKE WERZINGER**

1

WHAT'S THE DIFFERENCE BETWEEN DIRECT CURRENT AND ALTERNATING CURRENT? AND WHY DO WE NEED BOTH TYPES OF CURRENT IN THE TRANSMISSION GRID?

Direct current may be familiar to you if you've ever played with certain toy train set models: one rail acts as the positive pole, while the other is the negative. With alternating current, however, the polarity is constantly being switched back and forth – in the European power supply system, 50 times every second; that is, with a frequency of 50 hertz. In the past, alternating current came out on top as regards the grid system, primarily because it's relatively simple to change the voltage of the power supply with the aid of transformers. This ability is crucial for grid operation, because it enables us to connect power plants – including wind and photovoltaic systems – and consumers such as distribution systems and electricity-intensive enterprises to our grid without any problem. Changing the voltage of a direct current is more complicated. It requires converters, which need a lot more space and are much more expensive compared with AC transformers. This is why direct current technology is more suitable for transmitting large amounts of energy over long distances with minimal losses. In future, Amprion will be using DC technology for our Ultranet link, the German-Belgian ALEGrO connection and Corridor A North.



DC current profile (top)
AC current waveform (bottom)

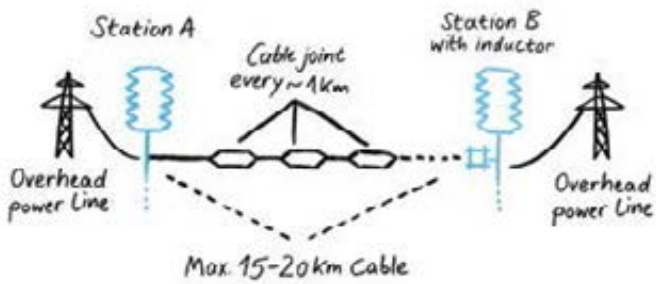
DR CHRISTOPH GEHLEN

manages the "Operation/Project Planning Lines and Cables" department at Amprion.

2

HOW DO DC AND AC UNDERGROUND CABLES FUNCTION?

Underground cables have a far greater capacity than overhead power lines. Before current flows, this capacity must first be "charged up". This requires what's known as "reactive power", and a DC cable needs to be charged up with it only once. Once this has been done, the current can flow – and over distances of several hundred kilometres. The situation is different with alternating current. Since the polarity keeps changing back and forth, reactive power is required continuously. As of a length of 15 to 20 kilometres, however, extra-high-voltage underground cables require so much reactive power that it "clogs" the cable and the amount of active power capable of flowing through the cable is minimal. The reactive power must then be compensated with the aid of inductors, which resemble large transformers. This results in a rather complex system technically speaking, which is more susceptible to faults and makes the grid less stable.



Schematic diagram of partial cabling in an AC application

The cable transfer stations, inductors and joints that connect the roughly one-kilometre-long sections of the underground cable can give rise to a technically complex system.

3

WHAT ARE THE CONSEQUENCES OF THIS WITH RESPECT TO UNDERGROUND CABLING OF DC AND AC POWER LINES AT AMPRION?

When it comes to transmitting electricity in the EHV range, the overhead power line fundamentally remains the best solution from both the technical and the economic point of view. Whenever new lines are required, DC connections are, for technical reasons, much more suitable for underground cabling. However, the only experience available with this technology to date relates to submarine power cables. In December 2015, Germany's legislators decreed that in future, priority must be given to underground cables when planning all DC connections – with the exception of Ultranet. In Amprion's case, this affects the ALEGrO and Corridor A North projects. We are currently developing planning and technical solutions for this connection. The situation is different with regard to AC underground cables. Here, too, practical experience is very limited, especially in relation to transmitting high power levels. For this reason, legislators have given the transmission system operators the opportunity to test cables in pilot projects. Amprion has already built the first such pilot section in Raesfeld. Trial operation is set to begin in summer 2016. We'll then be able to see how this technology fares. After a period of around five years, we'll have gained initial experience with this technology and be able to assess how reliable and safe AC cables function in the transmission system under the conditions cited.

3

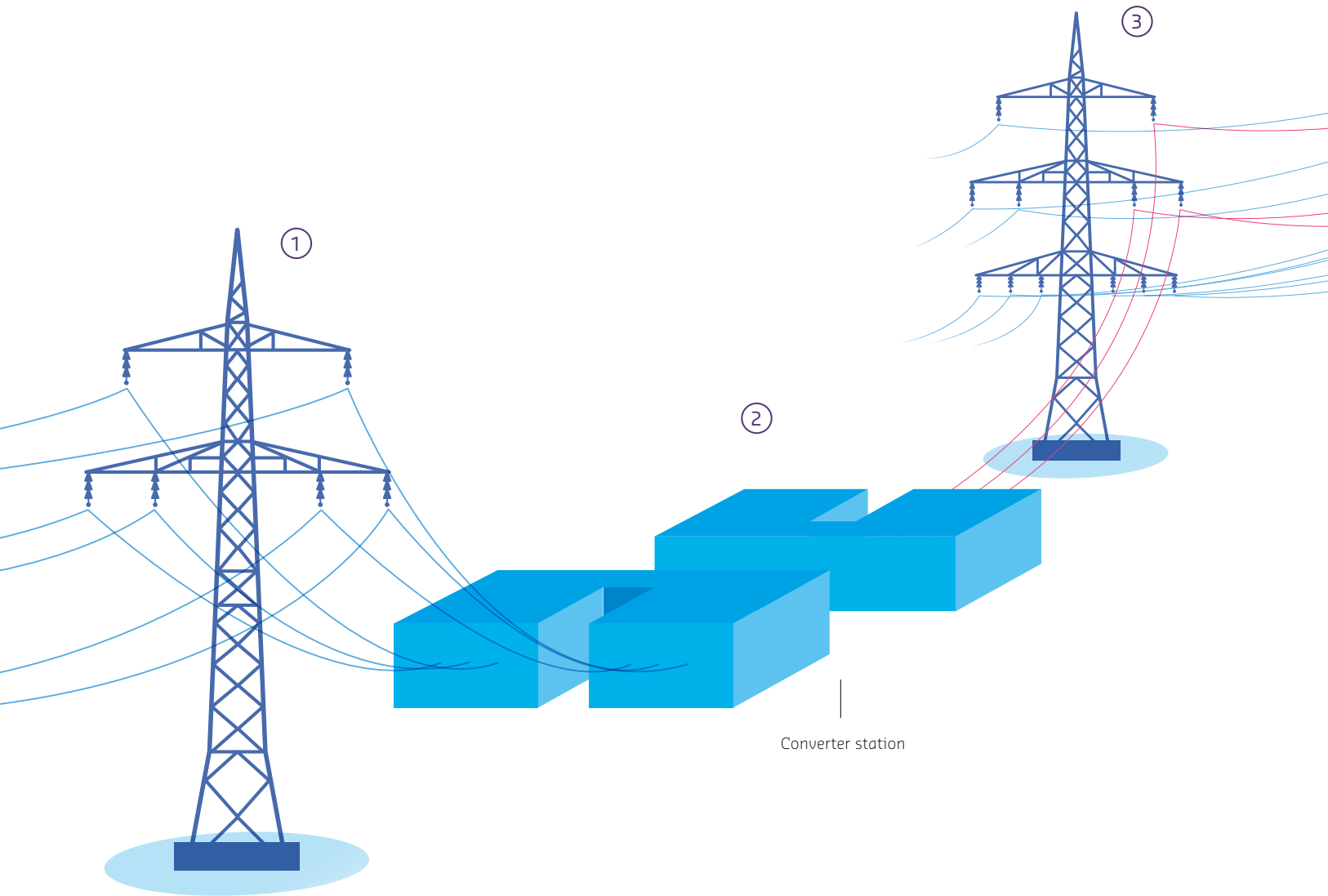
NEW START

Amprion is pushing on with the new start into the energy world of tomorrow. In the context of our grid expansion work, we are developing and integrating new, innovative technologies. These will strengthen the system reliability of the grid and help us to overcome the challenges of the energy transition and the growing electricity trade.

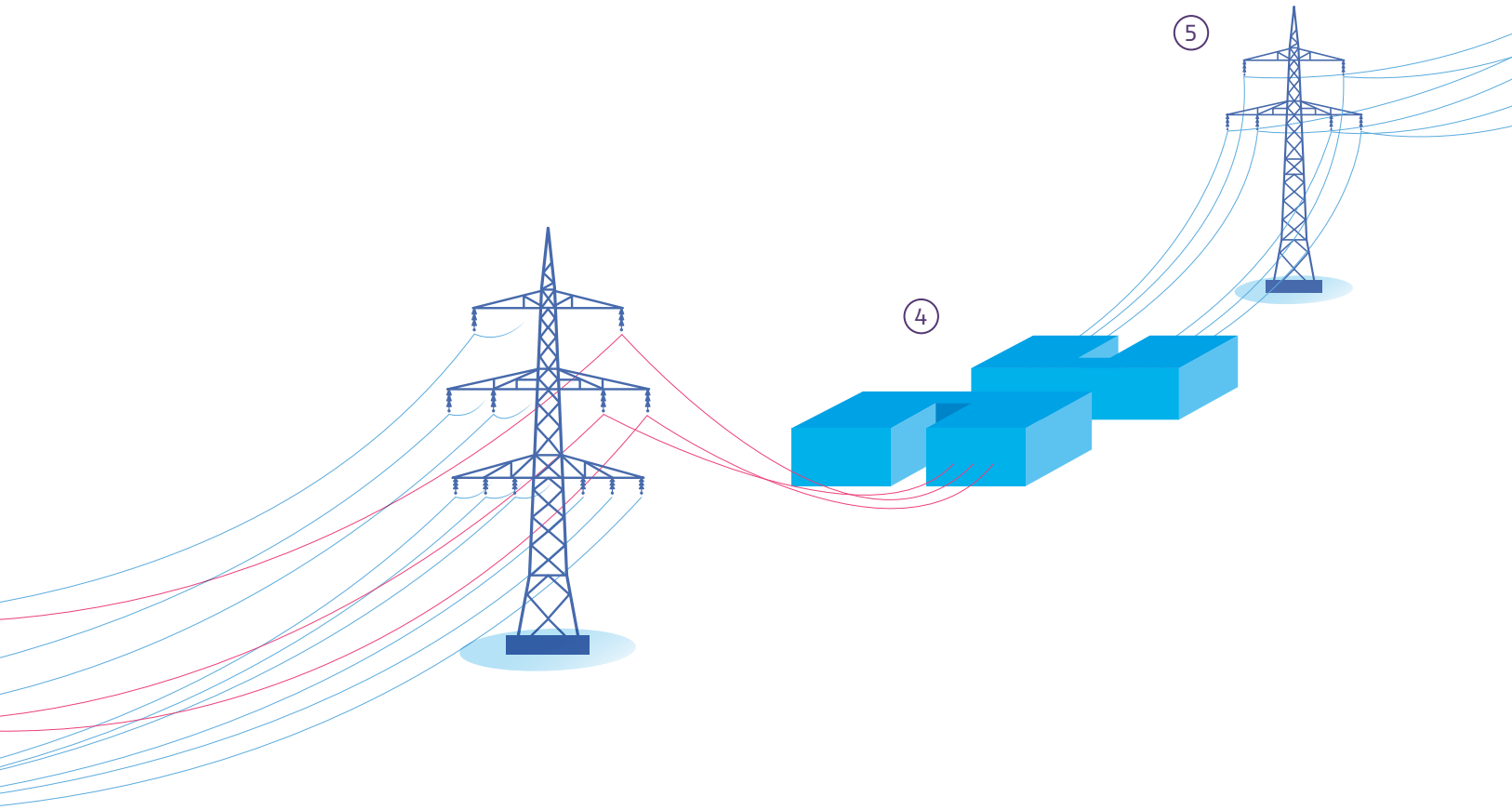
6,000

SUBMODULES will be controlled by the power electronics integrated into the Ultranet converters planned. These high-tech units are indispensable for this key project of the energy transition: they will facilitate the low-loss transmission of wind and solar power and at the same time make the grid even more reliable.

EFFICIENT OVER LONG DISTANCES



① Pylon with AC line ② Converter station in Osterath area
③ Hybrid pylons with AC and DC lines (HVDC)
④ Converter station in Philippsburg area ⑤ Pylon with AC line



Ultranet is the first of the three major north-south DC links to take shape. This also applies to the converters that will enable the low-loss transmission of electricity over long distances. Amprion, TransnetBW and Siemens are jointly planning the high-tech facilities.

PHOTOS · **MARCUS PIETREK · DANIEL SCHUMANN** TEXT · **VOLKER GÖTTSCHE**

The pencil flies across the paper. “This here is a switch,” explains Jochen Haude, “and that’s a capacitor.” With short strokes of the pencil, the engineer draws circuit symbols and current paths. “When the switch is in the one setting, the current flows through the capacitor; in the other setting, it bypasses the capacitor,” he explains. A single switch consists of two high-power transistors and two diodes. Together with a control unit, these elements form what’s known as a “submodule”. “By interconnecting a whole array of submodules, you create the core of a converter.” Haude lays the pencil to one side. “Technically speaking, it’s actually an amazingly good idea, put together from what are familiar, standard components.”

But what these submodules achieve is remarkable. Without them, one of the key projects of the energy transition simply would not be feasible. Ultranet is one of three major north-south DC links in Germany that above all are intended to transmit wind power from the north to southern Germany. Transmission system operators Amprion and TransnetBW are working together to plan the 340-kilometre-long “electricity highway” to be built between North Rhine-Westphalia and Baden-Württemberg. Transmitting high power levels over long distances in DC mode is particularly favourable, above all because transmission can be better controlled and losses are low. As, however, the rest of the grid operates with alternating

» Premium-performance control electronics: the switching behaviour of each of the 6,000 submodules is computed separately and precisely in a matter of microseconds. «

JOCHEN HAUDE, PRIMARY AND OPERATING EQUIPMENT MANAGER AT AMPRION

voltage, the power first has to be converted to direct voltage – at the extra-high-voltage level. Only then can the electricity be transmitted efficiently over this long distance. The same applies before the current can be fed into the AC grid again. This function is performed by two converters, one at either end of the Ultranet link.

Each of these Ultranet converters comprises almost 6,000 submodules that are arranged in three strings connected in series and put together to form "inverters". In addition to these submodules, the converters are equipped with transformers and cooling systems, inductors and mechanical switchgear. Together, they are capable of transmitting two gigawatts (GW) of power. As you can see, this type of unit plays in the champions league in the power transmission world, so to speak. "This enables us to transmit electricity to keep around two million people happy," says Jochen Haude, who heads the Primary and Operating Equipment department at Amprion and who, together with his team, is responsible for converter technology, among other things. The high supply capacity of Ultranet is required to compensate the energy shortfall in Baden-Württemberg when the two remaining nuclear power plants there are taken offline in a few years' time.

The electronics built into the converters must perform an extraordinary task, switching over the submodules electronically in line with precisely computed models and with timing accuracy down to the microsecond. "Each individual submodule is switched approximately 150 times per second," Haude explains. "Each switching instant of every single submodule is continuously computed by central control units." It's these very control units that make the converters such high-tech devices. The transmission system operators are investing around a billion euros in the Ultranet link, including the two converters. Planning, approval and construction are expected to take four to five years.

In autumn 2015, Amprion and TransnetBW commissioned Siemens to plan and build the Ultranet converter stations. The technology giant has extensive experience in the field of high-voltage DC transmission (HVDC). "By linking up with Siemens, we have an accomplished partner at our side," says Amprion's Managing Director, Dr Klaus Kleinekorte (see interview on page 44). To date, Siemens has commissioned more than 40 HVDC lines, with the latest converters to go online last September, being in Spain and France.

The project planners are presently in the middle of the 18-month engineering phase, computing and designing each individual component and the system as a whole by means of simulations. "How does the converter behave in specific situations in the high-voltage grid?

THE COURSE TAKEN BY ULTRANET

The DC link will run between North Rhine-Westphalia and Baden-Württemberg. Amprion (violet section of the route) and TransnetBW (pink section) hold joint responsibility for the project. With the exception of a few kilometres, Ultranet can be installed on existing pylons. A converter will be installed at either end of the link.

»KEY PROJECT OF THE ENERGY TRANSITION«

DR KLAUS KLEINEKORTE
Dr Klaus Kleinekorte, Managing Director of Amprion, talks about the significance of the Ultranet DC link – and the collaboration with Siemens.

WHY ARE DIRECT CURRENT LINKS LIKE ULTRANET SO IMPORTANT FOR THE ENERGY TRANSITION?

A number of factors come together here. Wind turbines being built in the north of the country are generating more and more electricity. This electricity is needed in the south of the country, where the nuclear power plants will be decommissioned over the next few years. The grids that exist now are not up to transmitting the huge amounts of electricity being generated in the north. This is why we need Ultranet and its extension to northern Germany, Corridor A North. This link will carry the East Frisian wind power to the south, bypassing today's already overloaded grid routes. In addition, solar power generated in the south can be brought to the Rhine-Ruhr region. These are the reasons why Ultranet is a key project for the energy transition – and the plans are already well advanced. One advantage of the project is that we can combine the new DC lines with the existing AC lines by using what we call "hybrid pylons" along the south-bound route. This will save a great deal of valuable time.

THERE ARE PLANS TO INSTALL A CONVERTER AT EITHER END OF THE LINK. COULD WE DO WITHOUT THEM?

In a word, no! Ultranet is a long-distance power link and transmitting electricity over such long distances works best with direct current. This requires converters that connect the link to the AC grid by converting alternating current to direct current and back again. These converters are indispensable for Ultranet. Apart from that, they have another significant additional benefit, for the technology on which they are based will help us make the grid safe, secure and reliable to operate well into the future.

THE CONVERTERS ARE AMONG THE MOST MODERN OF THEIR KIND. IS ULTRANET TECHNICALLY PERFECTED AND CONTROLLABLE?

The answer to that one is a definite "yes". You see, converters are nothing new in the world of electrical engineering. Systems like this have been around for decades. What we are doing with Ultranet is developing this technology further so that we can deploy it in a new power range and connect it to overhead power lines. And to help us achieve all this, we – meaning the transmission system operators Amprion and TransnetBW – have linked up with Siemens, an accomplished partner.

HOW'S THE WORKING RELATIONSHIP WITH SIEMENS GOING?

Very good. We've become a well-organised team. Based on our requirements, Siemens is carrying out calculations aimed at determining the exact design of the converters. And we're working closely with them, offering our own technical expertise. This collaboration is running very smoothly. Once we have completed these detailed plans, we will then quickly switch our attention to the approval process. Our goal is to implement Ultranet, one of the key projects of the energy transition, as quickly as possible.

How does the control software respond? How are the components loaded? To find the answers to these questions, we're working through every conceivable scenario possible," says Haude, "so that in the end, we know exactly what we have to do technically and practically to ensure that all demands are met." The Amprion team is in contact with the engineers at TransnetBW and Siemens on an almost daily basis. "Teamwork is what's required here, and across company boundaries, too."

For the first time in Germany, what's known as "full bridge technology" in the gigawatt range is to be implemented in the Ultranet converters. This is a special variation of what's known as "VSC technology". VSC stands for voltage-source converter. A dozen or so installations with VSC technology have been built over the past years in Europe alone. It can be used to regulate and stabilise the grid voltage, a function that until now has chiefly been performed by conventional power plants. In the event of an emergency, i.e. a power outage, the converters can also help reconfigure the grid. This technology also enables us to set precisely the direction in which electricity is to be transmitted and how much energy. Depending on how much wind power is being generated in the north and how much solar power in the south, the HVDC link can supply electricity to exactly where it's needed. "With this new converter technology, we are taking an important step towards securing the transmission of electricity both during and after the energy transition," says Klaus Kleinekorte.

Furthermore, full bridge technology also makes it possible to repair faults – such as those that result from a lightning strike in a power line – quickly and reliably. What's more, Ultranet is highly flexible should it need to be expanded. The planned DC link from East Frisia to North Rhine-Westphalia – known as "Corridor A North" in the network planning – is to be connected directly to the converter at the northern end of the Ultranet, in the Rhineland. "Thanks to VSC technology, we will then be in a position to flexibly control the flow of electricity between East Frisia, North Rhine-Westphalia and Baden-Württemberg," explains Jochen Haude.

And it's not just with respect to the converters that Amprion and TransnetBW are backing new innovations – their route planning concept is also going down new paths. Ultranet is to be the first transmission link to carry both direct and alternating current, with a voltage of 380 kilovolts – and for the most part using existing pylons, to boot! "We're certain," continues Kleinekorte, "that we will succeed in implementing this hybrid concept quickly and in running it reliably."

And that applies to the converters, too. "There are similar installations already up and running," notes Haude, enthusiastically. And how reliable are they? "As reliable as any conventional substation. On that score, the converter is like any typical electrical appliance – just bigger." With standard technical components, such as capacitors and switches.

High-tech installation built for the French-Spanish project Inelfe: the converters pack high-performance electronic equipment for efficient electricity transmission.

WIND OF CHANGE

Amprion is constantly working to make its grid even more flexible and intelligent. To this end, the company will be installing more than 400 weather stations along its transmission routes during the next few years. By doing so, Amprion is implementing the requirements laid down in the Power Grid Development Plan with regard to weather-dependent operation of overhead power lines and we are continuing to further develop the approaches already in place today.

TEXT · **PETER GAIDE**

A clear morning in December 2015. A helicopter takes off from an airfield in Essen-Mülheim and quickly gains height. It heads for the Siegerland, a region in central Germany on the border triangle of the states of North Rhine-Westphalia, Rhineland-Palatinate and Hesse. On board are the pilot, two measurement engineers and Dr Thomas Butschen. Together with a team of 12 Amprion experts from various specialist fields, the latter is currently developing models and methods for implementing weather-dependent operation of overhead power lines.

The team takes thermal images of overhead power line conductors. In view of the total length of the lines to be examined, this job is much easier to do from a helicopter than it is from ground level. The images reveal whether or not lines are up to the additional task asked of them. "We are currently examining the lines pylon by pylon. We will then decide whether or not the lines can be approved for weather-dependent operation or not," Butschen explains.

This "overhead power line monitoring" is a grid optimisation measure and therefore part of what's known as the "NOVA principle", a key statutory principle of grid expansion in Germany. This stipulates that the existing grid must be optimised first. Only once all options available have been fully exploited are lines then permitted to be upgraded or new ones built. As such, weather-dependent operation of overhead power lines is an integral part of the Power Grid Development Plan.

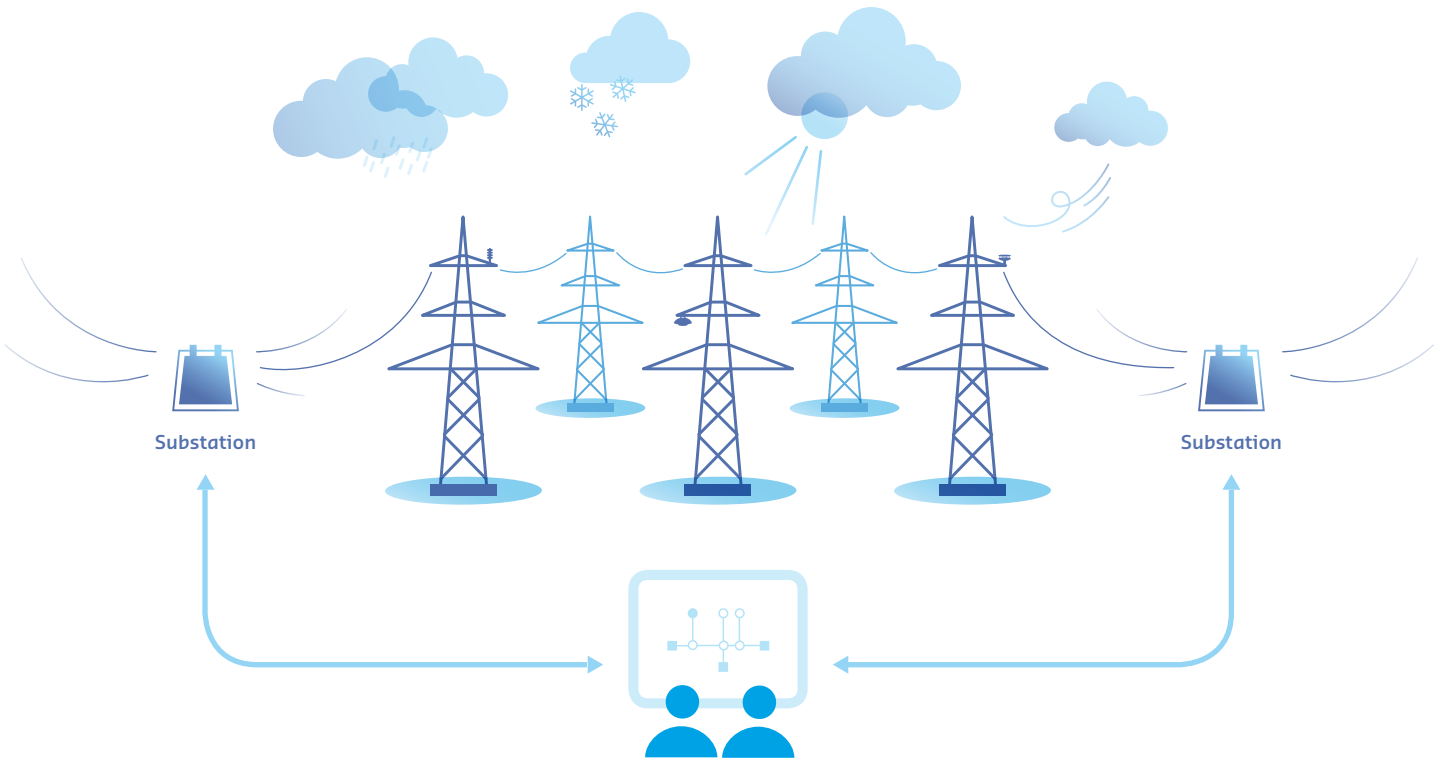
The key lies in joint consideration of physics and meteorology: when current flows through overhead power line conductors, these conductors heat up. Furthermore, the weather – i.e. the wind, ambient temperature and insolation – also impacts on the conductors, either cooling them or heating them up. As a basic principle, the operating temperature of a typical overhead conductor should not exceed 80 degrees Celsius. These factors dictate the maximum amount of current an overhead conductor can carry.

Until now, the engineers charged with calculating this limit have based their work on seasonal assumptions relating to the development of temperature, wind and insolation levels and used these figures to derive the transmission capacity of the overhead power lines. This approach is now being significantly refined. Instead of general assumptions and empirical values, Amprion's experts will in future employ actual weather data recorded on site. "What one needs, then, is precise knowledge about the actual weather that prevails – not just everywhere, but at many different points along the actual grid," says Thomas Butschen.

That he would spend so much of his time recording weather data is something the engineer could never have imagined when he first joined Amprion in September 2012. Butschen was appointed manager of this project in 2013. His team has consulted with and taken the

THE GRID IS INTELLIGENT

Overhead power lines are exposed to all weathers: the wind, sun and ambient temperatures either heat up the conductors or cool them down. This impacts on the maximum amount of current that can flow through the cables. In future, by measuring local weather data, Amprion will be in a position to plan the maximum current load of the conductors even better.



Amprion System Operation and Control

Recording of measured values and computing the limit values

WEATHER SENSORS

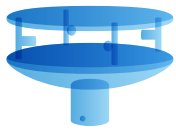
The sensors of the weather stations measure a number of meteorological data. They will be mounted on the overhead power lines and equipped with solar cells and mobile communications data modules, so that they are completely autonomous as regards their power supply and they can transmit their data online.

Thermo-hygro sensor

Relative humidity and temperature

Pyranometer

Insolation



Ultrasonic anemometer

Wind direction and speed

» Weather-dependent operation of overhead power lines and the planned grid expansion go hand in hand.«

DR THOMAS BUTSCHEN, PROJECT MANAGER OF OVERHEAD POWER LINE MONITORING AT AMPRION

advice of meteorologists and developed its own weather stations, whose sensors are capable of measuring the air pressure, ambient temperature, wind speed, wind direction and the intensity of insolation, and transmitting this data back to the team.

The first two weather stations are already undergoing trials. Amprion plans to install more than 400 stations by 2022 – at locations where there is less cooling wind and insolation is particularly intensive. "These are the points on the transmission routes at which the conductors heat up most. If we have accurate figures for these temperatures, we can calculate precisely the maximum load the conductors will be subjected to," Butschen explains. The weather stations installed at these "hotspots" are equipped with solar cells and a mobile communications data module, so that they are completely autonomous as regards their power supply and they can transmit their data to System Operation and Control without any need for wiring.

Once the project is fully implemented, the 400 stations distributed across our entire network will continuously supply precise data about the specific local temperatures, wind speeds and directions as well as insolation levels. This will enable Amprion's experts to compile even more detailed weather forecasts, which in turn will allow them to compute the maximum possible current loads that can be sent down the lines in the coming hours and to plan grid operations based on this data. This is what distinguishes this model of overhead power line monitoring from others, in which the temperature in the conductors is measured directly. "That said, we will only be able to fully exploit the benefits under certain weather conditions," Butschen observes. "In summer, we won't be able to transmit any more current than we can now."

The helicopter trip is coming to an end and the airfield in Essen-Mülheim is in sight again. The measurement engineers in Thomas Butschen's team will assess the thermal images he has taken during the course of the coming weeks. They will then be yet another step closer to achieving their goal. "Weather-dependent operation of overhead power lines and the planned grid expansion go hand in hand: one cannot function without the other. All in all, we'll succeed in making our transmission system fit for the increasing demands that lie ahead."

Driving forces

Amprion continues to develop and advance.
It's an opportunity for all members of staff to play an
active role in shaping the ongoing transition.

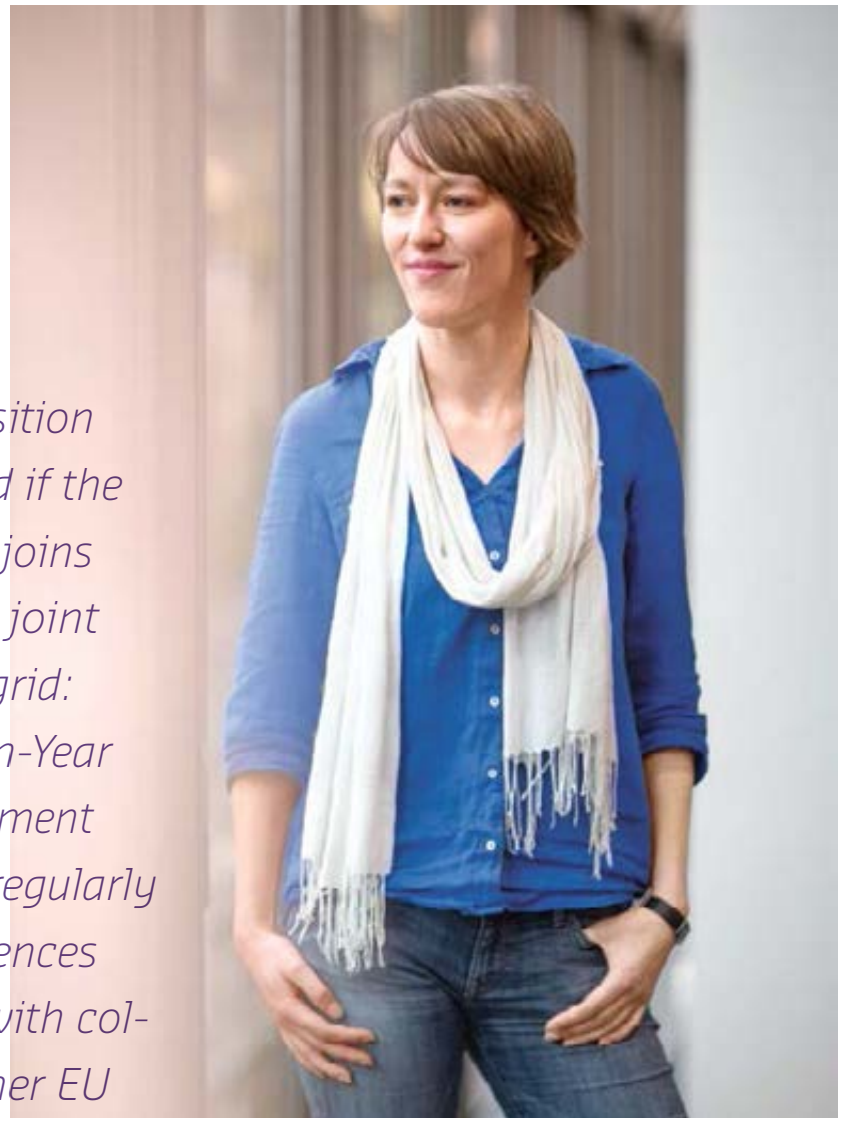
PHOTOS · **MATTHIAS HASLAUER** · **MARCUS PIETREK**

I have specialised in public law. For a lawyer dealing with planning legislation, there is no more exciting a challenge out there in the coming years than that offered by grid expansion in Germany and Europe.«

Mona Fachinger is a lawyer and joined Amprion in February 2015.

I like working in a team that tackles innovative issues. This includes planning work for the Ultranet converters. What really excites me about my work is that we're implementing the very latest technologies – it's this that makes the energy transition tangible.«

Dr Daniel Eichhoff is an electrical engineer and has been at Amprion since September 2015.



The energy transition can only succeed if the whole of Europe joins in. This requires joint planning of the grid: the European Ten-Year Network Development Plan (TYNDP). I regularly exchange experiences and know-how with colleagues from other EU countries. It enriches my day-to-day work.«

Yvonne Surmann is an industrial engineer and joined Amprion in 2013.

Amprion is a relatively young company. New technologies and workflows keep us on our toes. Among other things, I'm currently coordinating scheduled outages and carrying out maintenance work on our systems. I look forward to being able in future to work even more intensively with innovative technologies.«

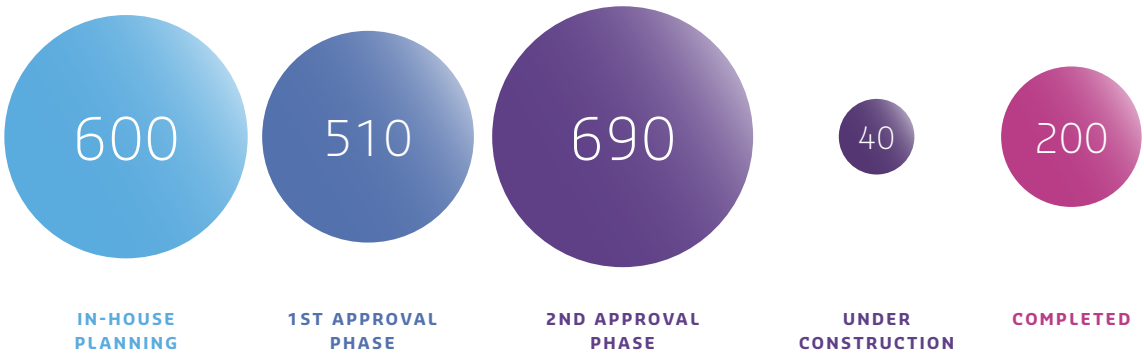
Timo Jonas is a fitter and has worked for Amprion since 2010. He has successfully completed a degree in engineering while continuing to work full time.

Systems and IT security go hand in hand at Amprion. I'm involved in planning a whole range of IT projects. Project management means that I'm faced every day with new problems and it's precisely this that makes my work so exciting.«

Dr Frank Brüggemann joined Amprion in October 2015. He manages IT projects.

STATUS QUO 2015

GRID EXPANSION AT AMPRION



(km)

In 2009 and again in 2013, Germany's legislators commissioned Amprion with the task of expanding and upgrading around 2,000 kilometres of power lines. It takes at least five years before all the planning work and approval procedures for an expansion project are completed. The situation at the end of 2015 was as follows: in-house planning activities were still underway for projects with a total line length of around 600 kilometres. 510 project kilometres were either about to have an application submitted for or were already in the first approval phase – what's known as "federal sectoral planning" (Bundesfachplanung) or "regional planning procedures" (Raumordnung). 690 new or expansion kilometres were just about to enter or were already in the planning approval phase, the second approval phase. Around 40 kilometres of line were under construction. Expansion projects with a total length of 200 kilometres had already been completed.

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NOTE REGARDING USE OF MALE/FEMALE

We would appreciate your understanding that for reasons of readability, we have not used the male and female forms of language throughout. Naturally, all texts refer equally to men and women.

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