R&D

Statnett
Forskning og Utvikling
Research and Development

2019

A selection of R&D projects from the 2015–2019 programme period

Sustainable system development

Planning an optimal energy system for our future

Innovative technology

20 per cent faster, 20 per cent safer, 20 per cent cheaper

Smart grids

Preparing the power system for a more complex future

Photo: Thomas Negård

Six years ago, Statnett launched the slogan "The future is electric". Now, we are seeing the contours of a fully electric society.

Much has happened since the EU adopted the Renewable Energy Directive and the EU 20-20-20 climate targets in December 2008. But it is from today and until 2030 and on until 2050, that the development and changes in society and the power system will really speed up.

In the future, we expect major changes in consumption and production patterns. The proportion of renewable energy is growing, driven by sharply falling costs, while the electrification is driven by new demands, increased climate risk and higher carbon prices. We will also be affected by what is happening in the countries around us. In the coming years, for example, we will feel the effects of nuclear power plants being shut down in Sweden and the continuing phase-out of coal power in Denmark, while the share of wind power production increases, both in our neighbouring countries and in Norway.

Statnett aims to facilitate this development, and we are now preparing for how all of this will lead to new ways of planning, dimensioning, maintaining and operating the power system. These are changes that are only possible if we have the will and the ability to innovate and to create new solutions, and the efforts of research and development environments become a driving force.

In January 2019, the Research Council of Norway presented a report that concluded that energy research has created value in the amount of NOK 16 billion for Norway since 2008. The same report estimates the potential value creation at NOK 100 billion in the years to come. Our experiences are in line with this, and in the years to come, we believe that R&D efforts will be even more important.

Research and development should contribute to establishing a power system that will facilitate the reduction of climate emissions, increase value creation and maintain security of supply. R&D should also result in major cost-savings for society, so as to ensure that the bill for this transformation of the energy system stays as low as possible, while also developing new and improved HSE solutions.

As a consequence, Statnett is increasing its R&D efforts by 30 per cent in the period 2020 to 2023. Our efforts will be directed towards three key development trends. We will focus on data-driven decision support and automated decision-making that must happen in real time. We will focus on developing digital, secure and cost-effective facilities. And we will focus on cooperation in the energy system across national borders, internally in Norway, and between the power sector and other parts of society. Because as the UN has asserted, the average temperature is already rising. If we are to stop this trend, there must be a collective effort.

In this magazine, you can read more about our new focus areas and learn about some of our results from the last period. Enjoy!

Kind regards, Auke

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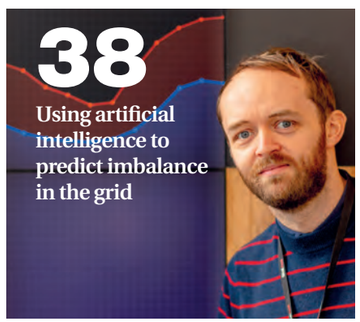

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R&D for a fully electrified Norway

Statnett is currently defining new R&D programmes and their contents for the next four-year R&D period. The main objective is to stimulate and encourage innovation in the realisation of a fully electrified Norway.

Photo: Morten Brakestad

"According to the IPCC, we must cut our carbon emissions by 45 per cent by 2030 and reduce them to zero by 2050 to meet climate targets. We are in the middle of a climate crisis. Studies have shown that the full electrification of mainland Norway is possible, and by doing so we will contribute towards reaching the target in 2050 as long as all production is from renewable energy sources. Our perspective over the next four years will be to stimulate and encourage Norwegian research environments to contribute to realising this vision," says Sonja Monica Berlijn, R&D Director at Statnett.

New technology

In order for Norway to be fully electrified, new technologies, solutions, know-how and innovations will be needed. In addition, digitalisation will be an essential part of the development. Statnett wants to follow up on these perspectives in the coming programme period of 2020–2023," reports Berlijn. Three new R&D programmes have been highlighted, with the working titles "Data-driven decision support in real time", "Digital, safe and cost-effective infrastructure" and "Co-operation in the future energy system". In addition, we will be working continuously to generate the know-how required to meet this challenge. "We are looking forward to working towards the ambitious goal of the full electrification of Norway. Such a goal can be realised in many different ways, and it raises a number of interesting and exciting issues for us to address," acknowledges Berlijn. She continues: "What kind of market mechanisms would be appropriate in such a scenario? How do we ensure good maintenance, protection and control of the power system of the future? What kind of infrastructure and (digital) technologies are needed? What remains to be done to achieve this goal? How do we balance local environmental considerations with global climate goals, and where should new consumption be located?"

> "When we have such large challenges ahead and the results of R&D are so indisputably positive, it is not surprising that ambitions have increased for the next programme period."
>
> **SONJA MONICA BERLIJN**
> DIRECTOR OF RESEARCH AND DEVELOPMENT
> STATNETT

Massive savings for Norway

The systematic focus on research in Norway in recent years has resulted in a large number of potential cost-saving technologies, methods and solutions. Statnett R&D has estimated that the research conducted over the past 20 years has delivered savings of at least NOK 10 billion. "This shows that R&D is a strategic tool and that the way we organise our R&D is working. Cost savings, HSE, security and digitalisation, generation of know-how and value creation for Norway as a nation have been and will continue to be our main priorities. I still think it is possible to achieve significant cost savings in the years to come," says Berlijn.

When we have such large challenges ahead and the results of R&D are so indisputably positive, it is not surprising that ambitions have increased for the next programme period. Statnett's research budgets will increase significantly in the period, from approximately NOK 90 million in 2018 to NOK 110–120 million per year in the coming years.

Cooperating on good solutions

Berlijn is clear on the biggest challenge in the next programme period. "It is important that we continue to strongly involve the line organisation in Statnett.

Cooperation with external research partners is another important aspect of our R&D work. This is crucial for producing good results. Furthermore, we need to identify good Nordic projects because TSOs have a lot to gain from collaborating more closely across borders," she states. In Norway we have good R&D funding mechanisms, which is not the case in other countries, and therefore we also need to work with Nordic funding schemes and good innovation models. The kind of product development that we need is not the kind that is typically provided by small entrepreneurial environments, because it often requires larger, more established businesses to extract the value. Therefore, it is important to work with the 'golden triangle' of innovation, with suppliers, universities and ourselves combined in one project. There have already been a number of occasions where this has been successful.

Diversity is needed. To be able to reach our ambitious goals it is not only important to work together, but we also need to work on diversity. It is well known that this fosters innovation. We also need a balanced portfolio. We must utilise both long-term and short-term efforts, and we need diversity in our way of working, including both classical innovation methods and more agile ways of working.

"We see that when we work together new products, markets, know-how and values are being created, which has always been an important goal," says Berlijn. One final, important challenge is to ensure an adequate number of new employees with the right expertise for both the industry and research institutes, by working closely together with colleges and universities. "We must further develop. The know-how we need in the future. We represent an interdisciplinary environment that ranges from the classic professions within electrical power to IT and the social sciences. It is in the intersection of these fields that we will create value for the future," concludes Berlijn.

The power system itself notifies of when it needs inspection

The R&D project SAMBA shows that it would be possible to base asset management on the facility's actual condition – rather than on routine service intervals.

SAMBA has researched the methods and methodology needed to transition asset management from routine maintenance and parts replacement to an approach based on the actual condition of power system components. It can be compared to a car telling you when it needs service, instead of having it done at regular intervals.
SAMBA has produced 12 innovations. The results and conclusions from SAMBA will be an important part of the continuing work on establishing Statnett's future approach to asset management.

"The key is to collect, manage and act on large amounts of data," says Project Manager Arne Smisethjell. Dashboards, health indexes and automatic responses can be set up. However, the information must be indexed in a way that allows it to be linked together, whether it is collected from sensors, weather data, drones, historical data or other sources.

Monitors the health status of the power system
Since the project started in 2016, extensive research has been conducted on how Statnett can identify the health status of various power system components. The work has been led by SINTEF Energy Research, in collaboration with ABB, GE, IBM and Statnett.

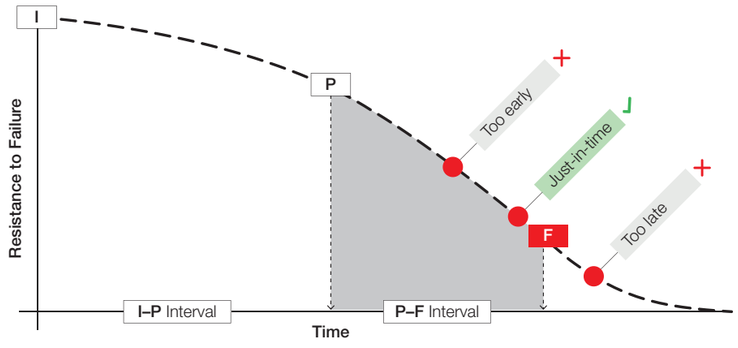
"There is a great potential for cost-savings and streamlining to be found in the monitoring and follow-up of the various power system components. In addition, there is considerable potential for increasing knowledge about how the components react to different loads. This can also give us the opportunity to utilise the power system more efficiently," explains the project manager.

SAMBA is based on the four main areas of: transformers, power lines, cables and circuit breakers. Under these main areas, research was conducted on 19 specific areas, including aging in transformer windings, the condition of a large number of line joints and the temperature of high-voltage cables. The four main areas are linked to an overarching project that comprised research into the collection, managing, processing and use of data, as well as recommendations related to smarter asset management for Statnett.

SAMBA received project support from the Research Council of Norway as an Innovation Project for the Industrial Sector (IPN) through ENERGIX. The project was officially completed in January 2019.

"The key is to collect, manage and act on large amounts of data."

ARNE SMISETHJELL
PROJECT MANAGER
STATNETT



Statnett's first patent achieved through innovation and creativity

"Applying for this patent was important to ensure that we and others would have the right to use the method," says Statnett engineer, Ivar Brovold. The solution that has been patented is designed to create a good distribution of the forces in thin composite material.

The method was developed as part of the R&D work on composite pylons and consists of a bracket attached to the pylon leg, adapted to the design of the cross arm which is bolted to it.

"The fact that we have received a patent confirms that we are an innovative company. I am proud of that," says Sonja Berlijn, R&D Director.

Decided to apply for the patent
Since a number of companies work with composite as a material, it was important to avoid others receiving a patent for a similar solution and then possibly preventing other players from using it. Statnett therefore decided that it was important to apply for the patent itself.

"At the same time, it has been a demanding process to have this patent approved and our strategy to secure the rights to use the methods and technology we develop in the future will probably go in the opposite direction. We will prioritise making methods and technology that we develop available for everyone to use – or develop further. In this way, we can prevent other companies from obtaining a patent for what we have developed, while at the same time increasing competition among the suppliers," says Berlijn.

Congratulations to R&D receiving Statnett's HSE award for 2018

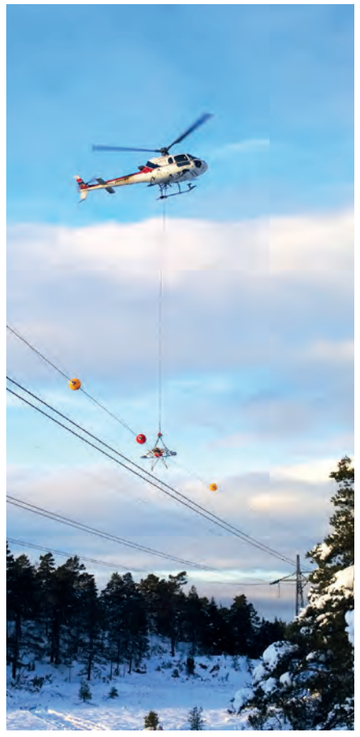
On 18 December 2018, Statnett's internal HSE award, SIKKER, was awarded for the fifth time. This time, the award went to R&D for their systematic HSE work over a long period of time.

"It motivates us in our work moving forward, and we are very pleased to receive the award," said a very pleased R&D Director Sonja Berlijn at the award ceremony.
The SIKKER award was created to recognise and highlight good HSE performance internally, which helps to remove the highest risks at Statnett. The award was presented by CEO Auke Lont at a congregation of employees on 18 December.

R&D challenges the status quo
The motivation for giving the award to R&D was described as follows: "An important task for R&D is to challenge existing ways of doing things. A number of project results which elimate HSE risks have been implemented. There has been particular focus on work operations with a high HSE risk, such as work at height and with helicopters."

In addition to personal safety, areas where Statnett's R&D activity has improved the company's HSE work are: climate, environment, information security and the quantification of HSE risk assessments and benefits .

"It is important for everyone to stay safe at work, and we must have a reliable energy system in terms of security of supply as well as cyber security. At the same time, we must contribute solutions that both reduce our environmental footprint and reduce climate emissions, while also safeguarding our facilities against climate change," explained Berlijn at the award ceremony.



New award to AutoDig

AutoDig recently won second place in the Norwegian Smartgrid Centre's innovation competition. The award was introduced in 2018, and it is established to raise awareness of projects that lead the way in smart grids. This is not the first time that AutoDig has been noticed.

Photo: Jørgen Braastad

"Everything that is happening in the energy sector under the umbrella of "digitalisation" is incredibly exciting, and it is fun for the team – and for Statnett – to develop a product that stands out in the crowd," says product owner Christian Sundal Melaaen.

Each year, the Norwegian Smartgrid Centre selects one or more themes in connection with the competition. This year's theme was "Leading-edge project that uses smart grid technologies to increase operational security and cost efficiency in the grid system". First and third places, respectively, went to Agder Energi Nett for "Digitalisation for optimal construction and operation of the power grid" and to eSmart for "Connected Drone". In 2017, AutoDig came third in the Innovation Challenge, and Jørn Schaug-Pettersen has previously received Statnett's own innovation award for the project.

"We are proud of this recognition for AutoDig. It is great to be involved in an innovative, important and long-term project that is also noticed outside Statnett," says data scientist Gunnhild Svandal Presthus.

Automatic diagnosis of operational interruptions in the power system

AutoDig, which started as an R&D project back in 2009, automatically identifies and reports operational interruptions in the power grid. By "listening" to various data streams, AutoDig can deliver a summary of the operating interruption – less than 60 seconds after the failure. The summary is used by Statnett's operational environments to find and implement the right measures. The first version of AutoDig was launched in 2016, and the development of AutoDig 2.0 started immediately the following year.

"Clearly, the increased attention from this award makes us even more eager to seize the opportunities ahead. We have great expectations for what we will be able to create in the future together with our users. We can already see that there is great value in using data smarter, which will only increase as we learn more. This award only strengthens our expectations," says Melaaen.

Statnett has put together an autonomous team to continue the development of AutoDig. The team will have a lot of latitude and authority to solve the task at hand. It is an interdisciplinary team with expertise in both electric engineering and IT. Together, the team covers a large part of the value chain, from when a sensor is installed to when the sensor data is used – via AutoDig – as decision support in operational activities.

Melaaen explains that they work in short sprints and continuously make functionality available to users. This facilitates frequent improvements and contributes to a tightly integrated collaboration between users and the team.

"The AutoDig team is a good example of how our commitment to digitalisation has yielded results, and everything indicates there are still many necessary digitalisation processes to come in the operation of the power system," concludes R&D Director Sonja Berlijn.

AutoDig automatically identifies and reports operational interruptions in the power grid.

"Billions more in benefits can still be realised"

Statnett's research and innovation work has delivered billions in cost efficiency improvements in recent years. "There is no reason to believe that we have reached the full potential. Quite the contrary," say Statnett's three programme managers.

Photo: Christian Søgaard

For nearly 20 years, Statnett's research projects have contributed to smarter, safer, more sustainable and more efficient solutions. Norwegian energy research has changed its focus several times during this period: from energy consumption, energy economy and technical solutions to market, innovation, climate adaptation and digitalisation in recent years. Research activities have become thematically broader and the scope has increased.

According to a recent report from the Research Council of Norway, energy research has yielded billions of kroner in direct cost savings to Norwegian society. Statnett's calculations show that R&D work in the period from 2014 to 2018 has delivered projects with potential savings of more than NOK 7 billion for Statnett and the industry as a whole. In addition, R&D work has contributed to increased safety, improved environmental conditions and increased expertise.

The three programme managers Oddgeir Kaspersen, Jørn Egil Johnsen and Ingeborg Buchalik in Statnett's R&D department lead research on innovative technology, smart grids and sustainable system development, respectively. They all believe that this research will play an even more important role in the years to come, especially in laying the foundation for the changes that the power market will undergo.

Oddgeir Kaspersen, Programme Manager for Innovative Technology, and Ingeborg Buchalik, Programme Manager for Sustainable System Development.

“Seven billion kroner is an impressively high number. Does that mean that the big benefits have already been realised?”

Oddgeir: “No, I don’t think the full potential has been extracted yet. I believe we can realise equally significant cost savings and secure new values in the coming years. And it is not as if we have only focused on areas or fields where we thought the prospect of cost savings was highest. Certain projects, such as the use of robots for installation work, also deliver very well on HSE.”

Jorn: “A lot of exciting things are happening in the areas of digitalisation, automation and artificial intelligence. We have a lot more to gain. Thanks to research, the power system of the future will look quite different.

Ingeborg Buchalik points out that the potential for adopting new, efficient and innovative solutions is increasing in step with the increasing electrification in society. This leads to potential savings and value creation on the bottom line.

“There are an increasing number of different players who can make use of new innovations. I don’t think the potential is less. On the contrary,” she says.

One challenge for anyone working with research and innovation is that no one knows which ideas or projects will produce results and which will run aground along the way. Accordingly, a basic principle at Statnett is to secure a sufficiently large supply of ideas and project proposals at all times. The programme managers compare the process from idea to results to a funnel: A large number of ideas eventually get funnelled down into a handful of promising innovations.

“How is the rest of the organisation involved in R&D work?”

Jørn: “We can be proud that we have been able to involve so many from the line in the research work, and I believe it is a strength and one of the reasons why we get results from our research to such a large extent. There are many enthusiastic people here who have made great contributions.”

Oddgeir: “The line is important for ensuring that research is heading in the right direction. There may be 150 project applications at each call for proposals and we have probably assessed almost 600 ideas on an ongoing basis in the last 4–5 years. As we work through the qualification and testing process, some projects are dropped, while others are combined. Involving our own people is important for guaranteeing relevance to specific issues we face. This is something that only our own people can see, so it is immensely important to involve them. We wouldn’t be able to deliver research and development to the same extent without the line.” Statnett’s R&D work focuses on four goals: Digitalisation, cost savings, skills development and sustainable development.

“Can you give any examples of research projects that deliver well on all four goals?”

Jorn: “Most projects fulfil two or three goals. But it is more important that the projects as a whole deliver well on all four goals. For example, the SAMBA and digital substation projects are good for skills development and cost efficiency, and the Icebox project is good in terms of savings, sustainable development and skills development. The project on alternatives to expanding the power grid delivers very well on all four targets.

Oddgeir: “The development of a new aluminium pylon is also a good example of an innovation that provides many and compound benefits.”

“How important are environmental, nature conservation and climate considerations in research work?”

Ingeborg: “It is a crucial perspective. We work to minimise the negative impacts of our facilities on biodiversity and landscape values, as well as to reduce greenhouse gas emissions from construction and operation.”

“But doesn’t nature often lose to people’s need for growth and progress?”

Ingeborg: “It’s not ‘either or’. We can take environmental considerations into account and at the same time build the power system of the future. We aim to create acceptance for taking into consideration nature conservation, the climate and the environment in all our operations. It’s also a reason why we have social economists at Statnett and not just business economists – to promote solutions that are in the best interest of society.

Jørn: “I often find that the goals coincide. Many times we see that more environmentally friendly solutions are also cost-saving. Take robot installation of aircraft warning markers, for example. Far less use of helicopters results in cost savings, improved safety and environmental benefits. Our focus on drone and sensor technology will have similar effects.”

“What challenges will research face in the future?”

Ingeborg: “Developments in society are constantly speeding up and this poses new challenges both for research and for Statnett. We must deliver innovations and solutions within shorter time perspectives and adapt methodologies to a world that is changing ever faster.”

Long trajectories will still be important, as it is the nature of research that results can take time to realise. But research environments must adapt to shorter time horizons than three or four years, because the world is shifting faster than before.

“This will be particularly important with regard to digitalisation and IT. We will probably see a shift towards reporting partial results more often. If four years pass between each time, the whole foundation for the research may no longer be present,” says Jørn.

A final challenge shared by the entire research community is a general shortage of professionals in the field. In some areas there are fewer than ten people in the entire Nordic region who possess the necessary expertise. This creates a vulnerability that Statnett hopes to address through stronger cooperation with other research environments and universities in the years to come.

Programme Manager for Smart Grids, Jørn Egil Johnsen.

“Many times we see that more environmentally friendly solutions are also cost-saving.”

JØRN EGIL JOHNSEN
PROGRAMME MANAGER, SMART GRIDS
STATNETT

FACTS

Public funding
Public funding for research plays an important role in the R&D projects in which Statnett is involved. Of about 60 active R&D projects, the Research Council of Norway / Skattefunn, the Norwegian Water Resources and Energy Directorate (NVE) and ENOVA contribute to more than half.

Digital substation – from substation bus to process bus

"Smarter, safer and smaller. If we were to formulate the goal of our research on digital substations in a few words, then these would best describe the benefits that we believe are within our grasp."

Photo: Terje Borud

We had made the trip to Furuset substation, just north of Oslo, to have a look at the R&D project "Digital substation", and were shown into the iconic building from the 60s by Rannveig Løken, Project Manager and Nargis Hurzuk, Specialist Resource and Technical Manager. And the three words – smarter, safer and more compact – would turn out to be a very good summary of a project that is so ground-breaking and complex that even gifted reporters with above-average insight into technology and digitalisation are struggling to keep up.

Environmentally friendly and cost-effective

And it is precisely digitalisation – at the social, business and process levels – that is at the core of Løken and Hurzuk's enthusiastic and animated explanation of how exciting the project "Digital substation" is for Statnett, for Norway and for them. "'Digital substation' is naturally about digitalising processes and equipment at Statnett's substations," explains Rannveig Løken. "At an overarching level, the work we do in this project will put both Statnett and Norway in a better position to handle the challenges we will be facing in the future. By this I mean renewable energy sources, new data centres and the need for increased security, for example.

In other words, we are working to make grids smarter," she continues. "At the same time, this project also has a sustainability and life cycle perspective. Statnett is constantly working to find environmentally friendly and cost-effective solutions. For example, a digital substation will take up much less space, with less wiring and reduced installation time compared to the digital substation with station bus that we have today. These are also important factors that we address in our research."

Digitalisation against the primary system

Calling today's substations analogue is a wrong description. "The control system at today's substations communicates over a TCP/IP network with IEDs (intelligent electronic devices) that exchange data digitally – both with each other and with the systems control centre. This network is called a station bus. At the same time, the interface between the control system inside and the primary system outside is analogue and hardwired. As many as 800 conductors or copper wires are physically stretched between the primary system and the control room," explains Løken and points to the back of the swing frame in the control cabinet in the room where we're standing, to show us what this looks like in practice. The difference between the old and new cabinets at Furuset is striking, not least when you know that a single optical fibre cable can replace hundreds of copper wires.

"At a general level, the work we do in this project will put both Statnett and Norway in a better position to handle the challenges we will be facing in the future. By this I mean renewable energy sources, new data centres and the need for increased security, for example."

RANNVEIG LØKEN
PROJECT MANAGER
STATNETT

At Furuset in Oslo, a realistic pilot installation has been set up in parallel with the existing substation.

“It goes without saying that the work required to build a substation of current standard is extensive. The conductors must be pulled through culverts from the primary system on the outside to the inside of the control building, where they are terminated at the protection and control system. Control rooms need to be large to make room for all the equipment, and scalability is limited by new available conductors for new signals. The flexibility of this kind of solution is really quite poor.”

From one bus to another

At Furuset, the two research colleagues have set up a pilot project in parallel to the existing substation. It’s realistic, although Nargis Hurzuk says they have cheated a little. “In a fully digital substation, the equipment inside the control room will be connected to the primary system on the outside, which communicates over an optical fibre network. Instead, we have connected directly to the existing control system in the same room and retrieve our data from there and transfer it over to our digital substation.

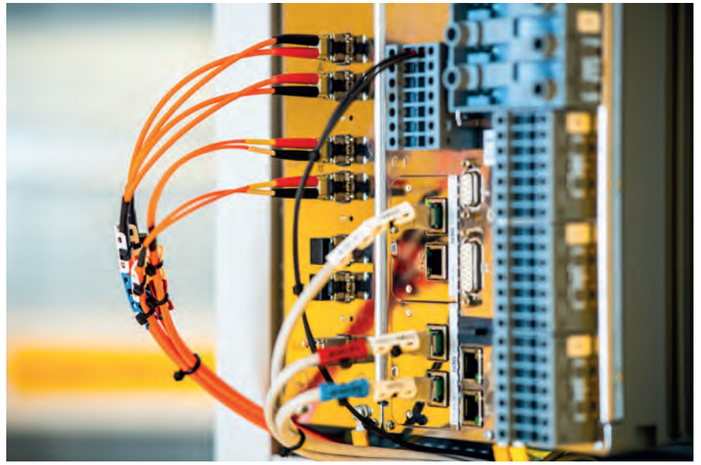
“In a digital substation, the cables to the primary system will be replaced by a process bus: a digital interface between the control system and the primary system. Although Furuset is not the world’s first digital substation, we are at the cutting edge in terms of using a standardised bus that enables the transfer of data and communication between units from many different suppliers using the same standard. This is one of the benefits of the substation of the future: we will be less dependent on one supplier and can put together more flexible solutions than we have been able to before.

“Although this project has been running for a while, we are really at the start of an exciting development. Just seeing how different components work together, or testing whether we can use one IED to control two lines, provides valuable knowledge. Every time we are up here, we see that a digital substation is easier to build and takes up less space. We anticipate 30 per cent shorter installation time compared to current substations, both because the equipment is easier to set up and because more of the testing can take place at the factory, before delivery to the substation,” says Nargis Hurzuk.

Research colleagues Nargis Hurzuk (left) and Rannveig Løken expect that having digital substations will reduce installation time by 30 per cent compared to today’s substations.

“We anticipate 30 per cent shorter installation time compared to current substations, both because the equipment is easier to set up and because more of the testing can take place at the factory, before delivery to the substation.”

NARGIS HURZUK
TECHNICAL MANAGER
STATNETT



The benefits of a digital substation

“We have been working with the pilot project at Furuset substation since 2016, and we have learned a lot about how the digital process bus concept works in practice – about compatibility and coexistence with the existing control system and primary system and about the potential that lies in the standard we have adopted,” says Rannveig Løken. There are a number of benefits to be had from implementing this technological solution at substations:

- More work can be done remotely. One example is routine testing of protection measures. Less work at the station also means improved safety for personnel.
- A more compact facility.
- Using process buses and less cabling provides greater flexibility and scalability – and lower costs.
- Shorter installation time and less of a need to test equipment at the substation. More can be done at the factory.
- Easier data collection from the primary system in connection with maintenance and digitalisation.
- A greater degree of self-monitoring will result in higher quality at the facility.
- Increased opportunities for remote access and remote diagnosis also reduce operating costs.
- Reduced electromagnetic noise due to the transition to optical fibre connections.
- Optical current transformers remove the HSE risk of high voltage in the circuit in the event of faults / when opening these circuits.

“Having partners to collaborate with on this type of project is essential,” emphasise Løken and Hurzuk. “In the first project, we have been working with Jacobsen Elektro, Sprecher, Siemens, ABB, Omicron, Cisco, Meinberg and Landis+Gyr. In the next phase, where one of the issues relates to how TSOs (Transmission System Operators) and DSOs (Distribution System Operators) can share ownership to exchange information in a digital substation, our collaboration partners will be Hafslund, the Norwegian Water Resources and Energy Directorate (NVE), Skagerak Energi, Agder Energi, SINTEF, the Norwegian University of Science and Technology (NTNU) and Eidsiva,” conclude Project Manager Rannveig Løken and Technical Manager Nargis Hurzuk.

Health, safety, the environment, quality and costs are assessed as a whole when we analyse new alternatives for pylon solutions," say Andreas Istad Lem and Øyvind Welgaard.

Aluminium and composite as an alternative to steel in the pylons of the future

Lighter, safer and easier to transport and assemble. Fewer helicopter flights and better use of weather windows during construction periods. CO_2 emissions cut in half. And reduced costs. Statnett's research on new pylons will have consequences for Norwegian infrastructure, the environment and the use of resources in the future.

Photo: Christian Søgaard

"The work to develop new pylon solutions that will replace or supplement current steel-based structures is based on the challenges these represent from a holistic perspective," says Project Manager Andreas Istad Lem. "We consider health, safety, the environment, quality and costs as a whole, and when we analyse an alternative, we focus on the 'total cost of ownership' (TCO) and a life cycle perspective.

"With that as our starting point, we have developed a new aluminium pylon ready for a pilot project next summer. But it hasn't just been clear sailing to get to this point."

Partners are essential

Existing standard pylons are made of steel. In the search for new materials, aluminium is the obvious choice, but composite materials based on fibreglass are also currently being tested in a separate R&D project that is right on the heels of the aluminium pylon.

"The work on an aluminium pylon started with our existing standard steel pylon and the challenges it presents," continues Istad Lem. "For example, gravity – it weighs roughly between 10 and 30 tonnes and in most situations must be transported by helicopter – with all the safety risk that hanging loads entail. Steel pylons rely on a very large number of screws and bolts and are more time-consuming to set up than a lighter aluminium pylon would be. In addition, the properties of the materials are different: steel is very well suited to long, slender beams while aluminium works best as slightly shorter or wider beams. We also knew from the outset that it is easier to obtain large steel profiles – that is, broad beams – than correspondingly large aluminium profiles and that limitations related to production would be a factor.

"Precisely because of the complexity of the project, it has been important for us to work with players who both have experience in the field and who would be

"Precisely because of the complexity of the project, it has been important for us to work with players who both have experience in the field and who would be in a position to contribute to the production of the final result."

ANDREAS ISTAD LEM
PROJECT MANAGER
STATNETT

Project Manager Andreas Istad Lem (left) and Øyvind Welgaard considered various pylon constructions before they made their choice.

in a position to contribute to the production of the final result. Here, the Raufoss cluster has been essential, with invaluable support from HAP and Kapp Aluminium in particular. In addition, our other partners – the Norwegian University of Science and Technology (NTNU), SINTEF and Hydro, and the highly competent gang at EFLA have also had a key role. And Statnett has taken an active role in the project right from the start, to ensure that our demands were kept clearly in focus throughout the development process," says Istad Lem.

Resilliant and environmentally friendly

"We considered different constructions in the design phase and looked at several solutions. However, the pylon we have decided to go with closely resembles the existing steel pylons that have been in use for decades. That testifies to the good design of our current pylons.

"A 30-metre prototype was put together on the ground as a test and later erected in Seville and subjected to a number of hard stress tests. The pylon was twisted, bent and pressed, and over a three-day period, we exposed it to such great strain that it eventually broke. During the process, we were able to confirm that the structure was able to withstand what it was designed for, with a good – but not too good – margin, around 20–30 per cent. This confirmed the quality of both the material and our calculation methodology."

Thinking in terms of TCO during development also entails a strong focus on the environmental impacts of a new pylon from a lifecycle perspective. "Here too, we experienced very positive results. The carbon footprint of the pylon that will be installed near Kobbelv in the summer is 50 per cent less than current solutions, provided that we use European aluminium and that the pylon is recycled when it is taken out of service.

Composite – right on the heels

In Statnett's other R&D project on pylons, Project Manager Øyvind Welgaard is responsible for the development of a solution using composite material. "Our starting point is the same as for Andreas and the group that has been working on an aluminium design: we are working for a lighter solution that is more cost-effective, safer and easier to assemble and with the smallest environmental footprint possible. We are currently on the third version of the design, where we are using fibreglass with a good ratio between strength, weight and price.

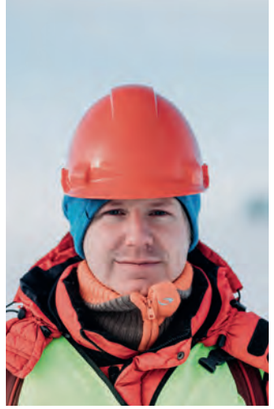
"We know that there are composite solutions for pylons that will carry 132 kV lines, but there are none that can take 420 kV lines. Our solution is also similar to the existing steel pylons, and we are aiming to produce a prototype and start testing early next year, with a possible pilot project scheduled for 2021. The requirements for cost-effectiveness and TCO are equally high and the results of a life cycle analysis must be at least as good as for the aluminium pylon. All the tests we have conducted so far give reason to be optimistic," concludes Øyvind Welgaard, Project Manager for composite pylons.

Up against several world records on Ålvik Mountain

With its high mountains, coastal climate and freezing temperatures, Norway is particularly vulnerable to icing on power lines. The unofficial world record was set in 1961 on Lønahorgi Mountain in the municipality of Voss. Now, Icebox is up against new records. We made the trip up to the exposed measurement station on Ålvik Mountain to remove ice and mount sensors on the power lines.

Photo: Christian Søgaard

The new sensors that are being installed will send data on the weight of the high-voltage line and when they have to be de-iced, directly via the 4G network.



"We believe there is unexploited potential in the use of heat to melt the ice on power lines, but the method is best suited if we start when there are small amounts of ice."

ØYVIND WELGAARD
PROJECT MANAGER FOR ICEBOX
STATNETT

"Ålvik Mountain is really the reason why we're working on this project," says Øyvind Welgaard, Civil Engineer at Statnett and Project Manager for Icebox.

It is just a few minutes past eight in the morning. It is still dark outside as we drive along the winding roads towards Ålvik Mountain in Kvam municipality in Hardanger.

An extraordinary event in 2014 served as the impetus for the *FRonTLINES* project, which later became the *Icebox* project: Only two weeks after a power line was put into operation, the earth wire peak on an electricity pylon cracked under an ice load that was almost three times higher than the line was designed for.

"Then we realised that we had too little information about the effects of ice build-up on power lines," says Welgaard.

A risky operation

The Icebox project is a collaboration between nine partners: Statnett, Kjeller Vindteknikk, Efla Norway and Efla Island, Independent Insulation Group (I2G), the University of Tromsø, Ucar, Cicero and Landsnet. The project started last year and will run until 2021.

The aim of the project is to find new solutions to the problem of icing, which not only results in major repair and maintenance costs but also entails a great risk for the personnel responsible for de-icing power lines.

When we arrive at the heliport, Petter Aker from Kjeller Vindteknikk comes over for a chat while the helicopter is preparing for take-off.

"This is a bit of a special case because it's not far to the measurement station – only a few kilometres – but it's 1,000 metres above sea level, and the area is highly exposed to foul weather blowing in off the fjord," says Petter.

He himself has made the trip up to Ålvik Mountain three times before. One time, bad weather left him stranded up on the mountain. Then they had no choice but to strap on their skis and defy the challenging landscape. Since then, they have implemented new employee safety practices, in the event of a sudden change in the weather. Today, there is an emergency shelter on the mountain for personnel stranded in bad weather.

Moderate icing

From where we're standing, the sun is shining and there are no threatening clouds overhead. It looks like we have the weather on our side – for now.

After a short helicopter ride, we arrive at the measurement station at the top of the mountain, and the magnificent winter landscape opens up in front of us.

Petter points down towards the fjord.

"What happens when the wind blows the moisture in the air against these high-voltage power lines is that they slowly but surely start rotating as the ice builds up. This is because they become heavier on one side, causing them to twist. They are often completely encapsulated in ice, and the ice layer becomes so strong that it doesn't break off so easily," he says.

The ice is knocked off the power line using a helicopter and a wooden pole.

The environmentally friendly power supply will supply power to a webcam, which makes it possible to monitor the weather situation on the mountain.

He points to the gauge hanging on one of the wooden pylons.

"So that's why we have a rotating gauge. It measures how much ice forms on the iron bar, which will be the same as on the power lines."

"It's not a very big installation, but in the future it may be possible to use smaller and better instruments," he says enthusiastically.

Maintenance under harsh climatic conditions

The helicopter makes several trips to bring

Petter Aker from Kjeller Vindteknikk has personally experienced being stranded on Ålvik Mountain in bad weather. Since then, they have implemented new employee safety practices, in the event of a sudden change in the weather.

“It’s not a very big installation, but in the future it may be possible to use smaller and better instruments.”

PETTER AKER
TECHNICIAN
KJELLER VINDTEKNIKK

up all the equipment needed to install the new sensors that will transmit data on the weight of the high-voltage power lines, and when they need to be de-iced. The new sensors send data directly via the 4G network, and have batteries that last for about a year. Eventually, they will be switched to Narrowband, which will boost battery life, allowing them to operate for up to 10 years.

According to Øyvind, the plan is to mount new sensors on more power lines in the autumn, after they identified where they have the greatest problems with icing.

“In addition to sensors, a completely new type of environmentally friendly power supply will be installed to supply power to a webcam, which will allow us to monitor the weather situation on the mountain and the amount of ice on the high-voltage lines,” says Petter.

“The idea is to create a more environmentally friendly measurement station, which can be self-sufficient for two to four years, so that we don’t need to refuel or perform any maintenance at all,” says Øyvind.

Icing forecasts

Currently, Statnett mainly uses two methods to remove ice: by using a helicopter that knocks off the ice with a wooden pole or by heating the wires.

“In addition to receiving information on how much ice is on the power line, we will use icing forecasts to help us predict how much ice is expected to form on the power line over a period of 48 hours, for example,” says Øyvind.

This will enable Statnett to do something about the problem before it is too late. During periods when icing is at its worst, helicopters are often grounded due to high winds and poor visibility.

“We believe there is unexploited potential in the use of heat to melt the ice on power lines, but the method is best suited if we start when there are small amounts of ice,” he adds.

A successful operation

The sound of the helicopter breaks the silence on Ålvik Mountain, as it lifts off from the ground with a wooden pole hanging underneath. The snow and ice fly off the power line with every hit. Cleaning it all off requires precision and patience.

Fortunately there is much less ice than when Øyvind was here one cold January day last year – when one of the power lines was hanging a mere 2.5 metres above the ground under the weight of massive amounts of ice and snow.

“Then, we could stand over there, jump up and touch it,” says Øyvind, pointing to the ice-free power line now hanging high above the ground.

The two experienced technicians have put on their snowshoes and are getting ready to climb up the pylon to mount the new sensors.

“Beautiful weather,” one of them says, before moving away across the snow.

New framework to increase environmental responsibility in construction work

Ellen Torsæter Hoff is responsible for the GRAN project, which started in 2018. The aim of the project is to develop a methodology to improve the planning and execution of construction work.

“Interventions in nature and the destruction of habitats are the biggest threat to biodiversity – in Norway and in the rest of the world. At Statnett, we are working actively to minimise the negative consequences of construction work and land use both for society and for the environment. For us, it is natural to use research to find a better framework for greener interventions.”

Photo: Terje Borud

These are the words of Ellen Torsæter Hoff, Senior Advisor for Land and Environment at Statnett and responsible for the GRAN project, who continues: “Changes in land use are undoubtedly one of the biggest threats to biodiversity, with potentially major consequences for species associated with certain natural habitats. When developing renewable energy resources and the power grid, we must ensure that our construction projects inflict minimial damage to vulnerable natural environments, and that our consumption of various non-renewable resources during construction activities is so low that our total environmental accounts do not end up in the red.”

A framework that will be used

Statnett is always working on research projects to help minimise the negative environmental impacts of our facilities. “The GRAN project”, which was initiated in 2018, will collect data on the interventions made by Statnett’s development projects and thus provide knowledge of the consequences and a starting point for developing a methodology for better planning and execution of construction work.

“There are already many general recommendations and guidelines for mitigating measures and environmental considerations. We have also gathered a lot of knowledge on the implementation and effects of specific measures, but this knowledge is fragmented and rarely takes into account the challenges associated with our specific facilities. Climate change also means that the environment is constantly changing, and knowledge must be updated. In addition, it is an important goal to ensure that environmental measures are adapted to the development project’s feasibility frameworks and applicable standards for design, contracts and follow-up. To put it simply, There is no point in having a framework that no one can live up to or wants to use,” explains Torsæter Hoff.

Climate and environment – seen in context

A new framework must include all the phases of a development project, from the early planning phase, via the actual construction work to operation and any dismantling of a facility that is no longer in use. GRAN’s goal is to provide knowledge that is relevant throughout the entire mitigation hierarchy. “In the planning phase, we have the opportunity to avoid vulnerable areas and set out good guidelines for mitigating measures, while during and after construction, it is important to examine opportunities for mitigation, restoration and – as a last resort – compensation.
“There is a need for a systematic review of a large number of measures and an analysis of these based on environmental and construction data. This will allow us to document both good and bad solutions – in order to limit short-term and long-term consequences. This knowledge and systematic review are important because we have examples of measures that

A part of the GRAN project will be to use existing emission figures per habitat type and specific land use plans to identify the amount of climate gas emissions from removed soil and vegetation.

SUSTAINABLE SYSTEM DEVELOPMENT

"A new framework must include all the phases of a development project, from the early planning phase, via the actual construction work to operation and any dismantling of a facility that is no longer in use."

ELLEN TORSÆTER HOFF
SENIOR ADVISOR FOR ENVIRONMENT AND LICENSING
STATNETT

are effective in some areas, but which may have a negative effect under other conditions," explains Torsæter Hoff.

"We must develop routines to limit land use in our construction projects, especially in marshes and wetlands. The total amount of carbon in all the world's marshes is about the same as what's in the atmosphere. Other habitat types also act as carbon storage, so all construction in natural areas contributes to greenhouse gas emissions in addition to the destruction of habitats. Limiting land use is therefore a good environmental measure. In GRAN, we will use existing emission figures per habitat type along with specific plans for land use for a variety of facilities – including transformer substations, service roads and pylon locations. By using GIS analyses and project plans, we can map the extent to which different habitats are affected and thus calculate carbon emissions for different solutions."

"Environmental requirements and plans that are used as a basis for project planning and design, contracts and follow-up are often general and do not follow the same form and standard as technical/financial requirements. This makes them difficult to implement and follow up. In order for the knowledge of damage minimisation and restoration to be fully implemented at the individual facility, we must improve the system for collaboration and implementation. In GRAN, we will carry out document analyses, including regulations, guides/manuals, tender documents, contracts and minutes of construction meetings to evaluate how measures and plans are converted into solutions in the field," concludes Statnett's Land and Environmental Advisor, Ellen Torsæter Hoff.

Value-creating renewal

GRAN was launched in 2018, and received project support from the Research Council of Norway as an Innovation Project for the Industrial Sector (IPN). The purpose of IPN projects is to lead to innovation (value-creating renewal) in the companies that participate in the project. GRAN is headed by Statnett, in cooperation with the Norwegian Water Resources and Energy Directorate (NVE) and the Norwegian Public Roads Administration (NPRA). The Norwegian Institute for Nature Research (NINA) and the Norwegian University of Science and Technology (NTNU) are conducting the research work.

In 2018, the project has mainly worked with specifying goals, making plans for further work, finding relevant literature and communicating with other actors who can assist in finding good solutions. An inspection has been carried out along Statnett's Western Corridor project in Rogaland. In this area, there are facilities of various ages and sizes in a diverse natural environment, which makes it very suitable for field surveys. Field work is planned in the summer of 2019 and 2020, and will be carried out by NINA in collaboration with summer interns employed by Statnett.

What are the alternatives to expanding the grid?

In the wake of the R&D project “Alternatives to expanding the power grid”, research is now underway on potential solutions as alternatives to grid development. In the long run, the goal is a more efficient power system.

HARRIS UTNE
PROJECT MANAGER
STATNETT

“We want the market to adapt itself and for consumption to match production,” says Harris Utne, Project Manager for the exciting and innovative project that is currently taking shape.

According to Utne, an important aspect of further project planning is to examine the resources that are currently available and specifically what can be done to reduce the need for new grid development in Norway.

“Everyone wants a secure and robust power supply. At the same time, grid construction is both costly and time consuming, while the demand for and production of electricity are constantly evolving. Consequently, it is important to look at what solutions are available to achieve a more efficient power system,” says Utne.

Power consumption sets the pace of development

Harris points out the importance of good collaboration with other players in the project, especially with other grid operators.

“Changes to the power system cannot take place without extensive cooperation in the industry. Statnett is involved in several research projects, including with CINELDI and the Norwegian Smartgrid Centre, which aim to help to develop an intelligent power system based on information and communication technology. In addition, Statnett’s Matthias Hofmann is writing his doctorate on consumers and price elasticity,” says Utne.
As power generation corresponds to the power used at any one time and the power grid is dimensioned based on maximum usage, the balance between what is produced and what is used mainly depends on consumers.

“If we reduce consumption peaks, we will also reduce the need for a larger grid. This can either happen in the market by consumers adapting to spot prices and grid tariffs or by, for example, Statnett asking consumers to reduce their consumption in given situations and at certain times,” says Utne.

Important to keep up with the times

In order to find the best options for future development, we are reliant on examining and testing existing opportunities and solutions. Harris highlights three points that are important for the further development of the project.

“The first is an issue that concerns many people: the electrification of transport, and the opportunities this provides for efficient system operation. Consumers can contribute to a more efficient power grid by facilitating the management of flexible consumption. One example that is often used in this regard is the charging of electric cars, but examining the heating and ventilation of buildings probably has an even greater potential. And we can also enter into agreements with consumers who control demand. By limiting new consumption or new production in given situations, we may be able to avoid new grid investments,” says Utne.

Point number two is about what Harris describes as price elasticity and implicit flexibility. In other words, how consumers adapt to market prices.

“In big cities where there is high consumption on the coldest days, with little electricity production, it is a challenge to have enough capacity. The question then is how much we adjust power consumption in line with increased electricity prices,” Harris says.

Finally, point three focuses on how we can make the most of existing opportunities and how they can be combined to create a more efficient power system. He himself is positive about the process and not least about Statnett’s role in the forward-looking project.

“In many cases, grid construction will still be necessary. But we want to be involved in testing and using new solutions to see what effects they could have. Regardless, the power system will become more complex with the advent of more wind and solar power and new types of consumption – such as electric cars and data centres – and new and cheaper system management technology. It will be important for Statnett to keep up with the times, to use new technology and other methods to control consumption, and to manage the power system for the benefit of all,” he concludes.

Photo: iStockphoto

SUSTAINABLE SYSTEM DEVELOPMENT

Beneath the streets of Oslo, Statnett is digging a four kilometre long tunnel for the new cable connections between Smestad and Sogn. The entire construction site is fossil-free. The drill in the photo runs on electricity when it is in operation. When it needs to be moved, it runs on fossil-free fuel.

This is a fossil-free construction site

How can Statnett's construction sites become completely emission-free? This is the challenge being addressed by the R&D project "Fossil-free and emission-free construction site", which is investigating how electrification can move construction activities into a new age.

Photo: Christian Søgaard

Senior Advisor Marte Bakken strongly believes that electricity is the long-term solution for an emission-free construction site.

The first part of the project was completed in January 2018, with the presentation of a report on how Statnett can plan and implement fossil-free construction sites.

The results were used in Norway's first project involving fossil-free construction work, specifically the renovation of the power lines between the Smestad and Sogn substations in Oslo. Veidekke is the contractor for the work. All of the machinery and equipment at the construction site as well as construction transport run on fossil-free fuel.

Two fossil-free construction sites

"The R&D project is twofold. The first step was to assess how we could plan and execute our construction work in a fossil-free way, i.e. without using diesel or petrol. This means that all machines are either electrically powered or run on renewable, palm-oil-free and non-food-based diesel," says Marte Bakken, Senior Advisor for Climate and the Environment at Statnett.

Statnett currently has two fossil-free projects: Smestad–Sogn and the Ålfoten substation. There are numerous benefits at many levels. Greenhouse gas emissions are reduced by about 80 per cent. In addition, feedback from personnel indicates that working conditions have been improved in terms of air quality.

Electrical solution

However, according to Bakken, fossil-free construction sites are not the long-term solution either. They are a step in the right direction.

"Fossil-free construction work is an important and necessary step, but it is not good enough. It isn't really optimal. For example, many fossil-free fuels are based on palm oil, which contributes to deforestation of the rainforest. For the record: we use palm-oil-free, renewable diesel with a sustainability certification in our projects. But if Norway as a country were to significantly increase the use of renewable

Marte Bakken says that emissions-free construction sites will represent a completely new paradigm, while at the same time posing major technological challenges.

diesel, we would simply have a problem with access," explains Bakken.

She is therefore of the clear opinion that electricity is the solution. It is also where the great shift will come. While conventional construction machinery can be run on renewable diesel, a 100 per cent electrical construction site requires all new machinery.

Part two of the project

That is precisely the focus of part two of the project, which is being carried out in collaboration with Rambøll. Part two was started in September 2018, and the report will be delivered by 1 March 2019.

Marte Bakken continues:
"While working towards emission-free construction sites, we must have two perspectives. The short-term perspective is what we can already do electrically today. This means using available technology for the electrification of machinery and equipment at the construction site. But then there is the long-term perspective: when can we carry out a completely emission-free construction project.

1 excavator =165 cars

The climate benefit from the electrification of construction sites will be tremendous. According to Bakken, the electrification of one excavator will correspond to the electrification of 165 cars with a fuel economy of 5 L/100 km (56.5 mpg). The calculation is based on the assumption that on a large excavator that uses 100,000 litres of fuel per year, and that the average annual fuel consumption for Norwegian passenger cars is 600 litres.

"Emission-free construction sites will represent a paradigm shift. But this is also where we face the greatest technological challenges. As yet, there is no emission-free heavy machinery available in Norway, and the market is still small. Finding electrical solutions for heavy machinery will be key, and the fact that many suppliers are currently developing electrical machinery is a very positive step in the right direction," she says.

The industry is on board

Logistics is one of the challenges that need to be addressed. What should use a cable connection and what should run on battery? Where should the battery packs be located? And when should the machines be charged? Bakken explains that we will have to be innovative when it comes to organising procedures and logistics. But the construction industry is on board.

"Parts of the industry are very progressive, and often more offensive than both politicians and many of their clients. The major industry players see the potential for long-term cost savings that electrification represents, and they want to be involved in the transformation of the industry. The industry is an important part of the solution," concludes Marte Bakken.

"The climate benefit from the electrification of construction sites will be tremendous. The electrification of one excavator will correspond to the electrification of 165 cars with a fuel economy of 5 L/100 km (56.5 mpg)."

MARTE BAKKEN
SENIOR ADVISOR FOR CLIMATE AND THE ENVIRONMENT
STATNETT

Researching the risks and costs of the largest power outages

What characterises the most socially critical power outages, and what investments should we make to reduce the risk in a socio-economically profitable way? This is the focus of the R&D projects “HILP” and “Interruption costs”.

Photo: Johan Wildhagen

From the left: Analyst Eivind Norum and Economist Rolf Korneliussen.

Good security of supply for electricity is critically important to society. It makes demands on those who plan and operate the power system. This is the theme of the R&D projects “HILP” and “Interruption costs”.

The projects are closely linked. At a general level, they are about how Statnett can best prepare for the loss of power on a catastrophic scale – and how to invest society’s resources optimally and be socio-economically profitable, in order to reduce the likelihood of this happening.

Low probability – major consequences

“Highly simplified, we can say that the HILP project focuses on events with potentially major consequences but with low probability. The project on interruption costs picks up where HILP leaves off, and focuses on the socio-economic costs,” explains Statnett analyst, Eivind Ødegaard Norum.

HILP stands for “high impact, low probability”. SINTEF is leading the project, but Norum is responsible for following up on behalf of Statnett.

An expanded toolbox

“Major and long-term power outages would have enormous consequences for society. But we need more knowledge to understand the underlying mechanisms that cause this type of power outage. HILP is providing us with an expanded toolbox for describing this type of risk – and for identifying, understanding, analysing, averting and handling such events,” explains Norum.

Fortunately, Norway has largely been spared for such catastrophic events, unlike both Europe and the United States, which have seen numerous power outages with major social consequences. At the same time, the power system is becoming increasingly complex because of amongst other increased integration of distributed renewable power production, more extreme weather and a stronger connection between the Nordic power system and the power systems in Europe.

“The benefit outweighs the cost”

It is precisely the socio-economic aspects of such events that are the focus of the R&D project “Interruption costs”.

“All investments we make must have the best possible basis for decision making, and a correspondingly good basis for the authorities when they process our construction applications. Therefore, we are dependent on showing that the project is economically profitable, that is, that the benefit outweighs the cost. You can’t spend as much money on home insurance as it would cost to build a new house,” explains Statnett economist Rolf Korneliussen.

Balancing act

He explains why the projects are so closely linked.

“In brief, the essence of the matter is: what costs should we accept for reducing the risk of an event that is basically very unlikely. It is about finding the balance between security of supply on the one hand and investment costs on the other.”

The drones of the future will manage on their own

At the Aura substation in Sunndalsøra, the future is here, in a hangar that looks a lot like a shipping container. “The goal of the R&D project is to develop an unmanned, autonomous drone that can carry out inspections at substations – and eventually also on power lines.
But really, our research is not primarily focused on developing drone solutions, but rather on gathering information in a more efficient and safer way than today.”

Photo: Thomas Negård

Those are the words of Thomas Negård, who spends his days monitoring Statnett’s power lines, but he is also the project manager of the R&D project “Automated flight and inspection of substations” which is based at Aura substation in Sunndalsøra. Sunndalsøra is also home to Statnett’s drone school, and not far away, you can find Viklandet, another one of Statnett’s 160 Norwegian substations.

Drone, hangar and system

Negård explains that the R&D project is a collaboration between KVS Technologies, Nordic Unmanned and SINTEF and consists of several components. “The drone itself is a modified Camflight FX8 that can fly in winds of up to 15 m/s, withstand gusts of 25 m/s and handle rain and snow while it carries 5 kg of camera equipment in temperatures as low as -20 °C.

“When the drone isn’t busy working, it is docked in a mobile hangar that was specially developed as part of this project. Inside, the climate is optimal for parking after jobs in harsh weather and for charging the batteries. There is room to

The drone should be able to fly in winds of up to 15 m/s, withstand gusts of 25 m/s and handle both rain and snow.

To date, the project has come so far that the drone is ready and operational, but it must be tuned and adjusted along the way.

perform repairs and maintenance, and all communication and computer equipment needed on the ground to carry out operations is installed in the hangar. The drone, which takes off from a small, mobile platform that moves in and out of the hangar wall, is operated from a separate control room which is located at Statnetts monitoring centre in Sunndalsøra."

"The final component is the software and systems for navigation and data collection. A substation is a dangerous place for aircraft, with a high potential for experiencing a physical crash or electromagnetic disturbances. Therefore, we are developing solutions for navigation and pre-programmed flight routes and an advanced "sense and avoid" system that continuously scans the environment around the drone and defines the area as safe or dangerous on an ongoing basis. In this way, the drone should be able to operate as independently as possible, with people taking control only in special situations."

Well underway

Thomas Negård says that the project has already come so far that the drone is ready and operational, but that it must be fine-tuned and adjusted as they gain experience using it. The first hangar is in place, tested and prepared at the station and the drone is just back from one of the project partners, where it was upgraded and fitted with new equipment. The work on testing will continue throughout the spring, towards the summer.

"In the phase we are in now, we are working to program so-called "points of interest" (POIS), i.e. specific locations that we want the drone to fly to at the substation, and then set the cameras at the right angle to collect visual data. On the way to the POIS, we can challenge the drone with various obstacles and we can fly in varying weather conditions – all to learn more about how it works so that we can develop the most independent system."

"When this system is fully developed and hopefully implemented, we envision a whole new way of performing monitoring and inspection. An operator can either activate a drone by selecting a substation and then a pre-programmed route or task. Alternatively, the drone and the system can activate themselves based on a system of maintenance intervals. Once the drone has completed its task, it returns to the hangar where it downloads information for analysis and is made ready for new assignments."

Safe and profitable

Although the project that Thomas Negård and Statnett are participating in is primarily focused on developing the drone, the hangar and the navigation systems, he emphasises that the real value is in the data that is collected and how that information can be used in relation to monitoring and maintenance of substations and the power grid.

The real value is the data that is collected and how it can be used.

Project Manager Thomas Negård has great faith in the project.

"When this system is fully developed and hopefully implemented, we envision a whole new way of performing monitoring and inspection."

THOMAS NEGÅRD
SENIOR ENGINEER
STATION MONITORING/DRONES

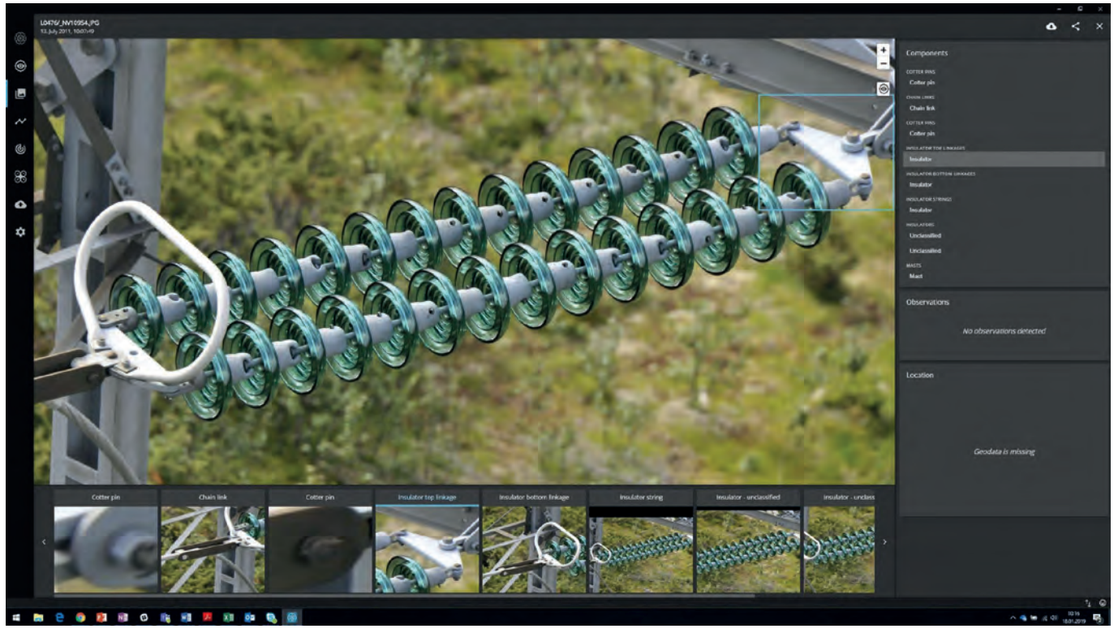
"The knowledge and solutions we are developing in one of the other drone R&D projects, AI-4-UAS [see separate article], where visual data is analysed using artificial intelligence, gives the maintenance a predictive quality. When the machines learn more about faults and the different stages of wear and tear, we will have a better idea of when to take action. The result is proper maintenance, where parts are replaced when we have gotten the most out of them, but before the risk associated with their use increases due to failure or wear and tear."

And then there is an important factor to consider both in the project and in R&D in general: "Research is expensive. We use a lot of time and resources developing these solutions, and even though we learn a lot, we also need to focus on the cost in a long-term perspective. In other words, unmanned drones in combination with, for example, analysis using artificial intelligence must become a cost-effective activity for Statnett in the future. We mustn't forget that these projects both have an environmental upside and reduce the risk to people in relation to inspection, but when we calculate the bottom line we must also see that it pays off financially. And I strongly believe that we will manage to do that," concludes Project Manager Thomas Negård.

Analyses data from drones with artificial intelligence

With the help of artificial intelligence and data collected by drones, inspections at the substation and along the power line could be carried out completely without human intervention in the future. Powerful processors and advanced algorithms can analyse 100,000 photographs per hour – more than one person can do in a year.

Photo: eSmart Systems



The AI-4-UAS project is researching the use of data analysis from sensors on drones in the monitoring, operation and maintenance of the power grid.

"In the long term, the goal is for the solution and algorithm to learn independently, based on all the new data collected through new inspections and assignments."

ROLF BROCH
PROJECT MANAGER
STATNETT

"In the future, we must get more done with similar resources to what we have today, and we must work smarter in a world that is becoming increasingly digital. This presents challenges, but first and foremost, the technological development offers enormous opportunities for a player such as Statnett."

These are the words of Rolf Broch, Senior Advisor at Statnett. He is central to the work on one of two R&D projects researching the use of drones in the monitoring, operation and maintenance of the power grid.

Everything should run automatically

The project has been given the catchy name "AI-4-UAS" – artificial intelligence for unmanned aerial systems. "We play the role of a demanding partner in a collaboration run by the Norwegian company eSmart Systems in Halden. They have extensive experience in developing solutions that use artificial intelligence to analyse vast amounts of visual data in the search for deviations, errors and wear and tear on the grid and at substations. "Our collaboration will help make these solutions even better suited to our needs and the needs of other grid operators," says Broch.

"The first goal of the project is to reduce the degree of manual work needed to analyse the images from drone inspections, but in the long term, we definitely have greater ambitions. Along with the results of other R&D projects on drones, we must try to develop a tool where the drones and software together comprise an autonomous solution that our technicians and engineers only need to consider when it is reporting errors or wear and tear."

The solution will learn to learn

Tomas Collin of eSmart Systems says that the work on AI-4-UAS is divided into two natural phases. "In the first phase, we must teach the solution to recognise the parts that need to be inspected at a substation and along a power line. Ceramics, insulators, switches, aircraft markers and cords – these parts and components must not only be recognised and kept separate from other parts, but the system must also learn to understand the large variations in wear and tear and possible faults. To that end, we are using a large image database that Statnett has made available.

The next phase involves uploading the new knowledge and features to the intelligent assistant we have developed, which will conduct the actual analysis of the images captured during an inspection. When a nonconformity is detected, this must be tagged and marked with a pin on a map, so that the grid owner – in this case Statnett – can generate an error report to follow up on the problem. In the long term, the goal is for the solution and algorithm to learn independently, based on all the new data collected through new inspections and assignments," says Tomas Collin.

Enormous capacity and important for HSE

"In the AI-4-UAS project, the drone's task is to function as an advanced camera stand," explains Rolf Broch. "But in the context of the other R&D projects focusing on drones, we are talking about an automated solution for inspection and monitoring – and an advanced analysis program that finds faults and wear and tear – well in advance of the situation becoming critical. A computer program does not get tired and inattentive in the same way as I do at the end of the day. Although the capacity is already at 100,000 images per hour – more than a human being can get through in a year – the precision is always just as high."

Knowing that Statnett maintains over 11,000 kilometres of high-voltage lines and 160 substations across Norway, it goes without saying that a project which can eventually reduce the human effort in the analysis work offers great benefits. "But we are also thinking about HSE in this context," says Broch. "Today, much of the work is done either by helicopter at low altitude or by climbing the pylon. Helicopters have an obvious negative environmental impact, while both types of inspection are risky – and drones represent a clear improvement in both areas."

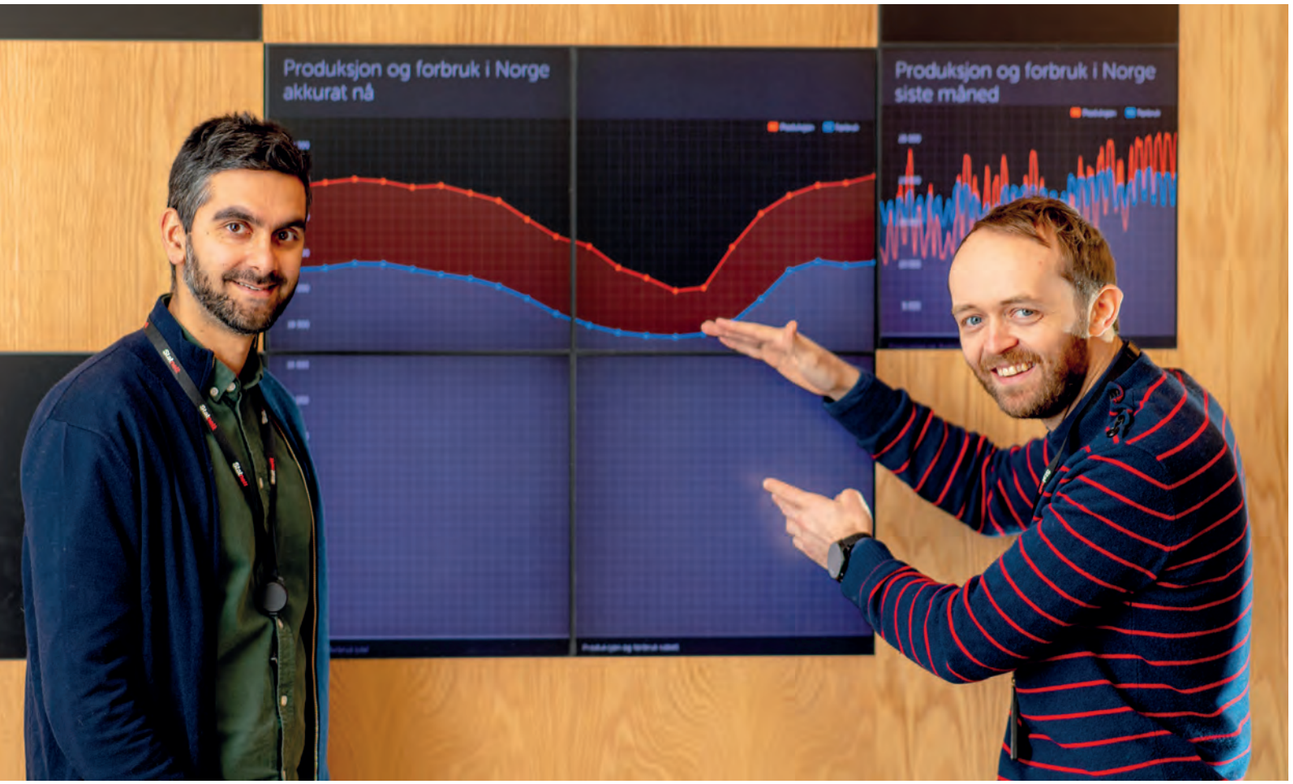
Photo: Rolf Magnus W. Sæther

"In the future, we must get more done with similar resources to what we have today, and we must work smarter in a world that is becoming increasingly digital," says Rolf Broch, Senior Advisor at Statnett.

Using artificial intelligence to predict imbalance in the grid

The power system is changing. Climate, cables, new technology, new energy sources and changing political frameworks are creating both challenges and opportunities. One challenge is how to ensure balance in the power grid. The Impala project is researching the use of artificial intelligence in the search for solutions to keep it as stable as possible.

Photo: Terje Borud



Karan Kathuria (left) and Eivind Lindeberg are project managers for the exciting Impala project, which is researching how artificial intelligence can contribute to new solutions for keeping the power grid as balanced as possible.

"Simply put, we want to use machine learning and artificial intelligence to increase the precision level in our predictions of the difference between consumption and production of electricity two hours ahead."

EIVIND LINDEBERG
PROJECT MANAGER
STATNETT

"It's not about eliminating the human factor in relation to monitoring and balancing," explains Eivind Lindeberg, Statnett's Project Manager for Impala, "but rather, it's about organising the work so that machines do what they can do better than people, and the operators utilise their expertise where they make a unique difference."

Increasingly more demanding

The frequency in the Nordic power system is 50 Hz. At that point, consumption and demand are in perfect balance. However, since both the supply and demand are in constant flux, there is always a possibility of an imbalance. "The process of creating balance starts in the Elspot market, where the players try to predict consumption and how much they want to produce. Then, if prognoses change, they have the opportunity to trade in the intra-day market until the power is delivered to the grid. Once the power is delivered to the grid, Statnett is responsible for maintaining the balance, by means of activations in the balance markets.

"Currently, the operator manages to keep imbalances in check based on experience and gut feeling, but with limited support from IT systems. However, because of climate changes, new and less predictable energy sources and new technology, the job is more demanding today than it has been before. And it is not going to get easier in the future if we don't find a smarter way to do it," says Lindeberg.

Partner with a good idea

"We were challenged by Statnett to come up with good ideas for projects that we could work on together," says Karan Kathuria, Project Manager at Optimeering. The project, which has been named **Imbalance Predictions with Advanced Machine Learning** (Impala), started in 2017 and receives funding from the Research Council of Norway.

"Impala addresses precisely these challenges as it becomes harder to control the imbalances that arise in the power grid in the wake of climate change, new and less stable energy sources and new types of consumption. Simply put, we want to use machine learning and artificial intelligence to increase the precision level of our predictions of the difference between consumption and production of electricity two hours ahead. That is the key to maintaining balance in the grid, which is becoming increasingly difficult for Statnett's operators to calculate without the help of modern IT tools," says Kathuria.

"The tool and the technology we have adopted is machine learning. The result will be a model that predicts the upcoming imbalance in real time."

Better at predicting imbalances

"There are several ways to train a machine," explains Karan Kathuria. "The simplest is to write the rules yourself. Then the machine will never be able to do more than what you have taught it to do. Another approach is to help the machine learn on its own by supplying it with large amounts of structured data – in practice, this means well-formulated examples. This is called machine learning. Deep learning, which is on everyone's lips these days, is a separate area of machine learning that allows more abstract relationships to be found, but in turn, this requires more data and is more difficult to control."

"The Impala project uses machine learning because the solution we are developing needs to be able to say something about a future that is not always similar to history and because using the tool requires a robust solution based on a solid understanding of how artificial intelligence works. We use processed data sets with information on weather, wind, temperature and calendar data – because there is a difference between a bank holiday weekend and a regular weekend, for example – and lots of other information that affects production and consumption."

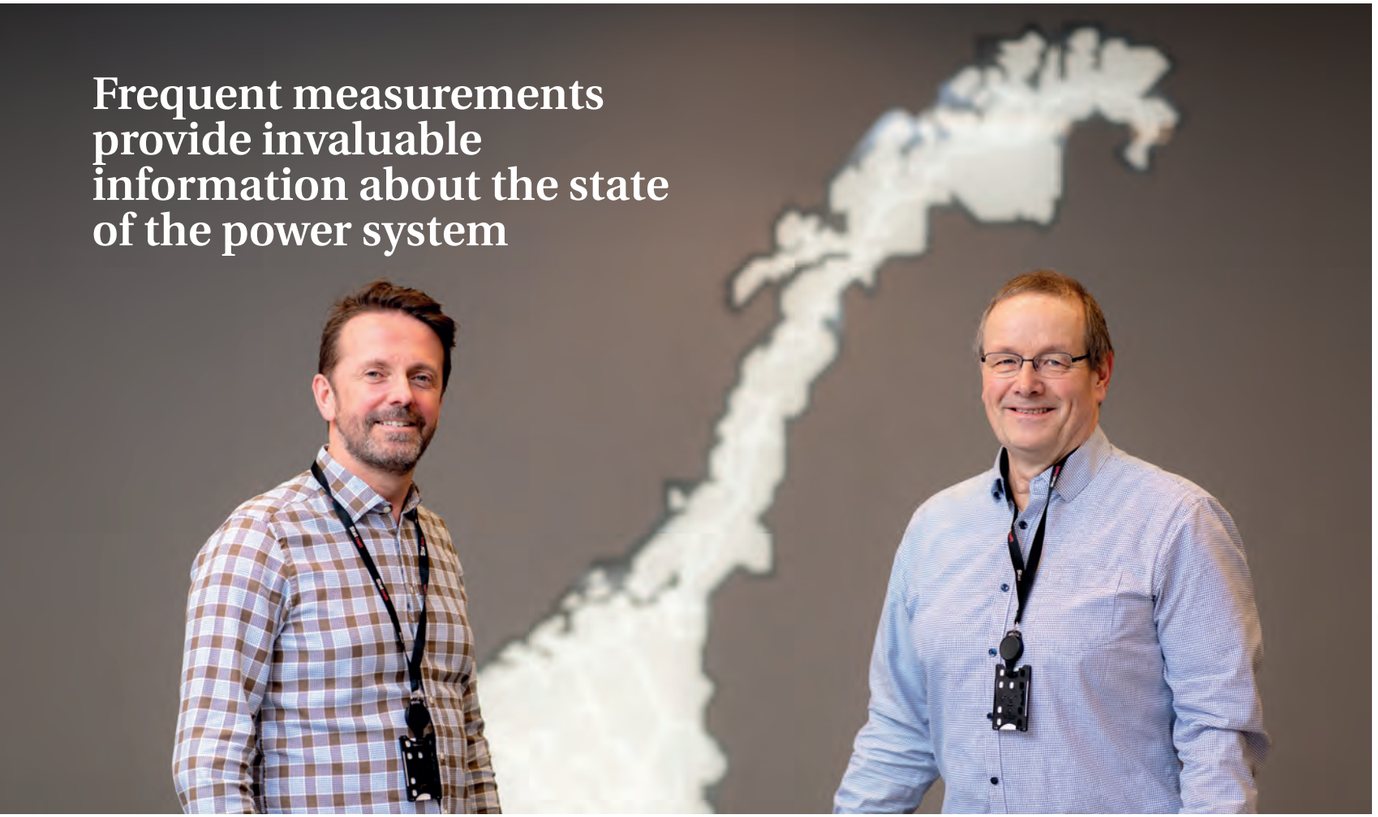
"Although we have not yet tested this solution 'live', we can observe that the machine is able to predict imbalance with greater precision than current systems. We also see that there is less variance in prediction errors. It is better to make small mistakes often than to make big mistakes sometimes."

Cooperation and automation

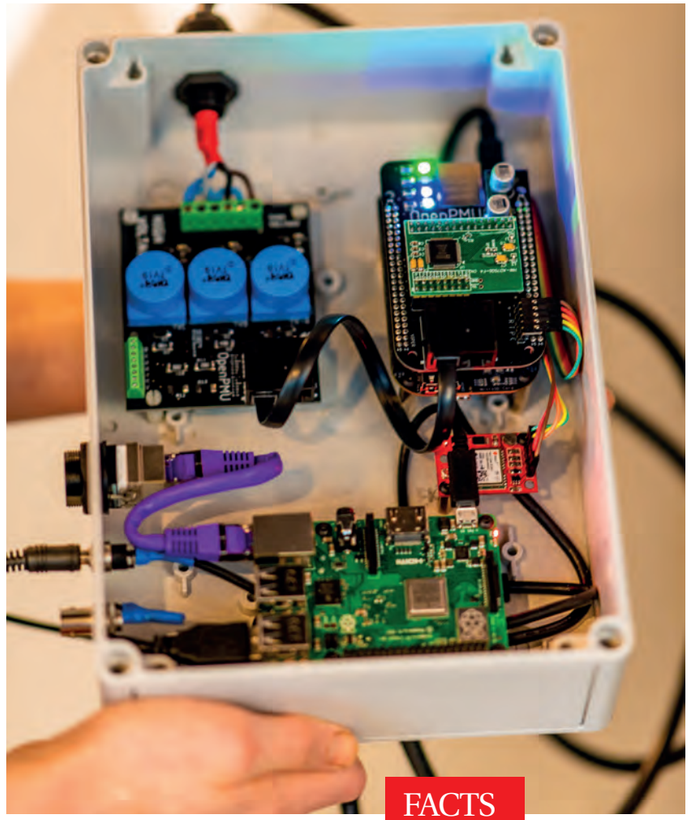
"We expect to test the solution on live data during the spring," continues Eivind Lindeberg. "One goal of the project is to give the people who are currently doing the balancing better support from the data tools and, in the long term, enable them to leave the most routine parts of the job to the computer. Then we can use their expertise where it makes a real difference. It is not realistic to envision a future where grid balancing is completely automated. For example, if a situation may suddenly arise where a large power plant experiences a failure. The machine would not have the background or experiential data to enable it to solve the problem."

"Impala is also part of a larger context where Statnett is cooperating with the other TSOs in the Nordic region to develop a new balancing model with new market solutions that are based on automated processes to a much greater extent. Statnett is also participating in the MARI project – a European market platform for exchanging balance energy across Europe. New technology and digitalisation, of which Impala is an example, pave the way for increased automation of system operations," concludes Statnett's Project Manager, Eivind Lindeberg.

Anders Skånlund, Project Manager for SPANDEx and Neweps (left), and Knut Styve Hornes, R&D Project Manager, Statnett.



Frequent measurements provide invaluable information about the state of the power system



There are a number of research projects aiming to solve the challenges of phasing in new, renewable power and the need for better utilisation of the transmission system.

Photo: Terje Borud

Stability issues in the power system have been a topic of discussion since the 1920s. Frequency variances have always created challenges for system operators and the need for stable operation because the 50 Hz balance is a premise that keeps the system from collapsing.

More frequent and larger imbalances

Back then, the instability was often due to generators that were coordinated over long and weak transmission connections, while the causes today are far more numerous and more complex. The real-time collection of measurement data can help solve these stability issues and improve our utilisation of the power system.
If the power system can be better utilised, it can help reduce the need for new investments and even out power prices between areas.

Knut Styve Hornnes in Statnett's R&D department, like Eivind Lindeberg (Impala project), points to changed consumption patterns, the renewable revolution and a greater number of interconnectors as sources of increasing variances and imbalances, and the need for greater transmission capacity.

"Both structural and random imbalances are occurring more frequently than before, and the variances have also become larger due to more unregulated production. As a system operator, we need to find a solution to address this," says Hornnes. In the worst case, large frequency variances, fluctuations or other faults can cause the system to collapse. Large parts of the grid could fall out and the country would be left in darkness.

Operators discover hints of imbalances or faults within seconds, and they are usually dealt with by automatic control mechanisms in the system. But rapid changes bring new challenges that should be detected and managed quickly – for example, within a tenth of a second after they occur.

Records measurement data 50 times per second

This is the focus of the PMU projects SPANDEx, Sparc and Neweps. The first follows a Norwegian standard, while the other two are Nordic. Statnett has an important role in all three projects, and the goal is to research methods that can identify variances as they happen and process them long before an operator has time to react.

Small PMU boxes are installed in the grid at the substations to measure frequency, phase angle, voltage and current. The PMUs record measurement data 50 times per second. These observations can then be used to detect the variances. A PMU continuously monitors the grid and delivers observations 24/7. This means that billions of data observations must be recorded, stored and made available to applications that can calculate and automatically implement necessary actions.

"Initially, we are developing systems consisting of sensors that are spread out in the power system to provide real-time monitoring of large areas. This means that our operators will be notified much earlier of challenges in the power system. Later, these solutions can be expanded to include automatic response and potentially lead to a digital transformation in how we operate our grids," says Anders Skånlund, Project Manager for SPANDEx and Neweps.

FACTS

What is a PMU?
A PMU detects voltage and current, and based on these measurements, it calculates parameters such as frequency, active power (MW), reactive power (MVAR) and phase angle. PMU boxes are often installed at cuts in the transmission system and provide real-time information to TSOs.

"Both structural and random imbalances are occurring more frequently than before, and the variances have also become larger due to more unregulated production. As a system operator, we need to find a solution to address this."

KNUT STYVE HORNNES
R&D PROJECT MANAGER
STATNETT

Stability challenged by nuclear plant closures and low production at hydropower plants

Nuclear power still plays a role in the Nordic supply chain, with operational power plants in both Finland and Sweden. But several of the reactors are due to be shut down, including two reactors at Ringhals nuclear power plant in Sweden, which will be shut down at the end of 2019 and 2020, respectively.
Nuclear power plants are controversial, but an undeniable advantage of the large production units is that they have a high rotational mass. Rotational mass acts as an inherent buffer against frequency variances. In addition we will have low inertia in the hydropower system due to import, typically at night in the summer. Large production units, both nuclear and hydropower, contribute to the primary and secondary regulation, which bring the frequency back to normal. In the event of a failure or a change in production or consumption, the rotating mass and primary regulation reserves in the system will counteract the frequency variance and ensure a more stable power supply.
"The turbo generators at the Swedish and Finnish nuclear power plants have been important buffers in case of variances. The system has had enormous inertia which has greatly contributed to the damping of frequency variance. But now the Swedes are moving away from nuclear power – and we will definitely notice the difference," says Statnett's Knut Styve Hornnes. "Sudden reductions in production, such as tripping of large production units, will certainly hit the grid harder than before," he explains.

"We expect radical changes in the energy systems. This creates a need for new knowledge, new solutions and research activity."

LENE MOSTUE
DIRECTOR
ENERGI21

FACTS

About Energi21
Energi21 is the Norwegian strategy for research, development and commercialisation of new, climate-friendly energy technologies. Energi21 provides strategic advice and recommendations to the authorities on research, development, and demonstration activities aimed at developing new, climate-friendly stationary energy technologies.

FACTS

NOK 41.6 billion in research funding
Norway has various funding models for research and development. For 2019, the government allocated a total of NOK 41.6 billion, including funding for the SkatteFunn programme. The most important actors for Statnett in terms of allocations to the sector are the Research Council of Norway, Innovation Norway, SkatteFunn, Enova and The Norwegian Water Resources and Energy Directorate (NVE).

Norway – an electrical laboratory for the rest of the world

Lene Mostue of Energi21 believes that the full electrification of Norway is within our grasp. If we are to succeed, however, we need interdisciplinary collaboration, and we must dare to invest in research and technology development.

Photo: Peter Gløersen

"We're sitting on a golden egg here in Norway. Both in terms of infrastructure and energy resources. This gives us the opportunity to be a test arena – an electrical laboratory for the rest of the world. We are digitalised, quick to adopt new solutions and our population is quite small. We can alter course quickly in the face of change. At the same time, we have strong expertise and extensive industrial experience. This makes Norway a good candidate for full electrification," says Lene Mostue, Director of Energi21.

According to Statnett's calculations, the full electrification of mainland Norway will require 30–50 terawatt hours. At the same time, it is expected that new wind power will contribute 30 TWh by 2040.

"I think 2040 is a realistic perspective, and I think much will have happened by 2030 for Norway's part. By 2040, I think we will have come a long way. There is a lot happening in many sectors these days. The development of climate-friendly solutions and new business models has higher priority than before. Whether you build ship hulls or work at Microsoft, you're influenced by electricity and climate solutions," says Mostue.

At the same time, she emphasises that emission reductions in the transport sector are a challenge that is having a major impact on the energy system. Finding fully electric solutions for long-distance transport, shipping and aviation is a difficult task. "Both infrastructure and battery capacity need to be improved," says Mostue.

However, progress is also being made in the transport sector. The UN's maritime organisation, IMO, aims to reduce greenhouse gas emissions by 50 per cent by 2050. This has led to a marked increase in batteries on board ships. Norway now has the most electric ferries in the world, according to a report from Marine Battery Forum. Avinor aims to make Norway the first market where electric aircraft claim a significant market share, and to make domestic air traffic electric by 2040.

Such upheavals in the transport sector will force changes in the power supply, with an increasing need for power and extensive substations to provide access to energy.

"I believe the transport sector and the energy sector must increase their cooperation in the future. And that's just one example. All sectors must have a system perspective and we will need multidisciplinary collaboration between sectors if we are to succeed," says Mostue.

Research is the key

In January, Minister of Petroleum and Energy Kjell-Børge Freiberg received a report produced by the consultancy firms Impello and Menon Economics. It showed that energy research has created value of NOK 16 billion since 2008. In the future, the potential is estimated at more than NOK 100 billion.

"The report shows significant effects, which would not have been possible to realise without a systematic and long-term commitment to research, strong research environments and an adaptable business community," Freiberg said when he received the report.

Mostue completely agrees, and emphasises that research has never been more important than it is now.

"We expect radical changes in the energy systems. This creates a need for new knowledge, new solutions and research activity. The business community wants faster access to results. It is therefore important for the research system to adapt to this development without compromising the quality of the research results.
The goal is to have as many research results as possible implemented and commercialised," says Mostue.

She also believes that organisations should prioritise research activity and results to a greater extent.
"When I am at conferences, I often hear top executives talk about the future, but without mentioning the value of research and innovation. I think that's a bit odd. The future is very closely linked to knowledge development. It is important to boost research activity and integrate it into organisations, so it's not simply an isolated activity in the business. Statnett is doing a good job in this regard. They have a lot of research and innovation activity going on, which seems well integrated into the company."

Must keep up

When we ask the director of Energi21 to give us some predictions about the future, she has a lot to say. System operation, consumption patterns, value creation and information processing are a few key words. What pervades everything is digitalisation.

"Digitalisation is the tool we must use to succeed. If we are to succeed in having a secure energy supply in the future, it is essential that we get effective digitalisation in place. The system will become increasingly complex and many players will have to work together. This requires more management and more monitoring. Then you have big data management, artificial intelligence and machine learning. These are key success factors," says Mostue.

Photo: Christian Sogaard

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Statnett
The future is electric