Alfen
magazine

An enormous paradigm shift

STORE ■ CHARGE ■ CONNECT ■ TRANSFORM

ALFEN

Dear reader

Energy storage system at wind farm Giessenwind (page 18)

Welcome to this edition of the Alfen magazine. This year Alfen is celebrating its 80th anniversary. From the 1930s we have been pushing innovation in the electricity grid, but we've never seen a more exciting time than today.

As our journey towards renewable energy accelerates, we see an enormous pick-up in market interest in our energy storage system, called TheBattery. The first section of the magazine, titled 'Store', is entirely dedicated to trends in energy storage. This section explores BMW's and Nuon's views on stationary storage and showcases recent storage project references from Alfen.

The second section, titled 'Charge', discusses the rise of e-mobility. The Netherlands has played a leading role in the roll-out of EV charging equipment, but we see a rapid pick-up in other European countries. We zoom in on Alfen's participation in the world's largest smart charging project in the UK, and see some of our customers, Allego, Eneco and Heineken, share their views on e-mobility.

In the third section, titled 'Connect', we focus on how our everyday lives are connected to the grid: our homes, industries, renewable energy sources and cars. We discuss the trend of the so-called 'Internet of Things' that is increasingly digitalising our power grid, and talk to Solarcentury on the roll-out of solar PV.

The fourth section, titled 'Transform', is dedicated to our smart grid business. The energy transition has an enormous impact on the grid. As a consequence, the role of grid operators is changing, as highlighted in interviews with Enexis, ECW and Combivliet.

We hope you will enjoy reading this magazine and look forward to continue working together on the energy grid of the future.

Warm regards,

Marco Roeleveld

Alfen magazine

Store

Charge

Connect

Transform

Store

Energy transition: investing in the big breakthrough

The energy transition from fossil fuels to renewables is already well on its way, but expected to really kick-off in the years to come. A study by Goldman Sachs, a global investment bank, describes that we are in the early days of a capex super-cycle: upgrading power distribution networks and accelerating the development of renewables.

2016-2025 incremental power distribution Capex needs of European utilities to implement the energy transition

Source: Goldman Sachs, The Power Shift, European utilities to rediscover growth on path to Low Carbon Economy, September 7, 2016

€ 145 bn additional investment needs

The energy transition process could require almost € 145 bn of additional investments for European utilities, over and above business as usual, over the coming decade. A sizable portion of this is to be spend on renewable power generation such as wind and solar. However, the majority, some € 87 bn, will have to be invested in the infrastructure to incorporate the increasing penetration of renewables and electric vehicles.

Upgrading electricity networks, storage and e-mobility

These infrastructure investments can be broken down into three categories: upgrading electricity networks, energy storage and charging infrastructure for electric vehicles.

The rising share of output from renewables and the advent of prosumers (producers/consumers, normally from solar PV) is putting an increasing level of stress on the power distribution network; this network has to deal with an increased output volatility and with generating sources that often produce power simultaneously, but at different voltages. To facilitate these developments on the grid, investments of € 62 bn are foreseen. Secondary transformer substations will have to be upgraded to absorb the output generated by renewables, self-adjust the frequency of the grid, and fit all sensors and communication devices. In addition software and smart meters will have to be installed in order to monitor the grid and consumption patterns in real time.

In order to integrate renewables in the grid some € 18 bn of energy storage would need to be developed over the next decade. Storage would be used to back up renewables, allow for daily arbitrage and grant system stability. Finally, some € 7 bn would need to be invested in charging infrastructure to ensure the incipient electrification of passenger cars.

Alfen's mission

Enormous investments in the grid are required to enable the energy transition. It is Alfen's mission to develop, produce and connect the key elements of our future electricity grid. Bringing together our areas of expertise in smart grids, energy storage systems and EV charging equipment, we seek to contribute to realising these ambitious goals. ■

Nuon and BMW on the outlook for energy storage

At the request of Nuon, Alfen and BMW installed a mega energy storage system at the Princess Alexia Windfarm in Zeewolde, the Netherlands. The system stores surplus energy so that it can be used when the grid needs it at a later moment in time. For this project, Alfen made its energy storage system compatible with BMW i3 car batteries. The system currently has a capacity of 3 megawatts, which will be expanded over time to 12 megawatts, making it the largest storage project in the Netherlands. Boudewijn Tjeertes, responsible for energy storage business development at Nuon-Vattenfall, and Søren Mohr, Head of Stationary Battery Systems at BMW, talk about their views on the future of energy storage.

An interview with Boudewijn Tjeertes (Nuon) & Søren Mohr (BMW)

NUON

Can you provide some background on how the Princess Alexia storage project was initiated?
Some two years ago I was assigned a project to research and develop a business plan for energy storage in combination with wind energy in the Netherlands. After we identified a positive business case at the Princess Alexia Windfarm in Zeewolde, I attended a symposium on the energy landscape of the future, hosted by Alfen and grid operator Alliander. At this symposium I got inspired by the level of both Alfen's technical knowledge and the development of their energy storage department, and thus identified Alfen as a strong candidate for delivering our storage system quite early on. In the meantime, our parent company Vattenfall signed a deal with BMW for the delivery of a large quantity of BMW i3 batteries. Through a joint development effort, Alfen made its storage system compatible with these batteries.

After graduating from the Maritime Institute Willem Barentsz, Boudewijn Tjeertes held several engineering and asset management roles at Nuon-Vattenfall. Currently he is Business Development Manager in the Business Area Wind, responsible for decentralised roll-out of battery storage in the Netherlands.

Why did Nuon choose to work with BMW batteries?
The primary reasons are quality and safety. BMW batteries are developed to automotive quality and safety standards. This gives us a lot of reassurance for our storage projects. An additional benefit is the liquid cooling system, which allows the batteries to be used more dynamically. Finally, car batteries are approved for transport, making it possible to provide a green alternative for diesel usage at temporary locations, such as festivals or building sites in cities. These unique characteristics give us a lot of flexibility and open up new business opportunities that we are currently in the process of further exploring.

What is the importance of energy storage for Nuon?
Storage is key in our transformation from an energy supplier to a solutions provider. Offering solutions first requires a thorough understanding of our clients´ needs. Once those are clear we need a set of products and tools to deliver the most optimal solution for the client's situation. This set of tools needs to include wind and solar energy, but storage, demand management, e-mobility and trading are also essential building blocks.

How will this storage system be used by Nuon?
The primary objective is to provide grid stability through what is called 'frequency regulation'. Small deviations in grid frequency, increasingly an issue due to more wind and solar power, can be absorbed by the energy storage system. As a further upside to the business case we also use the system, for a small part, for arbitrage activities on the imbalance market. This project served a proof of concept, both technically in combination with the BMW batteries, and commercially around the functioning of the business case in practice. Things are looking good and we are planning to scale up the storage facility to as much as 12 megawatts over time, and possibly also integrate solar PV in the system. The combination of wind, solar and storage is in line with our vision to increasingly deliver integrated, multidimensional and hybrid solutions, instead of the traditional mono-technology approach.

I expect that almost all offerings of the future will have an element of energy storage included.

The project at Princess Alexia Windfarm involves large-grid-scale storage. What is your view on smaller local use of energy storage?
Storage will play a crucial role throughout our energy system. Upstream, it will smoothen the output of large-scale renewable generation sites, such as the Princess Alexia Windfarm project. It will also do the same downstream, close to demand centres that are both consuming more electricity and increasingly producing their own energy. I have a strong belief that storage at demand centres will develop in the form of community- or street-level batteries rather than home batteries, as community storage provides several big commercial and technical advantages.

Commercially it makes more sense to share a certain storage capacity over multiple households to make optimally use of the asset. Just like data storage in the cloud, a community battery can be used as virtual storage. When you are on holidays you don't need your storage, but your neighbour may need some more. And in the event some spare capacity is available, the utility company can switch the direction of the battery from behind-the-meter services to grid services, such as imbalance trading. All this will significantly improve the business case and thus lower the cost for the community and each individual household.
On the technical side, battery storage systems are complex instruments and the connection and interaction with the electricity grid has to be managed with great care and detail. I therefore prefer these systems to be integrated on a community level in the grid rather than in individual homes. In addition to this, many households do not have the space to integrate a relatively large battery system in their homes.

What is your view on the collaboration with Alfen?
Alfen has the deep technical knowledge and experience with the power grid to develop complex systems such as battery storage systems. I personally enjoy and appreciate Alfen's flexibility and adaptiveness. Together we are looking for solutions and will adjust to new insights or market opportunities whenever needed. Alfen's local presence helps in the joint development of this market, but its flexible and quick decision making processes set it apart from some of the large companies I have worked with in the past. Just as Nuon is undergoing a transformation from a traditional utility to solution provider around the energy transition, Alfen is using its 80 year legacy to develop products and services that facilitate the power grid of the future.

BMW

> “ Today I see the market accelerating much faster than ever anticipated ”

Søren Mohr is Head of Development for Stationary Storage Systems and Battery 2nd Life at BMW Group. After graduating from Munich University in the fields of Economical Geography, Industrial Networks and Business Development, he held various positions at BMW Group, amongst others he was Project Manager for the BMW i8.

How was BMW’s stationary storage business initiated?
We started our e-mobility programme around 2008 with the MINI E when it was called ‘Project i’, before being later renamed to BMW i. Right from the beginning, sustainability was at the core of this programme. For example, for the production of the BMW i3 and i8 in our Leipzig production plant we make use of four windmills for the 100% renewable energy supply. One question around the sustainability convictions was about the optimal recycling strategy which included of course the lithium ion battery. Just purely recycling them when they might come out of the cars would be an ignorant waste of the still existing performance capabilities. We quickly understood that many applications for stationary storage, ranging from peak shaving to frequency regulation, should enable us to re-use the batteries and give them a useful second life instead of ‘just’ recycling them.

The Princess Alexia Windfarm project involved new BMW car batteries. Why is a car manufacturer participating in this market?
There are two strong parallel motivations. The first motivation is timing. In recent years we have seen three mega-trends playing to the advantage of storage: the rise of e-mobility, digitisation, and the energy transition towards renewables. As a consequence, the market for stationary storage is accelerating rapidly, although the large-scale availability of second-life batteries from our cars will only become available in a decade or so. In order to play a meaningful role in this segment, we decided that we should already start to participate and actively contribute today to the further development of this market. We do this however with the philosophy that we must remain flexible so we can swap to second-life batteries in the future. As a parallel motivation, storage supports e-mobility. We realised that, by producing our BMW i series, we are contributing to the need for new market solutions around e-mobility. Charging infrastructure has to be rolled out and, to absorb the load of electric vehicles, peak shaving will increasingly be required. Our batteries serve perfectly to stabilise the grid and cut out peaks from the charging progress. As such, we stabilise the environment for e-mobility. Hence, the technology we develop is not only helping inside the car, but also for the customer oriented technical environment outside the car.

Are there specific benefits of using car batteries for stationary energy storage?
The technology for lithium-ion battery cells has made a big leap forward thanks to the rise of e-mobility. As part of the BMW ‘Project i’ we actively participated in the development of this technology and its integration into e-mobility. We had to ensure the batteries would function under all conditions in a vehicles life while meeting our safety and quality standards. This philosophy is integral to our batteries, and thus also benefits stationary storage systems. There are some more important benefits, such as our integrated cooling system, which, in combination with our deep understanding of operational control of the batteries, allows aging optimized power supply.. Last but not least, the solid battery housing provide a big advantage over single module or cell units during installation and maintenance of the systems.

What trends do you observe in the market for stationary energy storage?
From the very start of our ‘Project i’ programme we researched the potential applications and volumes for stationary energy storage. Back then we estimated a market potential of some 200 GW in Germany by 2050, driven by the energy transition and the integration of renewables and e-mobility. Today I see the market accelerating much faster than ever anticipated. What was expected in ten years from now, we will be realising over the next two years. Battery technology is, by far, the winning technology. All other technologies are either not mature enough, too big in size, taking too long to realise permits, or not flexible enough in terms of location. Measured by the height of the Mount Everest, we are only at the first metre in the roll-out of this market. I see the market for stationary storage could become even bigger than that for e-mobility.

Can you comment on your joint innovation with Alfen?
For our joint client Nuon-Vattenfall we have closely worked together to integrate our car batteries into Alfen’s energy storage system. We could really speed up by combining Alfen’s 80 years’ experience in stationary grid systems with BMW’s deep battery-specific knowledge. Alfen managed to develop its system in only six to seven months, and as an outcome produced a very nice and compact system with some unique features, such as its liquid cooling concept and transportability. This sets a benchmark for the industry. From a broader perspective, my impression is that Alfen is working in the mainstream of innovations for the future. Some companies with a history as long as 80 years are primarily looking back at their past, whereas I have the feeling that Alfen is continuously adapting to work on the solutions for the next decades. This is what I am most interested in, and it offers bright prospects for the future.

Mega autonomous energy system for sustainable cocoa production

Alfen is constructing a large and sustainable energy installation for the Theobroma cocoa factory in Nigeria. This innovative system combines solar energy, bio energy from cocoa shells and large-scale battery storage for the sustainable production of energy and steam. It guarantees a reliable energy supply and attains a considerable saving on both operational costs and carbon emissions, including an annual saving of over a million liters of diesel.

Processing cocoa beans

Theobroma B.V., headquartered in Amsterdam and part of global sustainable commodity merchant Ecom, processes cocoa beans into high-end cocoa products for the chocolate industry. As the energy grid in Nigeria is not always reliable, their factory in Lagos currently uses diesel generators.

Diesel however, is a polluting and expensive fuel, and its local supply is not always guaranteed as well, causing expensive interruptions in the production process. Theobroma therefore opted for a sustainable alternative that guarantees the continuity and cuts the expensive operational costs.

Solar energy with battery storage

Over 8,000 solar panels will be installed on the roofs and at the factory terrain of Theobroma. To optimally use the generated electricity, Alfen combined this solar energy with its in-house developed battery storage system. With a storage capacity of approximately 2 MWh, this is the largest energy storage project in Nigeria.

In addition to the solar energy system, also bio energy is produced with the cocoa bean waste of the Theobroma factory. Theobroma is expected to save over one million liters of diesel as a result of this project.

Optimizing wind energy with storage at wind farm Giessenwind

Alfen and C-Wind have launched the first-ever project in the Netherlands that combines wind energy with an energy storage system. The storage system is located at the Giessenwind wind farm, next to the A15 highway at Giessenburg.

Grid stability

Giessenwind is one of the tallest wind farms in the Netherlands. The three turbines are each 108 meters tall and jointly provide about 5,000 households with energy. Due to the intermittent character of renewable energy sources such as wind measures must be taken to stabilise the grid, and as ever more wind energy is being produced, this stabilization is becoming increasingly important. C-Wind is a consortium of Scholt Energy Services and wind farm Giessenwind. Wim Meerkerk, owner of Giessenwind, says, "Battery storage systems are absolutely vital if we want to achieve our ambitions for renewable energy within the Dutch electricity grid."

End-to-end solution

Alfen delivered an end-to-end solution for this project, including the energy storage system of approximately 1 MWh, a transformer substation and the grid connection. Andreas Plenk, who is responsible for global sales of energy storage systems at Alfen, said, “TheBattery balances energy supply and demand and as such, it prevents significant grid infrastructure investments. The pressure on the grid is reduced, and at the same time, the generated energy can be sold at the most profitable points in time.”

Energy trading

Scholt is an energy supplier to businesses in Belgium, the Netherlands and Germany, and will initially use the storage system for energy trading. “This installation provides a sustainable basis for the future and can easily be expanded when necessary. We are also looking at other locations and applications such as local grid stability,” said Sander Drissen, Director Innovation at Scholt Energy Services. Wim Meerkerk says: “We started with wind energy in 1999 and are continuously looking for new innovations. Thanks to this project with Alfen and Scholt we are again playing at the forefront of the energy market.” ■

Stedin and MisterGreen on combining fast charging and energy storage

In 2016, Alfen, Stedin and MisterGreen jointly launched a charging station for electric vehicles equipped with solar panels and a battery energy storage. All three partners judged this pilot to be a success: peak loads decreased, it achieved maximum flexibility in offering variable price rates, and the charging station itself became even more sustainable.

The number of electric vehicles is growing fast, creating a need for more charging stations. In 2013, MisterGreen built the rapid charging station 'Haarrijn' on the A2 highway between Amsterdam and Utrecht. Three years later, a pilot project of Alfen, Stedin and MisterGreen started, with the aim of providing sustainably generated energy, at low cost to the users. In the pilot project, the solar panels provide part of the energy required for charging cars. If no vehicles are connected, the generated energy is diverted into the energy storage system, to be used at a later time when electric vehicles connect to charge. This enables maximum usage of sustainably generated energy. And if the system of solar panels and battery storage runs out of energy, it can fall back on the central power grid. Part of the motivation for joining the project for Stedin was lessening the burden of fast chargers on the grid.

"Stedin needs to take a serious look at fast chargers because they require such a huge amount of energy from the grid. As they're often situated at remote locations, we may need to make major investments from our side to upgrade the grid. Creating flexibility through battery storage or Vehicle-to-Grid solutions can prevent these issues." said David Peters, Director of Strategy & Innovation at grid operator Stedin, at the start of the pilot. Reflecting on the project a year later, he says: "Daily practice tends to be more complex than theoretical plans, but that was not the case here. As vehicle charging processes were not constantly relying on our central grid, peak loads on our cables reduced, which has prolonged their lifetimes. It also taught us how to cope with peak loads on our grid for this specific application, which is highly valuable knowledge for the energy transition. We can now turn these lessons into cost reductions, and offer lower prices to our customers".

The project also proved to be a success for MisterGreen: "This pilot offered us many useful insights about energy storage, both in terms of its practical application and its influence on the central grid. Our ultimate objective is to offer electric vehicle users flexible rates. Combining solar panels with local energy storage provides maximum flexibility to do that. Wouldn't it be great if we can offer our users lower rates whenever there's more wind or sunshine?" said Mark Schreurs, one of the founders of MisterGreen.

Richard Jongsma, Commercial Director at Alfen, added: "It's great to see how our energy storage system contributed to making this station more sustainable and optimally utilise its assets, by using every last bit of locally generated solar energy to charge electric vehicles."

Charge

Electric Nation: the largest smart charging project in the world

Towards the end of 2016, Alfen was selected to supply its intelligent electric vehicle charging stations to the Electric Nation project in the UK. Electric Nation, the largest smart charging project in the world, was set up by Western Power Distribution, the electricity network operator in the UK.

The general objective of the Electric Nation project is to allow the numbers of electric vehicles (EVs) in the UK to increase, whilst avoiding the cost and disruption involved in upgrading local electricity infrastructure. Its goals are threefold: 1) expand current understanding of the impact on electricity distribution networks of charging a diverse range of plug-in electric vehicles at home, 2) build a better understanding of how vehicle usage affects charging behaviour given diversity of charging rate and battery size, and 3) evaluate the reliability and acceptability to owners of EVs of demand control services and the influence these have on charging behaviour.

Electric Nation is revolutionising domestic plug-in vehicle charging by engaging between 500-700 plug-in vehicle drivers in trials. The project seeks to provide an alternative for necessary upgrades on the electricity grid as the penetration of EVs increases. When 40% to 70% of households use EVs, at least 32% of the networks across Britain will require intervention. Intervention using smart technology, rather than digging up the roads to install new cables, has been predicted to give an economic saving of around £2.2 billion by 2050.

The results of this project will be of interest and will be communicated to the energy community, to UK government, to the automotive and plug-in vehicle infrastructure industry and to the general public.

Alex Earl, Alfen UK Country Manager, says: “We are very happy with the progress that has been made with the Electric Nation project. Alfen has over 8 years’ experience of building reliable, intelligent charge points for electric vehicles, including working with energy companies to ensure available power capacity can be optimised for EV charging, so we are pleased to bring our experience to bear on such an innovative project.”

Electric Nation is the customer-facing brand of CarConnect, a Western Power Distribution (WPD) and Network Innovation Allowance funded project. WPD’s collaboration partners in the project are EA Technology, DriveElectric, Lucy Electric GridKey and TRL. ■

HEINEKEN, brewing a better world

Some 150 years ago HEINEKEN started as a micro brewer in the Netherlands. Today, 25 million Heineken beers are served each day throughout 192 countries. Since 2010, HEINEKEN runs the ‘Brewing a Better World’ program, entailing six priority areas: promoting health and safety, protecting water resources, reducing CO2 emissions, sourcing sustainably, advocating responsible consumption and growing with communities. As part of these programs, Alfen is supplying its EV charging equipment to HEINEKEN Netherlands. In an interview with Esther Kruiper, Sustainability Manager at HEINEKEN Netherlands, we discuss HEINEKEN’s sustainability agenda.

An interview with Esther Kruiper, Sustainability Manager HEINEKEN

Esther Kruiper is Sustainability Manager at HEINEKEN Netherlands, where she implements the HEINEKEN sustainability program 'Brewing a Better World' in the Dutch operating company of HEINEKEN. Esther has a Master degree in Human Nutrition & Health and has developed a passion for sustainable development within the food sector. Before her role in HEINEKEN Netherlands, Esther has worked in various sustainability, project management, product development and regulatory roles within amongst others Douwe Egberts.

Can you describe the key elements of HEINEKEN's sustainability program?
Three of the focus areas from our 'Brewing a Better World' program are climate related. We protect our water resources and we try to use as little water as possible to brew beer. We also want to reduce our CO2 emissions as much as possible. In 2016, we generated 18% of our energy demand from wind, solar and biomass sources. In addition, as pressure on the world's resources grows, we want to guarantee a long-term, sustainable supply of quality raw materials. Therefore, we work with our suppliers on responsible agriculture and purchase more and more sustainable ingredients. At HEINEKEN Netherlands we already buy 100% of our barley and hops from sustainable agriculture.

What is your ambition for the future?
Regarding climate it is our ambition to make our breweries and logistics in The Netherlands climate neutral. For the breweries we need to green both our electricity and thermal energy. Next to our five wind turbines and 12.000 solar panels, we generate biogas from the waste water from the brewery.

To increase the amount of renewable energy we are working on new projects. For example, we realized a 2.2 km pipeline from a nearby municipality wastewater purification plant, which will deliver us 4.7 million m3 biogas per year once fully operational. We have plans to realize another four wind turbines close to our brewery in Den Bosch, and there are ideas to develop another 16.000 solar panels on the rooftops of our brewery and logistic buildings.

What does HEINEKEN do to reduce its CO2 emissions in transport?
HEINEKEN Netherlands has been working on CO2 reduction in logistics for many years. Before 2010, we mainly focused on efficiency improvement. During the past five years we have made some large steps in CO2 reduction through modality shifts. We already reduced 8.000 tons of CO2 by replacing 90.000 truck rides between our brewery and the port of Rotterdam with ships. Today, all incoming barley and finished product for export outside Europe is transported by ship. A new chapter in the reduction of CO2 emissions from transport has just been opened. We recently announced our intentions to develop a 'Green Corridor'. This is a multi-stakeholder initiative to make the water route from our brewery in Zoeterwoude to the ports of Rotterdam climate neutral. In light of this ambition we have just started a bio-fuel pilot with GoodFuels and Nedcargo, reducing the CO2 emissions with 25%. Additionally, we support Nedcargo with the development of a new hydrodynamic ship which can transport 52 instead of 42 full beer containers. This new generation ship is installed with an electromotor and technically prepared for electric drive.

Furthermore, we have nine electric trucks driving in Amsterdam and Rotterdam for delivery to our off-trade customers. Apart from the CO2 reduction, this also results a better air quality and less noise nuisance.

> "We welcome the use of electric cars and we want to facilitate this change"

HEINEKEN is working with Alfen charging equipment. Can you talk about where you place these chargers and with what philosophy?
Of course we welcome the use of electric cars and we want to facilitate this change. Both our employees and our guests make use of this charging equipment. We believe a good host needs to offer charging equipment to its guest. Today, HEINEKEN Netherlands has installed over 20 electric car charging points at various HEINEKEN locations throughout the Netherlands. Once the demand is rising above availability, we will increase the number of charge points. Our guests and employees are rewarded for driving an electric car, as the parking spots are right next to the entrance! ■

Eneco, accelerating happiness in e-Mobility

‘Accelerating happiness in e-Mobility’ is Eneco’s mission for its e-mobility business. It views electric vehicles as an important node between the electricity grid and the home. For more than four years Alfen has been supplying Eneco with its smart charging equipment.

A historical perspective

A picture taken in 1900 on 5th avenue in New York shows us a street filled with horses and carriages. Only 15 years later the same street was filled with the first automobiles and horses were the exception. “This is how fast things can develop”, explains Dennis Klinker, Manager Electric Charging at Eneco. “Today we are at an important turning point in the market for electric vehicles. Until recently owners of electric vehicles were so-called ‘innovators’ or driven by fiscal stimuli. This has brought us to over 100,000 EV’s in the Netherlands today. The end of 2017 marks the start of a wider roll-out of EV’s, driven by the availability of lower priced models, larger radius and increasingly competitive economics of EV’s versus traditional cars.”

Everyone’s sustainable energy

“The energy transition is also a mobility transition”, continues Dennis Klinker. “An increasing demand for renewable energy triggered us to develop new services around flexibility, digitisation of homes and energy storage. I see the charging of electric vehicles as a key node between the home and the power grid. Together with Alfen we started a pilot to enable the connectivity of the charger with homes via our metering and data management device ‘Toon’. In the direction of the grid smart charging and vehicle-to-grid services help to smoothen out peaks and throughs in renewable energy output.”

Innovations

Eneco is currently working on multiple innovations that further integrate the car in both our homes and the power grid. Through Eneco´s Jedlix application users receive a kick-back payment if they allow the application to manage their charging process over time. For business users Eneco developed a Chargemanager dashboard with a Charge & Share functionality, allowing multiple users to easily share a charging station. Dennis Klinker concludes: “Eneco wants to play an active role in accelerating the energy transition. Providing smart solutions around e-mobility will be the enabler to facilitate a large scale roll-out of EVs. I am convinced that the transition from fossil fuel cars towards EV’s will go even faster than that from horses to automobiles a century ago!” ■

Allego’s EV charging ambitions

Allego, a Dutch EV Charge Point Operator, is installing and operating charge points for all types of electric vehicles across Europe. In an interview with CEO Anja van Niersen, we talk about the future of e-mobility, Allego’s ambitions and the implications for our electricity grids.

An interview with Anja van Niersen, CEO Allego

Anja van Niersen has worked in the field of energy since 2010. Experienced in the field of product development, -management and IT she felt right at home in the upcoming innovative world of electric mobility. Building Allego since the start as CEO, she is accelerating e-mobility at this international charge point operator since 2013. At Allego Anja and her colleagues work for municipalities, businesses and transport companies to enable zero emission mobility for a sustainable world.

What is the vision of Allego?
Together with our partners we are working towards a world where everyone with an electric car can charge their vehicle wherever and whenever they want. We install and operate user-friendly and future-proof charge points for electric vehicles on behalf of municipalities, businesses and public transport companies. We seek to do this in a smart and intelligent way, always taking the impact on the electricity grid into account. We also operate charging infrastructure for other types of e-mobility like: taxi fleets, electric buses and an electric tourist boat in the canals of Amsterdam. At the moment we are operational in the Netherlands, Belgium and Germany, but we have ambitions for the whole of Europe. In fact, this summer we announced a cooperation with Shell in the UK, offering fast charging at designated Shell stations.

What is your connection with Alfen?
I feel that we share the belief that e-mobility is a large and complex market that has to be facilitated collectively, based on partnerships. Where Allego excels in knowledge and experience around e-mobility and services, Alfen brings in the deep technical knowledge and innovation power required to succeed. A successful large scale roll-out of charging points requires both. Through this partnership we are well set up to provide our products and services with the quality standards that our clients expect, at the most affordable price possible.

Can you talk about Allego’s so-called ‘Open Market Model’ proposition for municipalities?
The objective of the open market model is to ensure that everybody with an electric vehicle can have access to a charging point in their neighbourhood. The majority of the Dutch households do not have their own private parking space and are thus dependent on public charging infrastructure. The open market model aims to bring together the municipality’s and Allego’s strengths. The municipality’s key responsibilities are providing the required public space and arranging permits, while Allego focusses on installing and operating the charging infrastructure, facilitating customer interaction and offering service. Through this joint approach we can offer every resident in the Netherlands, via the website www.openbaarladen.nl, hassle-free access to a charger close to home.

What is the scalability of this approach?
In the Netherlands we have already rolled out about 4,000 public charging points using this model. Currently we are also replicating this model in other countries. We just went live in Germany. The challenge there is to work with the more than 800 local Stadtwerke and tailor to their individual demands and local boundary conditions. Next to the open market model we also work with other propositions, such as destination charging at places such as hotels, charging infrastructure and services for busses and smart charging and load balancing.

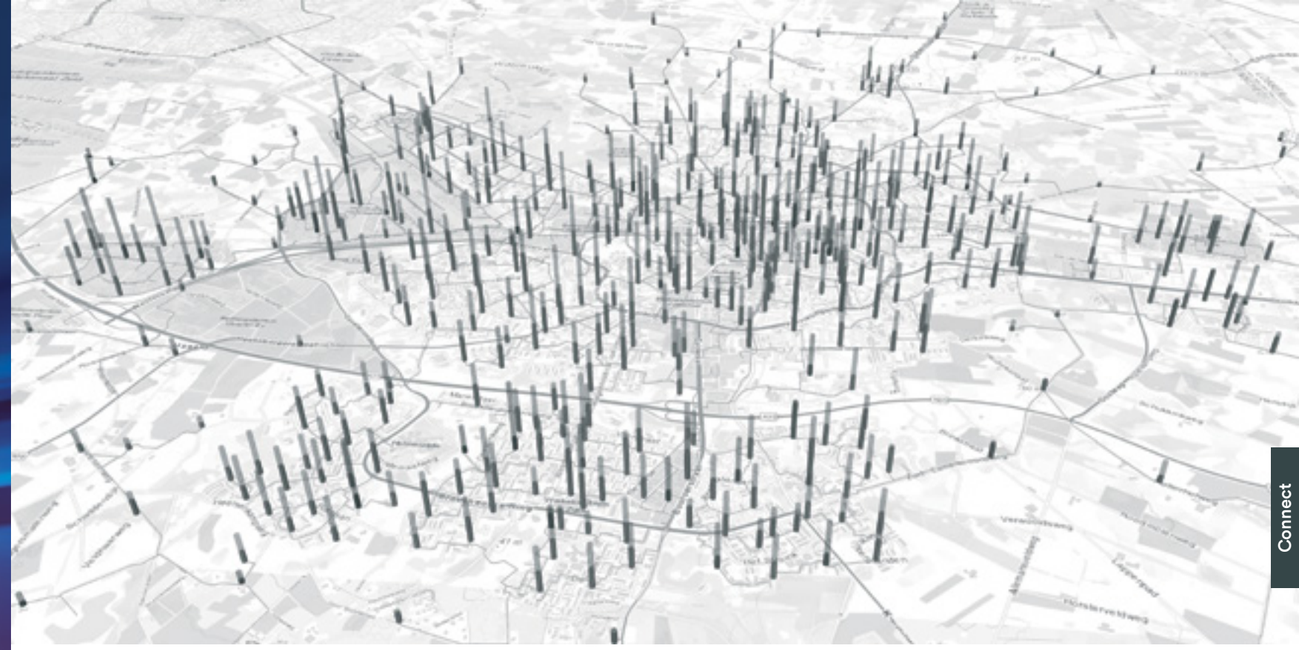
What do you see as key challenges in the roll-out of charging points?
It’s all about locations and sizing. Being successful requires foresight into which locations need to be developed for charging infrastructure, and getting contracts with the owners of those locations. The second question is how to develop these locations. What type of infrastructure is most optimal? In what quantity? What product, for example a Charging Plaza or a Fast Charger, should we deploy? Or are there already charge points but is there a big need for an advanced charge point management system? And what is the impact on the existing electricity infrastructure? Questions we ask ourselves every day.

In your opinion, what is needed to integrate large-scale e-mobility in our grids?
At many locations in the Netherlands the power grid is quite stable and very capable of incorporating a sizable number of electric vehicles. With our Charging Plaza solution we are already minimising the impact on the grid by managing the power distributed to each of the connected cars. In this way, we can often integrate a significant number of chargers in the current grids. Having said that, the locations where we want to install our chargers are not always fit for the integration of e-mobility on a large scale. Remote areas along highways or some foreign countries in particular face bottlenecks in their power grid infrastructure. As a consequence, we either have to upgrade the grid connection or balance supply and demand with storage. We are currently working on both, bearing in mind that storage does require valuable space that we could have otherwise used for placing more chargers. In all cases we have to realize that we are only at the very start of our journey towards full e-mobility. The key to success will be a joint approach of market players in close coordination with regulators on a European level. ■


Connect

Connecting the grid to the Internet of Things

The Internet of Things (IoT) refers to interconnected physical devices equipped with sensors that can collect and exchange data. Well-known examples include thermostats and cars that can be monitored and controlled remotely. IoT is a must for the energy transition, as the ability to gather data from machinery and devices in a network and to remotely control and monitor them enables the power grid to continue to run smoothly. In this article, we look at how Alfen's products are furthering the energy transition with the Internet of Things.



Substation automation

The energy transition means power flows are changing. Being able to gather data about these flows allows grid operators to monitor effects on the grid, anticipate potential bottlenecks, and respond to them in advance. Constant measuring in transformer substations of variables such as temperature and power quality enables operators to conduct preventative maintenance, and, in the event of unexpected outages, localise and address issues as soon as possible. Moreover, having immediate insights into instantaneous loads at different nodes within the electricity grid is a precondition for many smart grid developments. For industrial customers, the automation of substations also plays an important role. Continuous insights into the performance of transformers allow for improved service levels, and real-time monitoring. For example, temperature and fire-detection are features that insurance companies find increasingly important.

Electric vehicles

In contrast to traditional cars, electric vehicles behave and interact more like domestic appliances. Charging equipment connects EVs directly to smart meters so that energy use can be monitored closely, and so that grid connections are used optimally. Online monitoring platforms allow users to view and influence the charging process, wherever they are. Finally, thanks to 'smart charging', the power supply to different EVs within a street, parking area or even entire city can be optimised in such a way that all cars are fully charged when needed while minimising disturbances on the grid.

Virtual power plants

A third type of IoT in our energy landscape has recently been gaining a lot of traction: virtual power plants. These are local energy storage systems that can be used in residential areas. Just like software cloud services, virtual power plants aggregate the storage demand from multiple households in such a way that these households can locally store their solar PV energy without having to install batteries in their homes, which currently represent a large investment.

By locally or regionally sharing energy generation and consumption, a large proportion of the mismatches between supply and demand are levelled out. Residential virtual power plants are certainly a promising development. ■

Connecting the sun

Nearly 5 GW of additional solar PV capacity is expected to come online in the Netherlands over the next five years. Alfen's latest innovations in the field of substations provide unique solutions for connecting solar farms, saving money on grid connections and reducing energy losses.

Connecting our homes

Millions of homes are supplied with energy through substations developed and produced by Alfen. As more and more of our energy is locally generated and renewable, substations need to be upgraded and automated to facilitate changing loads and energy flows. Energy storage will also play an increasingly important role in balancing local grids.

Connecting the wind

Wind farms not only need to be connected to the power grid, their fluctuating energy output also needs to be balanced out to guarantee grid stability. Alfen's unique combination of energy storage systems, transformer substations and local smart grids play an ever-more important role in facilitating the roll-out of wind energy.

Connecting our food

In greenhouses for horticulture, the automation of operations, expansion and the use of renewables play an important role. Alfen's substations, CHP connection boxes and smart grids have been used for decades in this sector, and are currently facilitating the automation and remote control of energy operations.

Connecting mobility

Transformer substations are not only used for powering our homes and industries. Alfen also delivers the infrastructure to supply energy to Dutch Navy ships, such as the Joint Support Ship Karel Doorman, while they are docked in the harbour of Den Helder.

Solarcentury are rolling out solar PV in the Benelux

An interview with Dennis de Jong, Director Solarcentury Benelux

With more than 750 MWp solar PV (photovoltaic) capacity deployed across more than 100 sites and 25,000 homes, Solarcentury is amongst the most advanced players in the field of solar PV. In fact, it was recently recognised as the fastest growing renewable energy company in the UK. Alfen supported Solarcentury in the grid connection of the Ameland and Hengelo solar farms. In an interview with Dennis de Jong, Director Solarcentury Benelux, we discuss the outlook for solar PV in the Benelux.

Blackfriars bridge in London – the world's largest solar bridge

Dennis de Jong is managing director of Solarcentury Benelux B.V., one of the biggest solar developers in the Netherlands. Prior to joining Solarcentury in 2012 Dennis worked for several European solar and renewable energy companies in commercial and general management roles. Before joining the renewables industry Dennis was a global head of procurement at ABN AMRO and worked at Fokker Aircraft in sales financing and marketing and sales. Dennis holds a bachelor's degree in aeronautical engineering, a French DESS degree in air transport management and law and an MBA. He is also a board member of the Dutch Solar Association.

Can you describe how Solarcentury started and what your business model is today?
Solarcentury was established in 1998 by Jeremy Leggett. Being concerned about global warming, Jeremy initially joined Greenpeace in 1989. After almost a decade as a climate campaigner, he wanted to make a more tangible impact, so he founded Solarcentury to increase penetration and usage of solar PV. Today, Solarcentury is present in nine countries, and is active in development, EPC contracting and solar PV operations. Our business covers both large PV farms (that we develop ourselves) as well as smaller-scale rooftop solar for commercial and residential applications, some of which are through a partnership with IKEA. In the Benelux we currently employ some 20 people.

Solarcentury is actively supporting a charity around solar. Can you describe what you are doing in this field?
When Jeremy Leggett set up Solarcentury he wanted the company to be different from others: to do business with a social conscience and be innovative in using solar for social good. One of our first decisions was to establish SolarAid and pledge 5% of our annual profit to its work. SolarAid's goal is to eradicate the brutally expensive kerosene lamp from Africa by 2020, by getting affordable solar lamps into remote rural regions. As an example, after having built East Africa's largest solar farm on a tea plantation, we donated individual solar systems to the employees who live on the tea plantation there without grid electricity, allowing them to charge their devices during day and have light after dark.

Is solar PV still dependent on government support? How do you cope with changing policies around renewables?
Solar PV is increasingly reaching grid parity at many locations, meaning it can compete with other forms of energy without subsidies. Nevertheless, even in the case of grid parity, government policies have an enormous impact on our business — for example, by making land available for the roll-out of solar farms. We have offices in nine countries, ranging from Europe to South America and Africa, and projects in even more countries. This helps us to mitigate the risk of changing national policies. Our presence in both solar farms and rooftop solar, typically driven by different incentive schemes, also helps to mitigate these risks.

What is your outlook for solar PV in the Netherlands, and the importance of large versus small scale systems?
Currently we are experiencing an enormous boom in the Netherlands. This is partly driven by government subsidy schemes. In these initial stages we see large solar farms functioning as an accelerator for the sector. Eventually I expect the largest potential to come from rooftop solar, given the sheer amount of roof space available. In terms of size, growing to an installed base of 20 GW in the Netherlands is absolutely realistic. This is more than the current capacity of gas fired power plants in the country. So far we have realised two large projects in the Netherlands: one 6 MW project in Ameland and a 3 MW project in Hengelo. We currently have over 100 MW of ground mount projects in development, including several very large ones.

What are key factors for success in your business?
Scale is of absolute importance, and is one of our key assets. It gives us buying power, but more importantly, it supports the financing of our capital-intensive business. In addition, time-to-market can be a decisive factor in a project's success. In the UK we built up experience in realising projects of almost 50 MW within just a few months, with the timeline driven by subsidy deadlines. This was achieved by a seamless cooperation between the engineering department, mobilisation of our supply base, and project execution. We are now applying this experience in our projects in the Netherlands, where Alfen has been supporting us in supplying its substations and realising grid connections.

Can you say something about the cooperation between Solarcentury and Alfen?
I experience a very similar DNA at Alfen and Solarcentury, which helps us to do business together. We are jointly developing innovative new concepts that support our business cases. In our projects Alfen has demonstrated to be effective in its project execution and supportive through its wide service network. We have the feeling that Alfen, through its broad product offering around the power grid, will be able to support us for the long haul. In particular, its storage system may play an important role in balancing the intermittent output of solar. I absolute expect the term 'grid parity' to be redefined by the consequences of energy storage in the near future. ■

Transform

How grid operators are pushing the energy transition

After 14 years as director of asset management at Enexis, Jan Peters is now responsible for accelerating the energy transition on behalf of Enexis among other duties. In an interview he reflects on the role of grid operators in our journey towards a carbon neutral society. Alfen has been a longstanding partner for Enexis in achieving these goals through joint development and knowledge sharing.

An interview with Jan Peters, Vice President of Public Affairs and Principal Stakeholder Engagement at Enexis

After his physics studies at the Technical University of Eindhoven, Jan Peters worked eight years as development pioneer in Rwanda, establishing a micro hydro power station and a distribution grid. After several roles at KEMA, Essent and Enexis, amongst which 14 years as Director Asset Management, he is currently Vice President of Public Affairs responsible for the engagement of the Enexis stakeholders in the energy transition. Jan Peters sits in the Boards of the Foundation E-Laad.nl and EDSO (European DSO Association).

Can you describe what your current role involves?
I work with provinces, municipalities, housing corporations and energy cooperation's to address how we can reach a carbon-neutral society by 2050. On the supply side, key questions are whether enough renewably energy can be generated and how much can be generated locally and how much can be imported from other areas. When there's a desire to produce locally, the immediate challenge is urban and rural planning. On the demand side, we address questions around the reduction and management of energy usage. My role is to coordinate these processes and form coalitions between all parties involved. For Enexis, it's beneficial to be involved in early planning stages, as it enables us to optimise our investments in the electricity, gas and heat infrastructure.

Can you give an example of how this works in practice?
Recently Enexis was approached by a region where multiple individual wind energy initiatives were deployed. Although these initiatives were individually optimised, and there was lots of enthusiasm and energy around each of them, collectively they did not result in the most beneficial situation for society as a whole. Amongst other issues, the scattered roll-out of wind turbines would have had enormous negative implications for the electricity grid. This is where we got involved. We grouped together all local initiatives in order to minimise the impact on the grid, and by doing so, we also ensured that the wind turbines were better assimilated into the landscape.

What do you see as the key differences between what a grid operator did five years ago and what they do today?
In the day-to-day operations and execution there are not so many differences. However, in terms of our ambition and outlook for the near future, we are undergoing an enormous paradigm shift. Traditionally, we followed demands from the users of the electricity and natural gas grid. Today, we have to increasingly play a facilitating and coordinating role to connect the multitude of large central and small-scale local initiatives related to energy.

"In terms of our ambition and outlook for the near future, we are undergoing an enormous paradigm shift"

What do grid companies need to do to anticipate that changing role?
With the multitude of local energy initiatives, the centralised way in which we have worked historically no longer meets the demands from today's society. Increasingly, we have to work on tailormade solutions in close cooperation with local communities. Every municipality has its own boundary conditions and level of ambition, be it wind energy, e-mobility, storage, use of biogas, biomass or geothermic heat or demand management. Managing and facilitating this variety in initiatives not only requires grid operators to play new roles, but it also brings us much closer to achieving impact and accelerating the energy transition. Also, as our customers are accustomed to modern consumer oriented webshops and services, we need to take a more client-centric approach in our services. Applying for a new grid connection should be as easy as booking an online holiday. We are working hard to live up to that promise!

What are the key challenges for reaching a carbon-neutral society by 2050?
In terms of generation, it's clear that we have to continue to invest in large-scale wind and solar energy. The biggest challenge I foresee is the energy use in the industrial sector, which is responsible for a large portion of our CO_2 emissions. It is the most difficult sector to initiate change, due the way in which it operates across a global playing field. To fully replace fossil fuels in all industrial processes isn't possible yet; we need new technological breakthroughs to realise that. At the other end of the scale, realising change with consumers is also a challenge. Subsidies and incentive schemes help, but they typically end up in the pockets of relatively wealthy early adopters. Mobilising the masses is more difficult.

The easiest goal to achieve will be the transition towards electric vehicles. People doesn't consider business cases in purchasing cars and, just as with their mobile phones, they're often more interested in a car's appearance than in the details of the business case.

Electrification of energy demand, more renewables and decentralisation of energy generation: what are the implications of these trends for the power grid?
We will have to invest both in our electricity grids as in new grids for gas and heat transport to incorporate these trends. Storage will also play an increasingly important role. Short-term imbalances between supply and demand have to be absorbed, but longer-term seasonal fluctuations should be met by seasonal heat or new gas storage systems. In addition, big data will play a more important role in our operations. We are already rolling out smart metering and network sensoring and are starting to collect valuable data. We see enormous potential in using insights from that data to shape the grid, and doing so will help us to anticipate the needs of the electricity grid in the future. We value longstanding partners such as Alfen that are continuously working on these kind of innovations supporting the key trends in the energy transition. Sharing knowledge and partnerships are the key to success. ■

Innovative energy in greenhouse horticulture

Energy Combination Wieringermeer (ECW) is an energy company and private grid operator serving the Argriport A7 location in the province of North Holland, where over 400 hectares of greenhouse horticulture is situated. Its mission is to optimally facilitate renewable energy supply for the region. CombiVliet is a family company, producing about 70 million kilos tomatoes per year, amongst others in the Agriport area. Together with Alfen, ECW and CombiVliet are investing in smart grids to facilitate expansions and integrate more renewables on the grid. We spoke with Robert Kielstra, co-founder and CEO of ECW, and Roy van Vliet, location manager of CombiVliet Middenmeer, about innovative energy in the greenhouse horticulture sector.

An interview with Robert Kielstra & Roy van Vliet

Since 2010, Roy van Vliet is responsible for NoordVliet, one of the three locations of tomato producer CombiVliet. Prior to this role, he studied business economics and agribusiness and worked at other CombiVliaet locations where he was involved in the cultivation process and multiple expansion projects.

After his studies Business Agriculture (Hall Institute) and Business Administration (University of Groningen), Robert Kielstra joined the project developer Agriport A7 B.V. He spent three years working on environmental impact assessments, zoning plans, permits and energy. In 2006, on behalf of the joint greenhouse owners, he founded the company ECW and in 2008 a comparable company at Thanet Earth in the UK. Currently he is, together with his team, expanding ECW to a full service energy company for the Agriport area and is exploring the opportunities beyond.

How CombiVliet and ECW are connected

CombiVliet was founded in the mid 1950´s and over the years expanded to multiple locations, where five types of tomatoes are cultivated: cherry tomatoes, snack tomatoes, cocktail tomatoes, big tomatoes on the vine and medium tomatoes on the vine. Their largest location is NoordVliet Middenmeer, in the centre of the ECW Agriport area. At this location, CombiVliet is currently working on phase five of its eight-steps expansion plan. Roy van Vliet explains: “Each phase adds about 12 hectares of greenhouses to our facilities. We expect phase 8 to be completed by 2020. One of the big advantages of this area is the local energy infrastructure that is facilitated by ECW.”

Robert Kielstra talks about the start of ECW: “ECW was born out of necessity. In the years following the liberalisation of the energy markets, the traditional grid operators were not able to respond quickly enough to the increasing energy needs and grid connections that the greenhouse sector was asking for. Back then it was decided to establish an own energy company and develop an own energy grid.” Van Vliet adds: “Being both customer and shareholder of ECW ensures that decisions are always taking into account the needs of our sector. This gives us a lot of comfort to invest in this location.”

Smart grids at the centre of energy system

ECW is active in all elements that are crucial for the Agriport area: electricity, natural gas, heat, CO_2, water and data. One of the key challenges is to provide flexibility in this extensive and complex energy system. ECW operates an advanced trading system that optimises energy supply from multiple sources. Kielstra: “We work with a multi-resource smart grid that optimises heat, power and CO_2 supply for our customers. We therefore invest heavily in ICT and automation.” Also on the demand side the system is being optimised. “We recently connected a large-scale data centre in our Agriport location. With its different energy consumption patterns, this provides a nice synergy with the greenhouses in the area”, continues Kielstra. “Buffering also occurs in the form of demand management. The lights in the greenhouses can be tuned up or down when needed with acceptable effects on the crops that are cultivated. In a way, tomatoes serve as a large battery providing flexibility to our National electricity system.”

Innovative themes in greenhouse horticulture

Several trends can be distinguished in the greenhouse horticulture sector. Automation, increasing scale and year-round production have become the standard. Van Vliet explains: “Continuous innovation allows us to harvest tomatoes throughout the year. Also consumption patterns are changing: we see an increasing demand for tomatoes as a snack, which adds to the overall demand for tomatoes.”

Renewable energy supply is another important theme in the sector. ECW is active in large scale geothermal projects, transporting the heat from 2,500 meters underground to the greenhouses. Alfen is facilitating the grid connection for these projects. “We currently have two systems operational and are finalizing one more. Each system substitutes about 12 million cubic meters of natural gas. This scale is unique for the Netherlands and is amongst the largest geothermal projects in Europe”, explains Kielstra. Next to the geothermal energy the area is also supplied by a local wind turbine.

Growing together

Van Vliet talks about the vision of his company: “Apart from good products and a good strategy, it is primarily the people and their passion that form the heart of this organisation. ‘Growing together’ is such an integral part of our business we have made it part of our company logo. Also our partnership with Alfen is part of this philosophy: we are experts in and passionate about growing tomatoes, whereas Alfen is providing its expertise around the energy grid to offer us a reliable basis for our business.” Kielstra adds: “The complexity of our local energy system requires an extremely robust and reliable power grid. We see Alfen as a reliable partner that has worked with us from the very start.” ■

How Alfen is prepared for changing markets

At Alfen we continuously monitor key market trends evolving requirements from our broad customer base. We anticipate these changes before they happen by adjusting our ways of working and our organisation, and by leveraging our constant focus on product innovation. In this article we discuss three trends we recently addressed in our organization.

Shorter delivery times combined with more product customisation

A few years ago we started to experience increasing demand for shorter lead times, as well as demand for increased product specific requirements. We started a project to reconfigure the Alfen production facilities to accommodate for both of these needs. The outcome of that project was to introduce an automated flow production based on lean principles, which is very unique for this industry, to succeed the traditional batch production.

“Loading and moving multiple products of up to 15 tons on a roller conveyer required many innovative solutions. Now that we are fully operational with this new production method we are starting to reap the first benefits,” says Anne van der Werf, production manager at Alfen. “Our clients benefit from standardisation with shorter lead times and consistent quality. In addition, and this comes as a surprise for many of our customers, this production method also allows for more product-specific adjustments at the same time. So we managed to realise a double win for our clients”.

Marco Roeleveld, managing director at Alfen, adds: “In addition to the immediate benefits for our customers, this production method enables us to produce roughly double quantities in the same facilities, positioning us well for the anticipated market growth.”

Focus on circular economy and reduction of footprint

The footprint of our products during their lifetime also plays an important role and is of increasing importance for our customers. To address this, we work with a detailed break-down of product components and assess our products’ impact throughout the supply chain based on five criteria: sustainable design, fair materials, working conditions, cooperation throughout the chain and second-life applications and recycling. “We increasingly work with our clients and suppliers to implement footprint analyses and supply chain approaches for our products,” says Bas Bor, manager of CSR at Alfen. “In this way we simultaneously improve the footprint of our operations and products and maximise the (re-)use of materials”.

Shift towards complex integrated solutions

Increasingly, challenges related to the energy transition require a multidimensional solution that covers more than just one product or service. For example, combining multiple public chargers for electric vehicles may require an extension of the grid connection or load balancing through energy storage. Alfen’s broad product portfolio is uniquely qualified to supply these integrated solutions.

In order to also fully align our operations with this trend, we recently relocated our charging equipment business to new premises next to our existing production facilities for substations and energy storage systems. At the same time, we brought our charging equipment business line, formally branded as ICU, under the Alfen brand.

“We distinguish ourselves with smart and interconnected charging equipment. Next to providing state-of-the-art products for individual customers, our chargers are increasingly combined with other Alfen products to deliver innovative solutions on the grid,” says Wouter de Ridder, manager charging equipment at Alfen. “The relocation of our facilities and the joint branding help us to further develop these concepts.” ■

Colophon

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