Endless stream of data

**WIND MEASURING**

**ROTOR BLADES**
The final resting place

**DRIVE TRAIN**
Magic potions for metal surfaces

**DENMARK**
Pioneer to host EWEA Offshore
Amongst biologists, who study material and energy flows of ecosystems, there is the theory that systems under comparable framework conditions are more stable the more complex they are. The more players there are, and the more diverse their functions and activities, the higher the probability becomes that the system can stabilise itself through direct and indirect feedback mechanisms. No control centre is necessary here to maintain the status quo, no defined target values and no central control – and yet it functions anyway.

The “ecosystem” of power generators, distributors and consumers, however, has been centrally managed to the greatest possible extent – at least since electricity and gas grids were introduced – and is relatively simply designed. At one end are a mass of consumers who do not have to pay any attention at all to the stability of the system when taking power from the grid, and at the other end of the line are large centralised control centres which manage the power generation and distribution.

With a growing share of wind and solar electricity in electricity generation and increasing decentralisation, the task of the control centres is becoming more complex. That is the status quo right now. Approaches to still keep the supply of energy stable are currently being hotly discussed. One concept favoured by many players is capacity markets. There is no doubt that they are technically feasible, but their economic viability and their effects on electricity prices are being intensely debated.

Maybe it would help to take a look at the current discussion from an “ecosystem perspective”. Capacity markets would then be concepts which transfer the working mechanisms of simply structured systems over to systems with a multitude of players but the same low number of regulatory mechanisms. This may well work, but considering what has been said above, may not necessarily lead to the most stable solution and the condition with optimised functions.

A European electricity grid is – under the keyword of stronger connections – more future-oriented here. But what about the many decentralised generators? Don’t they still need a central control centre? No, say scientists at the Max Planck Institute for Dynamics and Self-Organization. Things would be much better with intelligent electricity meters which can decentrally and under self-organisation match demand with the electricity supply.

The surprising findings of the systems researchers: such completely decentralised “smart meters”, working without control signals from the power supplier, would indeed be perfectly able to autonomously react to frequency changes in the grid and control the electricity consumption of the appliances attached to them on their own. Until now this was thought to be impossible, as many units have a sluggish response time to short-term frequency changes on the grid. The researchers were able to show, however, that small oscillations often cancelled each other out on their own within a few seconds. For larger oscillations such time lags are actually helpful even.

Additionally, it would not be necessary to set up an expensive communication infrastructure linking millions of smart meters with the energy suppliers. And finally: where there is no central control centre, there are no controls for hackers to attack and in the worst case enable them to cripple whole electricity grids. Here too, having many players results in a lot of stability.

In principle it could work, but since when have engineers talked to biologists about control mechanisms?

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Self-organisation instead of centrality
Denmark was the first country in the world to start industrial production of wind turbines and purposefully make wind energy a cornerstone of electricity supply. Today, wind energy in Denmark is being developed significantly faster out at sea than on land. So Copenhagen seems to be the perfect place for EWEA Offshore 2015.

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Measuring: Endless stream of data

Thousands of wind measurement masts and a rapidly growing number of LiDAR devices are generating ever increasing amounts of data. How can this data, which requires complex processes to collect, be evaluated as comprehensively and profitably as possible?

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Shifting shares

Steady decline in European shares and growth in emerging economies – that’s the only constant factors in Frost & Sullivan’s outlook on the development of non-hydro renewables in a global scale. While other regions of the world show slight growth or rather constant shares from 2012 to 2025, it is Europe’s sad fate of a forerunner to lose importance in a globally growing market of renewables installations and – not represented in these figures – in production.

Global wind power installations alone are expected to grow from 297 GW in 2012 to 814 GW in 2025 according to Frost & Sullivan’s Research Authors Harald Thales and John Raspin.

Data Source: Frost & Sullivan, Annual Renewable Energy Outlook 2014

US$ 36.6 bn of green bonds

The labelled green bond market has once again seen a year of incredible growth. In 2014 US$ 36.6 bn of green bonds have been issued by 35 issuers – more than triple the 2013 issuance. Corporate (33 %) and municipal/provincial/city issuers (13 %) came up strong while development banks (44 %) continued to be the backbone of green bond issuing. Toyota made a remarkable entrance into the Top 10 of green bond issuers. The company kicked the year off with a green asset-backed bond in Q1 that showcased how proceeds from a bond backed by car leases and loans can be earmarked for future green vehicles.

Data Source: Climate Bonds Initiative

Top 10 green bond issuers of the year (by amount issued in US$)

<table>
<thead>
<tr>
<th>Issuer</th>
<th>Amount Issued 2014 (US$)</th>
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</thead>
<tbody>
<tr>
<td>EIB (European Investment Bank)</td>
<td>US$ 5.6 billion</td>
</tr>
<tr>
<td>KfW</td>
<td>US$ 3.5 billion</td>
</tr>
<tr>
<td>GDF Suez</td>
<td>US$ 3.4 billion</td>
</tr>
<tr>
<td>World Bank</td>
<td>US$ 3.1 billion</td>
</tr>
<tr>
<td>Toyota</td>
<td>US$ 1.75 billion</td>
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<tr>
<td>AIF</td>
<td>US$ 1.3 billion</td>
</tr>
<tr>
<td>Iberdrola</td>
<td>US$ 1.0 billion</td>
</tr>
<tr>
<td>Unibail-Rodamco</td>
<td>US$ 1.0 billion</td>
</tr>
<tr>
<td>Ile de France</td>
<td>US$ 829 million</td>
</tr>
<tr>
<td>Gruppo Hera</td>
<td>US$ 680 million</td>
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</tbody>
</table>

6.1 GW offshore wind capacity on their way...

Last year 781MW of offshore wind capacity was fully grid connected during the first six months in European waters – that is 25 % below the corresponding period of 2013, the year that saw a record-breaking 1,567MW of offshore wind connected to the grid. Still 2014 is likely to become another record year, as 1.2GW of turbines are still waiting for grid connection and further 4.9GW are at various stages of construction.

Data Source: EWEA

... investors see bright future

More than 60 % of the utilities and investors taking part in a survey by UK law firm Freshfields Bruckhaus Deringer believe that utilities are not sufficiently capitalized to fund alone their offshore wind project – yet two thirds also believe that there will be sufficient capacity in debt markets to meet demand during the next five years.

Data Source: Freshfields Bruckhaus Deringer, European Offshore Wind 2014

Bank lenders’ expected margins to charge for construction debt in the next 18 months

- $ < 200 bps above LIBOR
- $ 200-250 bps above LIBOR
- $ 250-300 bps above LIBOR
- $ 300-350 bps above LIBOR
- $ 350-400 bps above LIBOR
- $ > 400 bps above LIBOR
A pioneer on land and at sea

In Denmark, wind energy is being developed significantly faster out at sea than on land. The government set the course early on and created favourable conditions for setting up offshore wind farms.
Denmark’s entry into renewable energy was easier than Germany’s, because nuclear energy never played a role and coal was always only imported and not extracted. For this reason, there was no radioactive waste and no dependence on coal mining that would stand in the way of an environmentally friendly energy policy. Conditions were therefore ideal in 1977, when the Tvind School’s 2 MW wind turbine was installed and became a landmark for the nascent wind power sector.

Tvind was just the beginning

Denmark was the first country in the world to start industrial production of wind turbines and purposefully make wind energy a cornerstone of electricity supply. Although the Tvind MW turbine was a success, it was clear that initially only small turbines (30 to 55 kW) could be mass produced. That is why wind energy’s share in energy supply only increased slowly, reaching just 1.9 % in 1990.

In the following decade, however, the Danish wind industry boosted turbine capacity up to 2 MW. By the end of 2000, the share of wind power had grown to 12 %. Although there was not yet a particularly high number of onshore wind farms, the government envisaged offshore wind electricity generation early on.

When the pioneering Vindeby and Tunø Knob wind farms, which are considered to be the world’s first offshore wind farms (see table), demonstrated that they were able to generate electricity reliably, five further offshore wind farms were installed with a total of 400 MW of capacity between 2001 and 2003. However, technical setbacks and operational disruptions of several months during the construction of the Horns Rev 1 and Nysted wind farms temporarily caused disillusion.

Moreover, a government change brought political support for wind energy to an abrupt end so that both onshore and offshore development virtually came to a standstill until 2008 (see diagramme).

Overcoming a long lean period

The barren spell only ended in 2009, when expansion on the mainland finally restarted and more wind farms were also installed at sea. By the end of 2013, the installed capacity grew both onshore and offshore to 3,501 MW and 1,258 MW, respectively.

The natural conditions for erecting wind farms at sea are favourable in Denmark, since the Baltic Sea is shallower than the North Sea and the tidal range is small. In addition, the grid connection is less costly, because in Denmark (unlike in Germany, for example) wind farms can be built near shore. Public acceptance is relatively high, as
The drive train of a wind turbine holds a number of mysteries which even scientists have not yet fully understood, let alone been able to explain. One phenomenon around which many theories have evolved is that of “white etching cracks” – or WEC for short. White etching here describes microstructural changes in the materials of antifriction bearings and their rollers. These changes occur under the surface and produce fine cracks, which in turn lead to premature failure of the bearing and bring the drive to a standstill.

This special wear phenomenon is presumably unrelated to classic roller bearing fatigue, because the damage can already occur after just one to three years of operation. The experts are agreed, however, that the cause is in some way connected with the lubrication and with dynamic processes in the nacelle.

“The background is not yet fully understood. But WEC must definitely be taken seriously, because the failure of a roller bearing can be the starting point for considerable damage,” says Walter Holweger from Schaeffler Technologies. After all, these special bearings are used not only in gearboxes, but also in other elements of the drive train, the pitch system or the tower bearings. Depending on the size and purpose of the bearing, suitable replacement can cost up to € 100,000. No less disturbing are the loss of production and the necessary outlay for repair.

Well-lubricated lasts longer

While premature crack-related failure of the roller elements occurs rather seldom in paper mills or marine propulsion applications, the phenomenon is
much more common on wind turbines. Experts believe that this is in part attributable to the very frequent use of such bearings in the turbine nacelle. At the same time, they suspect unfavourable interactions between the very rapidly changing dynamic loads and the lubricants used.

In the meantime, it seems that Schaeffler has developed a promising cure for WEC with its protective coating Durotect, which makes bearing surfaces more resilient. The extremely hard surface coating acts as a “broad-spectrum antibiotic” for the selected steels, rendering surfaces more resistant to the metallic particles which accumulate in lubricants and gearbox oils due to wear, for example. Schaeffler offers proof for its successful fight against WEC with data from the past five years. Figures indicate a failure rate of up to 30 % for roller bearings without coating, depending on the precise bearing type. “With Durotect, premature damage has been reduced to between 0 and 0.01 % for the 50,000 roller bearings supplied, and there has also been little fluctuation in the degree of resilience,” says Holweger. All in all, Schaeffler is convinced that the risk of WEC can be contained with an appropriate bearing design and through the correct choice of suitable lubricants and materials.

This additional coating, however, only protects a certain proportion of mechanical drives. As the bearings can also be destroyed as a result of inadequate lubrication, bearing manufacturer SKF has teamed up with the Lincoln Financial Group to produce an automatic system for the fine lubrication of bearings in situations where accessibility is impaired. The “Condition Based Lubrication” solution consists of a maintenance-free central lubrication system in conjunction with condition monitoring. The idea is that service visits by a technician become superfluous, but the risk of bearing damage due to insufficient lubrication is nevertheless reduced.

The system monitors the lubricant distribution and the level of grease in the supply tank, and is able to control the lubrication pumps automatically. In case of an error message, alarms are sent directly to the SKF condition monitoring system. The lubrication for the generator, main bearings, slewing ring and rotor blade adjustment can be integrated in this way. On the basis of automatic and demand-oriented metering of the grease, the manufacturer claims that lubricant consumption can be cut by up to 50 %. The downside is that these savings can only be achieved with a condition monitoring system from SKF.

**Fishing in the oil flow**

Alongside such consumption lubrication, SKF also offers an oil circulation system for bearings subject to high loads. This system is incorporated into a main feed line and serves to split the oil into several parallel flows for delivery to the drive components. This slight diversion is meaningful for several reasons: Firstly, the oil can be cooled to the optimum lubrication temperature, and secondly, the system trawls condensation water and water particles from the oil. That protects the bearing against corrosion, keeps the oil clean, and provides for better lubrication.

It is precisely in the purity of the lubricants that operators could realise considerable cost-saving potential. This applies not only with regard to the expensive bearings, but above all for the gearboxes. “Many operators underestimate the correlation between lubrication and gearbox failure. And that despite the fact that the knock-on effects are often far more serious than the primary damage itself,” says Fouad Bouarfa from Stork Gear. The Dutch company Stork is a specialist for oil analyses, measurements and repairs to marine and wind turbine gearboxes.

One plain and simple, but at the same time significant cause of failure is dirty oil in which excessive amounts of metallic and non-metallic particles...
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