Speaking of Wind: Discussions from Germany

by Eize de Vries, Wind Technology Correspondent
Bremen, Germany [Renewable Energy World Magazine]

November saw the ninth DEWEK bi-annual technical wind energy conference, organized by the German wind energy institute DEWI, take place in Bremen. Eize de Vries rounds up some of the highlights.

New German tariffs

During the conference opening session, first speaker Joachim Nick-Leptin of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, provided a detailed overview of his country's long-term renewable energy objectives. He, among others, focused on details of the new (EEG) feed-in tariffs law that commenced on 1 January, 2009. With regard to these new tariffs, the onshore wind power rate has increased from 7.87 to 9.2 eurocents/kWh – including an annual 1% kWh pay reduction a change from the initial plan of 2%. The latter measure is aimed at boosting cost benefit gains through innovation. Also new in the EEG legislation is a repowering bonus of 0.5 euro-cent/kWh. This measure is designed to optimize the use of increasingly scarce land-based wind locations. Site repowering often increases yields by a factor 5–10, and generally means replacing smaller outdated turbines by fewer larger state-of-the-art equivalents.

TABLE 1. WORLDWIDE RENEWABLE ENERGY POTENTIAL

Solar radiation	1.5×10^{21} Wh/a
Wind streams	3.8×10^{19} Wh/a (2.5% of solar radiation)
Wind power potential	4.3×10^{15} W
Wind power installed	9.4×10^{10} W (0.00054%)
Actual worldwide electrical	
Power base installed	3.2×10^{12} W
Wind power share	2.9%

Source: DEWI, DEWEK 2008

The EEG offshore tariff is 9.2 eurocents/kWh, up from 8.74 eurocents, but that is not all. For early movers the German government provides an 'early bird' bonus of 2 eurocents/kWh for offshore wind projects operational before the end of 2015. A second incentive to encourage early movers is a binding obligation for utilities to connect these projects to the grid at their own expense.

Current German government research priorities include wind power and photovoltaics. Key focus areas for wind research include cost reduction, offshore wind, grid integration and environmental issues. Several presentations addressed these areas. Grid integration as a subject is subdivided into Virtual Power Plant (VPP) research and the development of an advanced e-grid also known as a Smart Grid. One groundbreaking VPP project highlight of the past few years is a joint co-operation between Germany's Enercon (wind turbines), Schmack (biogas plant) and Solar World (Photovoltaics). Their sustainable technologies were combined with pump storage to build and demonstrate an integrated high-tech flexible system that fully matches power demand and supply.

Fraunhofer wind energy institute

Other news presented by Nick Leptin included a report on the founding of a new Bremerhaven-based Fraunhofer Centre for Wind Energy and Maritime Technology that became operational early 2009. The initiative aims at concentrating the country's wind power-related R&D infrastructure into one specialized research body. In his closing statement Leptin clearly voiced concerns over plans to pool renewable resources at a European level saying: 'We are sceptical about these plans, specifically out of fear for a strong bureaucratic organizational structure. A centralized research body comprising 26 European member states simply cannot function effectively.'

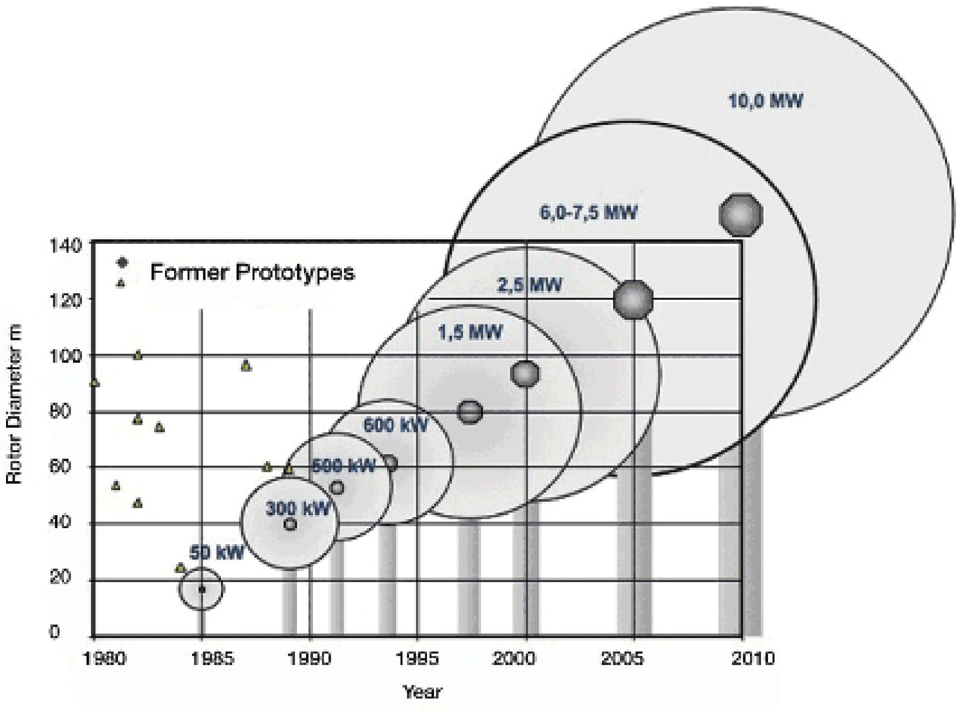
The second speaker, Dr Reinhard Loske, Bremen Senator for Environment, Building, Traffic and Europe, commenced by setting out Germany's ambitious objective of 25–30 GW of offshore wind by 2030. He stressed that German politics have to make a clear choice between 'a row of new coal-fired power stations situated all along the coastline' or 'offshore wind power plants in terms of future grid connection priorities.' Loske also pointed a finger at the credit crisis and hard lessons learnt, concluding that countries affected should rethink the importance of reinvesting into 'real Wirtschaft' ('real value-generating business activities, including manufacturing').

An important question raised during DEWEK 2008 was whether German offshore plans are realistic. Another conference speaker said that the wind industry is at the beginning of a steep learning curve, in which many key areas still need addressing. These include risk and cost sharing between the main project partners, efforts to bring down wind turbine and foundation costs, and solving grid connection issues. In addition comes the need to invest in new advanced offshore logistics, including installation and assembly concepts. This challenge is a major reason behind the German government decision to incorporate two dedicated research turbines as part of the 60 MW Research at Alpha Ventus (RAVE) offshore wind farm due to be completed this year. Once operational the wind farm will consist of six 5 MW REpower 5M and six 5 MW Multibrid M5000 turbines. For each turbine type a number of specific technical and other research aspects will be addressed for field tests and optimization. €50 million of federal research funds have been made available for the first five-year period.

Wind energy – quo vadis?

DEWI's managing director Jens Peter Molly provided an overview of key wind power developments in a presentation entitled Wind Energy – Quo Vadis? He commenced with a calculation of the world's wind power potential, see Table 1. He concluded that the total wind potential is over 1300 times larger than the worldwide cumulative installed electrical power base.

In a related statistic, Molly showed the global installed wind power density (kW/km^2) distribution among individual countries and geographical regions. Germany and Denmark are the only two countries that have installed over 50 kW/km^2. Spain, Portugal and the Netherlands all score 31–40 kW/km^2. The third category (11–20 kW/km^2) includes Austria and Ireland. Several countries in Europe and the major wind markets of US and India score only 1–10 kW/km^2. However, a wind power density figure of less than 1 kW/km^2 is still valid for the majority of nations, including huge countries like Australia, Brazil, Canada, and China. As Molly says: 'These statistics above all provide overwhelming proof of the world's huge wind potential, that is still largely unused, and the challenging task ahead to make



that potential productive without delay.'

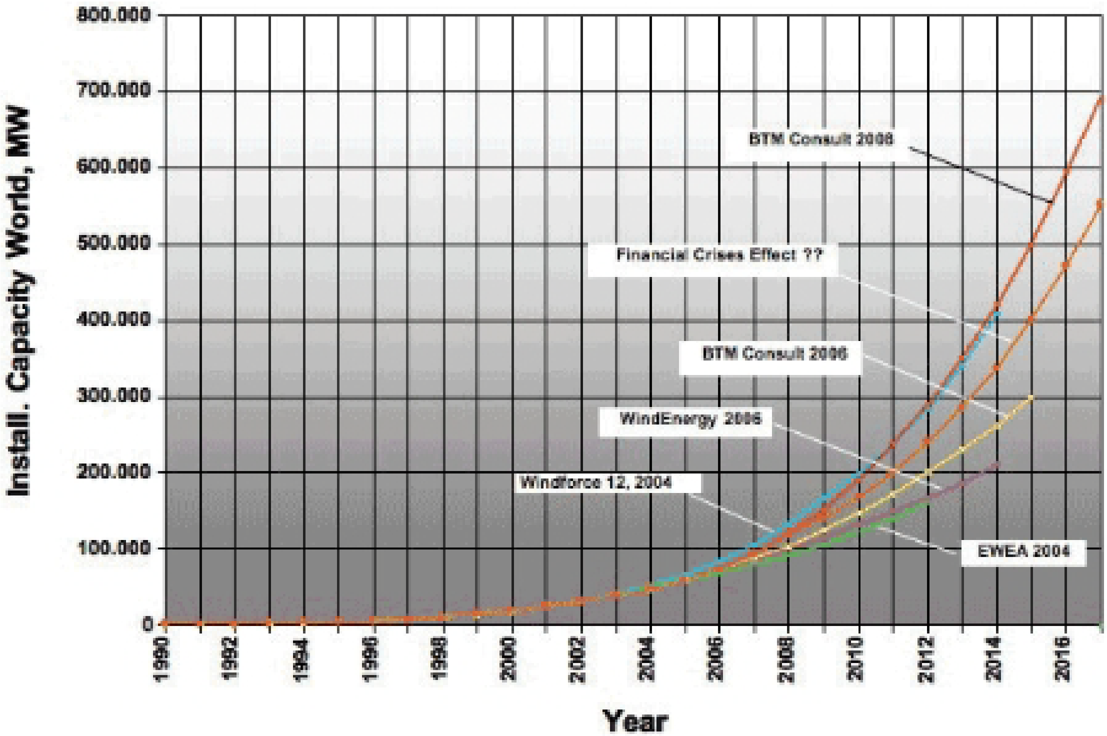
With regard to growth predictions, shown in figure 1 left, DEWI's forecast sits between BTM’s 2006 and 2008 medium-term curves, and corresponds roughly to a cumulative 245 GW total worldwide in 2012 and 400 GW by 2014. For 2009, Molly considers a substantial drop in installations from an earlier prediction of 32 GW to 20 GW as not unlikely. However, if BTM’s latest 2008 scenario prediction with 20% annual market growth can still be met, by 2017 some 6% of the world’s electricity can be generated by wind from today’s 2.9%.

Technology challenges

Elaborating on future challenges, Molly points at major design issues like load reduction, prolonging operational lifetime, and the application of new materials and production methods. One of his conclusions was that with increasing size wind turbines, suppliers succeed in curbing Top Head Mass (nacelle and rotor) increases due to increasing utilization of superior materials, despite the fact that up-scaling is inevitably linked to the infamous ‘square cube law’.

As wind turbines are designed for a similar 20-year operational lifetime, Molly drew the comparison between an average car and a wind turbine – a car during its 250,000 km lifespan covers about 4000 operational hours. As Molly explained: ‘Wind turbines by contrast are typically designed for 160,000 operational hours, which puts high requirements to overall (structural) design and product quality. If these stringent conditions are not being met, these 160,000 wind turbine operational hours are simply unachievable.’

For offshore applications he considered enhanced reliability, the development of dedicated maintenance strategies, and addressing foundation structure optimization, concluding that all are major issues requiring structural industry efforts. Another key issue is yield prediction. ‘Reducing operational economics risk by employing long-term wind energy yield predictions is among several technology-related challenges. Short-term wind power predictions on the other hand can serve as an instrument to integrate wind power into transportation and distribution grid networks’, he said.



Based on historical data provided by certification institutes DNV, Ris√∏ and GL, he showed the relationship between the increase in wind turbine capacity and time, as illustrated in Figure 2, above.

In the period 1978–2005/6 turbine capacity grew exponentially. If this trend continues, by 2010 turbine maximum size will have reached 10 MW. However, the chance that even a 10 MW prototype will be built during 2009/10 is slim, says Molly. Today's list with 6 MW turbine makes and models contains only two names – the second-generation semi-commercial Enercon E-126 (rotor diameter 127m), and REpower 6M prototype (rotor diameter 126m). It was recently reported that BARD Engineering intends to scale up its 5 MW turbine to 6.5 MW, while the rotor diameter will remain unchanged at 122m. Industry sources further suggest that the E-126 may finally exceed 7 MW. The largest announced offshore turbine product development is the 10 MW Clipper Britannia (rotor diameter 150m), however, further details are not yet available.

Mass reduction

Turbines with three pitch-controlled rotor blades and variable speed operation represent state-of-the art wind technology. Only by applying three or more rotor blades is an aerodynamically and dynamically balanced rotor provided, explained Molly. Two blade rotors are dynamically unbalanced, but proponents still see opportunities for offshore. Among the advantages of the two-blade system is that complete nacelle and rotor assemblies can be stowed more easily on a vessel deck. And, provided crane capacity is sufficient, complete nacelle and rotor assemblies can be hoisted to their mounting positions – potentially limiting offshore activity time and costs. Two-blade rotors have to spin faster for a given output, resulting in more noise, but this is not a consideration offshore.

Wind turbine drive train systems are either direct-driven (no gearbox) or gear-driven, featuring a low speed single-stage (Multibrid) or high speed multi-stage gearbox. As a key wind industry trend, drive train torque (Nm) loads passing through turbine gearboxes per kg of Top Head Mass, has increased dramatically since 1990. This maximum mass-specific torque value has increased from 5 Nm/kg in 1990, to 7.3 Nm/kg in 1996, 11 Nm/kg in 2002 up to 15.5 Nm/kg in 2008. This trend was likely to be have been reinforced as a result of general preferences to reduce Top Head Mass, as well as nacelle dimensions, enabling and easing containerized transport. However, critics argue that reduced design safety factors have emerged as a consequence of gearboxes becoming lighter with more compact housings. That has contributed to unacceptable gearbox failure rates, especially in some geared turbines (see REW, March/April 2006). Molly adds that another common failure issue is that secondary gearbox loads are being introduced as a consequence of increasing structural nacelle elasticity when size goes up.

Rotor size limiting factors

Molly further pointed at several key limiting factors that can hamper further future turbine growth, with a focus on rotor size. Some of these factors are transport logistics and assembly issues (length and mass), in addition to rotor blade tip speed (noise, erosion, cross-sectional moment of inertia). Manufacturing constraints (material thickness, production-related imperfections, quality control methods and so on), component stiffness and material properties are among other critical factors that can potentially put a brake on size increase. He added: 'When rotor size increases, a simultaneous materials saving trend can introduce growing elasticity as a result. This is a phenomenon that should be taken very seriously. Production errors as an unknown enhancing risk factor are further unavoidably linked to any wind turbine design phase. Such errors should become accepted as an 'integral' and unavoidable part of wind turbine design, but with the explicit ultimate aim to strive at fail-safe type components and systems.'

Condition monitoring (CM) systems are gaining ground in wind turbines, but this technology only reacts to upcoming failures. As Molly says: 'Due to their specific function, these CM systems do not contribute towards solving design-related failures. Another CM-type system monitors operational loads and uses the already known operational load spectrum as reference base. These CM systems are therefore well suited as a monitoring tool in combination with preventative O&M (operation and maintenance) measures.'

A largely ignored issue is how to deal responsibly with the environmental hazards presented by old rotor blades disposed of at the end of their operational lifecycle. ‘The 100,000 wind turbines operational at the end of 2007 contain about 660,000 tonnes of fibre-reinforced plastics, that at some time in the future will end up as a huge chemical waste pile. By 2017 the number of operational turbines worldwide will perhaps have grown to 400,000 units, which corresponds to about 6.6 million tonnes of fibre-reinforced plastics waste. The recycling of steel and non-ferrous metals is a relatively well-known straight-forward process, but this essential know-how is far more limited for fibre-reinforced future plastics waste’, Molly concluded.

New developments

In the session New Developments, Christian Keindorf of the Leibnitz University, Hanover, presented a clever new connection method for a tubular steel tower upper-part combined with a sandwich-type tower bottom section. The wider bottom section comprises an inner and outer steel shell, bonded together by a core material, which increases overall shell stability. The researchers further looked into the complex issue of joining a sandwich-type tubular steel section to a ‘conventional’ tubular steel section.

A ‘semi-standard’ state-of-the-art offshore monopile foundation comprises a pile driven into the seabed, and a transition piece that ‘loosely’ slides over its top, on which the actual tower flange is bolted. The main function of a transition piece is to accommodate any potential pile misalignment during the driving process. A permanent connection between pile and transition piece is achieved with grout that fills the annular gap between the two pieces. A disadvantage of this grout solution is that a relatively long overlap length between the two components is needed.

As part of the new solution, the upper steel section slides in a relatively short annular gap left at the top between the inner and outer section of the sandwich tower part, finally the shells are permanently connected with high-performance grout. Like the conventional monopile, the new method allows for vertical misalignments and other imperfections. Once the new system is proven both technically and economically, it might develop into an alternative solution for towers of larger (offshore) turbines. Keindorf says: ‘Our continuing research effort focuses at the best-suited core material, while already several mineral as well as non-mineral alternatives have been tried. However, a cost analysis of our tower solution – compared to conventional tubular steel towers – is not available yet.’

CO_2 evaporation generator cooling

The Wind Energy Research Group (WERG) of the German Saarbrücken University of Applied Sciences, presented a novel 2–2.2 MW WERG-85 (rotor diameter 85m) direct drive wind turbine concept at DEWEK. Wind industry veteran Professor Friedrich Klinger founded the renamed WERG (initially Windenergie Gruppe) organization in 1990. Several achievements of his wind turbine development group include the innovative 600 kW Genesys direct drive turbine (1997), the 1.2 MW Vensys 62/64 and an early version of the 2.5 MW Vensys 90/100. Today, WERG is unrelated to Vensys.

A 2 MW WERG-85 wind turbine version has been developed for a Chinese partner, while a 2.2 MW sister product is destined for an undisclosed European supplier. Both versions contain a number of innovations. This includes a multi-pole permanent magnet-type generator which is located inside the rotor hub – the generator rotor is thereby integrated with the rotor hub that also carries the blades, and the permanent magnets are located along the inner rotor hub surface facing inwards. The generator arrangement in which the rotating part featuring the multiple (field) magnets is located outside the stator, is known in German as Ausenläufer. A more common direct drive generator (i.e. Enercon) arrangement is a generator rotor that rotates inside the stator part (Innenläufer). Twin main rotor bearings further absorb generator magnetic forces, as well as direct rotor-induced forces, while the bearing arrangement results in minimized air-gap deformation, explained WERG’s

Benjamin Theobald during his presentation. He continued: ‘A second key innovation is our advanced generator cooling system, based on evaporating CO_2 as a refrigerant in the hollow conductors of the stator coil system. This compact, fully enclosed generator is ideal for offshore applications, as heat is released where it is produced and there are consequently no internal hot spots. This combination of design features results in a generator stator coil temperature level of only about 35°C, versus roughly 100°C for conventional direct drive generators.’

A distinct WERG-85 design feature that has remained from earlier Genesys and Vensys product developments, is the toothed belt drive for the rotor blade pitch system. Finally, the Top Head Mass is only about 110 tonnes (nacelle 30 tonnes, generator 56 tonnes, three rotor blades 24 tonnes total). ‘Our WERG-85 also offers full proof that the wind industry perception of direct drive turbines being inherently heavy, needs to be corrected’, concluded Theobald.

Evolution

At another DEWEK 2008 presentation, REpower’s Heiko Wuttke announced that the company had installed the first of three prototypes of its new 3.3 MW 3.XM series at a location near the Husum assembly facilities. The IEC WC IIA turbine model, is fitted with new in-house developed RE 50.5 rotor blades as standard. IEC certification is expected for the second quarter of 2009 and series production start is planned for third quarter of 2009.

Martin Städler of GE Energy focused his presentation on ‘controls for load reduction’ that have been introduced in the new 2.5 MW GE 2.5xl flagship model. One of the key novelties is individual pitch control, whereby the rotor blade pitch angle as an asymmetric load control measure is adjusted continuously during each rotor revolution. The measures resulted in substantial reductions in 2.5xl fatigue load: 10%–15% for the hub and blade flange, 6%–10% for the tower base (fore/aft), and 15%–20% for the tower base (side/side). Städler said: ‘However, the ‘price paid for’ by the substantial overall load reductions is a 50%–100% increase in pitch actions. Incorporating individual pitch technology itself provides the choice between two optimizing options, a larger rotor or a less expensive turbine. We chose to fit a larger 100 metre rotor instead of the initial 88 metre size. One of the key benefits is that the larger rotor produces more energy, without having to lower the IEC Wind Class and change major components like hub, drive train and tower. We also maintained the initial pitch rate of 8–10 degrees per second when introducing the new pitch technology.’

Grid management

Increasing renewable energy systems, while sharing an electric power generation and supply infrastructure, raises the need to develop sufficient energy storage capacity. This is essential to balance fluctuating power feed-in from these inherently variable power sources. Among several options being researched in Northern Germany is adiabatic (no heat exchange) compressed air energy storage in underground salt formations, and especially in naturally formed caverns. These structures, which have an average size of 500,000m^3, offer a storage capacity between 2.02–2.73 kWh/m^3. Total capacity for adiabatic energy storage in Northern Germany is estimated at 800–2500 GWh. The energy storage efficiency depends on the technology applied and is estimated in the range of 50%–70%. However, there are competing uses for these caverns – underground CO_2 capture and the long-term storage of nuclear waste. The storage issue is therefore far from being limited only to a technological challenge. Politics will have the final say. The challenge is therefore to set the right priorities in terms of future power generation and power and storage preferences.

Eize de Vries is Wind Technology Correspondent for Renewable Energy World magazine.
e-mail: rew@pennwell.com

http://www.renewableenergyworld.com/rea/news/article/2009/03/speaking-of-wind-discussions-from-germany?cmpid=WNL-Friday-March13-2009