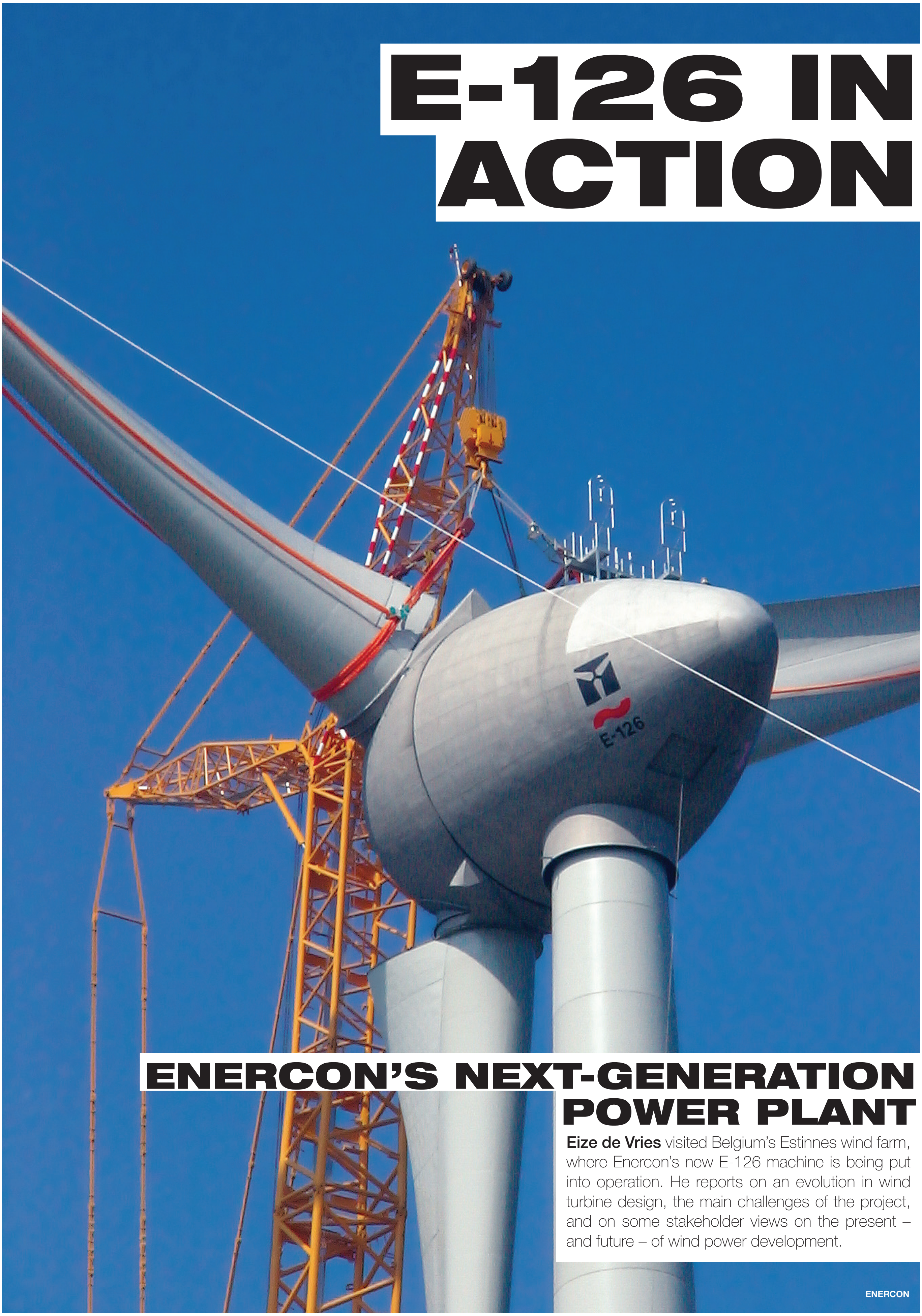
E-126 IN ACTION



ENERCON

ENERCON'S NEXT-GENERATION POWER PLANT

Eize de Vries visited Belgium's Estinnes wind farm, where Enercon's new E-126 machine is being put into operation. He reports on an evolution in wind turbine design, the main challenges of the project, and on some stakeholder views on the present – and future – of wind power development.

The new 1600-tonne Terex Demag CC 9800 crawler-type nacelle hoisting crane MATTHIAS GROTTKE (2009)

A wind farm being built by Belgian developer WindVision will have the world's largest onshore wind turbines, comprising of 11 of the latest generation Enercon E-126 direct-drive wind turbines, currently rated at 6 MW. However, well-informed German wind industry sources say with certainty the commercial E-126 power rating will be well over 7 MW.

From day one, project preparations, as well as the on-going construction phase, represented formidable technical, transport-logistical and other challenges to the developer, equipment suppliers, contractors, and installation partners alike.

Located north of Estinnes-au-Mont municipality and south of the N90 motorway that connects the Belgian towns of Binche and Mons, WindFarm Estinnes S.A. borders the so-called 'Levant de Mons' plain. This huge plateau, measuring 2.5 x 3 km, enjoys a relatively favourable wind climate for an inland location and is characterized by gentle hills. Multiple access roads cross the terrain where the wind farm is gradually taking shape.

WindFarm Estinnes is expected to generate at least 187 GWh a year. And, in a genuine achievement for the wind industry, the advanced power electronics built into the E-126 machines will, among their other functions, be employed to stabilize the voltage on the public grid within the entire border region.

SEGMENTED ROTOR BLADES

Driving along the N90 from Estinnes-au-Mont towards the construction site, several elegantly shaped towers and one operational E-126 could be seen rising high above the elevated plateau in late May. Close by, a number of the towers were either ready or at various stages of completion, flanked with cranes. At other sites the foundation construction was in progress. The final step in erecting each turbine is to hoist a giant 22-metre long nacelle to top these 131-metre high towers.

An E-126 erection crew is roughly double the size of a typical 2 MW turbine installation team. Between 100 and 120 staff, either directly employed by Enercon or by subcontractors, are working each day on the foundations or tower construction at the different turbine erection sites. During our visit, the next round of nacelle and rotor erection was about to commence at one site, with the colossal bright-yellow installation crane ready and waiting next to the tower. The often large and bulky supplies mainly originate from one of Enercon's German manufacturing facilities, at Aurich or Magdeburg, and are transported to Belgium either by road or water, depending on transport-logistics variables such as component width, height and mass (see 'EU innovation support' box).

BLADES

Enercon is currently not active in the offshore wind market and order to ease road transport logistics, Enercon chose to develop segmented rotor blades for the E-126.

Electrical engineer Bernhard Fink is Enercon sales representative in Belgium and has been with the company for many years. He explains the 59-metre rotor blades comprise a 35-metre outer section made of glassfibre-reinforced epoxy composite material that is bolted onto a 24-metre inner metal section. The composite part features Enercon's familiar winglet at the blade tip. The inner blade section consists of a conical-shape fabricated steel core with integrated weld-on pitch bearing mounting flange. Attached to this steel structure is a sub-frame covered by pre-shaped aluminium sheeting. The sections are joined by using 20 M52 bolts – a process that takes three workers inside the structure about a day and a half pee blade to complete. The steel–composite blade combination has the distinct Enercon airfoil shape that widens towards the blade foot where it meets a matching flange area at the spinner.

Fink further explains that, for structural reasons, Enercon always applies a cast iron or steel adaptor between the pitch-bearing and composite blade material. 'In the wind industry it is common practice to fit a composite rotor blade flange directly to the pitch bearing metal. It is our company philosophy that a pitch bearing, in order to safeguard long-time operational performance for mechanical reasons, needs to be sandwiched in between two rigid machined metal surfaces,' says Fink.

HEAVY LIFTING

Erecting a nacelle is the most critical part of the entire installation process, because the individual main assemblies often weigh hundreds of tonnes and require hoisting to a height in excess of 135 metres. A striking example of new and innovative installation equipment technology applied at Estinnes is the 1600-tonne Terex Demag CC 9800 crawler-type crane. This giant is owned and operated by heavy lift and transport specialist Sarens of Belgium, which is also a WindFarm Estinnes project partner.

Currently the largest crane of its type in the world, equipped with tracks over two metres high, it was specifically designed and built in Germany according to Enercon E-126 erection specifications. Due to its enormous length, the lattice-type beam needs to be supported to guard against excessive bending in the middle when it is in its horizontal assembly position. The beam and various other components comprise multiple sections to enable road transportation, but moving all the sections requires up to a hundred special heavy-duty truckloads. As an indication of component size, the maximum boom and jib length of the CC 9800 is 156 metres and 120 metres respectively, the maximum allowable crane-hook height is 230 metres. Bringing the beam from horiziontal assembly into a vertical operating position is a critical operation, as tensile forces in the steel cables are then at their maximum value. For this specific boom-hoisting operation the crane is carries a so-called Superlift counterweight at a 30 metre-radius from its central rotating point.

With the crane, either a complete rotor and generator assembly or a pre-assembled machine housing can now be put on top of the tower in a single lift. This represents a huge time saving during the installation phase as previously three or more smaller cranes and multiple hoisting operations were necessary for conducting the same erection tasks (see 'EU innovation support' box).

EU INNOVATION SUPPORT

With a consortium of nine project partners, WIP – a Munich-based consultancy specializing in the management of multinational renewable energy demonstration projects – obtained funds from the EU's 7th Framework Programme on research, development and demonstration. The funding is focused on E-126 serial production aspects, optimized transport and erection logistics, optimized grid integration, and advanced yield forecasting.

Speaking at the construction site, WIP's head of projects, Matthias Grottke, cited EU figures, saying: 'By 2020 wind power shall contribute 12%–14% of the EU's electricity demand. To achieve this target, installed European wind power capacity must increase from nearly 66 GW [at the end of 2008] to 180 GW by 2020. That requires annual increments of 10 GW. By comparison, in 2007, wind power-generating capacity in the EU grew by 8.5 GW, and in 2008 with another 8.9 GW.' Meeting such ambitious targets requires a dedicated political framework, state-of-the-art technology, and broad social acceptance.

In light of the enormous transport challenges faced during both the preparation and construction of the Estinnes wind farm, Grottke points at several components and assemblies awaiting erection at one of the construction sites, saying: 'Compared with similar main components applied in today's 1.5–2.5 MW volume class wind turbines, many of these components are very large and/or heavy. That requires, for instance, a balanced choice between transportation either by water or via road from factories to construction sites. As an example, the 35-metre long rotor blade outer composite sections are rather bulky, which seems to favour water transport by river barge. However, the relative modest weight of these components results in insufficient ballasting of these barges and that proves in practice to be a major restriction, especially when passing underneath bridges. The steel rotor blade inner sections also seem to favour transport by water, but I understand that several of these pieces were recently brought in by road and apparently for good reasons.' One challenge was to find suitable harbours, capable of dealing with the huge components that had to be handled.

Grottke elaborates upon efforts to further optimize employment of the new CC 9800 installation crane. He says: 'This crane currently has to be completely dismantled and assembled again even when it is only moved to a next turbine construction location within the Estinnes wind farm. This is due to a combination of hilly terrain conditions and substantial crane wind loads when the beam is in raised position. Crane dismantling and reassembly including compulsory commissioning inspection currently takes up to three weeks. This is a very costly and time-consuming process and considerably slows down nacelle installation progress.' Among a number of options under consideration is to only partly disassemble the crane for internal wind farm transport.

Grottke continues: 'These installations have the potential to significantly increase a wind park area utilization factor expressed in MW/km^2. By applying E-126 turbines the area utilization factor increases by a factor 2.3 compared to applying state-of-the-art 2.0 MW class equivalents.' He adds that the yield (MWh/km^2), of only 11 E-126 outperforms 17 2.0 MW installations that may otherwise be put in the same area, again a factor of 2.3. 'These positive indicators combined turn the Estinnes wind project into a genuine wind industry milestone. In addition, the project clearly shows that multi-MW machines of that size can indeed be well integrated into the landscape and its surroundings,' he concludes.

CONCRETE TOWER PIONEER

Enercon is a concrete tower pioneer. Initially 500 kW E-40 turbines were available with a modular design of prefabricated, steel-reinforced concrete towers. Consisting of several cylindrical-shaped concrete units these elements were manufactured in rotating moulds by specialist firm Pfleiderer of Germany. Later, Enercon switched concrete towers built on site with a sliding shuttering method known from factory chimney construction. Many 1.5–2 MW E-66 series turbines were, for instance, mounted on such in-situ towers.

For at least 10 years, Enercon has used its patented in-house manufactured prefabricated concrete towers for several of its wind turbine models, including the latest E-126. Elements of these towers are manufactured under controlled industrial conditions in several countries, including two German production locations at Magdeburg and Emden. The Emden plant is one of the latest and features an advanced automated production environment requiring minimal labour involvement. Among several distinct production technology features are unmanned overhead rail carts that continuously top-up the liquid concrete reservoir of a distribution device that fills the conical-shaped concrete element moulds.

CHALLENGES

Founded in 2002, WindVision is a European company specializing in wind farm development, construction and operation. Currently, a number of projects, mainly using turbines in the 2–3 MW class, are in various stages of development in Belgium, Cyprus, France, and the Netherlands. All of these projects are onshore.

Initial contacts with local authorities and landowners for WindFarm Estinnes date back to 2003, recalls WindVision co-founder and managing director Jaap-Jan Ferweda. He explains: ‘During 2004 we reached agreement with the landowners, and in January 2006 acquired final building permission for the project in its current size and configuration with eleven 5–6 MW turbines.’ In 2007 Enercon was selected as the turbine supplier with their new E-126 [the prototype of which was launched at the end of 2007 – ed].’

The project construction phase commenced in mid-2008 and initially two turbines had been due to be operational by the end of the year. However, a challenge that caused considerable delay was the requirement for an assembly and hoisting area at several of the sites located on non-flat terrain. Furthermore, the size of these platforms had to be enlarged from an original design of 70 x 50 metres suitable for the E-112 layout to 100 x 60 metres for the E-126, often implying a different orientation. Simultaneously, the permissible load-bearing capacity had to increase from 18 kN/m^2 to 26 kN/m^2. These issues meant a total redesign of the platforms.

Another unforeseen issue was a strategic underground fuel line that crosses the plateau relatively close to two turbines. ‘The responsible authorities demanded that this fuel line had to be covered by a concrete lining over two kilometres distance,' continues Ferweda, further explaining: 'Part of the track even required a double protection layer in order to meet these specific safety regulations.' Adding that these measures are aimed at the prevention of damage to the fuel pipe in the unlikely event, for instance, that a rotor blade might fail, be thrown from the rotor, and penetrate the ground, Ferweda continues: 'At the moment we face about six months delay compared to the original project planning.' One turbine is operational a second is due to be completed as this issue of *REW* goes to press (July 2009) and additional machines are expected to come on-line at one-month intervals until project completion.

In addition, each new machine has to successfully complete a 400-hour test run prior to commissioning. 'In general, this project represents a major almost daily challenge to all parties involved. But we are also achieving a steep learning curve. With the new crane now available and continuous improvements in the overall installation process chain, today's project delay will, for instance, be reduced to only three months at wind farm completion early 2010. Project commissioning is planned during Q1 2010,' states Ferweda.

Another unforeseen issue which caused delay and drove up costs was inadequate soil stability and limited load-bearing capacity on the plateau. This specific soil constraint rules out the application of rather common 'gravity based' foundations. A potential alternative, in the form of a thick, stable, sand layer underneath the soil surface enabling a pile-foundation, was also absent at Estinnes.

Enercon therefore chose to execute a 'gravel column' civil engineering solution, which it optimized for the specific soil conditions at the site. Foundation preparation begins by excavating a circular hole with a diameter of about 40 metres and depth of 4–5-metres. Next, approximately 200 deep columns are drilled across the area and the holes filled with a specific kind of gravel. New gravel is added in layers and compressed by a multi-purpose vibration device that also performs the column drilling. Thereafter all the columns are interlinked on top by a thick, level layer of gravel, with integrated geo-textile fabric reinforcement. Among other functions, this combination of measures is designed to optimized load distribution by creating a solid soil matrix. This gravel layer is compressed, smoothed and topped off with a thin concrete layer. The end result forms the base for constructing the actual 29-metre diameter ring-shape concrete foundation. Four metres high, it consists of more than 1400 m^3 of concrete and over 120 tonnes of reinforcing steel. It incorporates a flange for accommodating the concrete tower.

HEIGHT RESTRICTION

An E-126 with its 127-metre rotor diameter and 135-metre hub height has a cumulative 198.5-metre installation height. Ferweda explains that a total installation height of 200 metres (hub height + rotor radius) is the maximum for which permission can be obtained in many European countries, including Belgium, so the E-126 is just within limits. Enercon's highest (concrete) tower has a 138-metre hub height. Available for the 2 MW E-82 turbine, with an 82 metre rotor, it has a total installation height of 'only' 179 metres.

Each prefabricated E-126 tower is composed of 35 tapering concrete rings and one steel connector to accommodate the yaw bearing. The diameter at the foot is 14.5 metres, narrowing to a slender 4.1 metres at the top. The lowest rings are so large that they are manufactured in three 120º sections for transport/logistical reasons. Several smaller diameter rings comprise two 180º halves, while the remaining rings are manufactured in one circular piece.

All (35 + 1) tower elements are further pre-tensioned with steel cables that pass through the transition piece lower flange, pre-cast holes in the concrete wall, and the concrete foundation bottom flange. After post-tensioning, spaces between cables in the concrete wall are sealed and stabilized with a rapid-curing concrete grout.

Inside the foot of an E-126 tower, a large section of the available floor area is occupied by a so-called E-module. This two-storey high structure accommodates a modular-design Enercon-type 'grid side' DC–AC inverter on the upper floor, while at ground level sit four medium-voltage transformers with the associated switchgear.

TWO WORKING PLATFORMS

From a wind technology point of view, the E-126 further builds on E-112 design principles and seven years of operational experience with 10 turbines, including the August 2002 prototype. In 2005, 4.5 MW E-112 design was up-scaled to 6 MW, though the 114-metre rotor diameter remained unchanged. These machines were typically installed on a concrete tower built in-situ and with a 124-metre hub height.

Getting to an E-126 nacelle starts with a spiral staircase along the inner tower wall, followed by a roughly 100-metre elevator ride. The remainder is climbed by ladder, which extends into the main carrier. This huge main structural casting is directly bolted onto the yaw bearing and accommodates eight yaw motors along with other components. As standard in Enercon designs, also bolted onto the main carrier is a hollow stationary main pin. Fitted with two bearings in similar fashion to a bicycle wheel, this structure carries the rotor hub, generator rotor and (upwind) rotor as a single assembly, located in front of the tower. A unique feature of the 12-metre diameter disc-shaped air-cooled generator is that from an electrical power engineering point of view, it functions as if it were four individual generators each comprising a 90º section. All 'generators' are further fitted with an individual 'generator side' AC–DC rectifier, while DC power is fed down the tower centre to the 'grid side' DC–AC inverter located inside the E-module. [Note: When both a rectifier and an inverter are combined in a single unit, it is referred to by electrical engineers as a power converter.]

From the main carrier, the nacelle rear section is entered via a working platform. A second upper platform can be accessed by ladder, from which the nacelle top is reached via a hatch. Standing on this 142-metre high platform offers a spectacular view of the plateau, and all ongoing wind farm construction activities, far below.

Being a second-generation product, overall the E-126 turbine layout, generator and other main component positioning, and main system functions have remained rather similar to the E-112 predecessor series. For instance, a recurring part of Enercon's integral nacelle cooling system is a circular gap between the rotating spinner and stationary nacelle cover, allowing passing airflow to suck hot air out of the nacelle, creating internal air circulation.

New for the E-126 are an aluminium nacelle cover and that the centre rear is now completely closed. The E-82 is also fitted with an aluminium nacelle cover, for which Enercon applies advanced automotive industry manufacturing technology. The German market leader shifted to aluminium for various reasons. Fink explains: 'Despite the fact that our direct-drive wind turbine nacelles contain relatively few flammable materials, a main consideration was to further minimize total installation loss risks in the case of a fire.'

Other important, but by comparison secondary, reasons include a superior recycling performance, and the fact that an aluminium nacelle cover acts as a Faraday's Cage in case of lightning strikes. A third and final benefit claimed by Enercon is that heat transfer from inside the nacelle to the passing ambient air is far superior for aluminium when compared with composite material.

E-112 turbines were initially fitted with a large generator-cooling fan in the nacelle rear centre that would blow in additional air when required – a system aimed at boosting cooling performance at higher output levels and/or high ambient temperatures. However, as part of the new E-126 cooling concept, low-temperature air is instead drawn in through a circular gap between tower top and overlapping nacelle bottom section. Fink says this is relatively dry air, which is then blown into the nacelle through metal grates in the lower platform floor, creating slight internal overpressure.

The cooling air being forced through the generator is focused on the air gap between generator rotor and stator where the bulk of the heat is generated. The quantity of heat is substantial – assuming, for instance, 95% generator efficiency at 6 MW output, then 5% or 300 kW in heat energy is being released continuously.

MARKET PROSPECTS

By the end of May 2009 Enercon had erected a total of eight E-126 turbines, including the 2007 prototype. Currently the company manufactures one turbine a month, a number that will only gradually be expanded over the next few years and which is dependant on developing market demand, says Fink. At the moment, further projects are being developed in Belgium, France and the Netherlands as well as some other countries.

'Large installations like the E-126 should not be viewed any more as wind turbines in the traditional sense,' concludes Fink. 'One E-126, depending on its location, generates electricity for thousands of households. With regard to operational reliability and lifetime expectancy, in combination with the advanced built-in active grid support and grid stabilizing capabilities, there is not much difference any more between an E-126 and modern conventional power plants. In our view, therefore, it is likely that our new generation E-126 wind turbines at Estinnes and elsewhere will operate for a much longer period than today's common 20-year operational design life.'

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