CHAPTER 3

The technology

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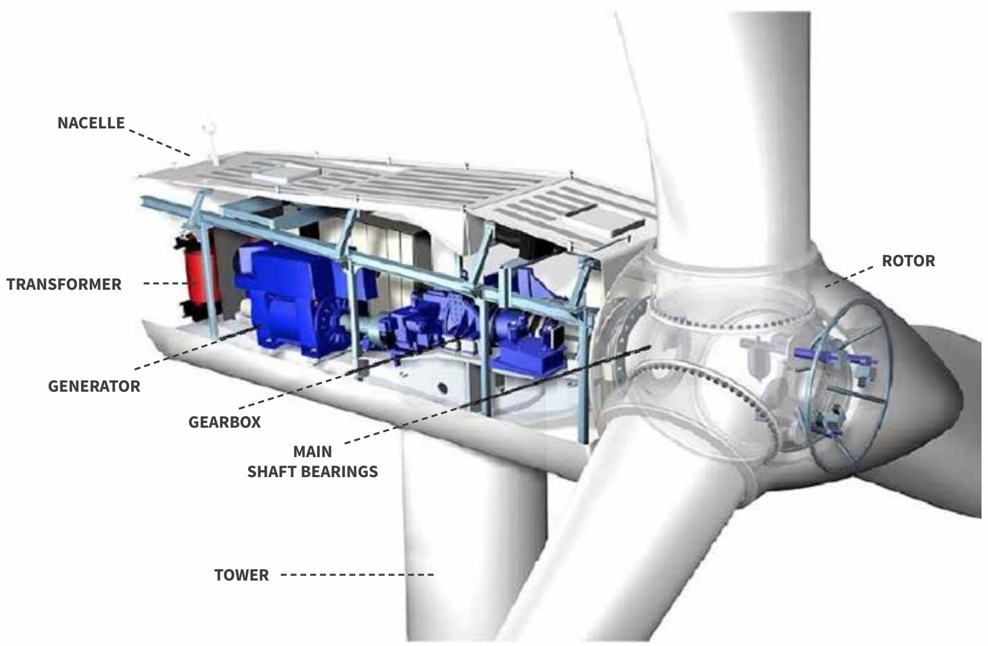
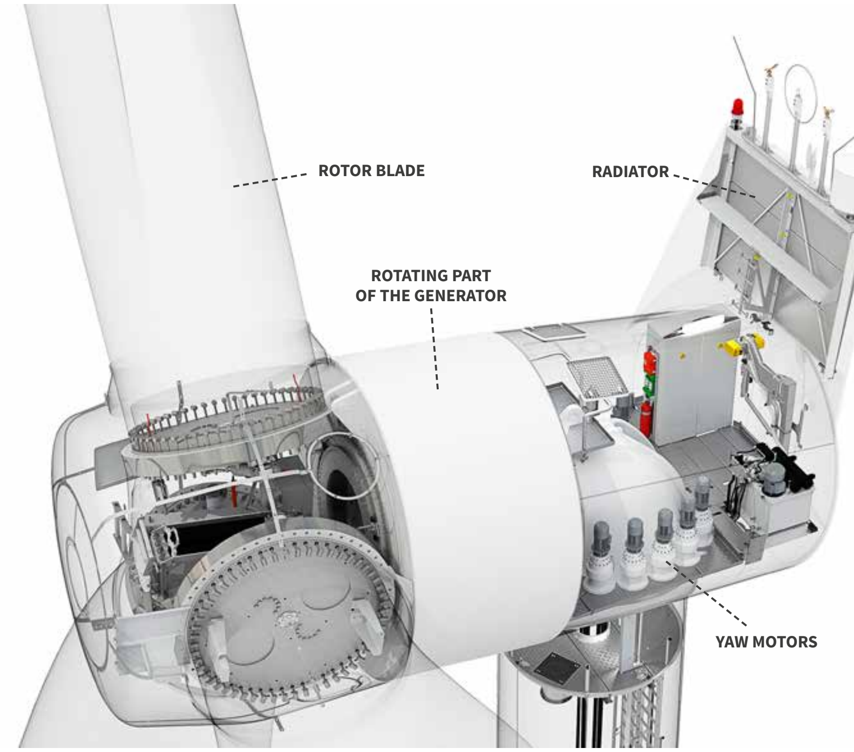
Manufacturing, assembly, transport, construction, installation and maintenance: all these activities occur in the development and operation of offshore wind farms. Technology is essential for this. Offshore wind energy is more complicated than onshore wind energy and requires a different approach when it comes to wind turbines, farm size, foundations, electrical infrastructure, logistics and maintenance. Turbines at sea are much larger than those on land and are clustered together in larger numbers. They must withstand waves, storms and the harsh salty marine environment. The foundations must also be able to withstand rough treatment. The technology required for this is developing thanks to research and experience in the construction and maintenance of wind farms. This is necessary when electricity from the sea is to be produced as cheaply as possible and competitively with other sources.



▲ Vestas' V164 turbine with a capacity of 10 MW.



▲ The direct drive turbine from Siemens. The rotor directly drives the rotating part of the generator.

The wind turbine

In a wind farm everything is about the wind turbine. The wind turbine converts wind into electricity. This takes place at the top of the nacelle in a number of steps. The wind turns three aerodynamically shaped rotor blades. The shaft of the rotor, in most turbines, drives the generator (dynamo) through a gearbox. In the gearbox, the speed is increased so that it can generate electricity in the generator using magnetic fields. A direct-drive turbine does not have a gearbox. The electric current from the generator is transported to a higher voltage directly in the nacelle or down in the tower. A cable carries this current through the tower and the transition piece to the transformer station at sea.

Parts of wind turbines

A wind turbine consists of a tower, a nacelle and a rotor with three rotor blades. Components in the nacelle are the main shaft, the gearbox, the generator, the transformer, the cooling system and the yaw motors. The yaw system keeps the rotor in the wind by rotating (yawing) the nacelle relative to the tower. When the turbine is no longer properly in the wind, a wind vane drives the yaw motors. Components such as the gearboxes, generators and transformers come from various European suppliers and are assembled in the nacelle at the factory. For maintenance of the wind turbines at sea, service technicians can enter the turbine from a boat through the tower or be transferred by helicopter to the deck on top of the turbine.

Capacity of wind turbines

The height and length of the rotor blades, the capacity of the generator and, of course, the wind speed determine how much electricity a wind turbine can generate. The amount of electricity generated is proportional to the third power of the wind speed. This means that if it is blowing twice as hard, eight times more electricity will be generated. Thus, small differences in wind speed produce large differences in yield. This is why the arrangement of the wind turbines, or the layout of the farm, always receives a lot of attention.

A new generation of wind turbines

The first offshore wind turbines were in fact modified land-based turbines. Now, large wind turbines specially developed for installation at sea are on the market, with a capacity of 8 to 15 MW. Offshore wind turbines are likely to become even larger and more robust in order to do their job in the extreme conditions of the North Sea. They are high-efficiency wind turbines with high yields even at relatively low wind speeds. Vestas's V164 turbine is an example of this. This turbine came off the drawing board in 2011 as an offshore wind turbine with a capacity of 7 MW, but it now produces 10 MW. This upscaling has been achieved step by step by adapting the generator to the rotor as well as possible and thanks to an improved gearbox and better controls. Now Vestas is bringing a 15 MW turbine to the market. V164 turbines with a capacity of 9.5 MW have been installed in Borssele 3 and 4 and in the Belgian project Northwester 2. In Horns Rev 3, there are turbines with a capacity of 8.3 MW. These turbines have a lifespan of 25 years.

Larger turbines, lower costs

Current offshore wind turbines are almost 300 metres high, a height comparable to that of the Eiffel Tower. The development of large turbines brings down the cost of the electricity generated. In addition, larger turbines reduce the operation and maintenance (O&M) costs of wind farms because fewer turbines are needed in a project and therefore fewer foundations and cables. Thus, for wind farms with such large wind turbines, the investments and risks are lower.

Direct-drive turbines

Direct-drive turbines are wind turbines without a gearbox. Siemens Gamesa, as the market leader for offshore wind energy, as well as GE, are using this technology for the new generation of offshore wind turbines. This robust, simplified drive concept has fewer moving parts and therefore requires less maintenance. The nacelle of such wind turbines, like gearbox turbines, has climate control (cooling). With these direct-drive turbines, Siemens Gamesa is not only targeting the European market but also projects along the east coast of the USA and markets in Asia such as China and Taiwan.

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▲ Siemens' new factory on the Elbe in Cuxhaven.

▲ Robots do a large part of the production at Siemens' new factory.

▲ Nacelles, ready for transport to the construction site.

New Siemens Gamesa plant

Siemens Gamesa has a market share of almost 70% with its offshore wind turbines. Siemens Gamesa has built a plant with a floor area of 56,000 square metres in Cuxhaven, northern Germany, on the banks of the Elbe. The nacelles of the wind turbines can be shipped directly through the nearby terminal. This ultra-modern plant of about 200 million euros was built primarily for the development of a new generation of offshore wind turbines. The plant provides employment for about 1,000 people, will also attract supply companies to the region and thus means a lot for local and regional economic development. Part of Siemens Gamesa's turbine production has thus been relocated to Germany, and that has negative effects for Danish supply companies and for the port of Esbjerg in Denmark. With this plant, Siemens Gamesa shows confidence in the further development of wind power in the renewable energy mix.

▲ Shipping of the first nacelles from the Cuxhaven plant for Belgium's Rentel wind farm.

▲ Although more and more is being automated, much manual work remains.

Rotor blades

The rotor blades of a wind turbine catch the wind and rotate the main shaft. The wing profile of the blades allows them to efficiently convert wind energy into a rotary motion. This motion drives the generator through a gearbox. In direct-drive turbines, the rotor shaft directly drives a large diameter generator. Most wind turbines have three rotor blades, which can be adjusted separately to make the best use of wind energy (blade angle adjustment). The major wind turbine manufacturers – Siemens Gamesa and Vestas – have their own rotor blade factory. The American GE has acquired the French wind turbine manufacturer Alstom and the Danish blade manufacturer LM. In addition, there are some specialized rotor blade manufacturers also in China. The rotor blades are made of composites. These composites or polyester, polyurethane and fibreglass mats are poorly recyclable. Burying discarded rotor blades in landfills as is now happening in the USA is not a solution. There are processes whereby the blades are processed into fibreglass-reinforced granules that can be used in the cement industry. The large numbers of wind turbine blades that will come from the sea in the next few years will require a recycling infrastructure and an outlet for recycled blade material. But that is only an interim solution. Work needs to be done on designs and materials aimed at reusing blades to avoid waste. The trick is to design and manufacture rotor blades with materials that are 100% recyclable. The wind industry is working hard on recyclable rotors. Gamesa announced in 2021 the world's first recyclable wind turbine blades ready for commercial use offshore, but there is still a lot of work to do before there is a circular offshore wind industry.

Manufacturing of rotor blades

The manufacturing processes of rotor blades differ from manufacturer to manufacturer and depend on the construction of the blade. Knowledge and calculation methods from aircraft are used for the design, construction and scaling of rotor blades, but they also take a close look at the wings of birds. The development of rotor blade technology has enabled the construction of 15 MW wind turbines with blades over 100 metres in length. And developments, of blades up to as long as 150 metres, will continue. However, although the blades may become longer, they should preferably not become heavier. The rotor blades of the future will consist of lightweight recyclable composite materials, which are flexible and, like the wings of birds, can withstand the erratic forces of wind and gravity.

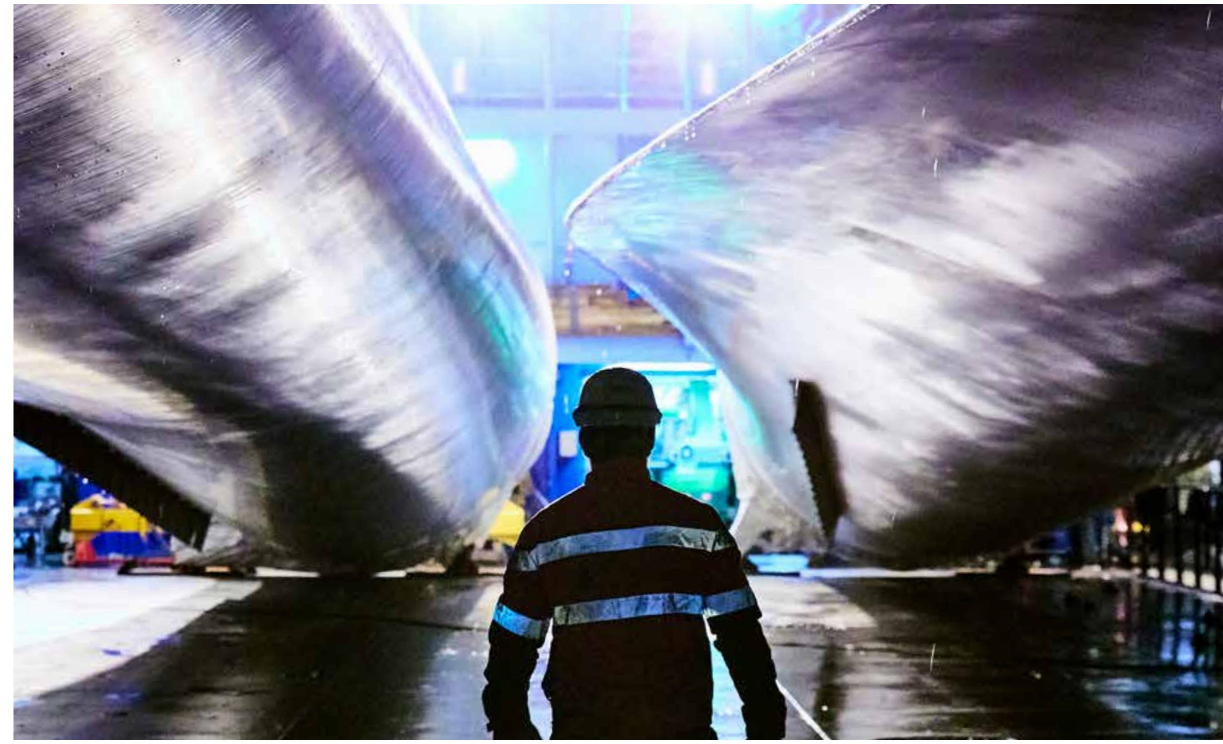
Production at LM

The Danish company LM is owned by GE. LM's rotor blades consist of two 'shells' of fibreglass and polyester. These are attached to each other using a reinforcing material on the inside. This material consists of a glass–carbon composite fabric infused with a special curing resin. Rotor blades make more than a billion rotations in operation, with an ever-changing force of gravity on the blade and a constant wind force pushing the rotor blades backward. Prototype blades are therefore extensively tested. During fatigue tests, they are rapidly bent back and forth millions of times in different directions. These fatigue tests are sometimes completed with heavy loads until the blades fail. The blades are also tested and protected against lightning strikes. Rotor blades have built-in lightning conductors. These conductors are intended to carry lightning through the rotor to the nacelle, mast, foundation and ultimately the seabed.

▸ Testing of an 88.4-meter LM rotor blade at Offshore Renewable Energy Catapult's test facility in Blyth, Northumberland (source: Catapult).

▾ Rotor blades, as the highest point of a wind turbine, can be struck by lightning. To prevent damage, a lightning rod is built into the blade. The lightning is conducted through the blade and passes through the tower to the sea floor.

▴ An overview of the test facility complex in Blyth.



Production at Siemens Gamesa

For the production of rotor blades, Siemens Gamesa has opened a plant in Hull, the UK. The epoxy resin blades are shaped in a special way in a mould made of fibreglass mats using the patented Integral-Blade technology. Siemens Gamesa claims that this technique reduces weak spots in the adhesive joints. As a result, lightweight, strong and reliable rotor blades can be made. This production process is also aimed at lower electricity production costs in a market without subsidies but not yet aimed at recycling.

The long rotor blades of the new large 15 MW wind turbines place high demands on production but also on transport. It is almost impossible to transport blades over 100 metres long by road. This is why manufacturers are opting for waterfront production sites and Siemens Gamesa has built a plant on the River Humber in Hull, UK. This plant has created 1,063 jobs, and 1,282 jobs in the local supply chain, with the prospect of over 600 more. This represents a large economic upturn in the region.

▼ Siemens Gamesa Renewable Energy factory quay in Hull, UK.