Drive & Control Technology for Wind Turbines

The Drive & Control Company
Everything is Going Round: Drive & Control Technology

Wind energy continues on its road to success by greatly increasing its share in electrical power production on a worldwide basis. The nominal power of wind turbines has risen from 100 kW to 3,000 kW. Now the first 5-MW installations are harvesting power. Rexroth as producer of hydraulic and gear technology systems is a competent partner and comprehensive supplier to manufacturers of wind turbines.

Broad Range of Supplies

No matter whether the traditional concept comprising rotor, gearbox, generator or a direct-drive solution is involved: Rexroth offers matching gearbox and hydraulics solutions for any type of wind turbine. Within our mechanical drive technology segment we develop and manufacture all types of gearboxes required for wind turbine installations: efficient generator gearboxes, highly precise yaw drives for permanent wind tracking purposes and compact pitch drives used for rotor blade adjustment.

Being the world’s leading supplier of industrial hydraulic equipment we also offer hydraulic solutions for wind energy applications: our supply range includes highly dynamic hydraulic pitch adjustment systems, reliable drive train brakes as well as yaw drive brakes.
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Drive systems to be incorporated in wind turbines must satisfy many specific needs: Variable wind loads, higher outputs, less available installation space and minimum weights are just a few technical requirements designers and engineers must observe aside from climatically induced strains.

**Experience and Know-how**

For about 100 years Rexroth have been producing drive system components. Already in the early nineties we built gearboxes for 3.2-MW turbines and thus were among those that from the beginning took part in the technical development of wind turbines. Long-standing contacts with leading universities and renowned antifriction bearing manufacturers help us to improve our products on a constant basis. Rexroth concentrates its know-how and technical expertise in its wind energy product sector and thus strengthens its position as sought-after partner of wind turbine manufacturers.

**Competence in Marketing and Design**

The importance of industryspecific drive system solutions is steadily growing. Rexroth has taken these trends into account by having established market-oriented application centers. In the application center renewable energies, product experts are at your disposal, who are not only specialized in drive technology and hydraulics, but are also familiar with the specifics of your application. This enables us to provide tailored solutions for each wind turbine project.

Being able to offer customer-specific engineering services is thus one of our strong points. The advantages our clients can thus expect from us are the result of decades of experience with planetary gears and hydraulic components as well as our innovative power. Moreover, unpleasant surprises may be avoided thanks to our know-how in engineering, manufacturing and testing. Before a complex component is actually manufactured, we have made sophisticated FEM calculations.

Rexroth gearboxes are designed for maximum safety and reliability. In their design and development activities, our experienced engineers are assisted by modern computer software for gearing design and component optimization.
Measurements on built-in prototypes are performed based on many years of experience. In the field we carry out, for example, air- and structure-borne noise as well as torque and load measurements.

**Top Performance from Start to Finish**

We know that quality greatly depends on selecting the right suppliers. Therefore, our suppliers must satisfy the same high standards we have adopted. Quality also means doing things right from the start: from machining, to heat treatment and assembly, including inspection, painting and shipment. In this context, our quality management system to DIN EN ISO 9001:2000 is the basis and guarantor of a consistently high quality level. Another area of major concern to Rexroth is environmental protection. For many years we have also been operating an environmental management system to DIN EN ISO 14001 at our locations.

Modern heat treatment methods have a decisive impact on the quality of gearings and components. Our vast experience in heat treatment technology is a most significant quality factor ensuring our gearboxes meet maximum standards in terms of strength, load-carrying capacity, compactness and service life. The know-how we have gained over several decades in the various milling and grinding operations involved in the manufacture of gearbox components and gear teeth is continually being further developed and forms the basis of the highest possible product quality. Rexroth invests systematically in advanced production machinery to ensure maximum quality and economic efficiency.

On our test benches all our components are checked to most stringent quality criteria prior to shipment. In our manufacturing facilities we subject our generator gearboxes to full-load tests up to a nominal power of 5 MW; special test configurations may be set up to comply with customer specifications. Advanced software packages enable temperature and noise characteristics to be recorded.
Facing the Wind Optimally: Rexroth Solutions for Rotor Blade Adjustment

100 m above ground. A strong wind is blowing at this height. The pitch drives of the wind turbines – compactly arranged at the root of the three rotor blades – constantly rotate with the rotor and make sure the blades are correctly positioned. They must meet highest requirements with respect to design and functional safety. Aside from reliability, precise positioning is of utmost importance. By providing both hydraulic and electromechanical pitch drives, Rexroth is capable of satisfying these technical needs.
MOBILEX GFB Pitch Drives
The Rexroth supply scope includes a complete range of MOBILEX GFB planetary gearboxes for all wind turbine sizes. To this end we can draw on 40 years of experience in the manufacture of swing gears for mobile equipment, such as excavators or cranes. The proven technological solutions in that field have been advanced to electromechanical pitch drives. The pitch drive supply range spans from small, two-stage planetary gears with output torques of about 1 kNm and ratios of 60:1 to three-stage types featuring output torques of about 20 kNm and ratios of 200:1. These space-saving drives consist of a compact two- or three-stage planetary gear unit equipped with output pinion and electric motor. Since electromechanical pitch drives are constantly rotating together with the rotor hub they are provided with special seal systems. Where confined mounting situations are encountered, an angle-type input gear stage is available as necessary.
Hydraulic Pitch Control
The hydraulic pitch drive combines all desirable characteristics in a single system: high positioning forces, compact size, distributed intelligence, high dynamics as well as long service life and reliability.

Plug & Play
After assembly all pitch drives are checked for correct functioning on the test bed. Moreover, our staff makes sure all electrical modules are attuned to each other. This enables the pitch drives to be mounted and put into operation as soon as they arrive on site. Thus complex matching of signals and other electrical characteristics can be dispensed with – plug & play.

Fail-Safe Properties
The Fail-Safe operation of the individual pitch drives is achieved by establishing logical connectives between the individual hydraulic components.
Their functions are based on purely mechanical principles and are highly reliable. Nevertheless, should complications arise all the same, the rotor blade, powered by hydraulic accumulators, will move into the safe end position without external control action being necessary.

**Distributed Intelligence**
Proportional valves with inherent processors and storage modules are capable of performing all necessary actions from simple open-loop control duty to complex closed-loop feedback control functions. This will reduce the loads acting on the control system and also the bus system.

**Hydraulic Pressure Supply**
Nothing goes without pressure. Even the most intelligent hydraulic system needs pressure to get things moving. Since oil has no definite shape the hydraulic unit can utilize even the smallest mounting space.

High-quality hydraulic components from company-own fabrication, amply sized filters for highest oil purity as well as coolers and heaters ensuring optimum operating temperature are prerequisite to a long service life.

Using hydraulically pressure-controlled variable displacement pumps in conjunction with hydraulic accumulators results in high actuating forces and spare capacity with only minimum space requirements and efficient energy utilization.

**Decentralized Arrangement**
The individual functioning modules of the hydraulic system need not necessarily be arranged side by side. Providing flexible connections between the individual modules enables the entire hydraulic system to be optimally integrated into the wind turbine.

**Technical Features**

**Electrohydraulic Pitch Control System:**
- Precise controllability
- Highly integrated
- Compact design
- Reliable fail-safe function
- Integrated safety functions
- Easy commissioning
- Long service life
- Highly environmentally compatible
- Flexible arrangement
- All common analog and digital interfaces
Quiet and Reliable:
The REDULUS GPV Generator Gearbox

An offshore wind farm in the North Sea off the coastal region of Denmark. A hard southwesterly wind of 8 Beaufort is blowing here. A rough climate – and high stresses for the generator gearbox as well.

It is the central element in the wind turbine’s drive train. While a car gearbox is designed for a lifetime of two thousand hours the generator gearbox shall reliably operate for 20 years, i.e. about 175,000 operating hours.

And this is what REDULUS GPV does. Day after day.
REDULUS GPV generator gearboxes of compact design comprising a combination of one planetary and two helical gear stages have meanwhile been in use in a variety of wind turbines with power ratings of up to 2 MW. Rexroth develops customer-specific solutions best matched to the needs of the relevant turbine configuration. The external teeth of our gears are case hardened and the ring gears’ internal teeth are nitrided. Our vast experience in heat treatment technology is a most significant quality benefit ensuring our gearboxes meet maximum standards in terms of strength, load-carrying capacity, compactness and service life. We are of course aware of our customers’ wishes for optimum gearbox noise characteristics. Already 40 years ago we built large-size low-noise gear units for cruise vessels. What at that time helped passengers to sleep well contributes today to the quiet operation of generator gearboxes. Aside from our design strategy, a highly precise profile grinding process assists in keeping the noise level in the nacelle down.

**Technical Features**

**REDULUS GPV for Turbines between 600 and 2,000 kW:**

- Ratios ranging between 50 – 120
- Tailored design solutions
- Compliance with Rexroth design guidelines to ensure maximum service life
- Compact design due to combining a planetary stage with two helical gear stages
- Case hardened and ground external gears
- Helical planetary gear stage
- Ground, nitrided ring gears
- High-grade antifriction bearings
- Injection lubrication for planet gear bearings and cooling system optional
- Connection of rotor shaft and hollow input shaft via shrink disk
- Sensors for pressure and temperature monitoring purposes
- Low-noise characteristics
Slender and Compact:
REDULUS GPV-D for the Multi-Megawatt Class

Design engineers have to master more and more stringent challenges to keep pace with the trend towards multi-megawatt wind turbines. The developers’ requirements specifications frequently include demands for more compact drives with the gearbox weight to be minimized as well. Rexroth with its innovative differential gearbox of type REDULUS GPV-D now satisfies precisely these needs by providing a multiple power-split design solution.

There is a significant difference in comparison to the conventional generator gearboxes of the multi-megawatt class: In the input stage of this unit it is not four or more planet gears that revolve around the sunwheel. Instead, REDULUS GPV-D includes two input stages each fitted with three planet gears which offers advantages in terms
REDULUS GPV-D offers major benefits in that it has slender outer diameters with the total length just being increased slightly. If higher turbine capacities are involved weight advantages of up to 15% may thus be achieved compared to the gearbox concepts currently in use, without compromising reliability. In this context, component sizes also contribute: The dimensions of the internally and externally toothed gears, antifriction bearings and planet carriers of REDULUS GPV-D are similar to those used in the 1.5- to 2-MW class gearboxes. Benefits for our customers: By utilizing reliable, reproducible production processes we manufacture these components already today in large quantities and with constantly high quality.

**Functional Principle of the Differential Design**

Power splitting takes place in the first planetary gear stage. Via the rotor speed, part of the power is directly transferred from the planet carrier into the first planetary stage, the other part is transmitted into the revolving ring gear of the second planetary stage as lossless coupling power. The power distribution percentage is subject to the stationary gear ratio of the three planetary stages.

The speed of the first planet stage sun gear also coincides with that of the planet carrier of the differential stage summing up the power. Moreover, the speed of the sun gear of the second planetary stage corresponds to that of the rotating ring gear of the differential stage summing up the power. The speed rates of ring gear and planet carrier of the differential stage result in a cumulative speed of the sun gear where the split power is brought together again.

**Technical Features**

REDULUS GPV-D for Turbines between 2,300 and 5,000 kW:
- Ratios ranging between 70 – 150
- Tailored design solutions
- Compliance with Rexroth design guidelines to ensure maximum service life
- Differential design concept with two planetary stages, one differential and one parallel shaft gear stage
- Case hardened and ground external gears
- Ground, nitrided ring gears
- High-grade antifriction bearings
- Circulating lube oil system to feed oil to all tooth meshing points and bearings; cooling system optional
- Sensors for pressure and temperature monitoring
- Low-noise characteristics
- Easy to service due to modular design
Keeping on Track: Yaw Drives MOBILEX GFB

Schleswig-Holstein – land between the seas. Days without wind blowing there are the exception, not the rule. Even in the brightest sunshine wind turbines may operate at an appreciable load. If the sensors signal to the control system a wind direction change of $8^\circ$ towards NNW the yaw drives are activated and position the nacelle exactly as necessary. Precision and the behavior of the meticulously matched individual drive systems are decisive factors. No problem for our robust and powerful yaw drives of type MOBILEX GFB.
Since 1968 planetary gearboxes have been part of the Rexroth supply range. In the eighties, starting from the technological experience gained with these gears in cranes we developed drives needed for optimum yaw control of the nacelle. Whether big or small, we have available a complete supply range of MOBILEX GFB gearboxes for any type of turbine size. The output torques here range from 3 kNm to 150 kNm while the ratios of the four-stage planetary gears are between 700:1 and 2,000:1.

The drives consist of a compact four-stage planetary gearbox equipped with output pinion and electric motor. The planetary gearbox has four planet stages offering high transmission ratios for highly sensitive rotational movements. The ever increasing size of the nacelles makes of course higher torque rates necessary. These can be achieved by arranging several drives arranged around the yaw bearing. All in all, more than 10 gearboxes may be employed for the yaw control system.

**Technical Features**

**MOBILEX GFB Yaw Drives:**
- Output torques between 3 and 150 kNm
- Ratios ranging between 700 – 2,000
- Compact, four-stage planetary gears
- Sturdy antifriction bearing
- For the attachment of electric motors
- Easy to install
- Convenient oil change
- Low-noise running characteristics
Both Strong and Gentle: The Drive Train and Yaw Drive Brakes

It’s inspection time for a wind turbine. Before the engineers can access the nacelle the wind turbine must be stopped. In fact, exactly in a predetermined position. After all, the service staff must be able to gain access to the hub. This necessitates that the rotor is secured in a safe position. Compared to the past, this is easily accomplished today: the electrohydraulic brake control stops the rotor exactly in the required position and automatically engages the rotor arresting system.

Brake Gently and Secure Firmly
If the design provides for the wind turbine to be stopped by the drive train brake alone, extremely high brake torque rates will act on the generator gearbox. Therefore, stopping the turbine solely for service work purposes would cause undue strains and unnecessary wear. For this reason Rexroth distinguishes between emergency braking and service braking operations. When the rotor is stopped in the desired position it only needs to be secured until the rotor arresting function has been activated. Following this, the brake is released eliminating loads otherwise acting on the drive train which is in the interests of a long service life of the entire wind turbine.

Always Facing the Wind
When the wind direction changes the entire nacelle has to be moved into a new position. For this purpose the clamping pressure exerted by the yaw brakes is reduced to slipping pressure and the entire nacelle is then moved by action of several yaw drives. As soon as the new position is reached the original pressure is restored which also results in the yaw drives to be relieved. Using proportional valves for slipping pressure control will bring down wear significantly.

And when the cables between nacelle and tower are untwisted the nacelle quickly rotates “backwards” due to the yaw clamping.

So, this enables the Rexroth staff to do what is expected of them: Carry out the inspection.
action being completely released to reduce wear.

Mechanically Blocked for Safety Reasons
If persons are to perform work on or inside the rotor it is mandatory in the interest of safety that the rotor is mechanically arrested. For this purpose a bore arranged in the rotor shaft is brought in alignment with the arresting cylinder which can then be engaged. If to be performed manually, at least two or three persons are needed for this work – an electronic control system does it automatically.

Technical Features
Electrohydraulic Brake Control:
• Precise open-/closed loop control capability
• Very compact design
• Integrated safety functions
• Easy commissioning
• Highly environmentally compatible
• Designed for an operating time customary for this application
• Tailored solutions based on modular concepts
• Drive rating between 0.18 and 4.0 kW
• Volumetric flow rates from 1.2 to 14.8 l/min
• Tank capacity from 1 to 60 l
• Tank of steel, aluminum or plastic
No Matter Where, When or Why. Our Service – At Your Disposal.

One thing’s for sure: In the event problems arise in your wind turbine installation our service team will be quickly on site to give professional servicing assistance. “Set them up and harvest power” – is the objective of all wind farm owners, which we not only appreciate but help to achieve as quickly as possible. In more than 80 countries and on a 24/7 basis, our service division is ready to provide assistance. Rely on our unexcelled service competence and performance. In-the-field support from failure analysis to repairs: no matter what Rexroth component is concerned – our qualified experts and dependable service people will be pleased to help you. To find a Rexroth expert near your location visit: www.boschrexroth.com.
Gearbox Inspection and Proactive Failure Detection
Preventive maintenance of the gearbox improves the availability of your wind turbine installation and its operational efficiency. Our qualified service engineers have comprehensive experience regarding the early detection of failures. They use proven inspection software and perform measurements and tests with the help of modern equipment and systems.

Repairs
Our comprehensive gearbox design knowledge makes sure faultless repairs are carried out on a cost-effective basis. Overhauls and the re-manufacture of equipment items are effected based on original drawings which are also drawn upon when gear teeth must be reground. Prior to delivery, any repaired gear unit is tested on our test benches according to most stringent quality criteria with relevant reports being issued.

Spares
This Rexroth service segment is characterized by speed, competence, efficiency, and worldwide logistics. We will furnish original spares of OEM quality, spares kits and upgrading sets for existing equipment – even after a given production series has expired.

The Drive & Control Company
Rexroth is unique. No other brand on the world market can offer its customers the full range of drive and control technologies, both on a specialized and integrated basis. This is one of the reasons why we are best-in-class on a worldwide basis when it comes to furnishing technological driving, controlling and motion solutions; a standard to be constantly confirmed by mastering new challenges. In more than 80 countries around the world, with about 30,000 employees. This is possible thanks to an infrastructure purposefully designed with partnership and customer proximity in mind.

As a company Bosch Rexroth looks back on more than 200 years of tradition. As a wholly owned subsidiary of Robert Bosch GmbH, we are part of a globally operating technology group. All this is both our drive and our commitment. And it is unique – just like Bosch Rexroth. The Drive & Control Company.