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Braking Ideas for Wind Turbines

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Windpower Engineering
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Altra® Industrial Motion

The Power of Experience

Braking Ideas for Wind Turbines

Brakes for wind turbines call for higher cycle rates, higher loads, greater reliability and often in more compact packages than those on conventional factory equipment.

Rotor brakes from Twiflex, Ltd., come assembled, provide high levels of reliability, easy electronic monitoring and maintenance, and are available with organic or metallic linings. Models are offered in a range of braking forces from 100 N to 1 MN. Rotor-brake models include the GMR (15 to 35 kN), the VCS (20 to 60 kN), and the VKSD (50 to 119 kN). VCS and VKSD brakes are available as both standard and floating models. Floating, single-sided brakes are mounted on sliding bushings to save space on the installation.

Slowing and halting an 80-m wind-turbine rotor involves converting its kinetic energy into heat. The same mechanical transfer occurs, for example, when stopping a large truck. A 40-ton mining truck, for instance, must be able to stop on a steep gradient. This involves a heavy load that opposes braking and provides a comparison to the aerodynamic torque delivered by a turbine rotor.

Let's compare the emergency braking requirements of a 1.5 MW wind turbine under maximum wind conditions with those of a 40-ton mining truck. Imagine driving a fully loaded truck down a steep gradient of 25% (1:4) at 85 mph when a road sign warns of a cliff a quarter mile ahead. The engineering required for effective braking in both cases is much the same. Braking for the wind turbine is, in fact, more demanding. Consider that unlike vehicles, wind turbines:

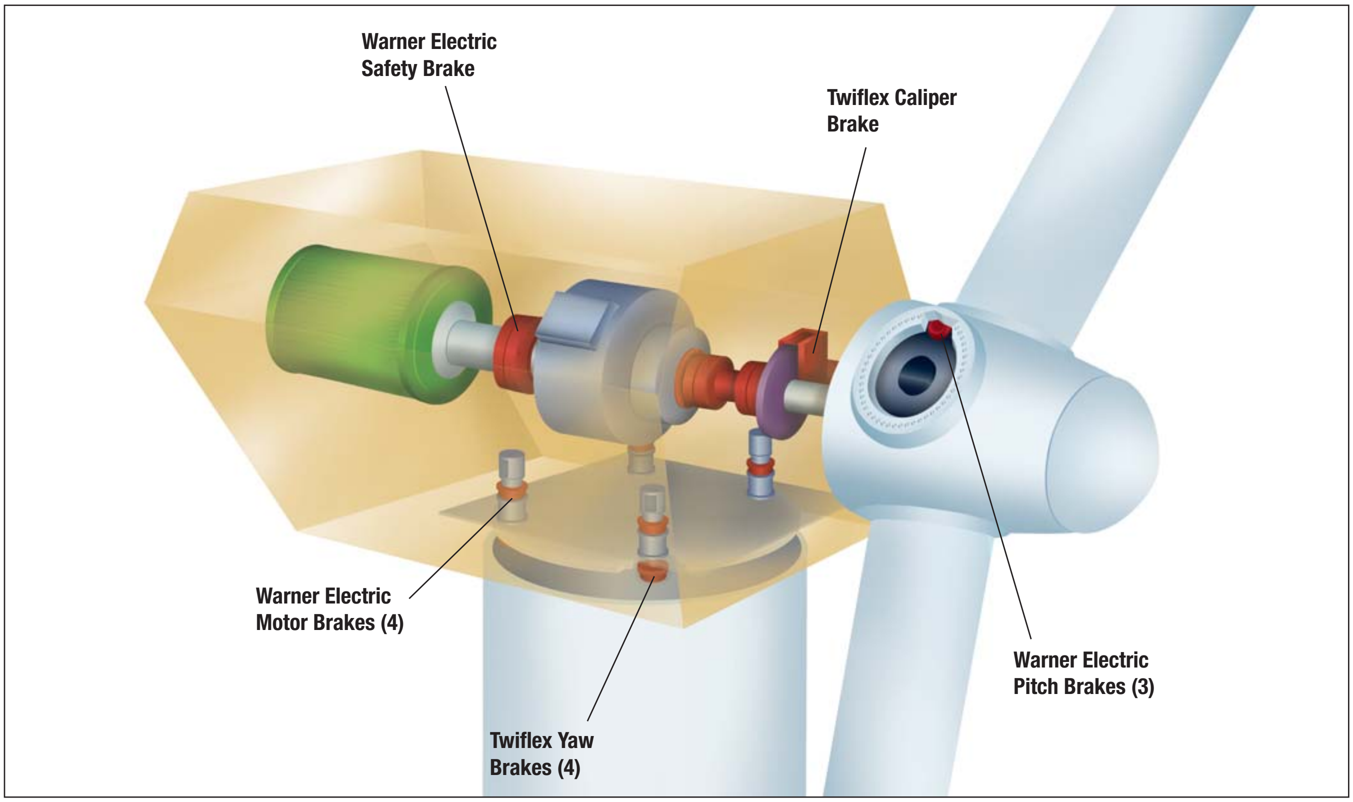
- Have no drivers, so braking must be automatically controlled.
- Use brakes that must operate unmanned for extended periods.
- Must achieve high standards of reliability with extended service periods.
- Must operate under extreme conditions as in desert or arctic regions.
- Can be sited offshore in salt atmospheres, high humidity, and temperature extremes. Brakes must withstand all these harsh conditions.
- Are located high above ground and sea level, making access difficult for maintenance.

Main rotor braking systems

Rotor brakes control overspeed, and provide parking and emergency braking. These brakes can be mounted on the rotor or low-speed shaft, on the generator (high-speed shaft), and in some cases on both shafts.

Low speed shaft braking is relatively straightforward in that a large disc brake, with a large friction lining area, is easy to accommodate. Unfortunately, installation here requires high braking torque. Generally speaking, the most cost-effective position is on the high-speed shaft between the gearbox and the generator. The high increase ratios of wind-turbine gearboxes produce a large reduction in output torque. In many cases, a serious criteria regarding brake selection is choosing a friction liner area of sufficient size to ensure adequate heat dissipation during emergency stops.

The energy which must be dissipated is the same wherever the brake is placed meaning the total lining area must be the same. It also means the brake-pad area must be sufficient to control the temperature rise.



These requirements are more difficult to meet on the high-speed shaft because speed and space will be limiting factors with regard to the maximum disc diameter and brake selections. Nevertheless, high-speed shaft braking has been used on many turbines rated up to 750 kW, although as the industry develops higher capacity turbines, the trend is leaning towards rotor-shaft braking.

A further consideration regarding brake position is the possibility of gear tooth damage. If brakes are installed on the gearbox output shaft and the turbine is stationary, gusts are likely to cause the rotor to transmit a rocking motion within the backlash of the input and output gears. Without forced lubrication between the mating teeth this effect could ultimately result in fretting and expensive gear damage.

Determining braking torque for rotor brakes

The braking torque level for rotor brakes is a crucial consideration that must be calculated during initial stages of a brake design. The maximum permissible braking torque on the rotor shaft is usually imposed by the blades, or their anchorage to the gearbox input shaft. On the other hand, high-speed shaft braking is usually related to the maximum permissible gear-tooth loading.

A minimum level of braking torque also exists, below which the variable nature of the frictional forces under different operating conditions could place the turbine rotors at risk.

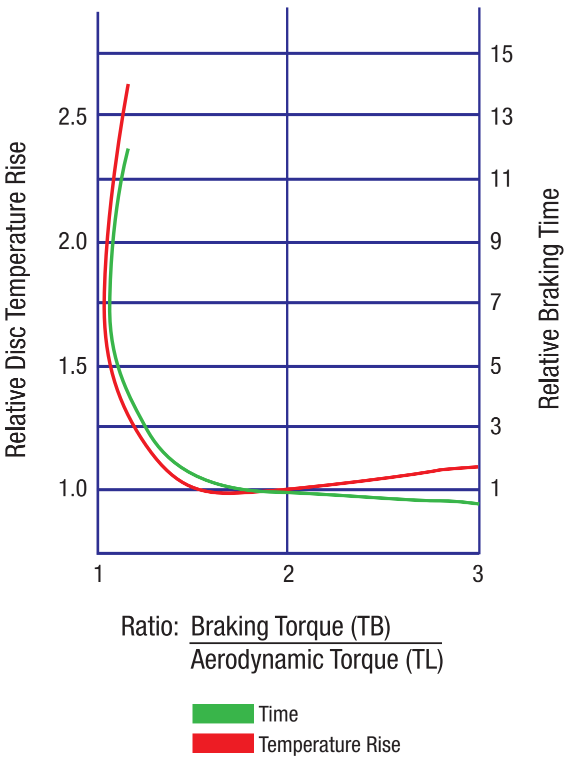


Fig. 1: The ratio of braking torque to aerodynamic torque provides one guide for selecting brakes

It is therefore important to allow an adequate window of safety, or service factor, to ensure that the brakes will always operate effectively and under all climatic conditions. To achieve an adequate service factor it is helpful to consider how braking performance can vary with the same predetermined level of braking torque. For example, suppose a 500-kW turbine has:

Rotor Inertia:	163,000 kgm2
Aerodynamic torque:	100,000 Nm
Rated rotor speed:	50 rpm

If the brake is applied during an emergency at 20% over-speed, the rise in disc temperature and stopping time will vary depending on the chosen service factors.

Maximum brake path temperatures (Fig. 1) show how these change using different service factors relative to a comfortably accepted factor of 2.00, that is

2.0 = Tb/TL
where
Tb = brake torque and TL = load torque.

In this case, the calculated braking torque is 200,000 Nm.

It can be seen that 3TL gives the minimum temperature rise and, although this is true for all values of inertia, speed, and load torque, it is to a certain extent dependent on the thermal properties of the disc.

Notice also that temperature rise and stopping time vary by only small amounts when the service factors are changed from 1.5TL to 3TL. In fact in the case of temperature the rise is only 6%.

This is certainly not the case when applying service factors of 1.5TL to 1.05TL. In fact, both stopping time and temperature rise increase rapidly.

Although precise figures for this steep increase will vary with the actual inertias, speeds, and aerodynamic torques, it is clearly and potentially hazardous to design a brake within this region.

Other factors, apart from the composition of the liner material, affect the achievable friction level. A summary includes:

- Bedding and conditioning of the liners
- Dirt on the braking surfaces
- Condensation
- Oil on the braking surfaces
- Rubbing speed and pressure
- Disc temperature
- Disc surface finish and hardness
- Wear debris on liner surfaces

Because wind turbines operate unmanned, it is not possible to monitor all of these conditions. Consequently an allowance must be made when calculating a safe torque level.

Experience shows that molded brake-pad materials can lose 50% of their friction, even under apparently good conditions. This fact suggests that a ratio of Tb/TL +2 should be regarded as a minimum.

Criteria for required braking torque can be summarized as:

- Minimum torque rating Tb/TL = 2.0
- Adequate pad area
- Acceptable rubbing speed
- Liner material compatible with maximum disc temperature

"Almost all wind turbine rotor brakes are of the fail-to-safe design, being spring-applied and hydraulically released,"says Jon Cooksley, Sales and Marketing Director at Twiflex, Ltd., UK, "They incorporate powerful springs which directly, or through an independently mounted thruster, apply force to press each brake liner against a disc. The brakes are released by compressing the springs with high pressure hydraulic oil supplied from a power pack".

Brakes for yaw control

Yaw brakes provide an effective means of smoothly controlling a wind turbine nacelle as it rotates "up wind" or yaws. They are usually installed as drag brakes and operate by controlling back pressure, which in turn controls the degree of spring force and therefore braking torques.

Under normal operational conditions, a horizontal axis wind turbine can be stopped by moving the blades out of the wind. However, the mechanism that controls this action usually relies on electricity and would be inoperative in the event of a power failure. While it is possible to design a control system to operate without electrical power, it would be cost-prohibitive. Also, adequate response time could present a serious problem when an emergency stop is required under high wind velocities. Without electrical load to restrain free acceleration yaw controls may not be fast enough to prevent dangerous over-speeding under gusty conditions. A braking system must also be 100% reliable because should power fail during high winds, brakes become the last line of defense in preventing a catastrophe.

An anemometer signals a change in wind direction which energizes the motor driving the gear ring on the yawing system.

A full array of caliper solutions is available from Twiflex, Ltd. to meet yaw-braking requirements of any size wind turbine. All brake models are reliable, hydraulically activated, and direct applied. Models T20 and T40 with up to 40 kN braking force, featuring two-bolt side mounting, are intended for light to medium-duty applications. Model VCH with 60 kN, featuring four-bolt center mounting, works well in medium sized turbines. Model VKH with 118 kN, base mounted caliper is designed for larger, heavy-duty turbine applications.

The new design of the Warner Electric ERS68 for wind turbine pitch drive applications provides superior emergency stopping power and improved protection from harsh environmental conditions for long service life.

The motor is de-energized by a further signal when the yaw mechanism reaches the optimum “up wind” position and the nacelle stops.

Typically, there are four to eight yaw motors per turbine. The brakes usually mount to the back end of the drive motors and are commonly positioned on the underside of the yaw gear ring. “Varying wind strengths cause varying motor loading and therefore determine the accuracy of the nacelle stop relative to the change in wind direction” said Edouard Haffner, Engineer at Warner Electric, France. “Motor load can be effectively controlled regardless of wind strength by installing a permanently applied, electromechanically released brake on the gear-ring face and varying its drag from the signal actuated by the rise or fall in motor current.”

This ensures accurate nacelle positioning and best operating efficiency. The design eliminates potential damage from erratic movement with the gear backlash and the brake is an effective clamp to lock the mechanism in position.

Wind-turbine engineers agree that a mechanical disc brake is the best solution in terms of reliability, simplicity of manufacture, ease of servicing and initial cost. Disc brakes are renowned for their excellent performance in hostile environments which is why they are used in cranes, heavy vehicles, and other safety-critical applications. Another reason is that a disc brake requires little physical space relative to the braking force it provides.

Depending on turret size and therefore the required clamping torque, caliper brakes may be used in multiples of 2 to 24. Turret brakes typically provide a combined clamping (holding) force ranging from 50 kN to 500 kN.

Blade pitch control braking considerations

Large horizontal axis wind turbines “pitch” or angle their rotor blades for best efficiency. The rotor blades are also pitched or feathered to minimize rotation in high winds and for turbine maintenance. “Pitch drives can be driven electrically or hydraulically,” says Warner Electric Sales Manager-OEM Tim Heikkinen. “Electric is most common, which lends itself to a cleaner, more compact design. In addition, the electric drive is more accurate and can be easily programmed to meet a variety of application variables. In either case, a power-off holding brake built into the drive serves as an added safety feature, as well as for dynamic braking in emergency pitch conditions.”

The general layout of an electric pitch drive includes: an electric motor, (ac, dc, or servo), a position sensor (encoder or resolver), and a power-off holding brake. Control logic releases the brake, drives the motor, senses the position, stops the pitch operation, and engages the brake to hold the blades in a predetermined position. The motor drives a large ring gear integral to each blade, typically with a gear ratio in the 1,000:1 range. The pitch drive must be a compact package because there is limited space to mount the assembly in the turbine's nose cone.

When selecting a brake for the pitch drive, allowance must be made for sufficient torque in a compact package. Typically, the brake must not be larger in diameter than the motor and position sensor, and must not add excessive length to the drive system.

Design life must also be factored in to component selection. A large-scale turbine can have an effective design life of twenty years, so individual components and packaged systems must meet or exceed this standard. The brake has to withstand a minimum of full speed dynamic stops, (up to 3,000 rpm, at 135+Nm) to be considered for incorporation into the package.

The number of estimated emergency pitch stops in a 20-year life is generally defined between 500 and 1,000. Due to the large inertia these stops can create, thermal dissipation and peak energy input criteria must be accounted for. A properly designed disc and caliper brake can meet torque and thermal specifications. However this style of brake tends to be quite large in diameter and can be difficult to mount in a limited space. A flange mounted electrically-released/spring-engaged standard motor brake can meet the space requirement, but normally falls short in the torque and thermal specifications. More robust brakes have been designed to meet the higher standards needed in this type of application.

Warner Electric has developed a series of high-torque, electrically released, spring engaged, static holding brakes which can withstand the severe conditions in the pitch drive of large turbines. This brake series, from Warner Electric, is typically smaller in diameter than the motor assembly and adds minimal length to the overall package. For example, the Model ERS-68 brake, rated at 135 Nm, is 6.5-in. diameter and only slightly over 2-in. long. "This brake is rated for 15,000 to 30,000 dynamic stops, depending on coil and voltage required, far exceeding the typical design life criteria of 500 to 1,000 stops," says Warner Electric Engineer Rich Silvestrini. An additional benefit from an electric brake is its short reaction time, 0.20 sec or less, making it a superior choice for wind pitch drive systems. The reliable design of this brake style, easily dissipates the heat generated far and above that required by the normal duty cycle.

About Altra Industrial Motion

Altra Industrial Motion (NASDAQ:AIMC) is a leading multi-national designer, producer and marketer of a wide range of electromechanical power transmission products. The company brings together strong brands covering over 40 product lines with production facilities in nine countries.

Altra's leading brands include Boston Gear, Warner Electric, TB Wood's, Formsprag Clutch, Wichita Clutch, Industrial Clutch, Ameridrives Couplings, Kilian Manufacturing, Marland Clutch, Nuttall Gear, Stieber Clutch, Twiflex Limited, Bibby Transmissions, Matrix International, Inertia Dynamics, Huco Dynatork, Ameridrives Power Transmission, Delroyd Worm Gear and Warner Linear. For information on any of these technology leaders, visit www.AltraMotion.com or call 815-389-3771.

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