Pitch battles

Words: Johnny Henrik Kjeldsen, Head of R&D Wind Solutions, Dellner Hydratech
Joel Cox, Global Sales Director, Dellner Wind Solutions

A wind turbine pitch system with higher redundancy and safety will be more cost-effective in the long term compared to a cheaper, simplified alternative. For example, can all three blades pitch at all times? Understanding the relevant design load cases is a crucial starting point.

The pitch system, which is responsible for rotating each turbine blade around its axis, is a wind turbine's primary safety mechanism. It plays a key role in regulating power output and ensuring the turbine performs safely under variable wind conditions.

Hydraulic cylinders, accumulators, sensors and valves are installed for pitch movement on the blades. If cost is the only design consideration, compromises to redundancy and fault tolerance become a risk, ultimately increasing the total cost of ownership.

Each blade rotates around its own axis to regulate the power output of the turbine. To keep the power output at the level of what the turbine is designed for, the blades have to be pitched out of the wind, which essentially makes the turbine less effective by harvesting less of the wind energy. This process is constantly impacting the power output from the turbine.

We're frequently asked by industry partners about the safety features built into pitch systems. Understandably, stakeholders want to know how pitch design can reduce stress and therefore costs, across the entire turbine.

Simply put: a more robust, redundant pitch system may increase upfront investment but can reduce mechanical loads on other turbine components, such as the tower, hub or drivetrain. A low-cost pitch solution may be appealing on paper, but rarely delivers long-term value.

A popular video on our YouTube channel shows a case study in which a turbine is fitted with three large pitch cylinders, one per blade. Some original equipment manufacturer (OEM) brands favour only two per blade, offering a pull / retract effect.

Some OEMs rely on electric motors and gearbox reducers for blade pitching, using sensors and encoders to verify motion and blade position. While different technologies exist, the goal remains the same: precise, safe and reliable pitch control. Getting pitch angles wrong, albeit even slightly, can lead to load imbalances, vibration issues or energy loss. And when things go wrong, redundancy determines how safely a turbine can stop.

Hydraulic pitch systems remain a reliable choice due to their built-in energy storage and straightforward redundancy using accumulators. In emergency scenarios, stored energy allows the system to bring blades to a stop, even if primary power is lost.

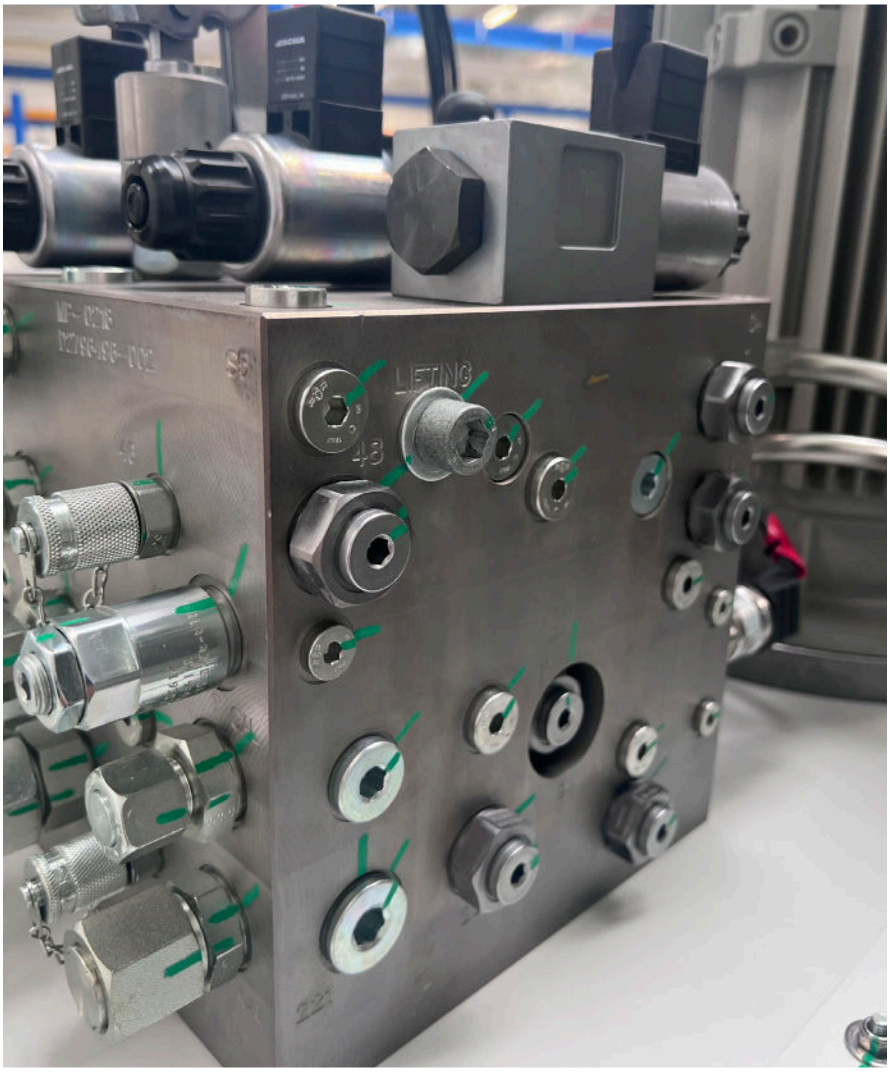
Challenges of operational life

OEMs designing turbines from scratch must follow IEC 61400, a globally recognized standard that outlines design load cases (DLCs) and safety requirements throughout a turbine's lifecycle. These simulations help engineers ensure that turbines remain structurally sound and operationally safe under all expected conditions. This standard is essential for ensuring that turbines can withstand the challenges they face throughout their operational life.

Additional safety can be implemented in several ways and since a pitch system is custom engineered for each turbine, there is not one correct way of doing it. However, one goal is universal: all three blades must always be able to pitch.

On older turbines one cylinder could rotate all three blades at once through mechanical connections. The first step in the process of improving safety was to separate actuators so that each blade has its own actuators. The choice between one or two cylinders per blade is less about safety and more about overall hub layout and system architecture.

Next is the separation of position control of the cylinders. Again, each blade would have its own monitoring and control of the cylinder position which, through mechanical geometry, correlates directly to the pitch angle. The energy backup that is achieved by the implementation of hydraulic accumulators is



also separated so that each blade has its own energy backup. This configuration represents the minimum baseline used by all turbine OEMs today. However, it is still not completely redundant or safe since failures on the individual blade will still cause a blade that is not in control.

Supplementary benefits can be achieved by strengthening the redundancy even further. One example could be to introduce energy backup for normal operation in addition to the backups on each blade. If one of the energy backups is failing the accumulators used for the normal operation conditions can assist the failing blade in the case of an emergency stop. When calculating machine safety multiple consecutive errors are not considered. Those types of events are so rare that they are not a part of the calculations.

Another way to strengthen redundancy is by using separate hydraulic lines for each cylinder. This ensures that a hose failure on one line won't disable both cylinders on a blade.

As turbine design continues to evolve, it's worth asking: How often do you factor in the safety and redundancy of your pitch system when calculating total turbine lifecycle costs?

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Pitch brakes

Since 1941, the Dellner brand has been synonymous with industrial braking. With the 2021 acquisition of Dellner Hydratech and the earlier integration of Pintsch Bubenzer in 2018, the Dellner Bubenzer Group now offers advanced hydraulic systems and brakes for wind, offshore and marine applications.

At the core of the portfolio are heavy duty rotor, yaw and pitch brakes, used in various wind energy applications.

Rotor brakes typically use calipers (active or passive), while rotor lock pins (manual or hydraulic) provide secure locking during maintenance.

Yaw brakes and sliding bearings assist with nacelle rotation, and pitch brakes, alongside high-end hydraulic systems, coolers and accumulators, ensure precise blade control under demanding conditions.

Why is IEC 61400 important?

The international standard IEC 61400 specifies certain operating conditions, simulated with special software to verify and validate that the wind turbines are appropriately engineered against damage from hazards within the planned lifetime.

As we explored in the main body of this article, the pitch system is obviously a big part of these simulations since it is the primary safety system in the turbine.

Wind turbine operators use IEC 61400 for several important reasons:

Design Load Cases (DLCs)

IEC 61400 outlines a range of DLCs simulating operating conditions to validate turbine durability.

Pitch systems play a key role in these simulations.

Enhanced redundancy can reduce the severity of some load cases, raising pitch system cost slightly, but significantly reducing structural demands elsewhere.

Some DLCs can be neglected or reduced in severity if more safety and redundancy is put into the pitch system.

The cost of the pitch system will thereby increase, but the structural loads in other places in the turbine will be reduced.

The additional cost by making the pitch system more redundant is much less compared to cost reduction that can be gained in other places in the turbine, for example, the tower or bedframe.

Safety and redundancy

The pitch system, which is the primary safety mechanism in a wind turbine, plays a significant role in these simulations.

By adhering to IEC 61400, operators can ensure that their pitch systems have the necessary safety and redundancy features.

This can reduce structural loads in other parts of the turbine, such as the tower or bedframe, leading to overall cost savings.

Reliability and performance

Following IEC 61400 helps in designing wind turbines that are reliable and perform efficiently.

The standard ensures that turbines are built to handle various environmental conditions and operational stresses, which is crucial for their long-term performance and cost-effectiveness.