YAWMO® / PITCHMO®

— Yield increase and load reduction

YAWMO®
PITCHMO®

Yield increase and load reduction through optimized nacelle positioning

Imagine you have a component in your wind turbine that enables you to increase the annual yield by more than 0.15 % and reduce unnecessary mechanical loads by more than 0.8 %. For a 3.3 MW onshore turbine with about 1,600 full-load hours, the increase in annual yield alone adds up to €1,100, without even considering the benefits achieved thanks to the reduced bending loads. If this type of component then also boasts a TUEV-certified service life of 25 years, which corresponds to the design life of today's wind turbines, you will have made a sound decision.

About the facts: The component described here is the YAWMO 900, an integrated and functionally safe limit switch for the yaw system, which is used for both the continuous identification of the nacelle's position as well as a safeguard against tower cable twisting (Figure 1).

Figure 1: YAWMO 900

The essential function of a wind turbine's yaw system (Figure 2) is to yaw the rotor into the main wind direction. The control variable of this fully automated control system is primarily based on the measuring signal of the nacelle anemometer, which is required to determine the wind direction. More recent wind measuring direction systems in some cases make use of sensors on the hub or a nacelle-based LIDAR system. Both enable a more precise measuring of the wind direction.

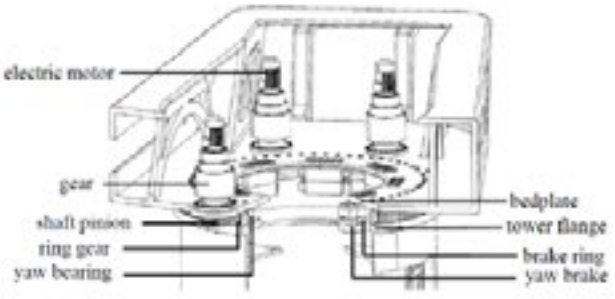

Figure 2: Yaw system

In addition to essential major components such as converter, brakes, motor and gear drives that are required for yawing the nacelle, the yaw system additionally consists of a sensor that is used to capture the position (0-360°) relative to the tower as well as a limit switch that acts as a functionally safe component against cable twisting.

LEINE LINDE

Leine Linde T +46-(0)152-265 00 F +46-(0)152-265 05 info@leinelinde.com www.leinelinde.com

Most wind energy turbines installed worldwide use two separate components: a sensor for position detection and an electro-mechanical limit switch to safeguard against critical tower cable twisting. The technology used and the associated resolution of the position signal have hardly changed over the last 20 years. For this reason, wind turbine manufacturers in the past have deployed various combinations of sensor (e.g. initiators, incremental encoders or absolute encoders) and limit switches (e.g. limit switches with drives, pull-cord switches), which in some cases were installed redundantly.

The YAWMO 900 has both functions (sensor and limit switch) integrated in one component. A specially developed inductive scanning technology reaches a 19bit single turn (= 524.288 positions per rotation) as well as 12bit multi turn (= 4096 rotations). The inductive scanning unit features a particularly high resilience against adverse ambient influences such as shock, vibration, temperature and humidity.

As the YAWMO 900 is a functionally safe and TUEV-certified component according to SIL 2, PLd Cat. 3, the implemented position identification and processing is installed fully redundant so that a malfunctioning is almost excluded and/or always detected. Single turn and multi turn detection are designed in such a way that position information does not get lost, even after a voltage drop. Even in the rare case that the nacelle rotates without power supply from the YAWMO 900, the component always measures the exact position. The certification thereby includes a mission time of up to 25 years, which is especially suitable for operation in modern wind turbines.

As electrical interface, PROFINET RT and failsafe relays are currently available to enable disconnection against too severe tower cable twisting. The following information can be queried via the fieldbus interface:

- Position information (single-turn, multi-turn)
- Status of failsafe inputs and outputs
- Alarm messages (electronics-/hardware errors)
- Warning messages (temperature overrun)
- Error storage to file recent errors

The nacelle position is measured via the gear rim at the tower head. The YAWMO 900 operates a pre-stressed gear at the pinion, which significantly improves the accuracy of the position information.

In order to demonstrate the yield increase potential initially mentioned, the following interrelations need to be stated:

- An incorrect yaw-alignment results in turbine yield losses: 1° roughly amounts to a potential revenue loss of about €1,400/annually (for a 3.3 MW onshore wind turbine) [1] [2] [3]
- An incorrect yaw alignment moreover results in elevated bending moments of the WTG: Per 1° this can range between 5.6 kNm to 7.5 kNm at a median wind speed of 8 m/s. [2] [4]
- The nacelle alignment in the main wind direction is mostly managed on the basis of a wind direction sensor which is installed on the nacelle. The measuring signal of this sensor is however inhibited by turbulences originating from the sensor's installation location behind the rotor. Results from a wide range of measuring campaigns result in a median measurement error of 4°.[3] [6] [7]
- A comparison between usual and pre-stressed gear drive at the position sensor results in a difference of 15 to 20 rotations at the yaw-motor. With an assumed total transmission ratio of 15,000 this can lead to a yaw error of up to 0.48°.[5]

By assuming the above interrelationships, the following table can be drawn up. In the process, various position sensor systems are compared with reference to their computed potential angular error. On this basis, the possible yield increases and load reductions are displayed. System 1 (incremental sensor with single gear) is used as a reference.

Comparison position sensors

	System 1: Incremental encoder (1024ppr) mounted to a standard pinion wheel	System 2: Absolute position encoder (13bit) mounted to a standard pinion wheel	System 3: Absolute position encoder (19bit) mounted to a standard pinion wheel	System 4: Absolute position encoder (19bit) mounted to a backlash free pinion wheel	System 5: Absolute position encoder (24bit) mounted to a standard pinion wheel	System 6: Absolute position encoder (19bit) mounted to a backlashfree pinion wheel + EMS
yaw error	4,83″	4,52″	4,48″	4,00″	4,48″	2,00″
AEP loss	0,532 %	0,467 %	0,458 %	0,365 %	0,458 %	0,091 %
Benefit in AEP over System 1						
in 1 year onshore	0,00 €	440,90 €	500,59 €	1,124,77 €	501,52 €	2,968,03 €
in 10 years onshore	0,00 €	4,408,95 €	5,005,91 €	11,247,65 €	5,015,19 €	29,680,32 €
Out of plane bending moment increase	4,89 %	4,58 %	4,54 %	4,05 %	4,54 %	2,03 %

Computations are based on the following assumptions:
Onshore: WTG capacity rating 3.3 MW / 1625 full-load hours / feed-in compensation: Euro-Cts4.66/kWh

Essential findings of the comparison of position sensors are that high-resolution position sensors can potentially lead to a smaller yaw error. Moreover, it is recommended to use a pre-stressed gear combined with a high-resolution position sensor, since this leads to significant yield increases and reduces bending stresses.

For the YAWMO 900 these interrelationships have been considered right from the start of the development. After a development and testing period of more than two years in a joint cooperation with a leading wind turbine manufacturer, the YAWMO 900 is now successfully in operation in several hundred of wind turbines on four continents.

Contact

Matthias Finke
Senior Product Manager
finke@leinelinde.com

References

1. M-G Kim and P H Dalhoff. "Yaw Systems for wind turbines - Overview of concepts, current challenges and design methods".
   In: *The Science of Making Torque from Wind 2014 (2014).*
2. M Kim and P Dalhoff. *Azimuth: Optimierte Azimutsysteme für Offshore-Windenergieanlagen.* Hamburg University of Applied Sciences, 2016
3. DNV GL. Review of the Spinner anemometer from ROMO Wind iSpin. DNV GL, 2015.
4. P Fleming et al. _High-Fidelity simulation comparison of wake mitigation control strategies for a two-turbine case_. In: ICOWES Conference 2013 (2013).
5. A Wobben. *Azimutantrieb für Windenergieanlagen. Patent-No: DE19920504A1.* 2000.
6. J Højstrup. *Spinner anemometer for relative power curve measurements.* ROMO Wind, 2012.
7. Fraunhofer Institute for Wind Energy and Energy System Technology.
   RAVE - LIDAR II, Entwicklung gondelbasierter Lidar-Technologien für die Messung des Leistungsverhaltens und die Regelung von Windenergieanlagen. IWES, 2013.