July 2017

LASER OPTICAL ALIGNMENT ON DRIVE TRAINS

EXPERIENCES OF USING THE LIVETREND FUNCTION

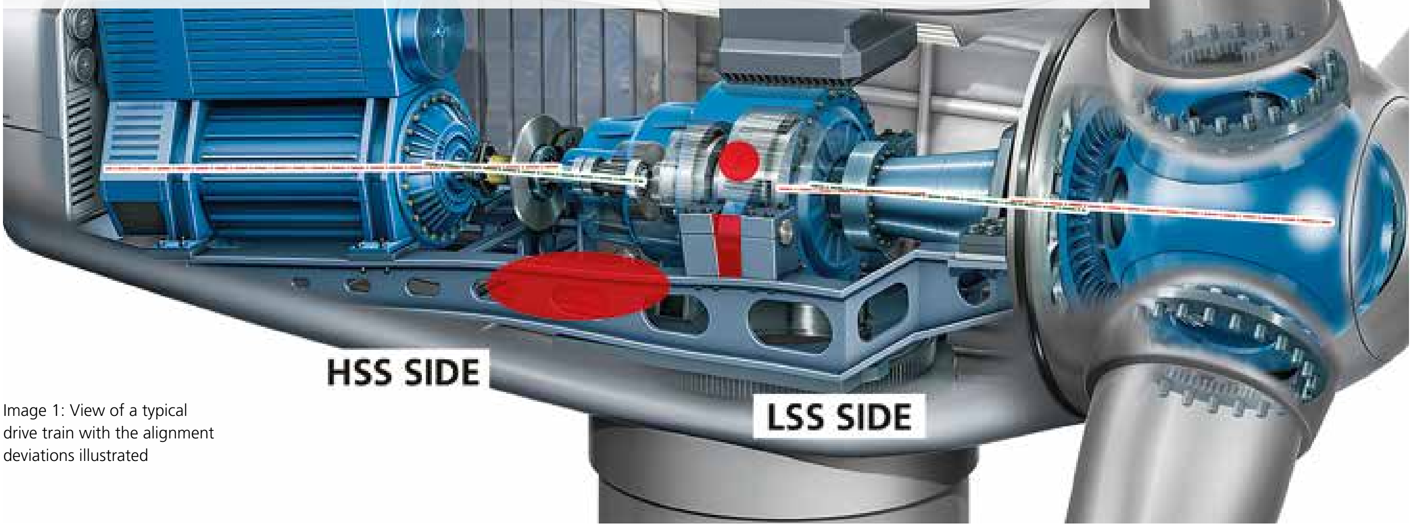

Image 1: View of a typical drive train with the alignment deviations illustrated

1. Alignment of machine trains

If a failure mode and effect analysis is carried out, it becomes noticeable in relation to drive trains of wind turbines that an application-specific alignment quality not only reduces the vibrations, but also reduces the stress on the drive train components that are coupled with each other.

The imperative need to consider alignment targets is a particularity associated with aligning drive trains in wind turbines /1/.

However, there are other influential factors that are to be recorded and considered when aligning wind turbines.

It can be deduced from FMEAs (failure mode and effect analysis) that alignment errors reduce the service life and availability of machine components in general and the roller bearing, toothing, seals, shafts and couplings in particular.

Alignment deviations in coupled machine trains are dependent not only on the alignment quality achieved, but also on the displacements and movements of the components that are coupled with each other and on the types of couplings used in each case. Machine components, which are rigidly coupled with each other, require high alignment quality. Machine trains with well balanced shaft couplings can "live" with lower alignment quality.

The prescription of laser shaft alignment even in maintenance manuals is a proactive approach to reduce premature damage arising as a result of alignment errors. Another option is to use the results of condition monitoring systems (CMS) to detect alignment deviations at an early stage. If, for example, the simple rotational frequency (1st order) and/or the doubled rotational frequency (2nd order) dominate in the vibration velocity spectra, the most recent alignment logs should be checked and the shaft alignment of the machine components that are coupled with each other should be improved.

2. Alignment of drive trains

With regard to wind turbines, laser shaft alignment between the gear and generator is now the state of the art. The alignment quality between the main bearing and the gear is, by contrast, still not given enough attention (see the cover photo). However, it can be seen in relation to multi-megawatt turbines, that aerodynamic loads, rotor masses and drive train weights lead to additional bending moments and reaction forces which also affect the alignment quality between the gear and generator. In /2/ it is even recommended that low-speed couplings be installed between the main bearing and the main gear with the same objective of preventing any interference with the alignment in relation to the generator.

As far as shaft alignment itself is concerned, the horizontal and vertical parallel misalignment as well as the horizontal and vertical angular misalignment are to be reduced to the extent that the coupling used balances the remaining constraints in a manner free of reaction force and low on wear. This is done on the basis of the operating conditions. The tolerances with which alignment is to be carried out depends on the type of coupling that is used and the respective running speeds.

Even with this approach it is noticeable that it is not only necessary to measure precisely, but also to store the alignment results carefully and view them systematically. With the introduction of the ARC4.0 software, PRUFTECHNIK created a basis for having alignment results documented, tracked in the long term and evaluated comprehensively. In addition, this systematic storage of the results makes it possible to even estimate across the fleet how certain machine alignments will behave over the years.

Image 2 shows an excerpt from the software in which data from various wind farms is stored – similar to CMS software.

The ARC software offers the option of storing commonly known, manufacturer-known or even proprietary offset values and the requisite alignment qualities in an application-oriented manner.

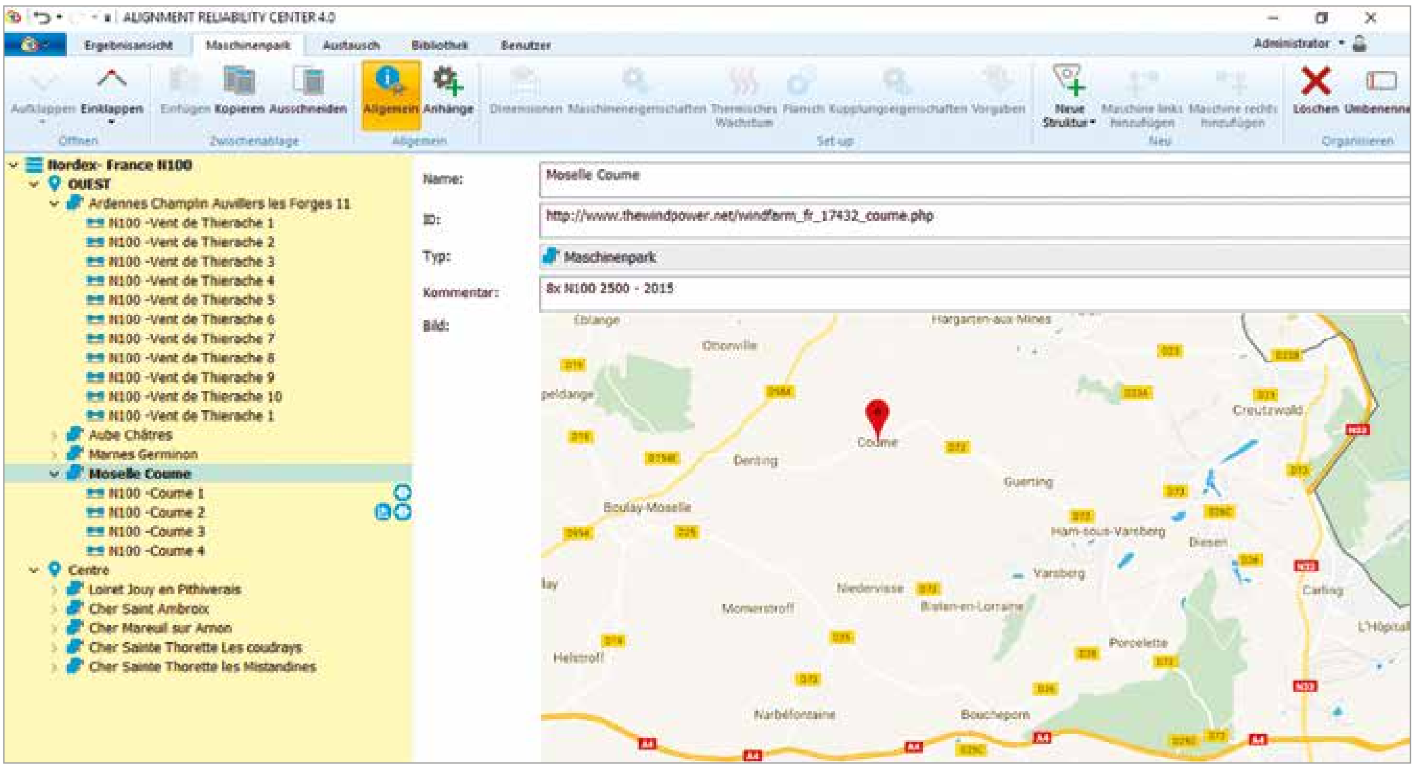

Image 2: Directory tree from the ARC4.0 software for managing alignment results for multiple wind farms

3. Measuring equipment requirements for shaft alignment

Shaft alignment can be done using gages or with laser optical alignment measuring equipment. Laser optical alignment is quick and secure and results are saved in the laser alignment device.

It is recommended that wind turbine operators ensure that the actual states of the machine alignment are clearly documented and that the documents are clearly legible, signed and interpretable.
Similarly, it is to be noted that on grounds of occupational safety it is preferential to use alignment systems in which alignment results can be recorded without removing the coupling and be recorded underneath the coupling protection even during rotation.

Alignment specialists know there are other alignment requirements to be observed in the wind energy sector. Depending on the type of turbine, the following additional interference may occur:

- Changes in the alignment depending on the installation state (measured with or without the rotor, measured on the ground or in the nacelle)
- Changes in the alignment depending on the position of the nacelle in relation to the wind
- Changes in the alignment depending on the balance conditionof the rotor blades
- Changes depending on yawing
- Changes in the alignment depending on the power
- Changes depending on deformations, movements and displacements /4/

The new LiveTrend function in ROTALIGN® touch offers the option of temporarily recording the stated interference metrologically.
The following sections provide examples of the additional results that can be determined and the recommendations that PRUFTECHNIK has deduced for the wind sector.


Image 3 (left) and 3a (right): Views of the mounted laser sensors, in order to record displacements, movements and tilting of the drive train components in relation to each other

4. The LiveTrend function in the application and recommendations

Images 3 and 3a show the laser components that are installed in order to be able to record changes in alignment conditions between both the main bearing housing and the gear housing as well as between the gear housing and the generator housing using the LiveTrend function.

In each case, magnets are used to fasten the laser components. The measurement results from the sensors were stored in the ROTALIGN® systems and then transferred to the ARC4.0 software for post-processing.
A preliminary remark would be to note that the following results and interpretations relate to only one specific wind turbine with a traditional three-point bearing and two-sided support in elastomer bushings. The results of similar measurements on other turbine types with analogous error phenomena are not shown. They are to be evaluate individually in each case.

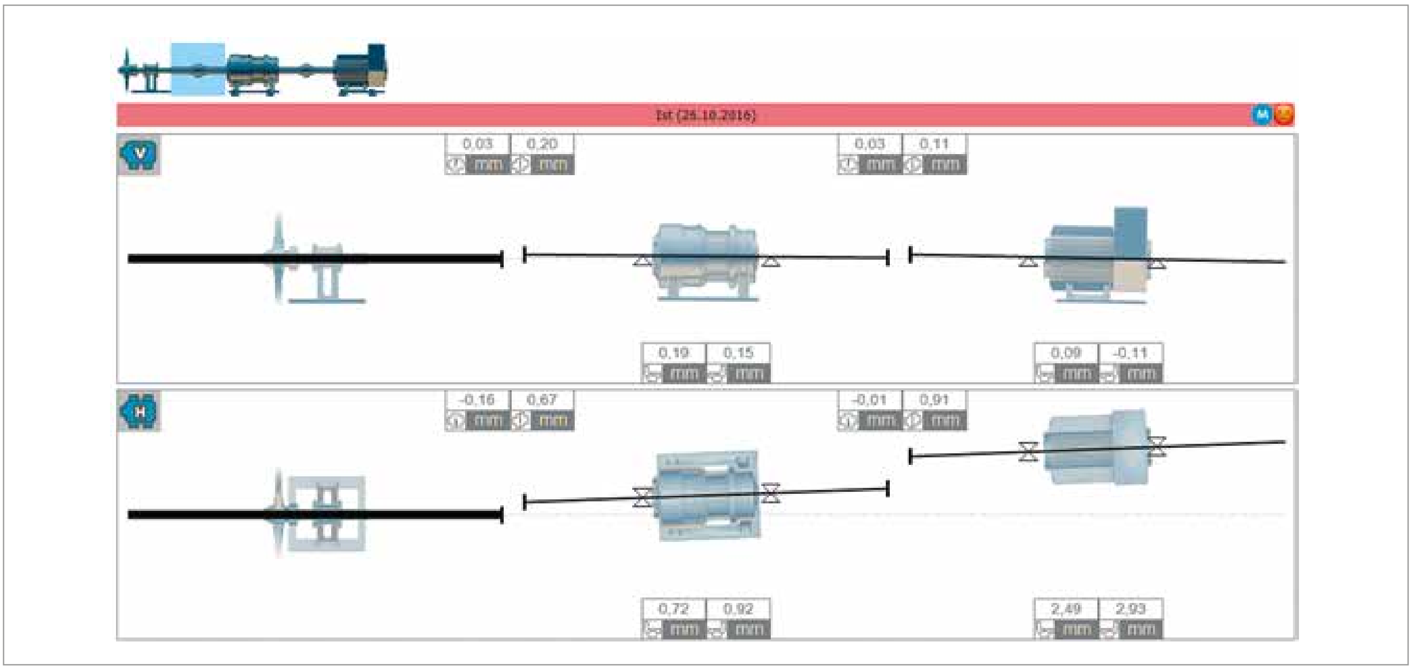

Image 4: Horizontal displacements of the gear and generator in relation to the main bearing when the nacelle position is at right angles to the wind (evaluated in the ARC4.0 software)

a) The influence of the nacelle position on alignment

Practitioners are aware that alignment is difficult if there is crosswind on wind turbines. Some users of laser optical alignment equipment have already identified that the position of the nacelle to the wind also affects alignment results. Using the LiveTrend function, these flexible deformations and geometric influences from the tower/nacelle installation can be documented online.

A straightforward test quickly offers clarity in this regard. Mount the sensors, switch on ROTALIGN® and the LiveTrend function, allow the nacelle to rotate 360 degrees and then check where, how, and to what extent the positions of the drive train components change in relation to each other as the nacelle rotates. Image 4 depicts the changes based on the nacelle position in wind direction (measured at approximately 3 m/s wind speed, with the main rotor brake engaged and nacelle position at right angles to the wind).

It can be seen that the gear housing is pushed away laterally in relation to the main bearing housing and the generator is pushed away laterally in relation to the gear. The generator is displaced to the left by approximately 2.5 mm and the gear by approximately 1 mm. In vertical direction, there were only negligible changes with this wind turbine.

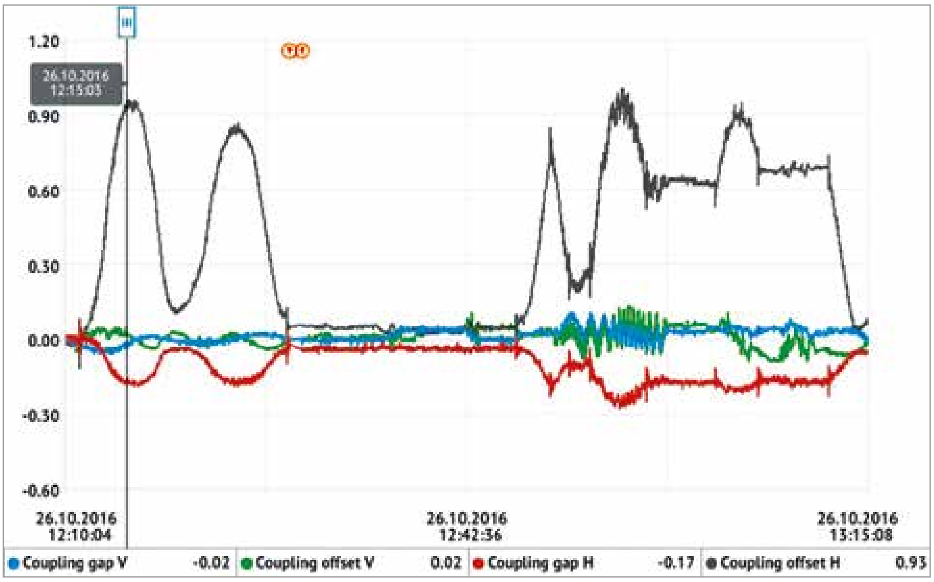

Image 5: Time signals from ROTALIGN touch for various test runs. The influence of the yawing procedure can be seen as a short peak

RECOMMENDATION 1

For laser optical alignment of drive trains, ensure that the nacelle is in wind direction.

RECOMMENDATION 2

When determining the alignment targets, take account of the flexibility of the flexible torque support.

b) Influence of the rotor blade position on the alignment

From the time signals that are recorded, it is relatively quick to check in ROTALIGN® touch whether there are significant influences of the main rotor, a rotor blade, and the shrink disc connection on the alignment between the main bearing and the gear. This applies even when the main rotor is rotating slowly. Image 5 shows a hard copy of the ROTALIGN® touch screen.

The left-hand section of the graphic shows trials when the nacelle is rotating and the right-hand section shows a total of 13 rotor revolutions. As the rotor blades of this wind turbine are very well balanced, there was only very minor Cardan interference. Even the effects of yawing and pitching moments that were introduced temporarily remained insignificant.

RECOMMENDATION 3

For laser optical alignment, ensure that at least one revolution of the main rotor is measured using the LiveTrend function prior to shaft alignment.

RECOMMENDATION 4

When determining the alignment targets, take account of the displacement of the torque support in relation to the rotor blade position.

c) Influence of the yawing procedure on the alignment

With ROTALIGN® touch, it is possible to record positional and angular change online to the tenth of a second.

This also makes it possible to record any tilting during the yawing procedure and to identify potential disruptions.

Image 5 includes the tilting that also occurs between the main bearing housing and the gear housing during yawing.

d) Influence of the load on the alignment of the drive train components

Changes of the housing positions in relation to each other during startup and loading of the wind turbine can of course be recorded by laser-based means just as precisely online for the drive side (LSS) and for the non-drive end (HSS). It is then possible to read exactly how the forces and moments initiated on the rotor transfer to the main carrier and to the drive train components.

The main bearing is firmly connected to the main carrier and is normally the reference point. The gearbox is indeed fastened to the machine carrier via elastomer bushings in an axially free manner. Nevertheless, certain reaction forces arise in bearing pedestals via the two-sided bearing of the gear. These reaction forces lead to the gear housing being deflected vertically and pushed away horizontally when loaded.

RECOMMENDATION 5

In trials of this nature, ensure that the main gear is also torsionally distorted when loaded. This can be compensated by an arrangement of a second laser pair displaced by 90 degrees when conducting measurements.

RECOMMENDATION 6

In mechanical engineering terms, stiffer torque supports should generally be preferred.

RECOMMENDATION 7

If the main carrier is too soft, additional laser-based deformation measurements should be planned.

5. Determination of alignment targets and laser optical alignment

Alignment targets can also be determined over extended time periods using laser-based condition monitoring systems. /3/

To this end, laser components and reflectors are mounted on the drive train components in vertical and horizontal direction respectively. These components and reflectors continuously measure the current horizontal and vertical radial and angular positions of drive train components in relation to each other. If there are spacial displacements, the precise laser beam is deflected to a new position on the receiver area and the parallel and angular area position is measured.

Images 6a and 6b show two representations of the mounting of laser/receiver units on the main bearing housing and the gear housing.

These target values that are determined are subsequently stored in the ARC 4.0 software, transferred to the alignment device and accounted for automatically during the alignment procedure. The drive train is then to be "incorrectly aligned" at a standstill in such a way that the ideal shaft alignment is achieved under operating conditions /1/.

It is recommended that operators obtain the system-specific target values for alignment from the system manufacturer or have them determined by the system manufacturer.

System manufacturers should calculate alignment targets as well as validate them metrologically.

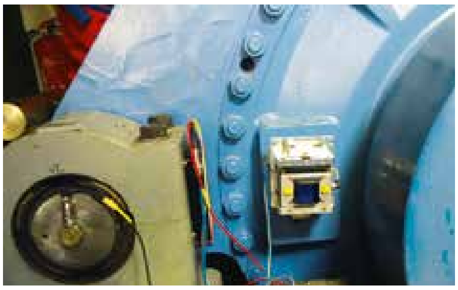

Image 6a (top) and 6b (bottom): Mounting of the laser/receiver unit, on the left on the main bearing, on the right on the gear for determining alignment targets

References:

/1/ Edwin Becker, Ole Holstein:
"Alignment with target values reduces vibrations"
Article originally published in German in "***Erneuerbare Energie***" 10/2007, pp.35-37

/2/ Alexander Kari:
"Zwangskräfte und Biegemomente-Non-Torque Loads- in Antriebssträngen von Windturbinen"
WIND-KRAFT Journal 2/2016, pp.22-26

/3/ http://wind.machine-reliability.com /de/#video

/4/ www.pruftechnik.com , Flyer "GEO6"

Author:

Dr. Edwin Becker
Head of Service Center
PRUFTECHNIK Condition Monitoring GmbH
Oskar-Messter-Str. 19-21
85737 Ismaning, Germany
Tel.: (+49) 0 89 / 99616-0
edwin.becker@pruftechnik.com
www.pruftechnik.com

Author:
Dr. Edwin Becker

About PRUFTECHNIK:
The PRUFTECHNIK Group, with its subsidiaries and partners in more than 70 countries worldwide, continues to set new standards with innovative technological advancements in the field of machine alignment and vibration measurement technology in order to maximize and optimize the operational safety of machines and plants.

Contact for press inquiries:
Christian Wanner
Tel.: +49 89 9916-344
christian.wanner@pruftechnik.com

PRÜFTECHNIK Dieter Busch AG
Oskar-Messter-Str. 19-21
85737 Ismaning, Germany
Tel.: +49 89 99616-0
Fax: +49 89 99616-200
info@pruftechnik.com
www.pruftechnik.com

A member of the PRUFTECHNIK group