Wind Solutions®

White paper

Rotor imbalance cancellation

Imbalance in a wind turbine rotor is a typical problem of both new and older wind turbines. This paper describes an approach for minimizing rotor imbalance using the WTC6 control system.

March 2016

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Rotor imbalance cancellation

The typical problem of imbalance in a wind turbine rotor causes oscillations in the mechanical components of the turbine, and thereby creates excessive wear which shortens lifetime. In this paper an approach for minimizing the imbalance is disclosed and results from testing on a Siemens 1.3 MW turbine are presented.

The problem

Rotor imbalance arises from two different problems. One is mass difference between the blades of a wind turbine; the other is an aerodynamic difference between the blades. Both problems create a torque oscillation on the rotor, mass difference due to gravity, and aerodynamic difference due to wind shear and tower shadow. The torque oscillation is transferred all the way through the drive train and to the generator. The oscillation which is known as a 1P oscillation, because it has the same period time as the rotor rotation, can be measured in rotor speed, generator speed, nacelle acceleration and power output. This means that all major mechanical components are affected by this oscillation, including gear box, generator and also yaw gears.

The typical source of aerodynamic difference between the blades is the accuracy of pitch calibration. One aspect of this is the accuracy of the zero markers, which for some turbines can be as high as ±2 degrees. Another aspect is the accuracy of the pitch calibration procedure, which is done during commissioning.

For mass difference between the blades, the solution is either to apply weights, or to introduce a 1P sinusoidal pitch signal to the blades and thereby eliminating the imbalance. For aerodynamic difference the traditional solution is to use vision based systems for measuring a pitch difference between the blades, and from this calculating a pitch offset to each blade which, dependent on the turbine type, can be applied either mechanical or by software. This approach for minimizing the aerodynamic difference between the blades requires expensive equipment, and must be done periodically in order to be sure the problem does not return.

This paper focuses on minimising the aerodynamic difference between the blades using a solution that is part of the turbine control system and does not require any external equipment.

The solution

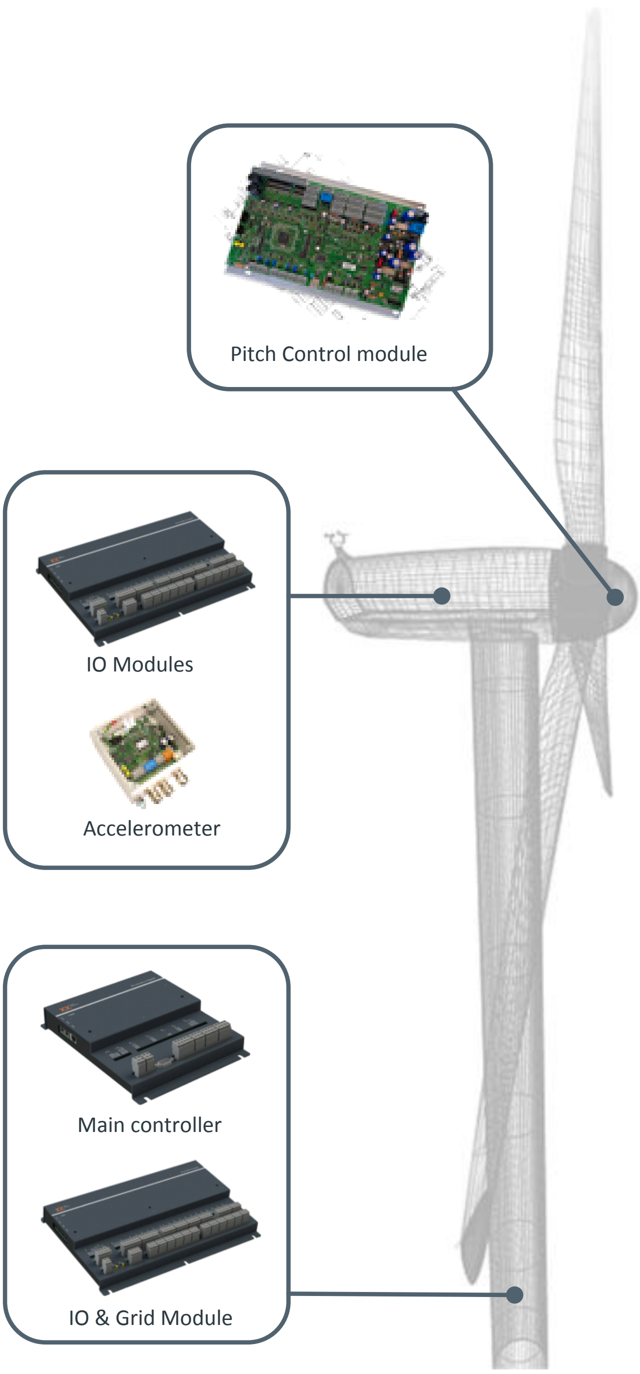
The WTC6 control system from KK Wind Solutions is a full wind turbine control system including modules for measuring the grid, controlling the pitch and operating all other components in a wind turbine. The WTC6 system can be installed as an upgrade in existing turbines to improve production and availability while lowering wear and tear.

In the figure on the right, a WTC6 installation in a Siemens 1.3 MW turbine is outlined. Regarding rotor imbalance cancellation, the important differences from the original control system of the Siemens 1.3 MW turbine and the WTC6 control system, are that the WTC6 pitch control module can control the three blades individually and measure the rotor azimuth position. Rotor azimuth position means in which direction the blades are pointing; a rotor azimuth of 0 degrees means that blade 1 is pointing up, while 180 degrees means that it points towards the ground.

An important difference is also that the WTC6 system includes an accelerometer for measuring the accelerations of the nacelle with high resolution.

The combination of measuring the nacelle acceleration, rotor azimuth position and being able to control the three blades individually makes it possible to minimize the rotor imbalance caused by differences in blade pitch or aerodynamics.

In the WTC6 system, the nacelle acceleration and rotor azimuth position are continuously measured, and based on these an imbalance vector is calculated. This vector shows the size of the imbalance as well as the imbalance position in the rotor plane.



From the imbalance vector a new pitch offset value for each blade is calculated which tries to minimize the vector amplitude. By applying this algorithm continuously, the pitch offset values converge towards the optimum point where the imbalance vector is minimum.

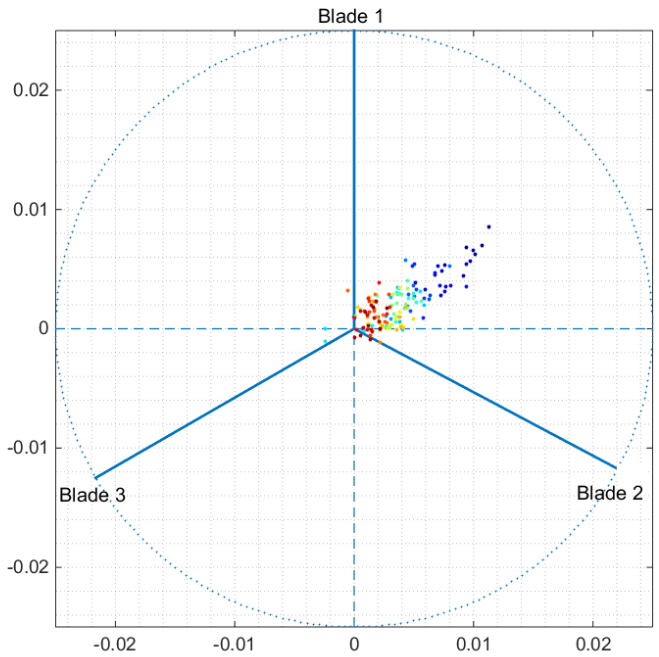
Field test results

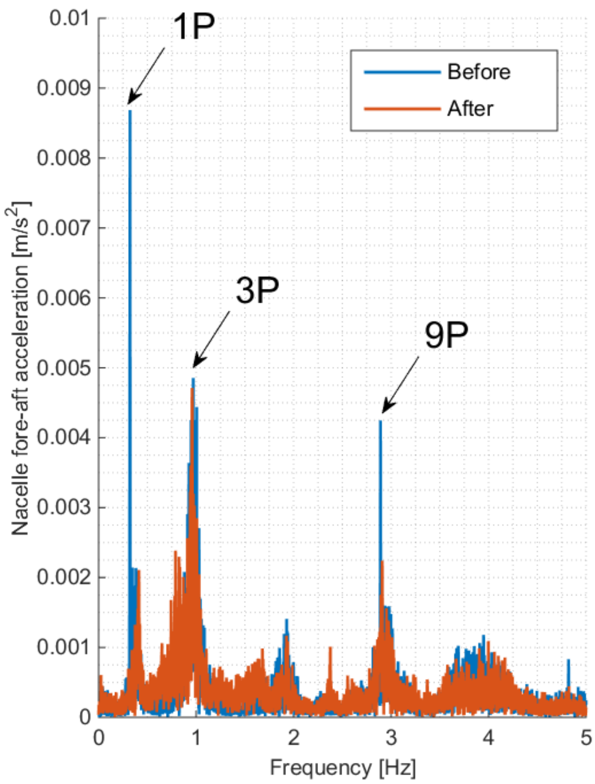
The WTC6 control system has been installed in a Siemens 1.3 MW active stall turbine. In the particular turbine, the service company experienced many problems with yaw gears, and believed that this was due to a rotor imbalance which created a torque on the yaw gears for every rotation of the rotor.

For this reason, the rotor imbalance cancellation algorithm in the WTC6 system was activated.

In the rotor imbalance vector shown in the figure to the right, the outermost blue points show the original state before enabling the algorithm, and the colour change towards red indicates the time passing while the algorithm converges.

The period of time shown in the figure is two hours. During these two hours the three pitch offsets were adjusted continuously. In this particular case, the optimum pitch offsets converged from 0 to -0.16, -0.17 and 0.32 degrees.





Even though the optimum offsets only changed the pitch positions a little, the impact on the 1P oscillations was large. The figure to the left shows a frequency analysis of the nacelle acceleration before and after enabling the algorithm. During both measurement periods, the wind condition was similar. In the figure it shows that the 1P is almost completely eliminated and also that 9P is reduced significantly. The same pattern has been measured in rotor speed, generator speed and the output power.

Since the output power is directly coupled to the torque of the drive train, this means that also the torque oscillations in the gear box is reduced significantly.

Even though it has not been measured directly, it is also fair to assume that the twisting torque on the yaw gears is reduced.

Conclusion

This paper first explained the problem of wind turbine rotor imbalance and the consequences hereof, secondly it outlined a solution to this problem. It also showed very good results from field testing on a Siemens 1.3 MW turbine upgraded with the WTC6 control system.

The results of the field testing focussed on minimizing oscillations in various mechanical and electrical parts of the wind turbine, which lowers wear and tear and thereby prolongs the lifetime of main components. However, another aspect of cancelling the rotor imbalance due to pitch incoherence between the blades, is that this can improve turbine performance and thereby provide higher annual energy production (AEP). By use of aero-elastic simulation tools it has been proved that a pitch incoherence of 2 degrees, which is not unrealistic, can decrease the AEP by up to 2 % depending on turbine type and site conditions.

The proposed solution of rotor imbalance cancellation is not unique for a Siemens 1.3 MW turbine, but can in general be used on all types of turbines.

Further information

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About KK Wind Solutions
Building on more than 35 years of experience in electrical systems for wind, KK Wind Solutions' capabilities span development of state-of-the-art technologies, high quality lean manufacturing, cost-efficient supply chain solutions and flexible service of turbines.