

# The guardian angel

As the world entered a new millennium, Dr. Peter Volkmer discovered that condition monitoring of the rotor blades of wind turbines not only reduces risks but also pays for itself. At the time, systems monitoring the power train were already available and so the obvious question was why the most stressed parts of a wind turbine – the blades – remained unmonitored. This idea has been developed and Dr. Volkmer explains to PES the all-round benefits of BLADEcontrol.



Physicist Dr. Peter Volkmer is Managing Director of IGUS ITS and inventor of BLADEcontrol

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Being a physicist, Dr. Volkmer thought of possible solutions and chose an approach common in power plant engineering: the analysis of variations of natural frequencies. The method is routinely used in conjunction with other technical systems such as steam turbine vanes and aerofoils.

#### Natural oscillation of elastic bodies

The basis of this technological development is the physical phenomenon of mechanical natural oscillation. Each elastic body vibrates when appropriately stimulated, just as a wine glass gives a tone when clinked. The natural frequency is immediately evaluated with respect to the attributes of the material (elastic modulus E and density) and in consideration of the geometric measurements and forms. This is true for rotor blades as well.

The question that arose in the first place was: is it possible to measure these oscillations on a running turbine and will it be possible to see changes in the spectrum of frequencies when damage occurs? The answer was found quickly and even more clearly than Volkmer could have hoped: it is indeed possible and changes can be detected as precisely as the finite element theory also used for modelling blades predicted.

Volkmer and his team took several measurements from different blade types on the ground using a shaker as a stimulation device as fundamental research. Blades were deliberately damaged to study the variations of the spectra. It turned out that all theoretical predictions held.

Years of research were invested into the idea until, in 2004, the first system was installed in a turbine. Two further years, with more than ten prototype and pre-series installations followed, and in 2006 the series production started with newly developed hardware that is exclusively produced for the use with the system called BLADEcontrol.

Over these years, it turned out that the method of analysing oscillation variations can be used as a multi-purpose weapon that is not only suitable for detecting blade damages. As a result of this, more features were built into the system to get the maximum utility out of the technical system (see next page).

#### Early damage detection saves money

“The main goal of the damage detection feature is to detect damages in an initial state to preserve the possibility of repairing the blade without demounting the rotor”, says Dr. Volkmer. “We know that damages get larger over time, and the next inspection done by a blade expert may be more than a year ahead, allowing the damage to grow.” By the time the expert detects the damage, blade replacement could be necessary, resulting in high costs.

Severe damages that affect the structure of the blade can be distinguished from weak damages and lead to a shutdown of the turbine. “As a severe structural damage can lead to blade breakage if the turbine stays in operation, immediately stopping the turbine can avert damage to the power train and danger to things and persons in the surrounding area of the turbine”, Dr. Volkmer explains. The same applies to lightning damages, but it lies in the nature of these damages that they don't start as weak damages. Because of this, BLADEcontrol is equipped with a lightning detection function that gives the shutdown signal in less than five seconds.

#### Features of BLADEcontrol:

##### 1. Damage detection

- Damages in the aero dynamical hull (cracks, delaminating, etc)
- Structural damages (belt separations, sparweb debondings, etc)
- Declaration of damage location and damage type
- Lightning damages (reaction time: less than five seconds)

##### 2. Ice detection

- Measuring directly on the blades
- Extremely sensitive (for example 2 kg of ice detected on a 5,000 kg blade)
- Measuring is possible during downtime (as long as wind goes)
- Automatic restart (no visual controls necessary)

##### 3. Dynamical loads distribution

- Recording of dynamic load distribution for each blade
- Basis for adjustment of pitch

#### Precise Ice Detection

Ice detection is a delicate issue in mountainous regions. On the one hand, no ice should drop from a running turbine as the chunks may fly up to 300 metres. On the other hand, operators want to keep the turbine in operation for as long as possible and restart it as soon as the ice is melted. Unlike all other ice detection systems available, BLADEcontrol measures directly on the blade: when we found out that ice detection is generally possible by measuring the variations in the natural oscillation that evolves from the blade getting heavier with ice on it, we searched for the frequencies most sensitive to the mass change, Dr. Volkmer describes the evolution of the system "By finding these frequencies and by increasing the resolution by factor four, we were able to decrease the mass necessary to detect ice-foundation to 0.04% of the blades' mass. Of course, two kilograms of ice on a five ton blade is no reason to shut down the turbine, but it shows how precise the measurements are." On-site measurements proved the superiority of the system: direct comparison with a sensor mounted on the nacelle controlling the turbine, yielded that the downtimes due to ice-foundation could have been reduced by nearly 70%. "The operating company lost more than 112.000 kW in just two months on that single turbine" Dr. Volkmer says. When the final report was out, the owner ordered BLADEcontrol for all turbines in the wind park.

#### Dynamical Loads as an Indicator for Pitch Optimisation

"The blades of a turbine often don't have exactly the same position to the wind", Dr. Volkmer explains, "There are different approaches to solve this problem, but with BLADEcontrol, a continuous monitoring is possible. We record the dynamic loads and transfer them to gain a load distribution for each blade. If they are different from one another, the reason will be a different pitch position in most cases. It's as simple as that." Operators are then able to check the blades and readjust them until the curves coincide. Moreover, the system counts the overloads. Adjusting the pitch to prevent overloads prolongs the lifetime of the blades and prevents damages. "BLADEcontrol does not engage in the pitch system at the moment – we just integrated the feature some months ago", Dr. Volkmer says. He expects that on average an increase of 0.5% in energy yield will be gained by pitch optimisation. Additionally, the power train has to endure less stress.

#### Technical Realisation with WLAN

The sensors of BLADEcontrol are accelerometers mounted in the blade at about one third of the blade's length (measured from the root). A Hub Measurement Unit, HMU, digitises the signals and sends them to the Evaluation and Communication Unit, ECU, via WLAN. The ECU calculates the spectra using fast fourier transformation and computes the evaluation. "Judging the measurements automatically was the greatest challenge of the whole project", Dr. Volkmer summarises. "We are proud of having developed evaluation algorithms that we think are far ahead." Damages detected are directly and immediately sent to a database server which informs the operator via e-mail and/or SMS. Heavy damages or heavy icing lead to a direct automatic shutdown of the turbine to prevent further damage.

The evolution of BLADEcontrol has not ended. "As an expert system, BLADEcontrol gets better every time we detect a damage", Dr. Volkmer explains. To have all systems running on the same development status, updates are always done for all systems, no matter how old it may be. This holds for algorithm software updates as well: "It would be far too complex to distinguish between different system versions. And, more importantly, the relation to the customer does not end with the system installed. Bits are for free and the updates are done remotely. We see no reason not to do it." This way, the Guardian Angel remains on constant duty. ■

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**Top: The sensor box is mounted in the blade  
Middle: The ECU is located near the turbine control  
Bottom: The HMU is mounted in the hub**