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Bird collision recording for offshore wind farms

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WT-BIRD: BIRD COLLISION RECORDING FOR OFFSHORE WIND FARMS

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ABSTRACT
A new method for registration of bird collisions has been developed using video cameras and microphones combined with event triggering by acoustic vibration measurement. Remote access to the recorded images and sounds makes it possible to count the number of collisions as well as to identify the species. Currently a prototype system is being tested on an offshore-scale land-based wind turbine using bird dummies. After these tests we planned to perform endurance tests on other land-based turbines under offshore-like conditions.

KEYWORDS: birds, environment, offshore, monitoring.

1. INTRODUCTION
The large-scale implementation of wind energy is hampered by the unknown effects that wind turbines may have on the environment. In that respect the effects of wind farms on bird populations, as casualties from collisions with turbines, are a topic of great concern. In environmental impact studies collision risks and the effects on populations are estimated prior to installation and assessed afterwards [1,2]. Yet no reliable cost-effective method is available to measure the number of casualties for offshore wind farms [3,4].

A new monitoring system for detection and registration of bird collisions, WT-BIRD, has been developed at ECN [5, 6]. It uses video cameras and microphones combined with event triggering by measuring acoustic vibrations, cf. figure 1.

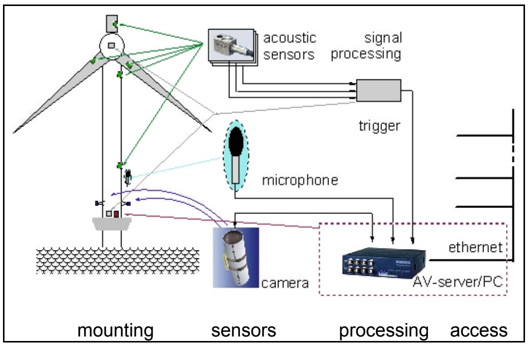

Figure 1: Schematic overview of WT-BIRD system.

Compared to other methods employed so far, this monitoring system will reduce the uncertainty in the results of the number of casualties from collisions with wind turbines. The monitoring system runs continuously and at several turbines in parallel. Video and audio registrations of collisions are stored automatically and can be accessed at any time to count the number of collisions as well as to identify the species.

This paper will present a description of the prototype configuration and operation as well as results of functional tests with bird dummies.

2. PROTOTYPE DESCRIPTION
In July 2005 a prototype of the WT-BIRD system was installed on a Nordex N80/2.5MW turbine, located on the ECN Wind turbine Test site Wieringermeer, cf. figure 2. The rotor diameter is 80 meters and the hub height is also 80 meters.

Figure 2: (upper) camera, rain sensor, infrared lights and WLAN antenna attached to tower, (left) camera at North side with four N80 turbines in line, (right) infrared lights at West side.

All equipment outdoors is mounted on four identical tripods mounted at a height of 9 meters, about 1 meter from the tower wall. The total weight with equipment is about 100 kg. Two steel cables, each forming a square, pull the tripods against the tower wall, so that the structure is fixed on friction. During installation the individual tripods with equipment were fixed to the tower with magnets. After the two steel cables were led through quarter circle steel tubes at the outside of each tripod and tied together, the magnets were removed. The electrical wiring was lead along the steel cables and through a vertical pipe to the inlet in the ventilation shaft.

The height is chosen to resemble the relatively short tower of offshore turbines and also to prevent damage through vandalism, as the turbine is located close to a public road. For offshore turbines however the equipment will be mounted on top of the transition piece, just high enough as to not hinder personnel.

At the North and South side a camera is mounted. The cameras are identical: an industrial FireWire B/W digital camera with 2/3" 1.45 Mpixel near-infrared sensitive CCD and fixed auto-iris lens with a viewing angle of 60 degrees. Two different housings are applied for testing purposes. Both housings are equipped with a washer and wiper unit, which is controlled by a timer and a rain sensor. For both housings a number of modifications have been carried out by ECN to make the structures more rigid and suitable for (practically) vertical mounting.

At the East and West side a pair of infrared LED floodlights is mounted to enhance the contrast of the images at night. Each of the four lights consumes about 50 watts and is rated for 70 meters with a beam angle of 30 degrees. The choice of the wavelength of 880 nm is a compromise. A lower wavelength would result in a better sensitivity of the camera, but would also make that the lights would attract birds. The horizontal distance between the lights and the cameras is large enough to prevent that light reflections by the tower wall, dust or fog become visible in the recordings.

Additionally three infrared floodlights have been mounted on top of the nacelle to improve the image quality at night, cf. figure 3.

Figure 3: Infrared floodlights mounted on nacelle.

The outdoor equipment is connected to an industrial PC in the tower base via FireWire repeaters, a washer-wiper relay control unit and a water supply tank with pump. Only low-voltage equipment is applied outdoors.

The network connection between the registration equipment in the tower base and the detection equipment (triggering system) in the rotor is established with a Wireless LAN link between an access point in the tower base and a bridge in the hub. Therefore two directional antennas are mounted on the tripods with the infrared lights and two are mounted at the root of two different blades.

The triggering system in the rotor consists of a compact measurement system located in the hub and acceleration sensors mounted in the blades. Each blade is equipped with two acceleration sensors with broadband sensitivity: one in the cylindrical part of the blade, at 4 meters from the blade root, and one at 10 meters from the blade root.

The measurement system has on-board real-time signal processing and triggering capabilities. An internal UPS suppresses short power failures and with non-volatile data storage the measurements can continue in case of a failing network link.

3. PROTOTYPE OPERATION

The sensors in the blades pick up acoustic signals from collisions as well as various disturbances, such as turbine operational noise (e.g. drive-train, pitch and yaw mechanism, blade cracking) and ambient noise (e.g. precipitation, weather).

The task of the triggering system is to generate a trigger event for each impact above a certain energy level by monitoring whether a sensor signal exceeds a certain trigger level. At the same time it should suppress the disturbances without compromising the signal quality by adequate signal pre-processing. Trigger events caused by disturbances that still exceed the trigger level should be identified as false and ignored. For this on-line data analysis and classification is required.

Obviously the number of false triggers will increase with the sensitivity of the detection, in other words with lowering trigger level. Therefore one of the implemented features is to adapt the trigger level to the estimated background disturbance per sensor. Also specific events, such as blade cracking are identified in real-time. These processing algorithms as well as the trigger conditions (levels, timing) and actions are stored in the device configuration. It also defines settings for data buffering and local and remote data storage.

However, as bird collisions are rare it is inevitable that a number of false triggers are generated by extreme events such as emergency stops, weather and wind gusts. Consequently the operator has to accept or reject these events based on the available audio and video recordings.

When a trigger is released a short fragment of all raw sensor signals (of 10 sec. with 1 sec. pre-trigger) is stored and an email is sent to the operator reporting the time of the event, blade number and other information, e.g. trigger level. A trigger flag is set, to start data transfer from the triggering system in the rotor to the PC at the tower base.

Also the video recordings during the collision are copied from a temporary to a permanent storage location. In case of loss of network connection the triggering system and registration system operate independently as both systems have local storage. After the connection is re-established the registration system polls the triggering bit to see whether new data has become available and stores this data. If old video image are still available (when the network down-time is only a few minutes) also the images at the time of the impact can be saved.

4. TEST DESCRIPTION

During the last quarter of 2005 a series of tests has been carried out to configure the prototype and to assess its capabilities and limitations.

Video recordings under various sight conditions were analysed to assess the image quality and to optimise the camera exposure control. Also a set of acoustic measurement data was collected for several operating conditions: normal operation at several wind speeds, blade cracking, yawing, pitching, emergency stop, and precipitation. This data was analysed mainly to configure the data processing.

For selecting proper sensor locations a separate test was needed in which we used a dummy that was connected to a rope hanging along a still-standing blade. By swinging the rope we have generated collisions at specific locations and with various impact energies. The blade was instrumented with four sensors at five different locations.

In December 2005 functional tests of the prototype were carried out with impacts from dummies. In these tests we shot ordinary tennis balls against the rotating blades using a gas-pressurised launcher.

5. TEST RESULTS

The image quality during daytime proved to be good enough to detect a fast moving tennis ball through the rotor plane. The cameras adapt well to varying light conditions. Viewing angle of the two cameras is large enough to fit almost the complete rotor swept area. The pixel size of 6 x 6cm at hub height is sufficient to recognize a contour of a bird. However the frame rate of 6,5 frames per second (continuous streaming and storage) is insufficient to measure the flap frequency, which is an important characteristic for species recognition. With newer camera models this will be solved soon.

A more fundamental problem is that the low signal-to-noise ratio of the images during nighttime is likely to be insufficient to recognise birds. Alternatives like thermal imaging, scientific cameras with very large CCD chips, etc., are far too expensive, moreover, these have other drawbacks. By applying image processing we gained some noise reduction. Increasing number of floodlights and optimising the positions will also improve the image quality. Further we can take profit from the rapid developments of industrial cameras.

After a blade tip was hit by lightning the video images clearly showed the blade damage, cf. figure 4.

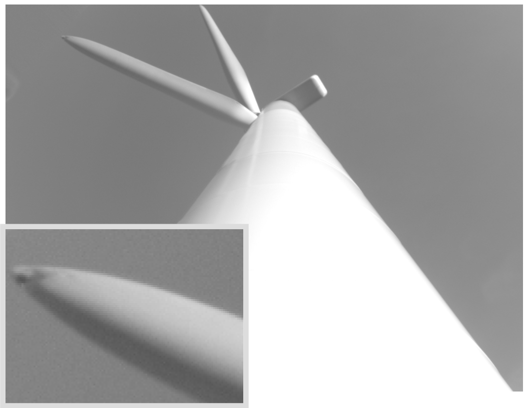

Figure 4: Recording of blade damage from lightning.

The impact test with a dummy attached to a rope showed that the sensors at 4m and 10m in most cases show the largest response, cf. figure 5. Especially the low-frequency content increases with the distance of the sensor to the hub because of the variation in stiffness of the blade skin. Also earlier tests showed that the sensor at 2m pick up more noise from the drive train. Based on these and other results of this test we chose to mount sensors at 4m and 10m.

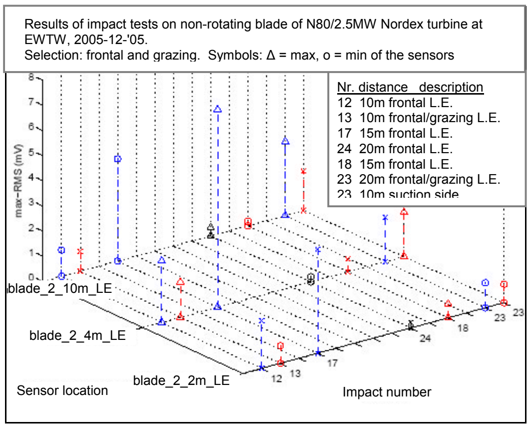

Figure 5: Response of sensors at different locations to impacts of a dummy with a non-rotating blade.

After the sensors had been relocated a functional test was carried out during turbine operation with wind speeds between 6 and 7 m/s. Figure 6 shows the response of the sensors to the dummy launch around 57.5 sec. and to the actual collision at 58.5 sec. In total three collisions were produced: two at about 5m from the tip and one about 10m from the tip, and all three showed a clear sensor response. This confirms that collisions from tennis balls at various locations on the blade can be detected.

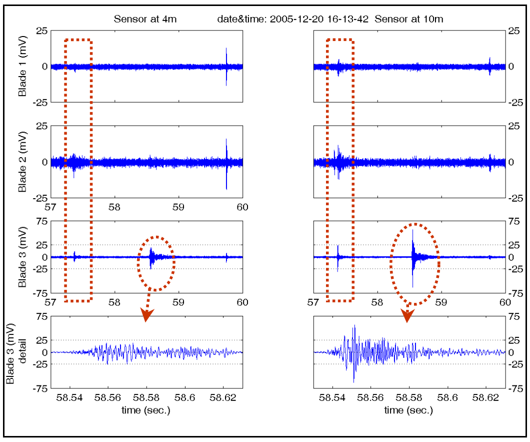

Figure 6: Registration of impact on rotating blade number 3 at about 5 meters from the tip.

A provisional signal-processing algorithm has been implemented, which can identify and suppress most of the turbine operational noise, blade cracking and ambient noise. However this needs to be improved as impulses with high magnitudes from mechanical origin occur that still cause too much false triggers.

6. FUTURE WORK

As said improvement and further testing of the signal processing is needed. It is also important to gain operational experience and to determine performance and reliability specifications for various conditions. If required the configuration will be improved. Besides, installation in other turbine types may also require modifications.

Subsequently the system needs to be calibrated. One suitable site has been selected, which is the North-sea Oosterschelde storm flood barrier in the Dutch province Zeeland, where a number of 3MW wind turbines will be installed this year. There the WT-Bird systems are exposed to offshore conditions with respect to wind, background-noise and corrosion. The abundant bird species at these sites are coastal birds and also bird migration occurs over these sites.

Calibration will be carried out by comparing the measurements of the WT-Bird system with results from daily field searches. Earlier field investigations have shown relatively high numbers of bird casualties, which shortens the period to collect enough data in order to determine the efficiency of the WT-Bird system with any statistical confidence.

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