Poster: Towards a Wireless Sensor System for Wind Turbine Control Optimization

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Abstract

The operational costs and lifetime of modern wind turbines are highly dependent on control strategies, which minimize the dynamical loads on the main shaft, gears and bearings of the wind turbine. To reduce the torsional strain in the drive train, real-time sensory information about the dynamical behaviour of the rotor hub and blades can be used to optimize these control strategies. To obtain these information, we propose a wireless sensor system, which utilizes a direct transmission of inertial measurement data from the rotor to the nacelle of a wind turbine.

1 Motivation

Wind power technology has become one of the most promising sustainable energy resources in the last decade [3] and the market share is still increasing. To maintain this development modern wind turbines are designed to have a lifespan of at least 20 years and power ratings of up to 8 MW. Since wind power plants are subject to highly changing loads, due to the turbulent characteristics of the wind, the operational lifetime can be diminished. These loads cause increased wear on the drive train components, which are illustrated in Figure 1 and are one of the main reason for failure. Therefore it will be necessary for future generation of wind turbines to employ advanced control algorithms in order to reduce these loads. Load minimizing control strategies commonly try to limit and minimize the peak torque on the main shaft of a wind turbine [1]. Since the torque in the drive train usually cannot be measured directly, it must be observed via other measured variables, like the speed of the electrical generator. Observing the torque via the generator speed means however, that any disturbance must travel completely through the drive train before it can be detected in the generator speed and thereby in the observed torque. In order to remedy this principle drawback and obtain a highly dynamic stress minimizing control, equally highly dynamic sensory information is needed. One possible way to obtain these information from the beginning of the functional chain is to deploy Inertial Measurement Units (IMU) in the rotor hub and rotor blades with a Wireless Sensor System. IMUs combine triple-axis accelerometers and angular rate sensors in a small form factor. With suitable motion processing algorithms the measurement data gives an appropriate estimate of the angular position and angular rate of the IMU, which can be used to determine the position and speed of the rotor hub. Besides the measurement of the dynamic behaviour of the rotor hub, the IMUs can be used to detect a change in the rotor blade bending [2], which is an early indicator for increasing or decreasing wind conditions.

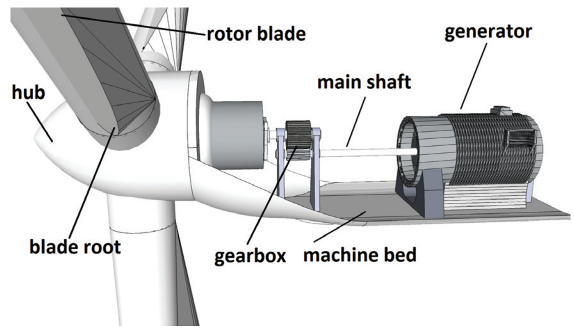

Figure 1. Wind turbine drive train consisting of generator, main shaft, gearbox and rotor

2 System Overview

The proposed wireless sensor system consists of three sensor nodes, which are equipped with IMUs. These sensor nodes are mounted on the rotor hub, the blade root and on the rotor blade utilizing a direct wireless link to a central base station, which is located at the nacelle of the wind turbine. The entire system consisting of the wireless sensor nodes and the nacelle mounted hardware is illustrated in Figure 2. Since the sensor nodes are mounted on different positions the corresponding IMUs experience unique motions and have to be analyzed via Digital Motion Processing. Therefore the raw data received by the base station is linked to an embedded PC, where the rotor speed and position as well as the rotor blade bending is calculated. The rotor speed and position are in turn input values for an observer structure, that will esti-

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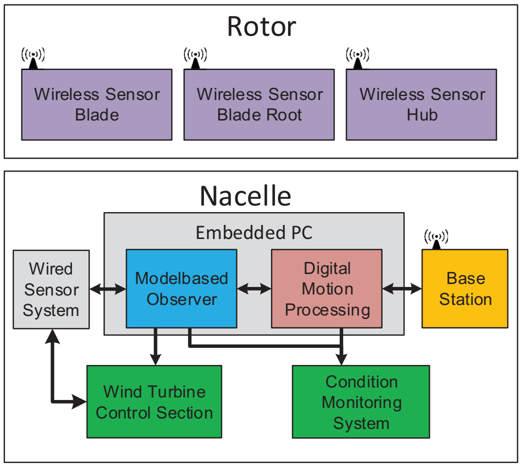

Figure 2. Topology of the Wireless Sensor System

Table 1. RSSI Inside Rotorblade Compartements

Antenna	Leading Edge	Midsection	Trailing Edge
Chip	-67 dBm	-82 dBm	-63 dBm
PCB	-65 dBm	-79 dBm	-62 dBm

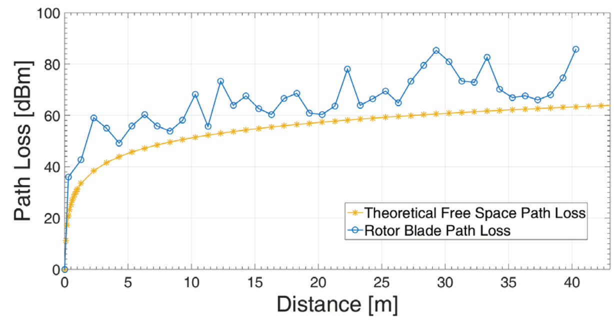

Figure 3. Path Loss Comparison 868 Mhz

mate the shaft torque in the drive train, which will be used for a load minimizing control. In addition all measured and estimated values are linked to a condition monitoring system. This system records the loading of critical drive train components and therefore enables a review of the occurring loads during normal operation. This drive train history can either be used in the design phase of new optimized wind turbine models or as indicator for the remaining operational life time of the observed wind turbine drive train.

3 Preliminary Evaluation

Since state of the art wind turbine rotor blades have reached length up to 88.4 m (ADWEN AD-180) and are build out of composite materials the feasibility of the proposed Wireless Sensor System was evaluated through range tests with single sensor nodes in advance. The rotor blade main components are glass fibre and balsa wood, but also carbon fibre as structural reinforcement and copper mesh as lightning conductor is used. Considering the range requirements and possible material effects sub-Ghz sensor nodes, working at a carrier frequency of 868 MHz, were used for this evaluation. Because the internal structure of the 80 m rotor blade is divided by shear webs in three separate compartments, several spots have been investigated. As for the desired control purpose minimum latency is desirable, the whole test was carried out with the maximum data rate of 250 kBaud. As base station the EM430F6137RF900 reference design by Texas Instruments was placed at the blade root and linked to a PC running SmartRF Studio Software to receive and log transmitted packets. For each spot 100 packets containing a consecutive serial number were transmitted. Since each packet can be determined by the serial number, every packet loss can be recognized by the Smart RF Studio Software. Moreover the base station adds a Received Signal Strength Indicator (RSSI) to each received packet, so that the average signal strength of each spot can be determined. The sensor nodes were placed at the maximum possible distance in each compartment and the measurement results are displayed in Table 1. As the distance in each compartment was different, it cannot be concluded which compartment is the most promising spot for the sensor node location. But since the receiving sensitivity of the base station at 250 kBit/s is approximately -90 dBm, each compartment is suitable for a transmission of IMU data. Because the midsection was the most accessible compartment a more detailed measurement series was carried out. Starting from the blade root the distance between sensor node and the base station was successively increased by 1 m. On the basis of the RSSI measurements the path loss inside the rotor blade was calculated and compared with the theoretical free space path loss, which is illustrated in Figure 3.

4 Conclusion and Future Work

In this poster abstract we introduced a wireless sensor system for wind turbine control optimization, that in addition can be used for condition monitoring purposes. The feasibility of the selected approach was demonstrated inside a 80 m offshore rotor blade. We are currently planning a measurement campaign on a 3.4 MW onshore wind turbine with a rotating diameter of 104 m. This measurement campaign will provide us with raw inertial measurement data of a rotating wind turbine sampled at 200 Hz. On the basis of this data our future work will focus on the development of suitable digital motion processing algorithms and a model based observer. In addition we will investigate possible pre-processing of raw inertial measurement data directly on the sensor node to reduce communication costs.

5 Acknowledgements

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6 References

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