Project title	Sensors for ice detection on wind turbine rotor blades
Project number	TG6-1
Organisation	Chalmers University of Technology, Dynamics
Project leader	Viktor Berbyuk
Other participants	Jan Möller, Bo Peterson, Stellan Wickström, Lena Klasén, Håkan Johansson, Olle Bankeström
Report for	2012-09-01 – 2014-09-30
Participating companies	WindVector AB, DIAB, SKF

Project description

The scope for this project was to provide theoretical background, experimental systems, algorithms and methods to detect ice build-up on rotor blades on wind turbines. The long term goal of the project is to transfer knowledge of the potential of the sensor concepts to the industry, to be used for cost effectiveness of the two sensors. The main objectives of the project was to design two prototypes of sensor systems and to evaluate them in Cold Climate Laboratory with respect to their applicability to be used for early ice detection on rotor blades of wind turbines. These two prototypes are:

- Ice detection system based on controlled acoustic waves & magnetostrictive actuators (Chalmers)
- Ice detection system based on LIDAR sensor (WindVector AB).

In the extension of this project it was planned to instrument a new experimental set up with the test objects based on rotor blade Vestas V47.

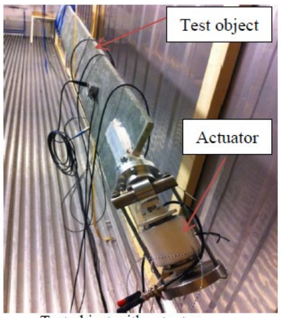
Results

The project provided a demonstrator for the ice detection system based on controlled acoustic waves, magnetostrictive actuator and accelerometers. An experimental set-up with the demonstrator in cold climate lab (CCL), composite test object and equipment for glaze and rime ice production have been developed (see Figure 16 – Cold Climate Lab and Experimental Set-up; Figure 17 – Equipment for ice manufacture). The composite material in the test object was the same as normally used in wind turbine blades. LabVIEW and DAQ system from National Instruments were used for measurement data gathering and processing. The propagation of three orthogonally polarized acoustic waves was studied for different scenarios of icing of the test object. Data was measured by means of 6 accelerometers positioned, 3 each, in 2 holders at approximately 0.4 m from each end of the 8 m long test object. A number of indicators were proposed and numerical algorithm has been developed to analyse the measurement data. The obtained results showed that the formation of ice, the ice mass, icing areas and the temperature have a significant influence on guided wave propagation w.r.t. Fourier transform, amplitude attenuation and RMS values as indicators. It was also shown that there is no significant damping in the material that has been tested concluding that the proposed ice detection system based on controlled acoustic waves is a promising approach for ice detection. Details of the results obtained have been presented at International Conference SPIE2014, Smart Structures/NDE, San Diego, USA, and published in [1].

The project also provided a demonstrator for the laser based sensor for ice detection (Figure 18 – LIDAR sensor for ice detection). Here the first phase of the work included specification of the experimental sensor set-up, LIDAR system assembly and design of the experiments. The cold climate chamber enabled measurements with the LIDAR system under conditions that allowed for comparison of how well the LIDAR system was suited for ice detection. The spectral properties of uncovered rotor blades have been studied in comparison to ice and snow build-up on the rotor blades, to detect anomalies indicating ice accretions. For water, the signal level does not decrease to a minimum as the water drops only partially cover the test object causing the received signal to be a mix of the “normal” signal level of the test target and the decreased signal level caused by the water drops on the test target. The same principle holds for ice accretion, that the signal level decreases gradually as the ice is built-up on the test target. As the ice layer gets thicker, the signal level reaches a minimum for ice layers of only a few mm. The LIDAR system and the anomaly based detection algorithm shows that the data can be used for early detection of ice and water. Part of the results obtained has published in [2].


Cold Climate Lab

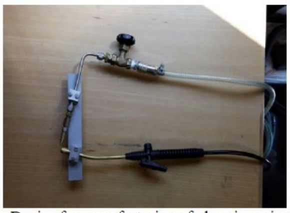

Data gathering and procession

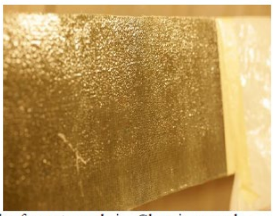


Test object with actuator


Sensors on test object

Figure 1: Cold Climate Lab and Experimental Set-up




Device for manufacturing of glaze ice using separate nozzles for water and air. Glaze ice sample.


Device for manufacturing of rime ice using one nozzle and mixing of water and air inside. Rime ice sample.

Figure 2: Equipment for ice manufacture

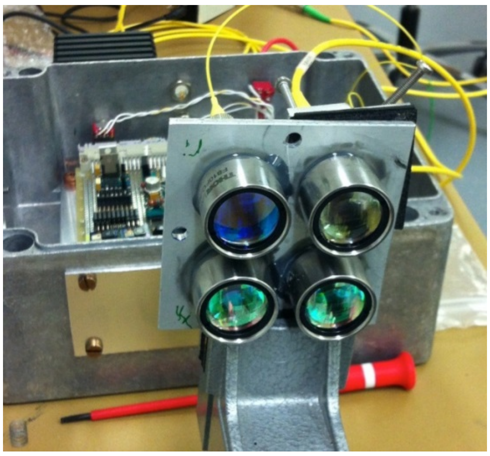


Figure 3: LIDAR sensor for ice detection

During the extension of the project the specifications for the test object to be used in experimental set up in Cold Climate Lab based on rotor blade of Vestas V47 have been developed and the analysis of available actuation and sensing transducers to be chosen for a new experimental set has been done. The test object, used rotor blade of Vestas V47, was received at the end of September 2014 from Connected Wind Services (Figure 19).

Figure 4: Vestas V47 blade at the Chalmers Cold Climate Lab

Fulfilment of SWPTC's goals

The results of the proposed project can be used to increase efficiency of de-icing systems of wind turbines in cold climate and in this way can significantly contribute to wind power system performance optimisation. Research on developing ice detection sensor technologies with application to wind turbine will support and accelerate moving wind power technology to cold climate. It will make possible to increase wind energy production, increase production of wind turbines and their components, like rotor blades, novel condition monitoring systems, others. The obtained results are used in engineering education and were published as internationally recognisable scientific papers.

Deviations from project plan

Due to late delivering of the Vestas V47 blade the work on instrumentation of the new test object and design of the new experimental set up in Cold Climate Lab have been delayed.

Publications

1. V. Berbyuk, B. Peterson, J. Möller, *Towards early ice detection on wind turbine blades using acoustic waves", Proc. of SPIE, Nondestructive Characterization for Composite Materials*, Aerospace Engineering, Civil Infrastructure, and Homeland Security 2014, San Diego, California, USA, March 09, 2014, 9063 pp. 90630F-1 - 90630F-11
2. L. Klasén, *Lidar Systems for Wind Energy Applications*, Proceeding of Swedish Society of Automated Image Analysis (SSBA) Symposium on Image Analysis, 2014

External activities

A new PhD project was granted by Swedish Energy Agency for the period of September 2013-December 2016. The project is running with PhD student employed at Chalmers from December 2013 in cooperation with Chalmers Industriteknik and WindVector AB. This project is considered as continuation of the work performed within the TG6-1 project.