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Experiences from Wind Turbine Pilot Test of a Remote Inspection System

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Abstract

This paper describes a pilot test of a remote inspection prototype system in a wind turbine. This test provided useful experience on how the system operated in this realistic location, and a preview on what kind of data it is capable of collecting. The test lasted for approximately 6 months before the system had a fatal failure in a part that has since been improved for future versions of the system. An exploratory analysis of the collected data has been performed, using principal component analysis and random forest regression, two commonly used machine learning methods. The results demonstrate that it is possible to extract some potentially useful information from the collected data and points to some possible uses of this, e.g. to trigger when to alert a human operator to investigate a set of data or when additional data should be collected.

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Keywords: Wind energy; Remote inspection; Pilot instalation; Data analysis

1. Introduction

As more and more wind turbines are installed offshore, or at remote locations on land, the operation and maintenance become increasingly difficult and expensive. Even with state of the art SCADA and condition monitoring systems [1,2], the turbines require both regular planned maintenance and unplanned corrective maintenance when there are alarms or failures. Each visit to an offshore turbine has a significant cost, which contribute to the high cost of offshore wind, which must be lowered for it to be a viable alternative [3,4]. It is

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inefficient that skilled personnel spend perhaps half of their day with transportation. Personnel safety [5,6] should also be considered, which alone is a good enough reason to reduce the need for manned visits to turbines.

A system for *remote inspection* of wind turbine nacelles [7] was developed within NOWITECH, starting in 2011. It consists of an instrumentation platform that can move on a monorail inside the turbine nacelle, and observe different equipment there. The platform can have different types of sensors, e.g. visual cameras, thermal cameras and microphones. Information gathered during inspections is collected, analyzed and stored as a history of the system condition and behavior. The system can perform inspection rounds, either scheduled or triggered by some event, to collect sensor information that can be accessed by maintenance personnel or included in a condition monitoring system. It can also collect information on demand, as preparation for a maintenance task, to verify the correctness of a condition monitoring alarm without having to visit the turbine, or in place of an on-site inspection.

This paper describes a pilot test with a remote inspection prototype inside of a wind turbine. The objectives of this test were twofold. Firstly, it gave valuable experience on how such a system could work in a realistic setting, instead of in an office. The nacelle of this older turbine is less protected from rain and temperature variations than the nacelle of a more modern turbine. Thus, operating in this environment would be a good test for the ability to operate in any turbine. The second reason for the test is to get some initial sensor data from an actual turbine. The intention was not to take an active part in the operation and maintenance of the turbine and attempt to predict failures, but to get data that could be analyzed for learning more about how such information can be used. Although wind turbine reliability is a concern, failures are not frequent enough that one could expect one to occur within a short test as this, as experienced in the CleverFarm project where data was collected from three turbines over three and a half year without major incidents [8].

As the turbine is an older turbine, and the prototype had to be installed at a location that did not give an optimal view of the nacelle, it was not expected to demonstrate the full capabilities of the remote inspection concept, only a subset.

The collected data was analyzed using principal component analysis (PCA) [9] to visualize the information within the data and look for trends. Secondly, random forest regression [10] were used to see if it was possible to use the collected data to make predictive models. In this paper these models predict the measured wind speed, but could also have been trained to predict load, power output or other related parameters if that information had been available.

2. Pilot Installation

2.1. Prototype Description

The prototype that was used in this pilot test is an instrumentation platform on a pan and tilt mechanism. It was intended as a proof-of-concept prototype with an expected lifetime of 6-12 months, not a version ready for commercialization. The prototype was built with typical rapid prototyping tools, i.e. 3D printing, aluminum building blocks and standard parts such as stepper motors, bearings etc. Both pan and tilt rotation could be performed with two independent motors for redundancy. All wires from the control electronics to the motors and sensors were inside the bearings, no slip rings were used. This limited the rotations the prototype could do, and would eventually cause wear and tear on these wires and reduce the lifetime of the system.

The pan rotation joint was considered a weak point, as many wires had to be on the inside of a 3D printed part that had to be on the inside of a bearing. Parts printed with a FDM type 3D-printer [11], consist of layers fused together, making them vulnerable to delamination of these layers. Especially when the layers are cross-sections of a thin part as this critical pan part. Due to this, it was reinforced with a small aluminum profile attached to the top and bottom with screws.

The prototype was controlled by two Hardkernel Odroid-U3 ARM development boards running Linux. Both had a slave Arduino microcontroller that controlled the stepper motors and the LEDs. These computers were connected through a 3G router, one with an Ethernet cable, and the other with a Wi-Fi connection. The reasoning here was to test how a Wi-Fi connection behaved, but at the same time have a reliable wired connection for at least one of the computers. The 3G router had a publicly available static IP, thus it was possible to connect to it from anywhere on the Internet.