Distributed Fault Detection and Diagnosis for Wind Farms

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ABSTRACT

Analyses of wind farm maintenance costs show that up to 40% of the outlay is related to unexpected component failures that lead to costly unscheduled amendments. Situations involving major failures of the braking system or the gearbox may result in catastrophic damage, jeopardising investments, reputation and the certainty of wind energy. Early fault detection by carrying out regular inspection of the system components helps to prevent and minimise the number of major breakdowns. This project will address the problem of automatic detection and diagnosis of faults within wind farms. The central thesis to be tested is that spatially correlated data, from the monitored assets within each turbine, can be used to improve the efficacy of fault detection and diagnosis algorithms. The benefit will be advanced-failure detection, resulting in superior planned maintenance, shorter downtimes and decreased revenue losses. This could also be used to either enhance safety or achieve a more affordable current level of safety.

1 INTRODUCTION

The project involves wide research, cooperation within the industry, plus sharing information and experiences to obtain detailed features of the trial products that will be designed to fulfil the requirements set by the wind energy industry. This involves collecting real samples from wind farms, as well as modelling and analysing the system. In order to proceed, investigation of the significant failures within the system and focusing on a particular sub-system and its related faults are required. Furthermore, specifying a suitable condition monitoring system (CMS) and fault detection and diagnosis (FDD) methods for operational turbine parts is being studied and executed. Subsequently, laboratory based simulations and evaluations will also be conducted to provide trial demonstrations under customary conditions. Consequently, comparison of the data being collected from a wind farm will be used to improve the FDD methods.

2 AIMS AND OBJECTIVES

The proposed work will be delivered through the completion of several well defined objectives:

- A general review of the FDD literature. To include model based approaches, parameter estimation and other pertinent methods.
- Develop a model for a wind turbine to enable FDD algorithms to be tested with simulated faults.
- Extend the model to consider multiple wind turbines in a wind farm. Assess the simulation in order to improve the efficacy of the algorithms.
- Develop a requirements specification for a wind farm condition monitoring system, based around a distributed embedded system.
- Determine the performance of the CMS during field trials.

3 CURRENT PROGRESS

As a part of a European Framework 7 project, Novel Integration Condition Monitoring of Wind Turbines (NIMO) [1], the opportunity of condition monitoring of the braking system is being considered in this thesis. In most countries, wind turbines are required, by law, to have two independent fail-safe brake mechanisms to stop the turbine promptly when required, especially with regards to over-speed control.

3.1 Brake System Health Monitoring

Figure 1 illustrates the mechanical brake system and the parts that will be monitored. Active hydraulic power, provided by the pump, is used periodically to maintain the pressure in the accumulator to release and keep the pads off the brake disc. At this stage the CMS of the three-phase pump has been carried out.

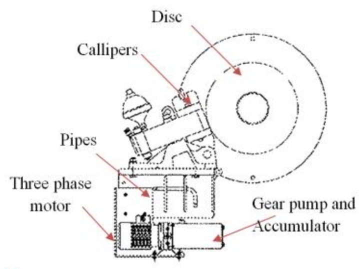

Figure 1: A fail-safe mechanical brake system

A battery back-up (to avoid data corruption in the event of power loss) data acquisition system, shown in Figure 2, is being designed to acquire, store and analyse data from the current sensors, installed on the three-phase motor. Ethernet connection to the supervisory control and data acquisition (SCADA) will be implemented in the later versions.

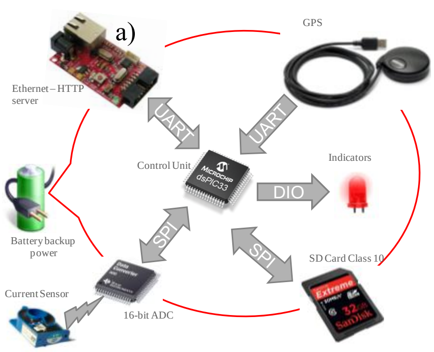

Figure 2: The overview of the deliverable system

To overcome the CMS and monitor the passive components of the brake (calipers and pads), a non-contact temperature and displacement measurements of the disc pads and callipers will be considered for further studies, plus investigation of the possible improvements in the FDD algorithms. Shaft and wind speed will be applied in the next stages of performance monitoring of the brake system. The final phase will involve instrumenting a whole wind farm.

3.2 Fault detection and diagnosis

Model-based and model-free techniques are being considered for the purpose of Fault Detection and this will also be applied to perform fault diagnosis processing. The model-free approaches, time-domain analysis in current and looking at the envelope of a signal, identify changes within the machinery and its characteristics. Vibration monitoring approaches could also be used for incipient fault detection. However, regarding the three-phase motor health, stator current monitoring has been established as being able to detect such faults without requiring access to the motor [2]. Depending on the severity and importance of the fault, a model-free Fault Detection System (FDS) has to take appropriate actions [3]. A general view of a model-free FDS structure is shown in Figure 3. Model-based fault detection mechanisms have also been reviewed and will be tested in future work, for instance using system identification approach and Kalman filters (observation method) [4]. The use of the Kalman filter supports estimations of past, present and future states, even when the exact parameters of the modelled system are unknown. Figure 4 illustrates the general idea of the model-based methods. The residuals may allow detection of changes in the system behaviour and lead to fault detection and possible diagnosis [6].

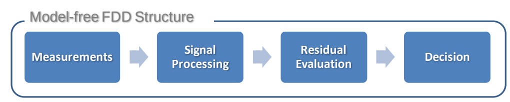

Figure 3: Structure of a model free fault detection system

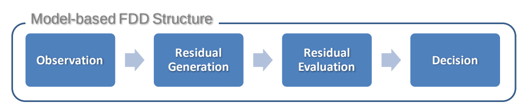

Figure 4: Model-based FDD structure and some of the methods

4 OUTCOMES AND IMPACT

The results of the experiments will lead to the implementation of an acceptable model, the testing of a few failure modes, and the study of different FDD mechanisms. Using an applicable FDD approach based on a SCADA along with comparison of the collected data within a wind farm will be considered to achieve an advanced deliverable CMS and FDD system. Additionally, some basic analyses and data processing procedures will be carried out by the embedded systems, and more detailed diagnosis will be carried out by a main control system.

ACKNOWLEDGMENT

This project is supported by the Railway Research Group at University of Birmingham and is partially funded by the European Commission FP7 project NIMO.

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