Condition Monitoring of Tidal Stream Turbines

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Work stream 8: Reliability

Introduction

Improving reliability and maintainability of tidal stream turbines(TSTs) is still seen as a significant challenge facing a bourgeoning industry in its move toward commercial realisation. It is evident that condition monitoring (CM) and associated condition based maintenance (CBM) practices can go some way to improving these aspects of TST design.

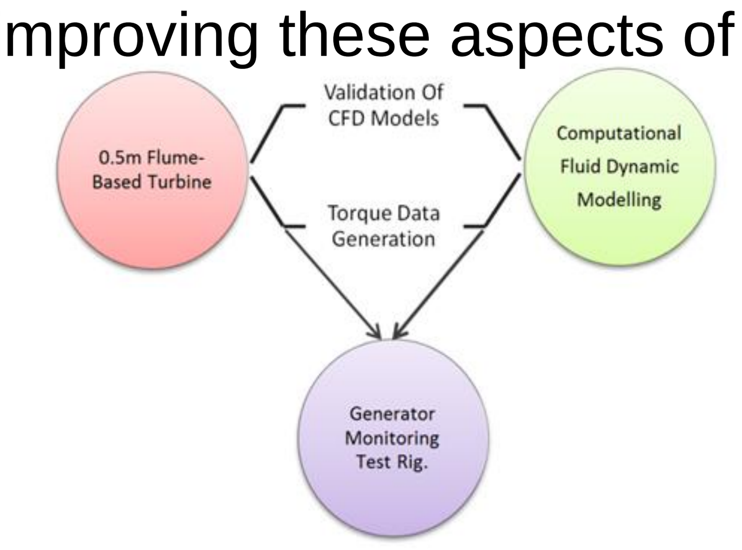

Figure 1: Overview of experimental Procedure.

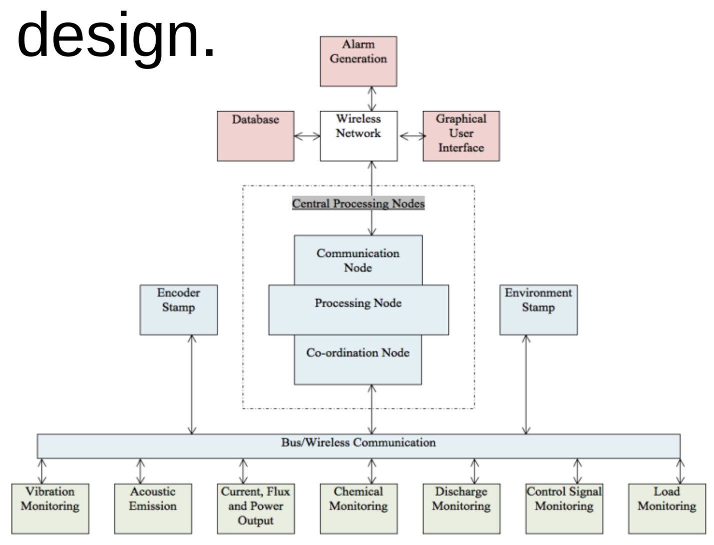

Figure 2: Condition Monitoring Architecture.

Experimental Procedure.

A three pronged approach to the development of testing procedures has been undertaken. The experimental methodology has been developed with adaptability as a leading principle, as well as addressing issues of suitable data acquisition methods and embedded processing power. The notion of adaptability allows for effective representation of fault conditions including unforeseen fault conditions uncovered throughout the course of the research project as part of an ongoing FMECA. The three areas contributing to effective testing and development of the CM system can be seen in figure 1. An overall monitoring architecture is show in Figure 2.

Various mechanical fault conditions have been modeled using computation fluid dynamics (figure 4), with results from simulations being analysed to establish characteristics with focus on time-frequency representation of faults for input into process models and for experimental investigation via the drive train test rig. Accuracy of fault condition representation, as well as, turbulent noise characterization will then be achieved via testing carried out on the flume-based 0.5 m diameter turbine. Figure 5 shows a syntheses for a drive shaft torque profile using the procedure outlined.

Figure 3: Instrumented Drive Train Test Rig.

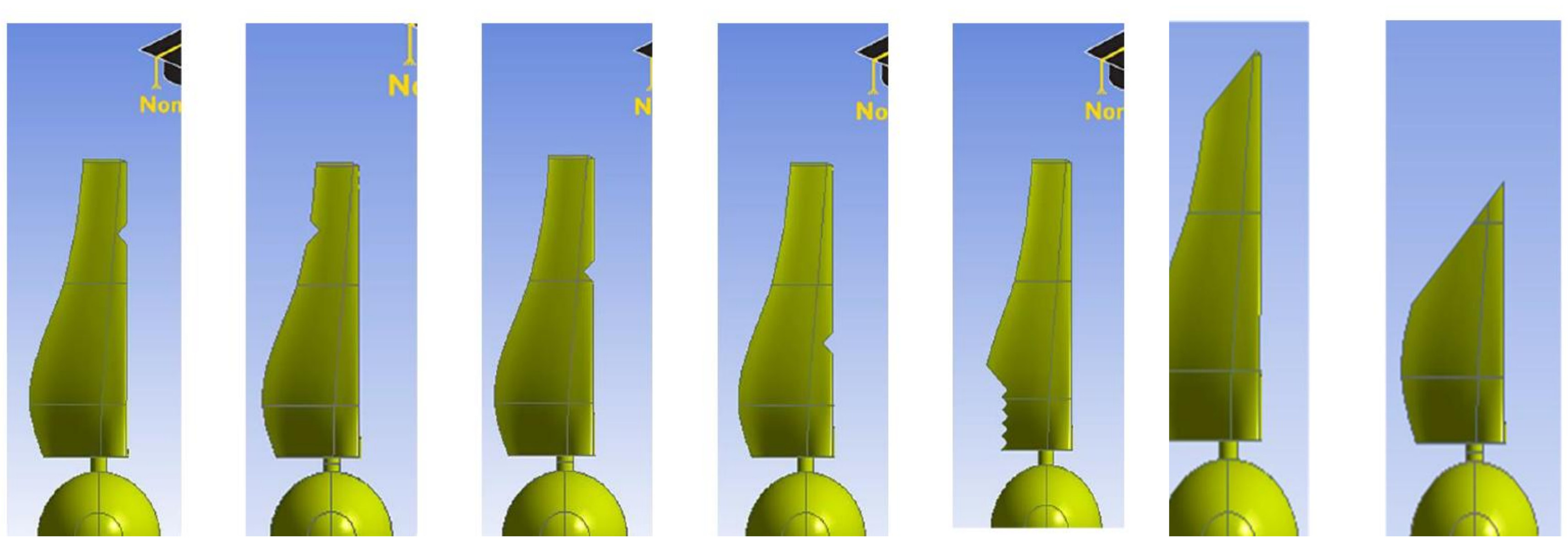

Figure 4: CFD Simulated Blade Damage.

Instrumentation.

The 0.5m diameter turbine has an instrumented with the ability measure blade loading both in terms of thrust and twist about the blade axis. The instrumented hub is also fitted with an accelerometer to allow for vibration analysis and the study of turbulent loading characteristics. Due to size restrictions, using an Arduino Nano as a DAQ device allowed for sample rates of 10KHz. The experimental control program constructed using NI LabVIEW then interfaces with the motor drive and encoder measuring drive shaft torque, rotational velocity, flux generating voltage and current and torque generating voltage and current as well as the PWM switching frequency. Furthermore the readings are taken from the drive every control cycle which operated at a rate of 500KHz. The testing process is then synchronised using a 10MHz clock supplied by the national instruments PXI hardware.

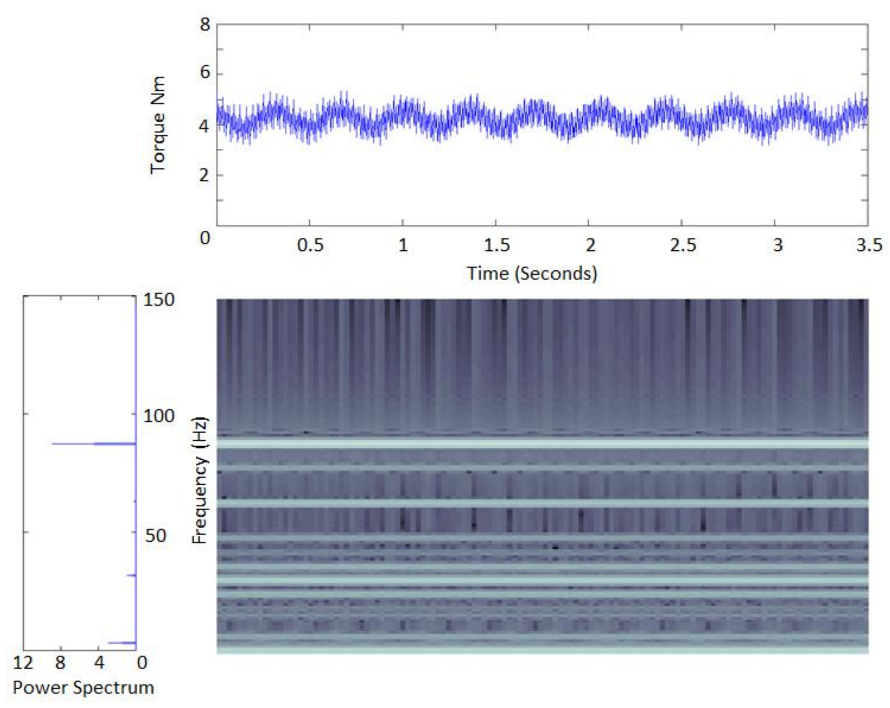

Figure 5: Time Frequency Representation of Drive Shaft Torque Profile Synthesised from CFD Results.

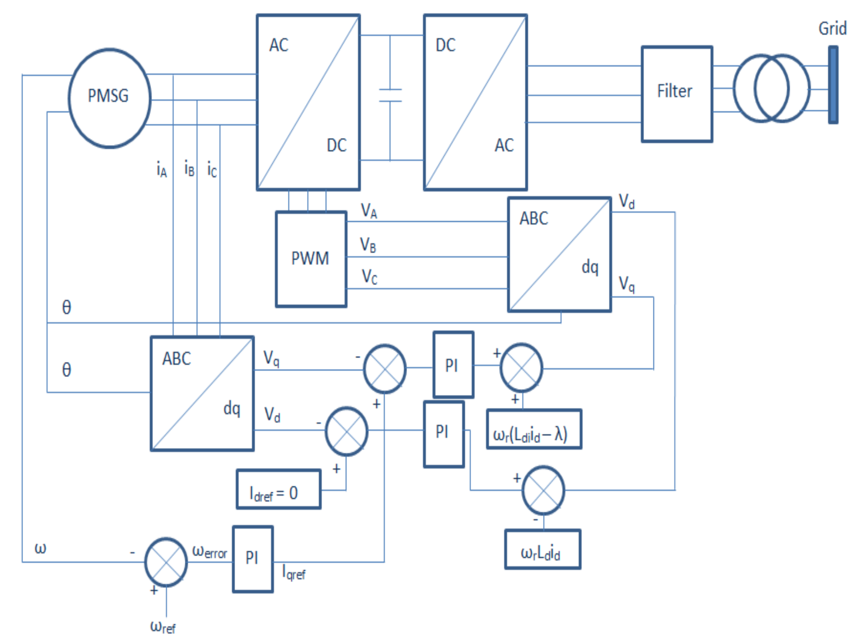

Figure 6: Field Oriented Control Scheme

Control System Integration.

In order to minimise monitoring system expense and to offset reliability issues associated with the installation of a vast sensors suites a key focus of the research is the integration of condition monitoring and turbine control processes. The drive train test rig (figure 3) utilises a field oriented control (FOC) algorithm for motor control and generator power point tracking. The work derives transient changes in mechanical power input as fluid velocity changes as the maximum power point is tracked. The research then seeks to characterise normal and faulty operational states w.r.t power take-off methodologies by monitoring generator outputs and power conditioning hardware such as current control pulse width modulators (CC PMW). The viability of diagnosing faults via such a process is currently being investigated with focus on the prognostic resolution of the outlined method. Figure 4 shows the field oriented control scheme adopted at the test rig generator output, based on [1].

Future Work.

The effectiveness of and a robust approach to the integration of condition monitoring solutions with control implementations will be further investigated throughout the research project. Focus will be on the applicability of this notion to direct drive permanent magnet synchronous generator type TSTs. The extrapolation of techniques toward a more general monitoring strategy will allow be considered. Based on experimental data and in particular the diagnostic information obtained from the embedded condition monitoring a prognostic (remaining life) model will be developed.

References:

[1] "Field Oriented Control of a Permanent Magnet Synchronous Generator for use in a Variable speed Tidal Stream Turbine", J. Liang and B.Whitby, UPEC, 2011.

Industrial Partnerships: