The development of a control system for turbine control and power generation for the Aeolus wind powered vehicle

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Introduction

This project aims to develop a controller for the turbine speed of the universities AEOLUS Wind powered vehicle shown in Figure 1.

Figure 1 – The University of Bristol's AEOLUS project vehicle , photo provided by the AEOLUS project.,

Motivation

The ability to control the turbine speed allows for accurate control of the turbines Tip-Speed Ratio, the ratio of blade-tip linear speed to wind speed which is directly related to the coefficient of power, the amount of available power extracted as shown in Figure 2

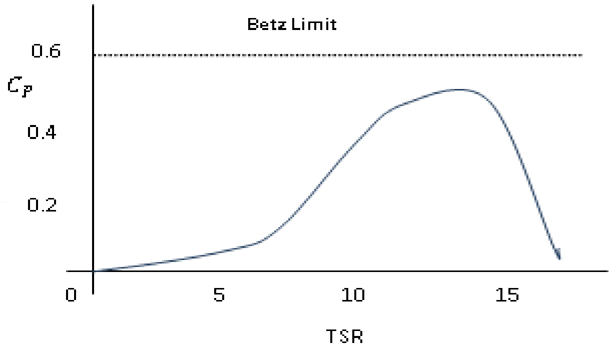


Figure 2 – Typical relationship between TSR and coefficient of power

Modelling

Analysis of the vehicles power channel allowed the control system and its constituent components to be identified as shown in Figure 3. The system actuator is identified to be the generator and the current drawn by the motor drive as the control signal. A thorough investigation of the components within ite control system generated the system equation below

$$J\dot{\omega} = T_{Turbine} - \frac{\sqrt{3}}{2} K_T I_{Draw} - T_{Friction}$$

The Turbine torque term is found to be highly non-linear with the lift and drag coefficients identified as strong non-linear functions

$$T_{Turbine} = N_{Blades} \sum_{0}^{N_{elements}} \left[\frac{\rho_{Air} {V_{Rel}}^2}{2} (C_L \sin\Phi - C_D \cos\Phi) L_C dr R_{mid} \right]$$

PID control

PID control was investigated as it is the form of control currently used on the vehicle. The system was linearized for PID design to be possible which limited the input range to 106.2 rad/s. PI control was the required format however once optimised and implemented against the non-linear plan model it visibly underperformed, Figure 3 indicating non-linear specific control is required

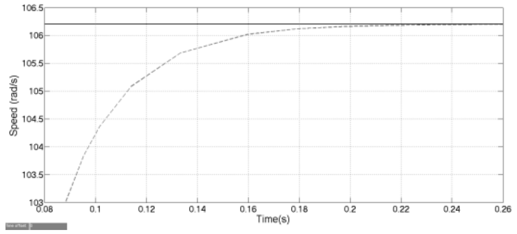


Figure 3 – PI performance against non-linear plant

Sliding mode control

Sliding mode control is a variable structure control system designed to cope with non-linearity's . It is ideally suited to the AEOLUS system as it is a first order and can be implemented through the use of a signum function on the error signal with a simple strength gain on the output. The sliding mode was implemented and compared to the PI control using many inputs with the step response shown in Figure 4.

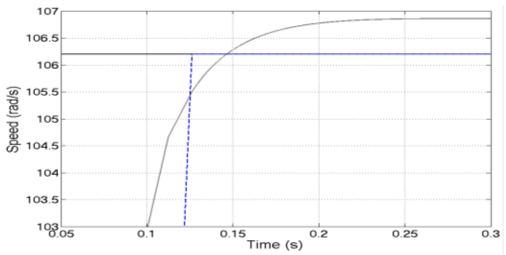
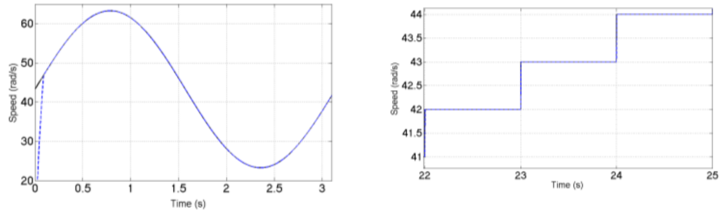


Figure 4 – sliding mode (dashed line) vs PI control

Adaptive control additon

Adaptive control is a form of online parameter estimation that is used to estimate the magnitude of the non-linearity's in the plant based on the error signal and to provide a response equivalent to their dynamics into the system, linearizing the feedback and reducing the effort sliding mode control has to apply. Its repsonse against a multitude of responses is shown in Figure 5



Conclusions

This project has shown that the AEOULS vehicle is highly non-linear and that a specific control methodology to cope with this is required with this project identifying sliding mode with adaptive on-line parameter estimation as the optimum control methodology