Design of Advanced Wind Turbine Controllers

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Introduction

Controller demands are increasing due to larger wind turbines and the requirements of load reduction and performance improvement and cost effectiveness.

Solution 1 – refine current control approaches – only limited improvements.

Solution 2- modify traditional control strategy with increased input information from models.

Above Rated Blade Load Controller Design History

Central pitch control (CPC) - basic low order dynamic controller with careful tuning used to control collective pitch angle demand.

Individual pitch control (IPC) [1] uses Coleman transformation. IPC makes adjustments to the collective pitch angle demand to control blade loads while CPC provides speed control.

Individual blade control (IBC) [2] creates an individual blade model with fictitious forces which allows the blade dynamics and the rest of the wind turbine dynamics to be decoupled. Individual blade loads can be controlled.

Alternatively **smart rotors** which modify local aerodynamics around the blade to be used with IPC or IBC can also be utilised.

Individual Blade Control [2]

Each blade has own sensor and moment actuator.

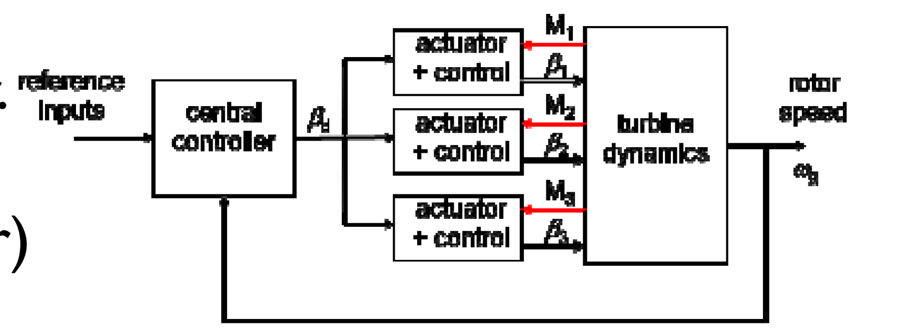

Figure 1 – Individual Blade Load Pitch Controller Schematic [2]

Individual blade (and actuator) dynamics decoupled using individual blade model including fictitious forces

Linear and rotational fictitious forces represent differences between rotating blade non inertia reference frame and inertia tower frame.

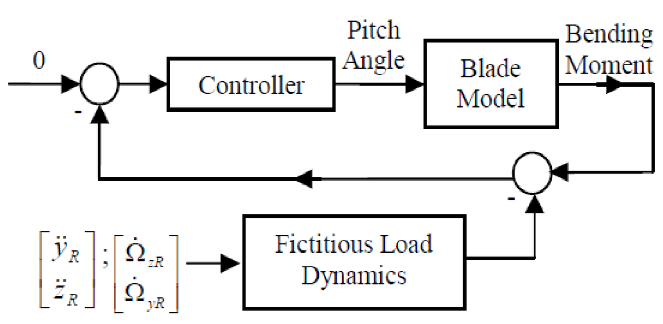

Figure 2 – Blade and Actuator dynamics for single blade controller with both linear and rotational fictitious forces [2]

Model Design History

Effective Wind Speed Model (EWS) [4] uses aerodynamic torque and spectral analysis to develop a spatial filter to model effective wind speed.

Effective Wind Field Model (EWF) [5] uses the concept of separability, with rotational sampling, and stochastic and deterministic wind components allows wind loads up to 6P to be modelled.

Effective Aerodynamic Model (EAM) [6] uses EWF model and reformulated blade element momentum theory to model dynamic inflow.

Anomaly Detector [7] uses EWF and EAM to develop an extended kalman filter which detects anomalies (blade imbalances, gusts) based on blade bending moments.

Anomaly Detector [7]

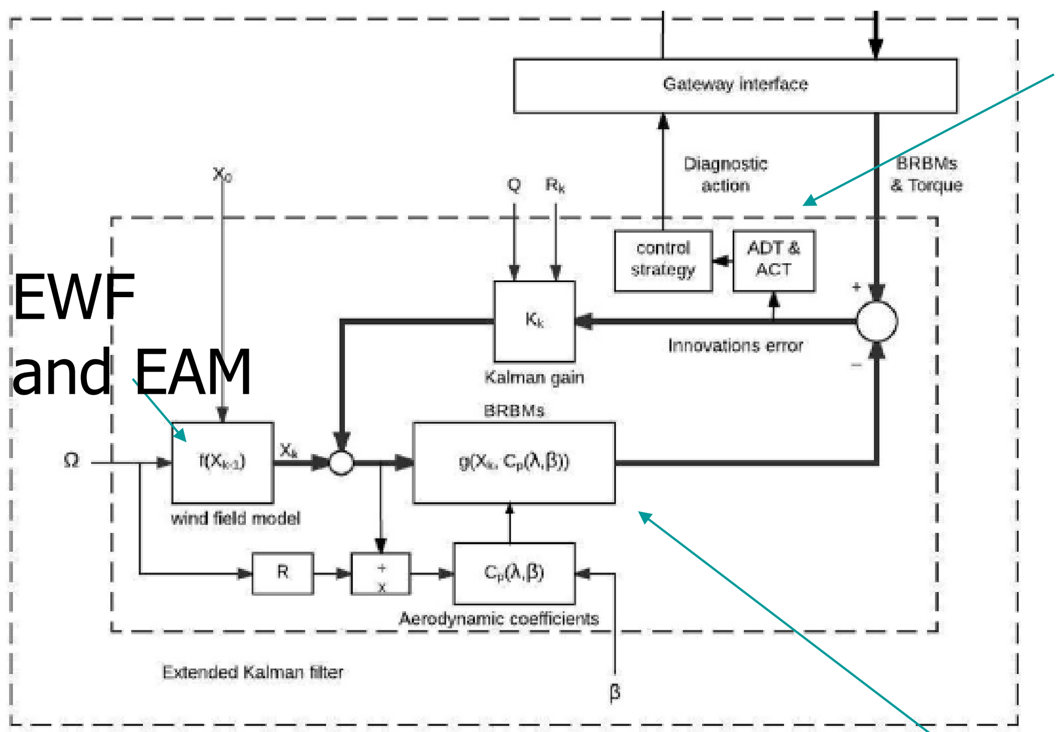

Figure 3 – Anomaly Detector [7]

Gust Detection

EKF innovations error Detection and confirmation tests (ADT & ACT)

Pattern Matching

Blade Mass imbalance

$$T_f = M_{IP,1} + M_{IP,2} + M_{IP,3}$$

$$T_f = 0 \therefore noimbalance$$

$$M_{IP} = \frac{1}{2}\rho\pi\hat{V}_s R^3 \frac{C_{mx}(\lambda)}{3} + gM_b\cos(\theta_a)$$

Proposed Solution

Use anomaly detector to find blade imbalances and use model outputs as inputs to individual blade controller control strategy to control blade loads.

Future Work

- Develop control strategy using outputs of anomaly detector.
- Provide blade load mitigation for blade load imbalances and gusts using new control strategy and IBC.
- Design, implement and test new advanced controller design.

References

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[4] W. E. Leithead, "Effective Wind Speed Models for Simple Wind Turbine Simulations," in Proc. BWEA Nottingham, vol. 1, 1992, pp 321 -326

[5] M. L. Gala-Santos, "Aerodynamics and Wind Field Models for Wind Turbine Control," PhD, University of Strathclyde, 2018.

[6] A. Stock, "Augmented Control for Flexible Operation of Wind Turbines," Ph.D dissertation, University of Strathclyde, 2014

[7] S. Hur, L. Recalde-Camacho, and W. E. Leithead, "Detection and compensation of anomalous conditions in a wind turbine," Energy, vol. 124, pp. 74-86, 2017.

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