Modelling and Analysis of Controlled Aeroelastic Tailoring Blade Wind Turbine

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Abstract

- The project presents a novel approach of a control system development for an aeroelastic tailoring blade (ATB) wind turbine (WT).
- Despite the huge gap of the ATB WT model, this research is certainly can improved the loading effects of a WT system and can offer the reduction of cost of energy(COE) of the system [1].
- A baseline controller is applied as the preliminary approach to the ATB WT and then is integrated with the ATB WT model for performance analysis.
- ATB is a new development in WT design that apply the benefits of composite materials blade design.
- The ATB WT is modelled based on the assumptions that only the twist angle is physically altered from the baseline blade.
- Then, the ATB WT model is linearised with the linearisation tools available in GL Bladed computational tools.
- The ATB WT behaviour can be examined for further investigations from the linearised model, .

Controller Objectives

- To develop a new controller for an ATB WT that is able to alleviate the loading effects without compromising the power production of the wind turbine.

Types of Controllers

- A new model of ATB is developed an examined with the standard WT PI controller. The model that worked well with the standard controller can be further investigated with different types of controllers such as Model Predictive Controller (MPC) and Linear Quadratic Regulator (LQR)[3].
- However, these controllers are not discussed here.

Development of ATB Model

- The actual data for the ATB is still in ongoing progress.
- Assumption is made based on the results provided by [3].
- The results is altered as shown in Table 1 to comply with the 61m blade.
- The distance along the blade is normalised to fit into the interpolated data.
  *Note that the modified value is only the aerodynamic twist

Blade Section	Base-line	Model A	Model B	Model C	Blade Section	Base-line	Model A	Model B	Model C
1	13.31	0.00	0.00	0.00	11	5.36	-7.20	-5.00	-5.70
2	13.31	-0.15	-0.01	-0.01	12	4.19	-6.82	-4.95	-5.65
3	13.31	-0.54	-0.09	-0.09	13	3.13	-6.16	-4.68	-5.38
4	13.31	-1.01	-0.20	-0.20	14	2.32	-5.18	-3.60	-4.31
5	13.31	-1.83	-0.46	-0.50	15	1.53	-4.20	-2.56	-3.10
6	11.48	-2.93	-0.90	-1.02	16	0.86	-3.51	-1.81	-2.21
7	10.16	-4.02	-1.49	-1.65	17	0.37	-3.15	-1.41	-1.82
8	9.01	-5.21	-2.33	-2.62	18	0.11	-2.88	-1.10	-1.55
9	7.80	-6.34	-3.42	-3.91	19	0.00	-2.80	-1.00	-1.50
10	6.54	-6.95	-4.47	-5.10					

Table 1 - Aerodynamic Twist Distributions Along the Blade (Degree)

Wind Turbine Performance

- Power Coefficient - the peak or Cpmax is slightly shorter than the baseline peak Fig 1.
- Electrical Power - the power production for Model A,B and C is lower than the baseline turbine Fig 2.
- Pitch Angle - It shown that Model B and C have slim gap between the baseline pitch angle Fig 3.

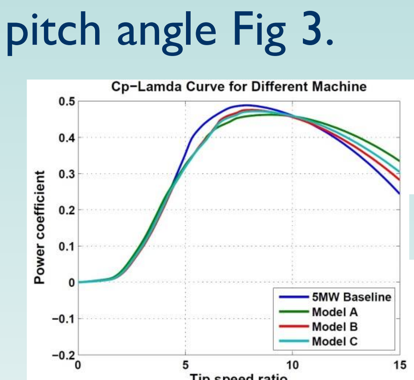

Fig 1

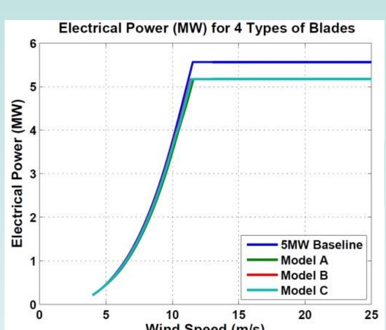

Fig 2

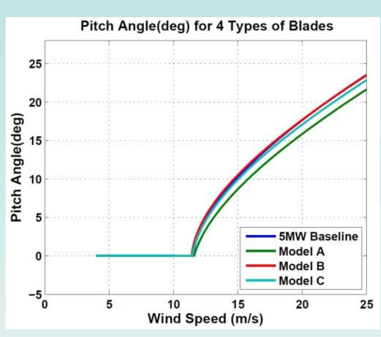

Fig 3

Results

Nonlinear Model

- The controller worked well on model A but not working with model B and C.
- Initial investigations found that the power coefficient table for model B and C is different from baseline and model A where had minimum pitch angle of 0 deg compared to baseline and model A minimum pitch angle was around -17deg.
- Note that the results were for 15m/s wind speed only.

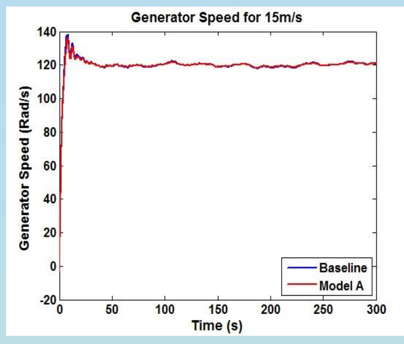

Fig 4

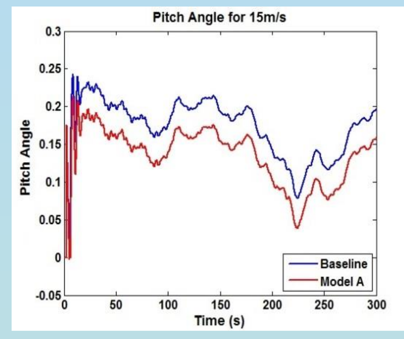

Fig 5

- Fig 4 – the generator speed output is similar for both models.
- Fig 5 - presented active pitch control for both baseline and model A with model A is below the baseline machine.

Nonlinear Model

- Fig 6 – the outputs from generator torque to generator speed for 15m/s wind speed and obviously depicted that the tower frequency is shifted to 14.2 rad/s from 10.7 rad/s for model A,B and C. The changes in the physical twist angle contributed to the shifting of the tower frequency value.
- Fig 7 – the peak shifting and numbers of peaks occurred on the bode plot.
- Fig 8 – the output shown that the 1 peak is reduced in Model A,B and C.

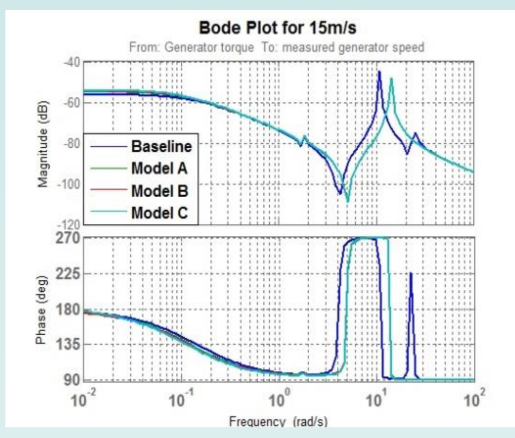

Fig 6

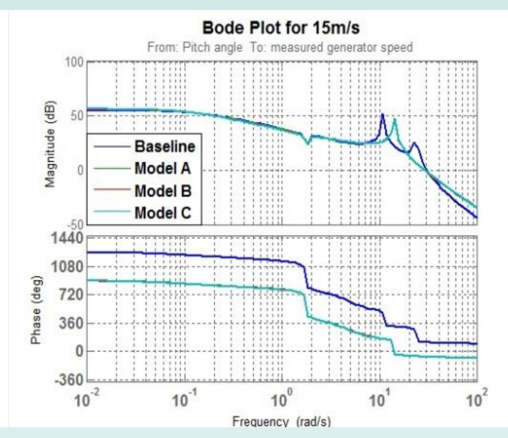

Fig 7

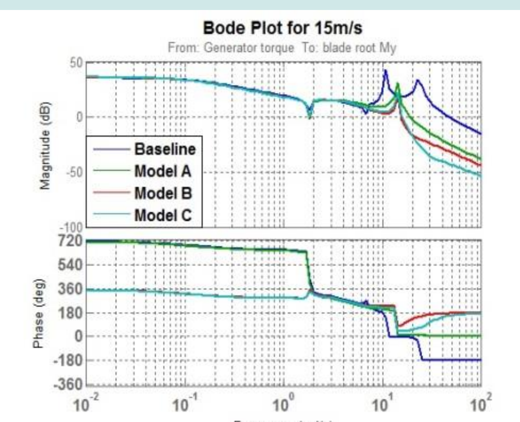

Fig 8

Conclusions

- As a conclusion, the preliminary studies demonstrate potentials in ATB wind turbine with improved load reduction performance and adaptive wind capture nature.
- The new design in WTs raise challenges to control system development (not much touched in this project) in that the need for the traditional active pitch regulation is questioned.
- Potentially, WTs with adaptive blades can be controlled only by generator torque, while perform to power standards comparable to current rigid blade turbines.
- This will bring large benefits to reduce complexity, cost and maintenance of wind turbines.

References

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