Answers to reports on wes-2022-109

Paul Mella and Matteo Capaldo

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Answer to anonymous referee 3

1. ROSCO will be in the introduction. In particular, we'll shortly describe the platform pitch control strategy around line 64 and we'll cite the state-of-the-art also.

2. Line 46. The difference between the two papers is related to the fact that, formally, we don't change the rated speed. In the text, to be more clear, "as introduced in this paper" will be changed by "in (Lackner et al.)". We will also explain that by modifying the rated speed as function of the platform pitch is actually equivalent to adding a compensation term to the blade pitch control that depends on the platform pitch. However, it implies a coupling between the proportional and integral gains related to the platform pitch and those related to the rotor speed control. This is different from the work presented in this paper, where those parameters are independent (moreover we consider only a proportional gain for the platform pitch control, the integral one being 0).

3. Line 193. We'ill reformulate in the text. We propose to replace the sentence by "When the equation is verified, it means that: τ_a is more sensitive to blade pitch than rotational speed and F_a is more sensitive to omega than blade pitch. Therefore, by increasing blade pitch ω increases and, then, occasions F_a to decrease. Then, ϕ increases."

4. Line 220. We'll add a graphic visualization of the roots of G(s), we'll show how those roots move when m_{τ_g} varies, and that will explain how k_{τ_g} is chosen and used. We'll give more details about m_{τ_g}, including its dependency on D_t. For this, the graphical representation of zeros and poles will be useful.

5. We'll revise the references to sections, figures, and tables.

6. Tables 1, 2, 3, Figures 2, 3, 4. display each table next to the associated figure. The values are determines arbitrarily as examples, to ensure the appearance of NMPZs. This is done in the purpose of a pedagogic example to show the effects of the NMPZs. The values are purely numerical. There are not so far from the coefficients related to the IEA15MW wind turbine because we started from those physical values and we found the right coefficients, in the order of 10% or 20%, to make the system unstable. The numerical section focuses on more realistic FOWT tests.

7. In section 3. (numerical simulations) the reference strategy (refered to as $k_\beta = 0$) corresponds to a "detuning strategy" (We will develop more about this when introducing the PI controller's parameters ζ_{rot} and ν_{rot}) which already reduces the coupling effect between platform dynamics and rotor dynamics. The ROSCO toolbox, downloaded from github, implements this "detuning strategy" with interpolated gain coefficients k_P and k_I when the floating feedback is disactivated. For given turbine characteristics and operating point, one might choose wisely a fixed parameter k_β (which corresponds to Fl_kp in the ROSCO toolbox), but the toolbox does not give indications on how to choose this parameter: instead, it suggests only one value of k_β for all operating points and turbine characteristics, while we prove (see Figure 12.) that the appropriated k_β depends on the wind speed. We think this value might be obtained by linearisation (by ROSCO toolbox), similarly to what is done for the gain scheduling of k_P and k_I (but independently to the wind speed). This method is similar to what is done in (Lenfest, 2020).
   Moreover we noticed that the platform pitch controller strategy defined in the article (Abbas,

2022) (see lines 305-310, and especially equation (47) in our paper) is not implemented in the ROSCO toolbox. (Abbas, 2022) gives an explicit formula for k_β, but as we will explain in the next point (see below, point 8.) the obtained values for k_β are very different (the sign is switched) from our formula. The results obtained by (Lenfest, 2020) are closer to our formula than the one given in (Abbas, 2022).
Concerning the simulations, choosing wisely (eg. with a linearisation by ROSCO toolbox), for a given operating point and turbine characteristics, a fixed parameter k_β would give similar results to our strategy. The added value of our work is to be able to compute explicitly (without any calibration) the value of k_β for any turbine characteristics and operating point, and to give an analytical support and an explicit formula corresponding to the numerical results already observed by (Lenfest, 2020). We consider that this question is very useful and we'll clarify this point in the introduction and in section 3.

8. Comparison about ROSCO platform pitch controller strategy and the proposed platform pitch controller strategy: The main difference in the two approaches can be remarked at lines $305-310$. As it can be remarked, the two ways to define the platform pitch compensation k_β. ROSCO derives the parameter imposing the rotor dynamics and the platform pitch dynamics to be decoupled at the first order. In other words, the effect of relative wind generated by the platform pitch dynamics is, at first order, compensated by feathering. The strategy proposed in this new paper aims at taking advantage of the blade pitch control influence on the platform pitch dynamics in order to introduce an extra term in the second order dynamics equation of the platform pitch. Thus the second order dynamics equation has an explicit form involving a damping ratio ζ_{plt} whose value one can explicitly define.

   On can, then, notice that the two formulas to define k_β for ROSCO strategy and the proposed strategy are different. Also numerically, they lead to values that are opposite in sign.

   Indeed, $\frac{\partial F_a}{\partial \beta} < 0$ (for an above-rated operating point) and therefore using inequality (51), we find that
$$k_\beta = \frac{1}{h_t \frac{\partial F_a}{\partial \beta}} \left(2\sqrt{K_t J_t}\zeta_{plt} - D_t - h_t^2 \frac{\partial F_a}{\partial v} \right) < 0$$

   On the other hand, ROSCO strategy, as it is defined in (Abbas, 2022) or (Sotckhouse, 2021) derives from the equation $A_{2,4} = 0$ where A is the matrix defined in (17) ((Abbas, 2022) introduces that same matrix) and expresses the platform pitch control coefficient as
$$k_\beta = -h_t \frac{\partial \tau_a}{\partial v} / \frac{\partial \tau_a}{\partial \beta} > 0$$

   It is negative since $\frac{\partial \tau_a}{\partial v} > 0$ and $\frac{\partial \tau_a}{\partial \beta} < 0$ (for an above-rated operating point). Notice that in (Abbas, 2022), β_{comp} is defined as in (Stockhouse, 2021) but with the convention $\beta_{comp} = k_{float}\dot{\phi}$ so that $k_{float} = -k_\beta = h_t \frac{\partial \tau_a}{\partial v} / \frac{\partial \tau_a}{\partial \beta}$ is negative, but this is just a question of conventions. If one takes the same convention, the sign is actually switched in our formula.

9. Line 254. This sentence is proposed: "It is complicated to explicit[ly determine] the damping"

10. Line 374. This sentence is proposed: "which was analysed at first order in [section] 2.5"

11. we should add a paragraph explain hox k_β is defined in ROSCO (right after 2.5.2 for example) and explain why the sign is switched.

12. For test cases in section 3.3, control signals are partially reported (rotor speed). The blade pitch can be added in the text. If this is interesting, we propose to report rotor speed and blade pitch in annex.

    For numerical tests in section 3.4, we can produce the the control signals, generator speed, and platform pitch for the proposed controller. However, we suggest to send you those figure in the discussion without reporting them in the paper. They would not add any further information and, since the wind is turbulent, they will be not easy to be interpreted. Alternatively, it can be done in an annex.

13. About the wind energy verbiage: We'll do our best to improve the verbiage and adapt it to the wind energy audience. However, "wave period" is, for instance, a typical way in offshore wind to indicate the period (inverse of frequency) of the incoming waves.

14. answer to Figure 10: Section 2.5.2 shows how the proposed strategy add an extra damping in the platform pitch by coupling rotor dynamics with platform pitch dynamics. It leads to reduce the platform pitch dynamics, however, it leads also to variation in the rotor speed. There are references to this effect at line 375 and 405.

15. Line 370. "diagram 5" will be changed to "Figure 5".

16. Figures 8 and 9 report Tower base moment (load on tower), where Figure 6 and 7 report platform pitch. The idea is to show that reducing the platform movements it will reduce the tower base moment. This is something one can imagine but it is interesting to show it by results.

17. Quality factor is defined by

    $$Q = \frac{1}{2\zeta}$$

    As some readers might be more used to work with quality factors instead of damping ratios, we thought it was a good thing to give the quality factors corresponding to the damping ratios. It is not mandatory for the comprehension of the paper. If you prefer, we could just delete the sentence about the quality factor, or just put it in a foot note (linked to the previous sentence).