First Author: Nikhar J. Abbas
Manuscript Title: A Reference Open-Source Controller for Fixed and Floating Offshore Wind Turbines
MS No.: wes-2021-19

**Author's Response to Reviewers**

We would like to thank the reviewers for taking the time to thoroughly review this manuscript. We have carefully considered all of their suggestions, and have attempted to acknowledge all suggested modifications, clarifications, and overall updates to the paper. The tables below directly address each of the reviewer comments and how we have updated the manuscript accordingly. All equation references correspond to the revised manuscript.

Please note that, outside of the changes directly addressed in this document, updates have been made to the results section of the manuscript in order to reflect the reviewers' suggested theoretical changes and more recent version of the ROSCO controller.

Additionally, a color-coded revised version is provided at the end of this document, which shows all of the changes that were made to the manuscript. All text in blue has been added to the manuscript, and the text in red has been removed. Figures that have received major revisions and updates are underlined in blue.

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<tr><th>Comments from Referee #1</th><th>Authors' Response</th></tr>
<tr><td rowspan="2">Page 6, p. about Region 2.5: You mention that "due to the PI and controllers and the setpoint smoother, there is no specific range for Region 2.5". Since the PI controller and the setpoint smoother as implemented should not change the steady states, it should be always possible to calculate, at which wind speed the steady state of the rotor speed reaches rated rotor speed (depending on k of your k*Omega^2) and at which wind speed the static pitch is larger than the fine pitch. This should also allow to calculate the limits of region 2.5 even with the peak shaving. Please consider this.</td><td><u>Response</u><br>Thank you for pointing this out. We have tried to clarify the description of Region 2.5 in the manuscript.</td></tr>
<tr><td><u>Changes</u><br>We have added and also edited the text in the region 2.5 description in section 2.1.</td></tr>
<tr><td rowspan="2">Figure 2 left: TSR seems to continue to be constant at the end of region 2, but rated rotor speed is already reached (which is not possible). For the 5MW, rated rotor speed is also reached before rated power. It would be</td><td><u>Response</u><br>Thank you for noting this. The figures have been updated accordingly.</td></tr>
<tr><td><u>Changes</u></td></tr>
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| further helpful to add region 2.5 in the plot (see comment above). | Figure 2 has been updated to properly to show the tip speed ratio and to have a shaded area to denote region 2.5. |
| Section 2.5: The authors write that the integral gains are in general negative for standard horizontal-axis wind turbines. However, this depends on the definition of your speed error (reference – measurement or measurement-reference). From my perspective, the positive gains are more common (see e.g. Jonkman 2009). Please revise this part. | <u>Response</u><br>Though it is true that Jonkman (and others) have denoted HAWT controller gains as positive, in ROSCO, the gains are negative because an increase of rotor speed results in a negative speed error, so an increase of collective blade pitch or generator torque is desired. This is consistent with others in the community, such as the Delft Research Controller. The manuscript has been updated to reflect *why* the gains are negative given our formulation. Section 2.5 now gives a more thorough formulation of the system used to tune the ROSCO controller. |
| | <u>Changes</u><br>Changes have been made to section 2.5 to clarify our convention. Equations (12) and (13) have been added to clarify the form of the input and output perturbations. |
| Equation (15): Equation (15) is usually obtained setting the rotor motion from Equation (2) to zero and integrating the aerodynamic torque from Equation (3), see e.g. Bossanyi 2000. However, the efficiencies of the generator and gearbox are not part of Equation (2) and (3) of your paper. From my perspective, the efficiency of the gearbox should be part of Equation (2) and thus also (15), but the generator efficiency is only important to calculate the electrical power from the generator torque and thus should not be a part of Equation (2) and thus also not of Equation (15). Please make this part more consistent. | <u>Response</u><br>Thank you for the detailed analysis of the equations – they have been updated accordingly. |
| | <u>Changes</u><br>We have updated equations (2) and (15) (which is now equation (17) in the revised manuscript). |
| Equation (21): If "constant power" is used, one can also include the partial derivative of the generator torque with respect to the generator speed in Equation (5). Neglecting this usually causes a large deviation from my experience, also for the 5 MW reference | <u>Response</u><br>Thank you for noting this missing piece of information. We have included a more detailed investigation into this term and updated the theory and results in the manuscript accordingly. |

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| wind turbine. For the ROSCO controller and for the paper it would be nice, if you could include this part or provide some investigation that in your case this is neglectable | <u>Changes</u><br>Equations (23) and (24) and their surrounding text have been added to Section 4 to clarify, theoretically, how constant power actuation can affect the second order linearized model (equation (5)) in above-rated operation. The results for the NREL 5MW wind turbine, which uses constant power operation, have been updated with the requisite theory included in the controller tuning process. |
| Section 5.5: Usually (in the Bladed interface), the tower top fore-aft acceleration is a translational degree-of-freedom and thus the integrated signal is the tower top fore-aft speed. This has been used in your reference (van der Veen 2012). However, you use the "tower top pitch angle" (i.e. rotational DOF), which is also possible (but much harder to measure/estimate in reality) and would provide similar results I assume. But since ROSCO is using the Bladed interface and aims to reflect the industrial state-of-the-art, please consider changing to the translational DOF. | <u>Response</u><br>Thank you for noting this. The equations and results in the manuscript have been updated to reflect this suggestion.<br><br><u>Changes</u><br>The formulation of the floating feedback gain in Section 5.5 has been updated to reflect the use of a tower top fore-aft translational acceleration signal. Additionally, the results for the IEA-15MW wind turbine have been updated with the updated controller. |
| Equation (5) etc.: Please use consider using $\delta$ instead of $d$ for $\beta$, $v$ etc. and introducing that $\Delta$ is the deviation from the steady state. Using simply $d$ might cause confusion with the operator "d". | <u>Response</u><br>Thank you for pointing out the potential confusion here. The equations have been updated as suggested.<br><br><u>Changes</u><br>$\Delta$ has been used throughout the manuscript as suggested in order to be clearer. |
| Equation (9) etc: Please consider that "d" is an operator and thus using $\mathrm{d}$ instead of simply $d$ would be more appropriate. | <u>Response</u><br>Thank you for noting this, the equation has been updated.<br><br><u>Changes</u><br>Many of the times that $d$ was used have now been converted to $\Delta$. $\mathrm{d}$ has been used in the necessary equations that remain (e.g. equation (9)). |

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| Equation (6) etc: the tip speed ration might be good to introduce. And here, using $\partial$ as in Equation (4) would be more appropriate, since the tip speed ratio depends on both wind speed and generator speed. | Response<br>The tip speed ratio is introduced in equation (1). Thank you for noting the necessity for using $\partial$ - the equations have been updated accordingly. |
| | Changes<br>We have added a reference to the definition of the tip-speed ratio in (1) right after equations (6)-(8). $\partial$ is now used in all necessary equations. |
| Equation (12): The transfer function $H(s)$ connects the Laplace transform of the input to the one of the output. The Laplace transforms themselves do not depend on $s$. Thus, the fraction with d\Omega_g(s) is a bit sloppy. Best might be to simply remove this and explain that the transfer function is obtained by using the Laplace transform and Equation (5) and (9). | Response<br>Thank you for noting this. The manuscript has been updated to be more theoretically rigorous. |
| | Changes<br>We have followed your suggestion and explicitly explained how the closed loop transfer function is obtained by taking the Laplace transforms of Equations (5) and (9) and combining them in a standard negative-feedback loop. |
| Figure 2 and Figure 5 caption, Appendix A etc.: Units are in non-italic in the rest of the paper (which makes sense, since they are not variables), but here you have $kNm$, $MNm$, etc.. Please consider changing them. | Response<br>Thank you for your attention to detail. The manuscript has been updated accordingly. |
| | Changes<br>All units have been changed to be non-italicized |
| Figure 3: setpoint smoother has more inputs than only the generator speed. | Response<br>Thank you for pointing this out, the figure has been updated. |
| | Changes<br>Figure 3 has been updated to more accurately show the setpoint smoother inputs. |
| l 297: “but the power is much more consistent” is not clear to me. Maybe just remove or add something to better explain it. Maybe you mean “more consistent compared to the constant torque case”? | Response<br>Thank you for pointing out this source of confusion – the manuscript has been updated for clarity. The subscript has also been fixed. |

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| in Equation (20) you use “rat” as subscript, but in the rest of the paper “rated”. Please consider to have this consistent. | <u>Changes</u><br>The paper has been modified to specifically state that the power is more consistent in the constant power case than in the constant torque case, and the subscript has been fixed. |
| Section 3.1, last sentence: From my perspective, the proportional and integral gains for the torque PI controller are often chosen to be constant for simplicity, since applying Equation (13) usually does not provide significantly differences over the considered operation points. Please check if this could be also helpful here. The reason provided in the paper (“less erratic control actuation…”) seems to be a bit vague for a Journal paper. | <u>Response</u><br>Thank you for your comments on this.<br><br><u>Changes</u><br>The phrasing here has been updated to note that fixing the controller gains simplifies the problem without negative effects. |
| l 377: Equation (17) should be included here since Equation (16) is TSR tracking only. | <u>Response</u><br>Thanks for pointing this out, equation (17) (which is now equation (18) in the revised manuscript) has been included.<br><br><u>Changes</u><br>The equation reference has been updated. |

| Comments from Referee #2 | Authors' Response |
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| My main comment after going through the very extensive manuscript is: while undoubtedly the ROSCO controller and toolbox are a significant contribution to the community and represent a very large effort, the authors should also consider highlighting the scientific contributions of the paper, avoiding reading the article as a "ROSCO user manual". It seems that most of the effort has been towards implementing well known methods and approaches, and automatizing some of the processes, which is of course a great effort that merits appreciation, however it does not automatically and necessarily entail publication in a scientific journal. | Response<br>Thank you for commenting on this – we certainly see how there may be some confusion as to whether or not this should have been published as a user manual. We believe this manuscript is much more than a user manual, and we have updated the manuscript and tried to improve clarity as to what the scientific contributions of this work are, and why this work merits publication in a scientific journal.<br><br>Additionally, we would like to note that this manuscript provides very little information as to how to actually use and implement the ROSCO tools. The paper itself focuses on the mathematical methods used for tuning and implementation of the controller, and how they are applied within the context of wind turbines. Though some of the methods and approaches have been discussed elsewhere in the literature (as cited), to the author's knowledge, there is no other publication that provides the theoretical and mathematical detail on automated controller tuning and implementation methods as completely as this one does. |
| | Changes<br>Changes have been made to the introduction to further highlight what we believe to be the scientific contributions of this work. |