1 General comments

Overall, this is an interesting, well-structured, and promising paper that introduces two methods for constraining the load reduction capability of classical Coleman-transformation-based individual pitch control (IPC) to mitigate its impact on actuator usage. The core idea is to modify the reference signals of the conventional IPC controller—traditionally set to zero for both non-rotating axis components—by assigning an alternative reference value. This adjustment reduces the control error, thereby lowering the control effort required. The authors compare these methods to a more straightforward approach: scaling the controller gains in conventional IPC, which also reduces actuator effort at the cost of some load reduction capability. The study evaluates the proposed methods under both laminar and turbulent inflow conditions across various reference load constraints. Results indicate that these approaches allow for a reduction in actuator effort while preserving a significant portion of the load reduction benefits of classical IPC. Additionally, the proposed methods demonstrate an advantage over simple gain scaling by offering a more effective trade-off between actuator usage and load reduction.

2 Individual scientific questions and comments:

2.1 General questions, discussions and comments:

- In this study, the outputs of the controller (i.e., the pitch demands) are indirectly constrained by modifying their reference signal. However, this constraint remains somewhat loose, as actuator usage can still vary significantly depending on inflow conditions. In a future study, do you think the new reference values used in these methods could be defined as a fraction of the estimated loads or as an offset from the estimated (original) loads, rather than a fixed value? This approach would allow the controller's output to remain adaptive, adjusting its magnitude based on inflow conditions. At the same time, partial IPC, i.e. operating between full and no IPC, would consistently maintain the same proportional reduction in actuator effort across different inflow conditions.

- Could you comment more on how to select a load reference? Would it be a constant value for all the wind speeds (or wind speed bins)?

2.2 Section specific comments:

i) Section 1

- The terms full IPC and no IPC are used before they are defined later in this section.

- It would be good if the authors commented more on the significance of reducing actuator duty cycle and its impact on pitch system wear.

ii) Section 2.1

- The statement "The periodicity of the blade load is caused by wind shear, tower shadow, and rotor misalignment" could be generalized, as these are not the only contributing factors. In addition to wind shear, tower shadow, and rotor misalignment, periodic blade loading can also result from wear, lateral misalignment (in the case of a waked turbine), static yaw, turbulence, or any other asymmetry in the inflow. I recommend broadening this expression to better reflect the range of possible influences.
- The statement "nP harmonics map to the nearest 3nP harmonics" is only valid for the 1P transformation. When using the 2P Coleman transformation, the loads are mapped to the harmonic at the rotating frame plus and minus 2P (e.g., 2P is mapped to 0P). I recommend updating the sentence accordingly.

iii) Section 2.3

- Azimuth offset is defined multiple times within the paper. In section 2.2, it is referred to as $\psi_{\mathrm{o,n}}$ while, in section 2.3, it is referred to as ψ_{r}. I recommend a consistent notation for this parameter.

iv) Section 2.5

- Filtering $M_{N,n}$ would also introduce a phase delay (e.g., for low-pass filters). Does the azimuth offset calculation take this into account?

v) Section 3.1

- Max pitch rate seems a bit small. Any potential implications? Did the controller saturate for any of the tests?

vi) Section 3.3

- For Fig. 5, I recommend indicating the crossover frequencies, either directly on the plot or in the text. This would enhance the readability and clarity of the figure.
- In Fig. 5, what does the shaded (gray) area represent? Additionally, what do the bars in the no-IPC case indicate? I assumed they are similar to those in Fig. 17, but I recommend providing a description here as well for clarity.

vii) Section 4.2

- Based on the statement: “If the reference is between the original tilt load and zero, the load is driven towards the reference, but if the reference is above the original tilt load, the controller is saturated and no IPC action is taken.” what are the implications of modeling inaccuracies in the load estimator? If the estimator overestimates the loads, could the controller become saturated, preventing load reduction in certain instances, which is an undesirable outcome as discussed throughout the paper? This concern may be particularly relevant in co-design scenarios where components are sized under the assumption that the IPC controller remains active.

viii) Section 5

- On page 3, the phrase "... (except for case 3)" is used. What does case 3 refer to? I recommend introducing and explaining it before its first mention to improve readability.

ix) Section 5.3

- On page 22, you state "...showing diminishing returns when opting for conventional full IPC." Could you clarify what is meant by "returns" in this context? Additionally, for which method are these returns diminishing?

x) Section 5.4

- Could you comment also about the load reduction performance of l^2-IPC?

xi) Section 5.5

- For the marked points, I recommend indicating the load references and crossover frequencies, either directly on the plot or in the text, similar to Fig. 5. This would enhance the readability and clarity of the figure.

- When comparing different references for DEL and ADC, what do you mean by a 50% reduction in DEL? Could you clarify with respect to which quantity this 50% reduction is calculated? Similarly, for ADC, when stating "...16.4% of the ADC, ...", could you specify what this percentage refers to?

- I assume that the reductions are reported relative to the performance of full IPC, indicating that ADC can be significantly reduced at the expense of sacrificing a small portion of the DEL reduction. However, if the no-IPC case is taken as the baseline, the relationship is reversed—achieving a significant reduction in DEL compared to no IPC requires maintaining most of the ADC effort used in full IPC.

3 Technical corrections

I recommend the following for improving readability:

- "leading to interactions between the tilt input and the yaw output, and vice versa" instead of "... so from the tilt input to the yaw output, and vice versa.", in page 8

- “Turbines with more flexible blades” instead of “Especially flexible wind turbines”, in page 8
- “full IPC” (as it is already defined in introduction), “baseline IPC” or “conventional IPC” instead of “baseline full IPC”, in page 10,
- “full IPC” (as it is already defined in introduction), “baseline IPC” or “conventional IPC” instead of “Conventional, full IPC”, in pages 12, 13, 18, 22, 25, 27, since conventional (or baseline IPC) is always a full IPC.