Wind Energ. Sci. Discuss.,
doi:10.5194/wes-2016-54-AC1, 2017

WIND ENERGY SCIENCE DISCUSSIONS

Interactive comment on "Simulation of an offshore wind farm using fluid power for centralized electricity generation" *by* Antonio Jarquin Laguna

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Received and published: 1 February 2017

Thank you to the reviewer for the comments on the paper. Indeed this submitted paper is an extended version of the work presented in the Science of Making Torque (TORQUE2016) conference. The author would like to emphasize that the content is not completely identical to the conference paper as the reviewer suggest. Following the received invitation where it was stated to "Prepare an expanded version of your TORQUE paper, indicatively containing 30-40% additional original material (in the form of a more detailed or expanded description of theory and/or methods, additional results, etc.)" the following overview highlights the additions and new content to this work (as indicated with the text in bold):

1 Introduction - Added conceptual comparison between a conventional and the pro-

posed offshore wind farm in Figure 1.

2 Wind farm model overview

2.1 Wind Turbines

2.1.1 Aerodynamic model

2.1.2 Hydraulic drive train model

2.1.3 Pitch actuator model - Added

2.1.4 Structural model - Added

2.2 Hydraulic network – Expanded with the addition of a schematic, see Figure 3

2.3 Nozzle and spear valve – A schematic of the spear valve was added, see Figure 4.

A graph showing the nozzle characteristic is added and presented in Figure 5.

2.4 Pelton turbine

2.5 Environmental conditions

3 Variable speed control strategy

3.1 Pump controller

3.2 Spear valve controller – Expanded with the details of the controller and filters, a schematic was added, see Figure 9

3.3 Pitch control – Added

4 Simulation example 4.1 Wind farm conditions

4.2 Time domain results

4.3 Performance comparison

5 Conclusions

The author acknowledge that no additional results were included up to this point, however all the added material is considered by the author to be of importance in the overall structure and completeness of the work and was not possible to be included in the conference paper due to page limitations. If consider necessary for publication, the author could address this issue by the inclusion of an extra case scenario which could add insight on the behaviour of the proposed model but most likely the current conclusions and findings will remain. New results and figures will be added in the revised version.

The specific replies to the reviewer comments [RC1] are addressed by the author [AC] in the following lines:

1. [RC1] "The paper should probably mention (e.g. in a footnote) that it is an extended and updated version of a paper previously presented at TORQUE2016 conference, and published in IOP Journal of Physics: Conference Series."

[AC] As this paper was invited for the special Issue on The Science of Making Torque from Wind (TORQUE) 2016, this was not considered necessary. The author will comply to the editors instructions.

2. [RC1] "Continuing from the previous item, the paper needs to contain at least 40 percent new content, which is currently not the case."

[AC] See general comment at the beginning of this document .

3. [RC1] "Introduction: 'This paper continues with previous work' - It would help the reader if the scope and achievements of the previous work were briefly reported. That way the research is placed more into context, and it becomes easier to evaluate what is new here."

[AC] The author agrees. The scope and achievements of previous work were in the context of a single turbine, while this paper considers a complete wind farm. The manuscript will be modified accordingly.

4. [RC1] "Are there any system effects when running the concept with more than one

turbine? The performance and results obtained for the wind farm should be compared (in a meaningful way) with results for a single turbine.

[AC] The main difference with respect to a single turbine is that in a wind farm all the turbines are coupled to the hydraulic network. This means that the pressure response in the hydraulic network is influenced by the individual flow rate of each turbine water pump and at the same time the transmitted torque to each turbine is influenced by the pressure at the water pumps. When abrupt changes in flow or pressure are induced as a result of either accidental or normal operation, pressure waves are introduced in the hydraulic network which have to be taken into account. With the 'secondary control' strategy proposed for the hydraulic system, the main large system effect of having several turbines connected to the hydraulic network is mostly determined by the ability of the spear valve and its controller to keep a constant pressure in the system. Provided that a relatively constant pressure is maintained, each turbine will be able to operate independently.

5. [RC1] "The concept is based on the use of seawater. I assume that corrosion becomes an important issue then. Does the author have some comments for the readers on this? "

[AC] In the proposed concept, an open-loop circuit is considered (i.e. the fluid is not circulating) with seawater as hydraulic fluid. The choice of seawater as hydraulic fluid is preferred because of its availability and environmental friendly nature when compared to oil hydraulics. It is important to consider that seawater contains a high concentration of minerals, which give it a high degree of hardness. It also contains dissolved gases such as oxygen and chlorine which cause corrosion. Despite its corrosive nature, the use of seawater hydraulics has already been used in some industrial applications, where in terms of safety, water hydraulics might be preferred due to potential fire hazards or risk of leakage as is the case of the mining industry. An example in the offshore industry includes the seawater hydraulic system for deep sea pile driving incorporating high pressure water pumps (IHC Hydrohammer, 2009)[1]. A key advantage of this system is that the use of an open loop circuit cancels the need for cooling equipment, a disadvantage is that it is likely that filters have to be cleaned more frequently.

The description above will be added to the manuscript.

[1] M. Schaap. Seawater Driven Piling Hammer. In Proceedings of the Dutch Fluid Power Conference in Ede, September 2012. (reference added)

6. [RC1] “As it is proposed to use only one turbine and generator, reliability of these becomes a critical issue. Has the author any thought on this that he would like to share with the readers?”

[AC] Indeed, by using only one or a few turbines and generators, the reliability of these components become an important aspect. Modern hydro-turbines have been developed with typical capacities of 500 MW operating for decades with enough operational and maintenance experience gained from conventional hydro-power plants. On the other hand using hydro turbines in combination with renewable energy sources such as offshore wind energy has not been explored. The concept itself is still in pre-development phase and therefore there is a lack of real data supporting the reliability. It is also expected that by having the whole electrical generation equipment in one offshore central platform instead of having it in a constraint space hundred meters above sea level, would have a positive impact regarding O&M costs.

7. [RC1] “Eqs. 6-7: The notation is slightly confusing. I assume that V(e) is a function depending on the variable e, later shown in Eq. 8. However, also other terms in Eqs. 6-7 are functions that depend on parameters. To be consistent, I suggest that you simply use V in Eqs. 6-7 and clarify V(e) = eVp;max in Eq. 8.”

[AC] The author agrees to modify Eqns 6-7 to include the reviewer’s comment.

8. [RC1] “Section 2.1.3: The pitch actuator model is based on a proportional regulator. Why not also a derivative or integrator component? Why is the pitch actuator model needed?”

[AC] The pitch actuator model is needed to account for any blade-pitch actuator dynamic effects. This means the slow or fast response of the pitching mechanism to the control command signal. The derivative or integrator components are considered to be included in the pitch control which is in series with the pitch actuator, see Section 3.3.

9. [RC1] “Section 2.3: The nozzle length Lnz should be indicated in Figure 4 as well.”

[AC] The author agrees, Figure 4 will be modified accordingly.

10. [RC1] “Section 2.4: What is the value of the vena contracta coefficient used here?”

[AC] A value of Cv=0.99 was used according to (Thake, 2000)[2]. Please note that the vena contracta phenomenon does not influence the nozzle efficiency.

[2]Thake, J. The Micro-hydro Pelton Turbine Manual. Practical Action Publishing, 2000. (reference added)

11. [RC1] “Section 3.1: ‘A low pass filter on the pressure measured is employed’ What are the filter characteristics?”

[AC] A first order low pass filter was used with the following transfer function form:

LPF(s)= 1/(1+s/wc)

where the cut-off frequency wc was set at 32 pi [rad s-1]. This description will be included in the manuscript. A new table adding the controller parameters of the augmented controller from Eqns 22 and 23 will also be included.

All the technical corrections will be incorporated in the text. The author hopes that the proposed modifications to the manuscript and replies to the reviewers satisfy your requests.

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