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Comment on wes-2021-39

Anonymous Referee #2

Referee comment on "Exploitation of the far-offshore wind energy resource by fleets of energy ships – Part 2: Updated ship design and cost of energy estimate" by Aurélien Babarit et al., Wind Energ. Sci. Discuss., https://doi.org/10.5194/wes-2021-39-RC2, 2021

Summary

The present paper examines a novel wind-to-liquid power conversion system (energy ship) and an energy infrastructure (FARWIND) with respect to energetic and economic performance.

The FARWIND system comprises a fleet of energy ships that harvest wind energy far-shore and convert in on-board to methanol, a smaller fleet of tankers that provide feedstock and collect produce, and on-shore terminals.

Energy ships are sailing ships with water-turbines attached at the hull to provide energy to a power-to-X process. In the present paper, methanol was chosen for energy storage. Tankers firstly provide cryogenic CO2 that is used in the power-to-methanol process on-board the "energy ships" and secondly collect produced methanol which is then discharged at the on-shore terminals.

A previously developed model and preliminary design form the basis of the analysis. In the first part of this contribution, the technical model and preliminary design are revised. In the second part, an economic feasibility study for the FARWIND system is carried out.

technical model revision

The authors present a revision to a preliminary design presented in an earlier contribution to "Wind Energy Science". The design features Flettner rotors for propulsion, a catamaran hull, and two turbines attached on either side of the hull. Revisions to the design include height of the rotors and rated power of the turbines. Model revisions include

* improved formulae to estimate aerodynamic coefficients of the rotors based on empirical data at higher (more realistic) Reynolds number,

* consideration of the effect of spin ratio on rotor driving power,

* consideration of rotor-rotor interaction,

* consideration of atmospheric boundary layer,

* revised mass-scaling of the hull, resulting in twice the mass of their preliminary design, and

* a revised turbine mass-estimate based on expert advice.

As a result, the authors report 10 to 20% less power generated than initially predicted.

economic model

Assumptions on service-cycle length and annual production rates are made including the power predictions from the technical model. The following analysis is formed on the basis of one tanker servicing 28 energy ships per week for 4 weeks until returning to a terminal at the shore.

Tanker weight and corresponding propulsion power are estimated from service time and required tank volume.

The authors estimate an annual methanol production of approx. 70 600 t/a if continuous production is to be ensured, while factoring in production downtime due to failures and maintenance.

CAPEX for individual components including cost reduction for the entire FARWIND system due to scale effects are estimated based on literature research. Expected maintenance and operation as well as insurance costs are assumed to be proportional to capital costs. Expected ranges are taken from literature, except in the case of hull auxiliary and tanks which are arbitrarily assumed to be 2%!

To assess economic performance, levelized cost of methanol are computed under uncertainty, yielding a range of 1.2 to 3.6 Euro per kilogram, which is reported to be three times higher than usual market prices.

With respect to model assumption and uncertainty, it is found that:

- Even at a learning rate of 10% (scale effect) the FARWIND system would not be profitable for reasonable installed capacity at current market prices for methanol.
- If the produced methanol was used as an alternative fuel source, prices could be competitive with current gasoline prices in the European Union.
- When benchmarked against a hypothetical power-to-methanol wind farm, the FARWIND system is may become competitive long term for large installed capacity.

General remarks

As is revealed in figure 6, the previous assumption on required power to drive the rotors (4 x 40kW = 160kW) deviates significantly from the new model for a number of TWS and TWA combinations! Similarly, predictions for generated power reduced significantly as a result of model improvement. This hints at the fact that it might be advisable to investigate other parts of the technical model for further possibilities of improvement.

Even though part one of the article is seen as an update to previous work, the discussion of the energetic performance model is kept too brief, as it leaves a few open questions. For example, power generation is surprisingly steady for different TWA and const. TWS while the peak-power stagnates with increasing TWS, which seems counter intuitive at first. I suggest that either, behaviour of the system at different TWS and TWA should be discussed in more detail, a reference to such discussion is given, or reports on model revisions should be shortened to shift the focus of the analysis.

In general, the analysis is based on many broad assumptions that undoubtably include considerable uncertainty. The notion of uncertainty is addressed by considering ranges for most parameters. There is however, no mention of distributions within the identified ranges. The expected rate of production, on the other hand, is assumed without any notion of uncertainty. It remains unclear how uncertainty is propagated through the model! It should be clarified which method of error propagation was used. For example, without the notion of distributions, it remains unanswered if, based on the assumptions, it is equally as likely to yield lower or upper LCOM as reported in figures 8 to 10. Besides, the mean with error bars would arguably more appropriate presentation in this context.

For a preliminary case study, the method of determining economic feasibility is probably sufficient. As the analysis was based on a predetermined design, the validity of the results is at the current state questionable. If the design of the "energy ship" was optimized for the specific purpose of increased profitability, the proposed system might become significantly more competitive compared to the current design, as noted in section 5.

I suggest to accept with minor revisions (see below)!

Revisions

* Section 2: behaviour of the system at different TWS and TWA should be discussed in more detail, a or a reference to such discussion should be given, or reports on model revisions should be shortened to shift the focus of the analysis --> see general remarks

* line 71: no definition of the Reynolds number is given

* Sections 2.4 to 2.6 list assumptions for the power-to-methanol plant, tanks and auxiliary equipment: No references were given! They might be included in the first part, but this isn't stated either. References are given later in section 4.1, it's unclear however, if those are the ones considered in 2.4 to 2.6 as well.

* Figure 6: polar plots are missing units of measure for power and speed!

* line 301: Please double check the units! The market price of methanol is given as 0.4 Euro per kilogram or 72 Euro per Megawatt hour. With carbon tax it is given as 6 or 13 Euro per Megawatt hour depending on the taxation, which is about ten times lower than the price given w/o tax.

* line 401. The title of the reference seems to have changed. Consider adding DOIs to your references where possible!