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D3.3. Theoretical /Conceptual systems of Blue Economy system for FOWTs

[Version 1.0]

STEP4WIND

Training network in floating wind energy

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1. Overview

This report discusses the parameters for optimum operation of hydrogen production systems in a floating offshore wind turbine (FOWT) farms and design a hydrogen system suitable for floating wind platforms and/or floating substations. This report has been published as an open access journal publication; in the Renewable and Sustainable Energy Reviews (*RSER*) journal titled "*Dedicated large-scale floating offshore wind to hydrogen: Assessing design variables in proposed typologies*" [1] with a link: https://authors.elsevier.com/sd/article/S1364-0321(22)00225-8. This document provides a general overview of the publication and its conclusions. The reader is directed to the journal publication for further details.

2. Abstract

To achieve the Net-Zero Emissions goal by 2050, a major upscale in green hydrogen needs to be achieved; this will also facilitate use of renewable electricity as a source of decarbonised fuel in hard-to-abate sectors such as industry and transport. Nearly 80% of the world's offshore wind resource is in waters deeper than 60 metres, where bottom-fixed wind turbines are not feasible. This creates a significant opportunity to couple the high capacity factor floating offshore wind and green hydrogen.

In this report we consider dedicated large-scale floating offshore wind farms for hydrogen production with three coupling typologies; (i) centralised onshore electrolysis, (ii) decentralised offshore electrolysis, and (iii) centralised offshore electrolysis. The typology design is based on variables including for: electrolyser technology; floating wind platform; and energy transmission vector (electrical power or offshore hydrogen pipelines).

Offshore hydrogen pipelines are assessed as economical for large and distant farms. The decentralised offshore typology, employing a semi-submersible platform could accommodate a proton exchange membrane electrolyser on deck; this would negate the need for an additional separate structure or hydrogen export compression and enhance dynamic operational ability. It is flexible; if one electrolyser (or turbine) fails, hydrogen production can easily continue on the other turbines. It also facilities flexibility in further expansion as it is very much a modular system.

Alternatively, less complexity is associated with the centralised offshore typology, which may employ the electrolysis facility on a separate offshore platform and be associated with a farm of spar-buoy platforms in significant water depth locations.

3. Objectives

The objective of this report is to investigate three typologies for a FOW farm dedicated to hydrogen production. The typologies discussed include for:

- centralised electrolysis conducted onshore;
- decentralised electrolysis conducted offshore;
- centralised electrolysis conducted offshore.

The three major variables that impact on these typologies include:

- selection of electrolyser technology (including for requirement of seawater desalination)
- selection of FOW platform
- selection of energy transmission vector (electric transmission lines or offshore hydrogen pipelines).

4. Conclusions

This paper proposed three typologies for a FOW farm dedicated to hydrogen production, namely: centralised electrolysis conducted onshore; decentralised electrolysis conducted offshore; centralised electrolysis conducted offshore. The typologies were assessed through assessing the three major variables: selection of electrolyser technology; selection of FOW platform; energy transmission vector (electrical power or offshore hydrogen pipelines).

Table 4 shows an overview of the main advantages and disadvantages for the three typologies which are discussed here. The energy transmission vector was the key feature of the three typologies discussed with emphasis on the major components of the systems, to limit the complexity of the paper while highlighting more detailed topics for future analysis.

For the centralised onshore electrolysis typology, AEL is the recommended electrolyser; Spar is the preferred FOW platform in significant water depths, with submarine HVDC cables for energy transmission to shore. This is suggested as a sensible solution for relatively near offshore distances, yet both energy losses and lack of flexibility in the potential for further expansion plans could be its main challenges.

The two offshore typologies (decentralised and centralised) would use submarine hydrogen pipelines as their energy transmission vector. In comparison with high voltage cables, the offshore typologies facilitate expansion as the system is not limited to 2 GW transmission per cable; offshore hydrogen pipelines are also believed to be more economical for large scale farms, especially those with longer offshore distances. For the decentralised offshore typology, PEMEL is suggested as a viable electrolysis candidate given its compactness and dynamic operational ability. A semi-submersible FOWT could accommodate the electrolysis facility on the deck without the need for an additional separate structure, or modifications to the electrolysis unit itself. This typology is flexible; if one electrolyser (or turbine) fails, hydrogen production can easily continue. This typology also facilities flexibility in further expansion as it is very much a modular system. From an environmental perspective, the brine discharge level has the potential to fall within the acceptable range, especially as compared to the centralised offshore typology. The typology is yet challenging in the complexity of the O&M and needs further validation in the offshore operational conditions. The centralised offshore typology may employ either PEMEL or AEL; the final choice would be based on a detailed analysis. The spar or the semi-submersible FOW platform can also be used in this typology; however, spar would be preferred if the site is of a significant water depth.

In contrasting offshore typologies, the centralised offshore typology may compete well when compared with the decentralised typology especially in the ease of maintenance of individual turbines. The centralised system in general is less complex and might open doors for more cost-effective options for some of the components. For example, the ongoing development work in scale up of large size cost-effective electrolysers may lead to cheaper hydrogen. On the other hand, the challenge to the centralised system is in the event of a failure, hydrogen production would cease for the whole farm. Another disadvantage of the centralised offshore typology is the concentration of brine discharge from the desalination facility associated with a large electrolyser in one spot with the associated environmental impact on marine life; or else the holding capacity of the brine if it needs to be discharged onshore. The centralised offshore system also has additional CAPEX of a floating vessel accommodating the electrolysis facility.

References

[1] Ibrahim OS, Singlitico A, Proskovics R, Mcdonagh S, Desmond C, Murphy JD. Dedicated large-scale floating offshore wind to hydrogen : Assessing design variables in proposed typologies. Renew Sustain Energy Rev 2022;160:112310. https://doi.org/10.1016/j.rser.2022.112310.