EFC23 European Fuel Cells and Hydrogen
PIERO LUNGHI CONFERENCE
September 13th-15th 2023 Capri / Italy

Designing and Sizing of a Green Liquid Hydrogen Supply Chain for Ship Refueling

A. Perna[a], D. Lanni[a*], G. D'Antuono[a], M. Minutillo[b], V. Cigolotti[c], M. Della Pietra[c]
* corresponding author: davide.lanni@unicas.it
[a] Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Cassino, Italy
[b] Department of Industrial Engineering, University of Salerno, Fisciano, Italy
[c]ENEA Portici, Piazzale Enrico Fermi I, Portici, Italy

Keywords: green hydrogen, shipping refueling, liquid hydrogen, offshore wind power

Abstract
Green hydrogen plays a strategic role in the decarbonization of the maritime transportation.
This paper is focused on the designing and sizing of a sustainable green liquid hydrogen supply chain based on an offshore liquefied production plant for ship refueling. The design-sizing procedure is based on an optimization algorithm that maximizes the hydrogen production from the renewable source.

Introduction
Maritime transport plays a crucial role in the European economy. It accounts for roughly 80% of international trade in 2020, according to UNCTAD [1]. To accelerate the decarbonization and the reduction of pollutant emissions in maritime sector, the International Maritime Organization (IMO) has set ambitious goals that can be complied by developing a synergic integration between low or zero-carbon fuels and innovative propulsion technologies [2]. Liquid hydrogen and ammonia produced by using offshore renewable electricity are considered interesting solutions for the medium and large ship market, respectively [3],[4].

Objectives
In this contest, the present study aims to design and size, through the development of an optimization procedure, a green liquid hydrogen supply chain (GLHSC), based on an offshore liquefied production plant for ship refueling that can assure the maximum hydrogen production from the RES (figure 1).

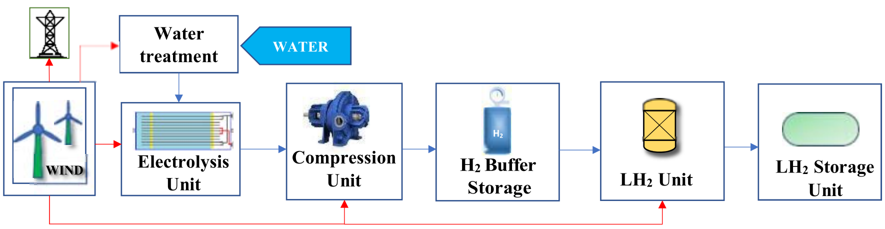

Figure 1. Schematic of the GLHSC

The plant, sized for supplying a maximum amount of LH_2 of 1000 kg/day, comprises a wind farm for renewable electricity generation, an electrolysis unit for hydrogen production, a water treatment unit for demineralized water production, and a hydrogen liquefaction plant for hydrogen storage and distribution to ships. Moreover, because the liquefaction unit would be in continuous operation, a buffer storage tank to store the gaseous hydrogen produced by the electrolysis unit is also considered.

Material and methods

The sizing of the GLHSC is carried out by means of an optimization procedure (built by using the modeFRONTIER software package) based on a multi-objective genetic algorithm which interacts with a plant sizing code developed in Matlab environment.

Results

The installation site of the offshore GLHSC (grid connected) is located at 25 km from Ravenna coast (Italy). Results of the optimization procedure in terms of components' size are reported in table 1. The annual hydrogen production is equal to 208.7 tons (the plant capacity factor is 57.2%), the annual electric energy consumption is 13260 MWh.

Table 1. GLHSC components' size

Parameter	Unit	Value
Wind farm size	MW	19
Electrolysis unit size	MW	5
Hydrogen compression unit size	kW	103
Hydrogen Buffer Storage capacity (at 200 bar)	kg	1200
Liquified hydrogen at full load	kg/h	41.6
LH2 storage size	m^3	14.1

Conclusions

A green liquid hydrogen supply chain for ship refueling has been designed and sized by developing an optimization model based on a genetic algorithm. A 19 MW wind farm coupled with a 5 MW electrolysis unit allows to produce 208.7 tons of liquid hydrogen per year with a plant capacity factor of 57.2%.

Acknowledgment

This research was funded by the European Union - NextGenerationEU from the Italian Ministry of Environment and Energy Security, POR H2 AdP MEES/ENEA with involvement of CNR and RSE, PNRR - Mission 2, Component 2, Investment 3.5 "Ricerca e sviluppo sull'idrogeno", CUP: I83C22001170006.

References

1. A. Nemmour, A. Inayat, I. Janajreh, and C. Ghenai, Int J Hydrogen Energy (2023)
2. M. Ruth and S. Goessling-Reisemann, Handbook on Resilience of Socio-Technical Systems 1 (2019)
3. C. N. Bonacina, N. B. Gaskare, and G. Valenti, Int J Hydrogen Energy 47, 1279 (2022)
4. Y. Seo, H. Park, S. Lee, J. Kim, and S. Han, Int J Hydrogen Energy 48, 15126 (2023)