Utility-scale renewable hydrogen generation by wind turbines

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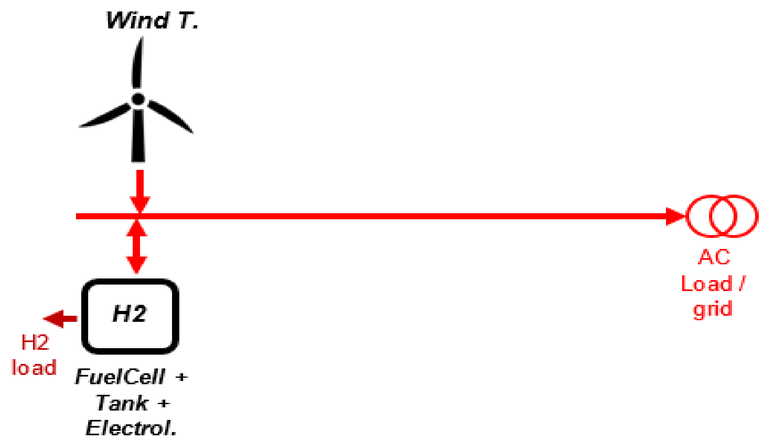
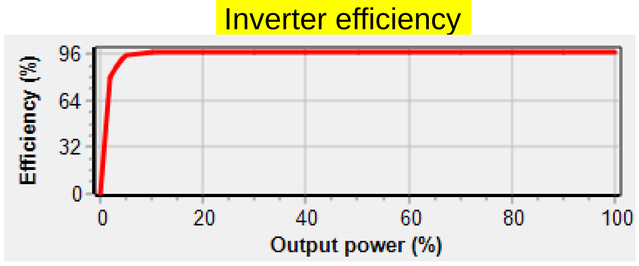
Optimization of a Wind-H2 system, obtaining the best combination of components (wind turbines and electrolyzer) and control strategy for the hydrogen production. Compared with the Wind-only system (wind farm which injects all the electricity produced to the gird). The Wind-H2 system can be competitive to the Wind-only system if the hydrogen sale price is 4.8 €/kg for the case of 2019 SPOT prices and 6.7 €/kg for the case of 2021 SPOT prices, considering 1% annual increase in the SPOT prices and 2% for the hydrogen price.



Inverter efficiency



REMARKS

- Optimization (maximization of NPV) of the Wind-hydrogen size and the control strategy variable X (electricity price setpoint for selling electricity or hydrogen generation: during a time step t, if the electricity price is higher than X, the priority will be to inject electricity from the wind farm to the AC grid; otherwise priority to generate hydrogen in the electrolyzer.
- System lifetime: 25 years.
- Comparison with Wind-only system.
- Variable electrolyzer efficiency
- Included costs and efficiencies of auxiliary components: rectifier, compressor, storage
- First, optimization of the Wind-only system
- Second, optimization of the Wind-hydrogen system:
  - Size of wind farm and electrolyzer
  - Electricity price setpoint
- Simulations and optimizations performed by MHOGA software (MegaWatt Hybrid Optimization by Genetic Algorithms).

SIMULATION AND OPTIMIZATION OF THE SYSTEM

- Location: near Zazarogza (latitude 41.66º, longitude 0.86º).
- Different cases:
  - A) Hydrogen sell price of 2.3 €/kg, with 2% annual increase
  - B) Different hydrogen sell prices: 4 or 4 €/kg, 2% inflation
  - C) Hydrogen sell prices needed to equal the NPV of the Wind-only system
- All the cases with 2 subcases: 2019 or 2021 SPOT electricity price of Spain.

Simulation of three consecutive days, optimal system, A) 2019 SPOT price

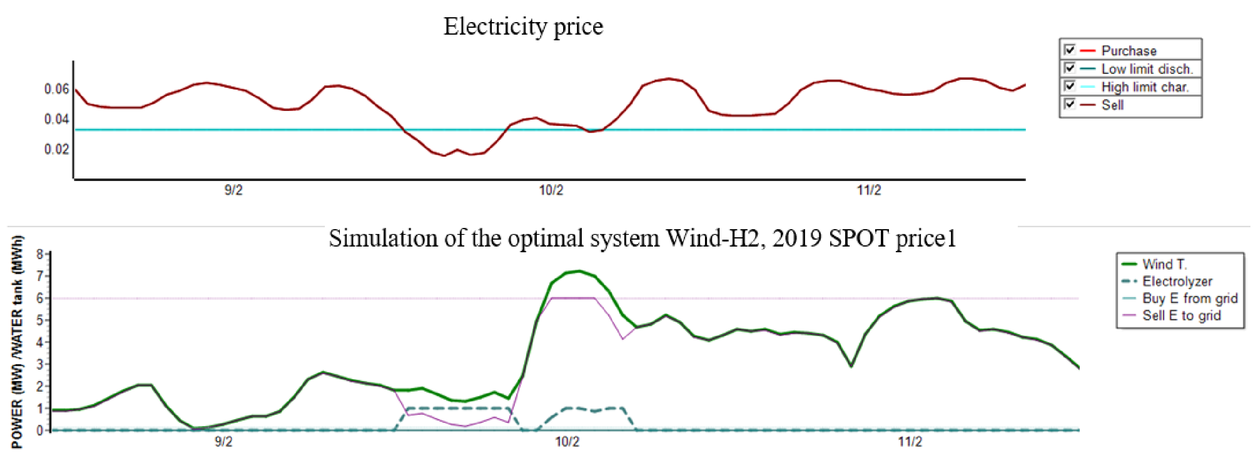


Fig. 9. Electricity price with X setpoint (upper graph) and simulation of the optimal Wind-H2 system for 2019 SPOT prices during three consecutive days (9th to 11th February).

Hourly values during one year, optimal system, A) 2019 SPOT price

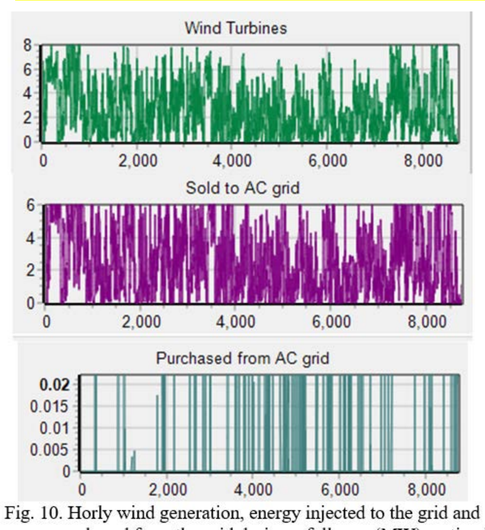


Fig. 10. Horly wind generation, energy injected to the grid and energy purchased from the grid during a full year (MW), optimal Wind-H2 system for 2019 SPOT prices.

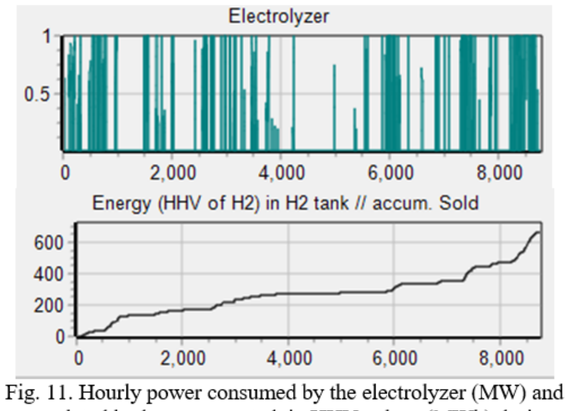


Fig. 11. Hourly power consumed by the electrolyzer (MW) and cummulated hydroen generated, in HHV values (MWh) during a full year, optimal Wind-H2 system for 2019 SPOT prices

OPTIMAL SYSTEMS, CASE A:

	2019 SPOT		2021 SPOT	
	Wind-only	Wind-H2	Wind-only	Wind-H2
Wind farm (MW)	8	8	8	8
Electrolyzer (MW)	-	1	-	1
X (€/kWh)	-	0.033	-	0.0045
NPV (M€)	1.59	-0.60	19.56	17.20
Investment cost (M€)	9.6	12.22	9.6	12.22
IRR (%)	7.4	0	26.22	20.37
Capacity factor (%)	32.08	32.02	32.08	32.3
LCOE (€/kWh)	0.037	0.045	0.037	0.045
Wind gen. (GWh/yr)	23.22	23.22	23.22	23.22
Electrolyzer consumption (GWh/yr)	-	1.15	-	0.665
Hours of electrolyzer operation per year	0	1,188	-	686
Sell electricity (GWh/yr)	22.48	21.77	22.48	22.31
Sell hydrogen (t/yr)	-	16.9	-	8.14
Sell electricity incomes, 1st year (M€)	1.04	1.02	2.60	2.58
Sell hydrogen incomes, 1st year (M€)	-	0.039	-	0.019
Sell electricity incomes, NPV (M€)	11.98	11.74	29.96	29.73
Sell hydrogen incomes, NPV (M€)	-	0.488	-	0.235
Wind farm cost, NPC (M€)	10.01	10.01	10.01	10.01
Hydrogen cost (electrolyzer and auxliariy), NPC (M€)	-	2.347	-	2.278

OPTIMAL SYSTEMS, CASE B:

	2019 SPOT		2021 SPOT	
	4 €/kg	5 €/kg	4 €/kg	5 €/kg
Wind farm (MW)	8	8	8	8
Electrolyzer (MW)	1	1	1	1
X (€/kWh)	0.066	0.082	0.0045	0.1103
NPV (M€)	0.377	1.901	17.373	17.78

CASE C:

The hydrogen price which equals the NPV of the Wind-H2 system to the NPV of the Wind-only system is 4.8 €/kg for the case of 2019 SPOT prices and 6.7 €/kg for the case of 2021 SPOT prices

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CONCLUSIONS

HOGA software for the evaluation of the economical viability of the Wind-H2 systems. Two cases have been considered: Spanish SPOT price of 2019 and of 2021, both with an expected increase of 1% annual. The hydrogen price in order to equal the NPV of the Wind-H2 system to the NPV of the Wind-only system is 4.8 €/kg for the case of 2019 SPOT prices and 6.7 €/kg for the case of 2021 SPOT prices, considering 1% annual increase in the SPOT prices and 2% for the hydrogen price. Both values are obtained for the optimal system management.