Sizing optimization for Islanded Microgrid with long-term Hydrogen Storage : A comparaison of 2 rules based operation strategy

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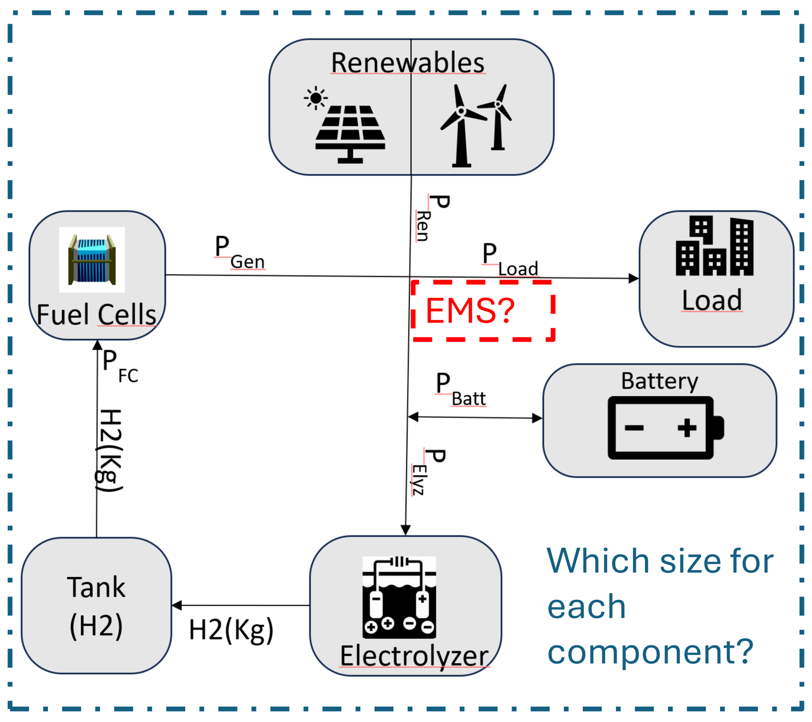
Microgrid & problem description



Our **islanded** Microgrid (100 REN)is composed of:

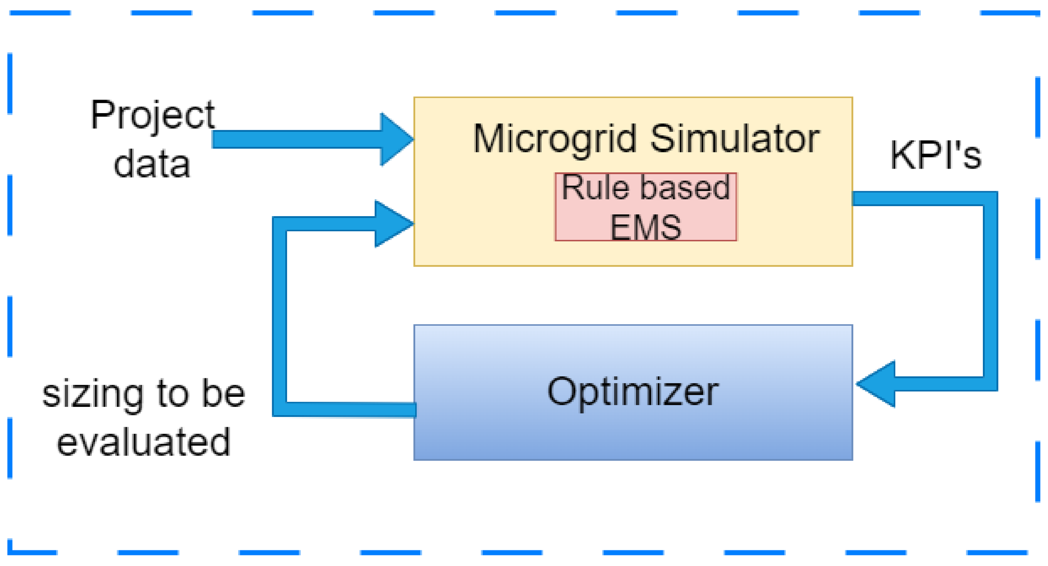
- Renewable sources - Photovoltaic modules and wind turbines
- **Short-term storage**: Li-ion batteries
- **Seasonnal storage**: PEM electrolyser, compressed Hydrogen tank and PEM fuel cell

Problem : Optimal components **sizing** intewined with the choice of the the **energy management system**

Contribution :

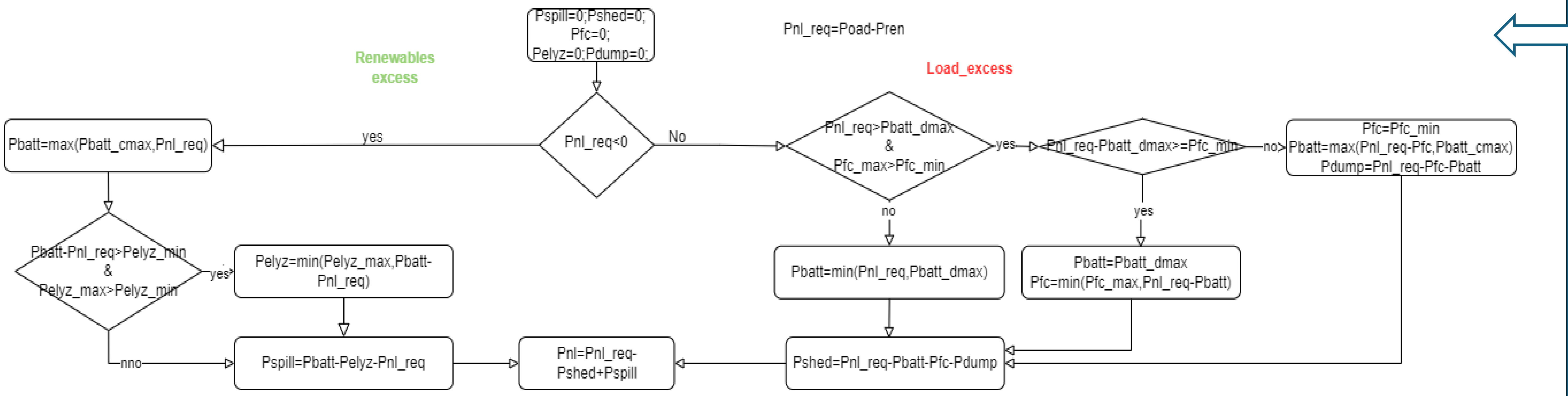
- 2 **rules based** energy management strategies proposed
- Techno-economic comparaison of these 2 strategies and their impact on the optimal sizing

Optimization Setup



- Black Box optimization
- Tool link Github: Microgrids-X/Microgrids.jl
- Gradient-free algorithm used : GN_CRS2_LM from Nlopt.jl
- Maximal evaluation number : 100 000

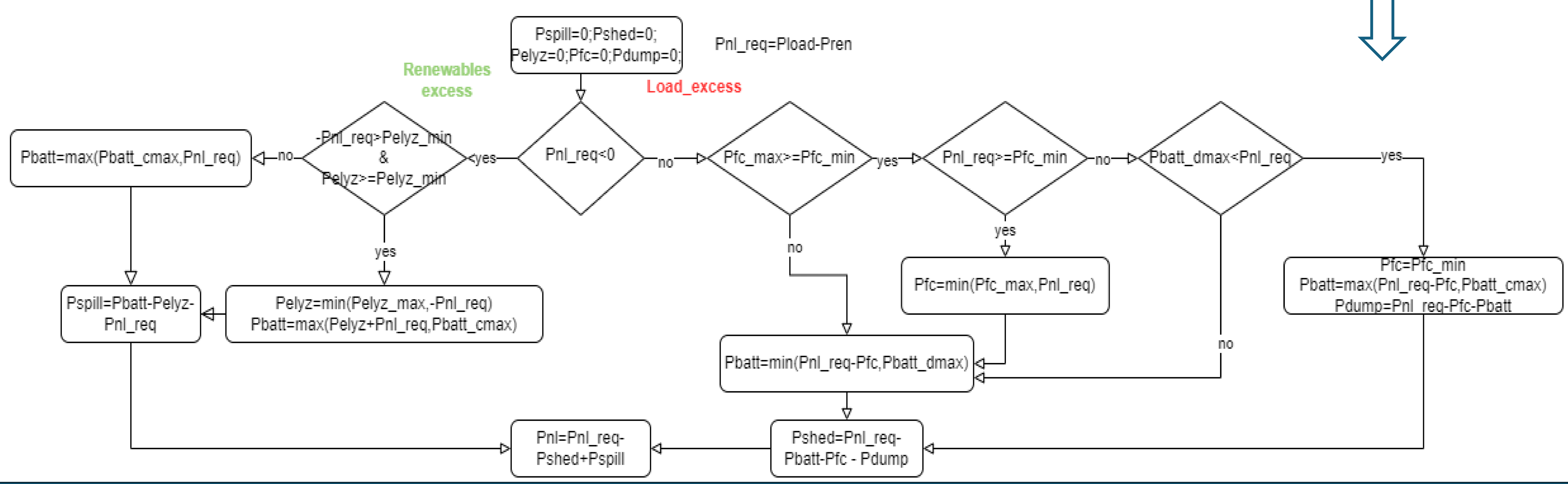
- Optimization variables : component sizes
- 2 criteria have been considered ; one economic: Levelized Cost of Energy (LCOE) ; and one for the Quality of Service : the shedding rate.
- Objective function : $f(X) = LCOE(X) + 10^5 \cdot \max\left((T_{shed}(X) - T_{shed\_max}), 0\right)$



Strategy 1: battery priority

Strategy 1 will use the battery before the hydrogen chain to store excess energy or power the load in the event of a lack of renewable generation. Strategy 2 do the opposite by using primarily the power-H2-power chain.

Strategy 2: Hydrogen priority



Note:

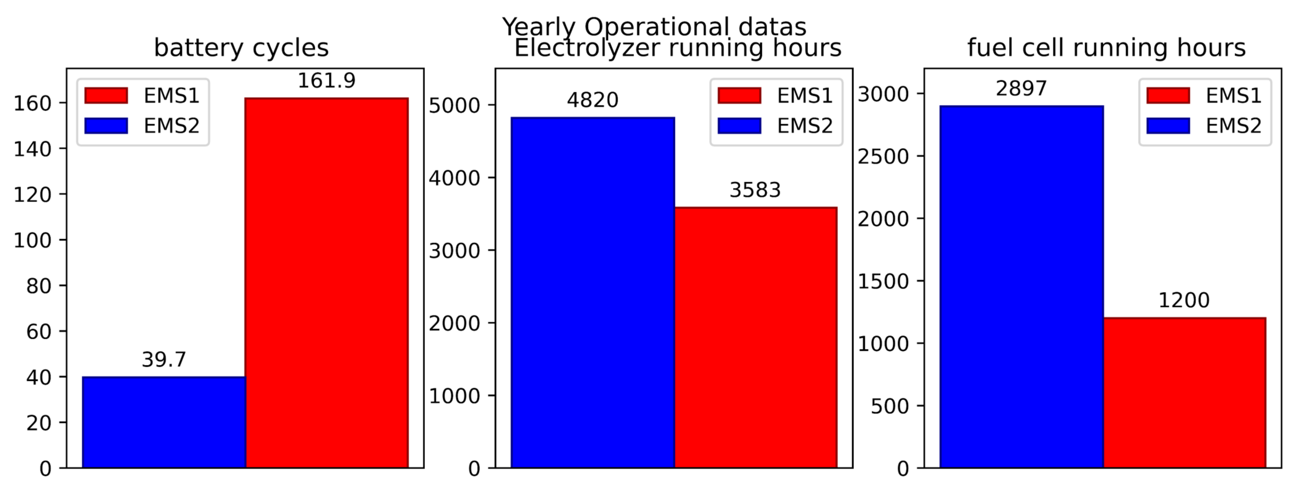
- **Batteries round-trip efficiency is 95%**
- **Power-H2-Power effeciency has been modelled to be equal to 30%**
- **PEM fuel and PEM electrolyser have a minimal running power equal to 5% of their nominal capacity.**
- **Simulations are made on 1 year with a time step of 1 hour. The results are then extrapolated over 25 years.**

Results

Optimization stats

- **Wind capacity is limited to 1800 kWc in our case of study**
- **Average simulation time (~5ms)**
- **Average optimization time (~24s)**
- **Average evaluation number (~21000)**

EMS	T_{shed}	C_{pv} (kWp)	C_{wind} (kW)	C_{batt} (kWh)	C_{el} (kW)	C_{fc} (kW)	C_{h2tank} (kg)	LCOE ($/kWh)
1	0%	4 001	1 800	5 489	866	1 537	16 270	0,3592
2	0%	6 681	1 800	262	1 901	1 423	17 000	0,4136
1	0,01%	4 001	1 800	5 492	864	1 435	16 238	0,3559
2	0,01%	6 649	1 800	198	1 911	1 389	16 990	0,4121
1	0,10%	4 033	1 800	5 406	863	1 240	15 923	0,3485
2	0,10%	6 546	1 800	132	1 935	1 241	16 805	0,4057



Observations & Conclusion

As might be expected for the 2 strategies, the higher the permissible load shedding rate, the lower the LCOE.

More renewable capacity with the EMS 2 due to the low efficiency of the Power-H2-Power chain.

More intensive use of the electrolyser and the fuel cell with the strategy 2. Which imply :

- Higher maintenance costs
- More frequent replacements

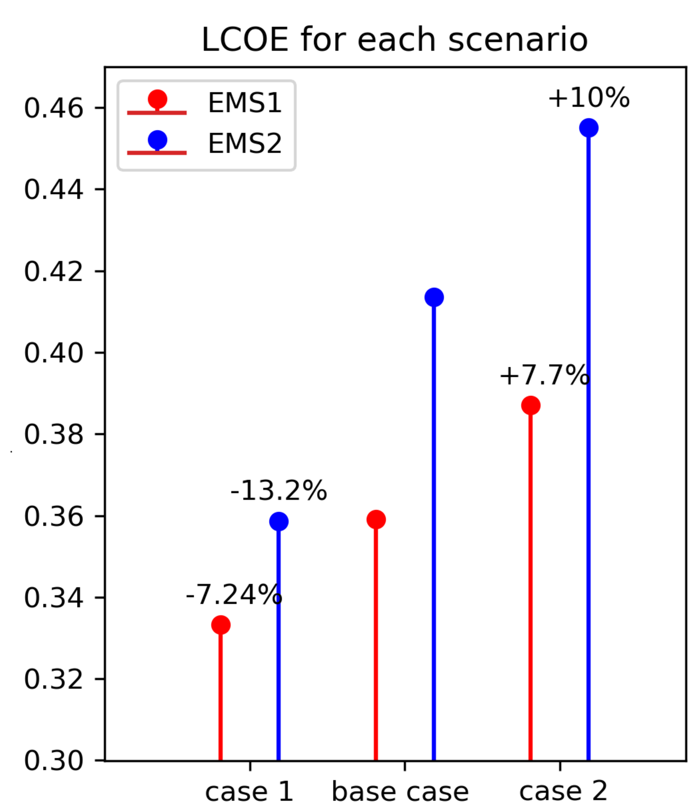
Strategy 2, is more sensible to fuel cell and electrolyser price variation.

In case of event of a significant fall in the manufacturing costs of these components, the competitiveness of the 2 strategies should be reassessed.

Sensibility analysis

A sensibility analysis have also been conducted on the electrolyser and fuel cell investment prices.

- **Case 1** : Respectively 500$/kW and 1000$/kW for PEMel and PEMfc in accordance with « Fuel Cell and Hydrogen Joint Undertaking (FCH 2 JU) » goals for 2030.
- **Case 2** : Respectively 2200$/kW and 2500$/kW for PEMel and PEMfc in case of slower industrialization than expected, and high raw materials prices
- For the **base case** prices were taken equal to 1600$/kW for both



Perspectives

Try more advanced EMS strategies based on predictive control or stochastic dynamic programming.

Study effect of these strategies on the optimization tool . If needed :

- Try Gradient-based algorithms
- Reduce the simulation time by performing it on representative days or weeks?
- Multistart with local optimization algorithms?

open energy modelling initiative

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