



Ea Energy Analyses

IEA Wind Task 51: Wind forecasts for operation of energy hubs with PtX

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Agenda

1. Case study introduction
2. Methodology and scenarios
3. Operational results
4. Conclusions



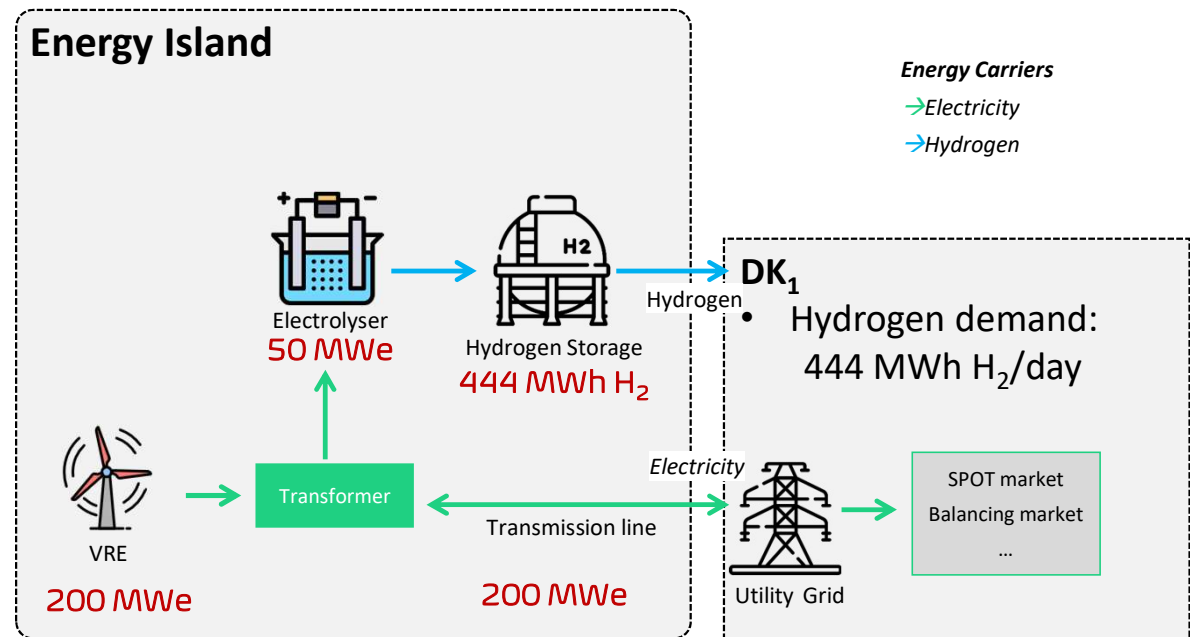
Case Study Introduction

- **What?** The study focuses on modelling and optimisation of operations of hybrid power plants over a year.
- **Why?** Having multiple energy carriers, synergies between units, and opportunities related to energy market participation, the complexity of decision-making process for hybrid power plant manager increases, so as opportunities to optimize the system.
- **How?** Application/development of stochastic programming (proactive) and rolling-horizon planning (reactive) techniques for energy market participation.



Case description and setup

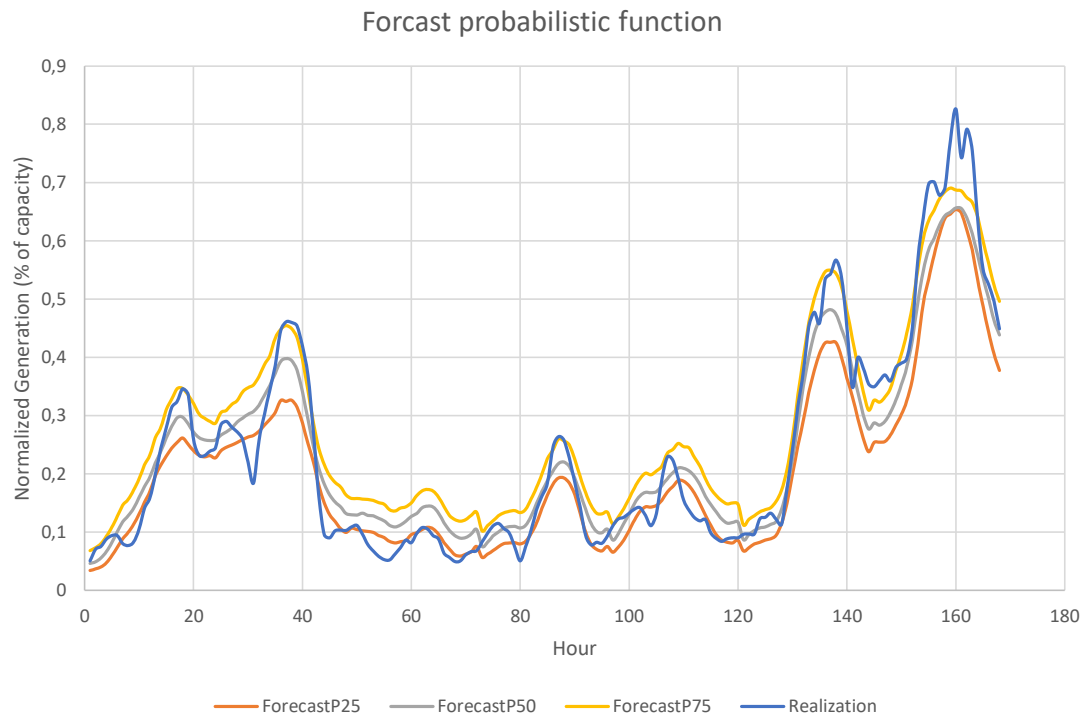
- Simple hybrid plant that consists of on-site wind power generation, electrolysis and H₂ storage to unlock implicit flexibility of electrolysis.
- Two carriers: electricity and hydrogen are considered.
- **Markets (DK1)** considered in this analysis include:
 - Spot /day-ahead market
 - Balancing power market
- No commodity market for hydrogen. **Fixed daily demand applied.**
- The analysis is performed using 1 year worth of data.
- Grid Tariffs reflect transmission costs.



Data Sources (August 2021 to July 2022):

- ✓ Wind forecast scenarios: ENFOR
- ✓ Power Market Prices: NordPool & Energinet
- ✓ Grid Tariffs: Energinet

Wind power forecast



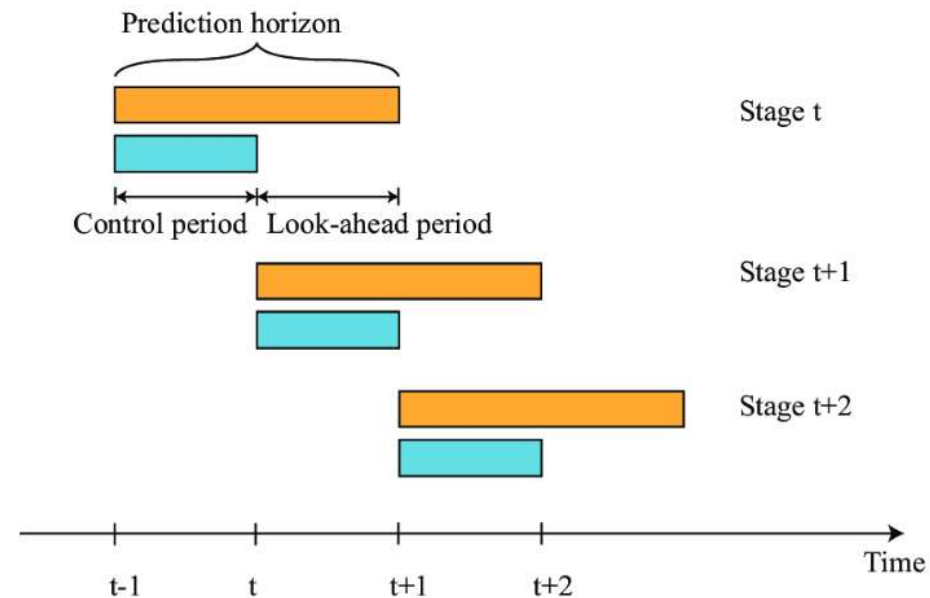
- 3 wind power forecasts:
low, medium, high
 - Period 2021-2022
 - Delivered by ENFOR
 - Probabilities:
 - P_low: 25%
 - P_mid: 50%
 - P_high: 25%
- And realised wind power generation



Methodology and Scenarios

Description of rolling horizon approach

- The decision-making process is divided into stages
- Each of the stages correspond to a decision point
- Predictive horizon defines the foresight for each of the stages
- At each of the stages input data is updated to check for forecast changes
- The decision for control period is made while taking into consideration future opportunities during the look-ahead period.



Scenarios

Case	Scenario Name	Description	Evaluation
1	<i>Ref</i>	Obligation to an H ₂ offtake agreement of 444MWh H ₂ per day at a maximum 10% hourly deviation.	Evaluation of the annual gross profit of a base case scenario.
2	<i>Improved Forecast Ref</i>	Case 1 with improvement of the forecast scenarios by a factor of 50%, bringing them closer to the realised scenario. Scenarios remain equiprobable.	Impact of improved wind forecasts on the gross profit levels of case 1.
3	<i>Price Maker Ref</i>	Case 1 with original wind forecast scenarios, but with endogenously defined balancing market prices for the wind farm (price maker considerations). The new prices are a function of the hub's imbalances, on the basis of whether they hinder or benefit the broader balance of the system.	Due to the limited volume of balancing needs in the system in the evaluated bidding zone, the impact of the hub's imbalances on the system's balance and therefore balancing prices is being evaluated against the deterministic price taker conditions of case 1.
4	<i>Price Maker + Improved Forecast</i>	Monetary effects of combining cases 2 and 3. To be compared against case 3.	Combined monetary evaluation of cases 2 and 3.
5	<i>Price Maker + Improved Forecast + Flex</i>	Monetary effects of combining cases 2 and 3, while allowing for more flexibility on the hour-to-hour deviation of hydrogen sales. The 10% condition of case 1 is being eliminated.	Assessment of the benefits that flexible offtake contracts can enable.



Operational Results

Gross profit in Ref. case and two alternatives



Ref

- Revenues and costs through the balancing market cancel each other out

Improved Forecast Ref

- Approximately halving both balancing costs and benefits. Gross profit from 32.1 to 33.0 m€
- Deviations between forecast and real time values have been reduced by 50% for each hour and each of the three wind forecast scenarios

Price Maker Ref

- Overall gross profit reduced with about 2.0 m€ (from 32.1 to 30.1 m€) per year. Increasing the balancing costs and reducing the balancing revenues



Savings enabled by improved operational conditions

Savings Against Base Case (+ is savings)



Price maker scenarios

Improved forecast

Plus 2.0 m€

Improved forecast

+Flex hydrogen

delivery

Plus 2.8 m€





Conclusions

About the model and setup of simulations

- A stochastic two-stage optimisation model with rolling horizon has been developed.
- The model is suited for simulating the operation of a multi-carrier energy hub consisting of wind power, electrolyser (H₂ generation) and H₂ storage.
- It is assumed that the hub is operating in the electricity market framework (day-ahead spot market and balancing market) and must deliver a certain amount of H₂ on a daily basis.
- Wind forecasts form part of the uncertainty on an operational basis.

Simulation results

Price taker:

- An improved wind forecast provides better day ahead trading results
- and approximately is halving both balancing costs and benefits
- rising the overall gross profit by about 3%.

Price maker:

- Switching from price taker to price maker conditions in the balancing market reduces the overall gross profit for the hub by 6% in the reference case.
- Balancing costs are increased and balancing revenues reduced compared to price taker ref.





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