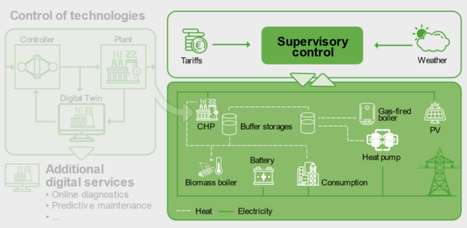

Supervisory control of gaseous hydrogen components in multi-energy systems

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AREA 2.2 Automation and Control

Motivation

Integrated multi-energy systems including hydrogen technologies and renewable energy sources provide a promising opportunity for reduction of green house emissions and grid stabilization. By using supervisory model-predictive controllers the benefits of such systems can be maximised. However, optimal control of such systems comes with a challenge, as the explicit consideration of pressure and mass flow requires non-linear models.

Energy Management System

Optimization-based energy management systems (EMS) provide offer such supervisory control for integrated multi-energy systems [1]. A descriptive model and objective function are required to solve an optimization problem and apply the resulting schedule in a receding horizon fashion. EMS for systems with **hydrogen components require non-linear models for pressure and mass flow**, that are detailed yet simple enough for timely optimization.

Modelling of H_2 components

The non-linear behaviour of the gas-law at high pressures can be approximated using piecewise-affine functions.

Electrolyser and **compressor** models describe mass flows via a multivariate efficiency curve and a control variable for the set-point. For **gas storages** integrator models are used. The flow of gas is modelled by the following constraints.

Pressure balance	$p^t_{source} \geq p^t_{sink} \Rightarrow \delta^t$
Mass flow	$\dot{m}_{min}\delta^t \leq \dot{m}^t \leq \dot{m}_{max}\delta^t$
Equilibration	$\dot{m}_{min}\delta^{t+1} \leq \dot{m}^t \leq \dot{m}_{max}\delta^{t+1}$

Case Study

The developed components were tested in the project HyFleet [2], using a co-simulation of the EMS and a simulation of a **hydrogen fuelling station**, provided by the HyCentA Research GmbH.

Simulations of multiple scenarios with varying electricity prices and hydrogen demands were performed and analysed. The chosen key-performance indicators (KPIs) are the H_2 production cost, the H_2 demand fulfilment and the imported electricity from the grid.

For prediction of H_2 demand, solar yield and electricity prices two benchmark forecasting methods, i.e. perfect foresight and a naïve forecast, have been used.

In Fig. 1 a comparison of the EMS control strategy, using perfect foresight, and the standard control strategy are depicted, for a scenario with variable electricity prices and random H_2 fuelling times. The KPIs for this scenario are shown below.

KPIs	Rule-based control	EMS – Perfect	EMS – Naïve
H_2-Costs	20.92 €/kg$_{H_2}$	15.70 €/kg$_{H_2}$	15.66 €/kg$_{H_2}$
Demand Fulfilment	91.01 %	89.34 %	92.06 %
Electricity Import	1452.48 kWh	1051.40 kWh	1164.83 kWh

Conclusion

Overall the EMS resulted in all analyzed scenarios in a similar demand fulfilment and a **significant reduction of costs and imported electricity** from the grid reduction compared to the standard control strategy. In scenarios with higher flexibility the gains due to the EMS control were more pronounced.

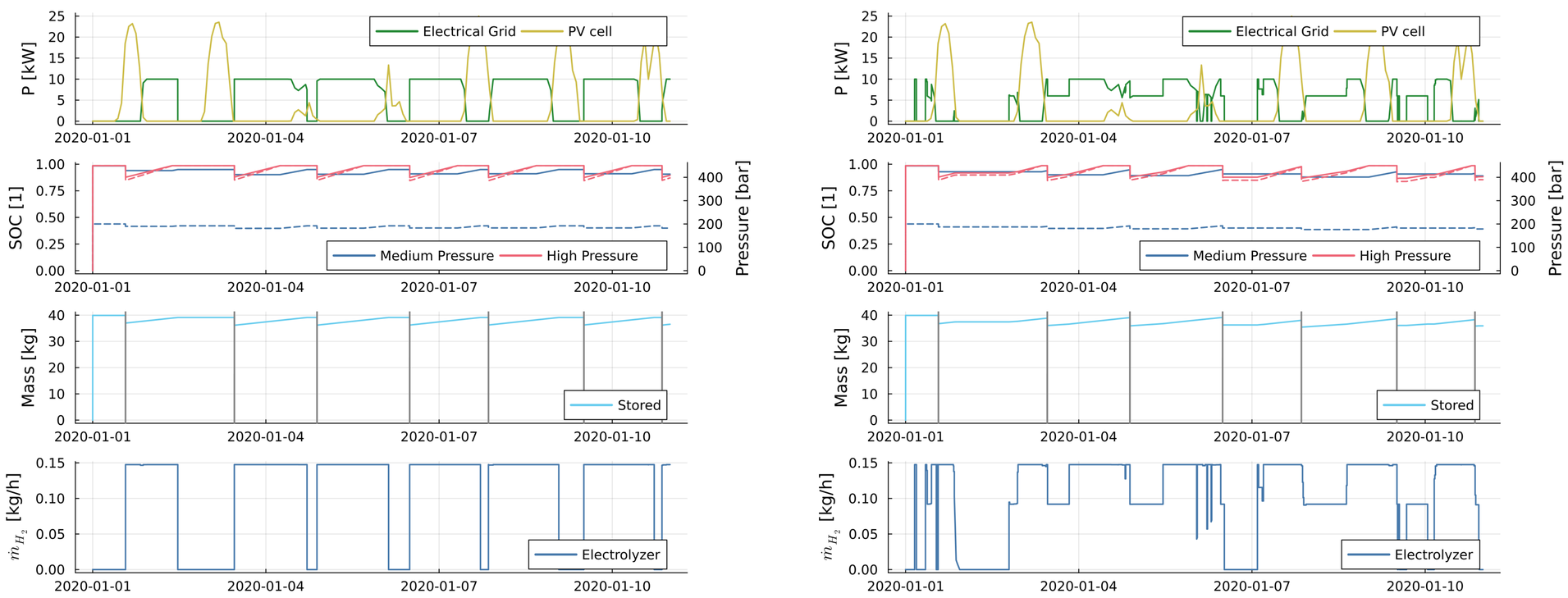

Fig. 1: Comparison of a standard rule-based strategy (left) and a model-predictive control strategy (right)

Highlights

- Usage of non-linear gas models in a MILP context.
- Application of EMS control in a co-simulation.
- **Reducing H_2 production costs** by up to 30%.
- **Reducing additional power import** by up to 30%.
- Equivalent H_2 demand fulfilment achieved.

Outlook

- Coupling to **Digital Twins of PtX plants** in projects ReNew and HyDestiny (together with HyCentA).
- Ongoing improvement of **non-linear gas-flow models** and addition of new components, e.g. **fuel cells** and **non-gaseous storages**.

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Literature/Acknowledgement

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[2] "HyFleet" wird über das Zero Emission Mobility Programm des Klima- und Energiefonds (KLIEN) und der Österreichischen Forschungsförderungsgesellschaft (FFG) gefördert. https://www.klimafonds.gv.at/themen/bewusstseinsbildung/serviceseiten/zem/hyfleet-wasserstofftechnologie-fuer-emissionsfreie-fahrzeugflotten/

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