

Model-Based Monitoring and Control of Thermal and Thermochemical Technologies

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BEST Annual Conference, Graz
September 30th, 2026



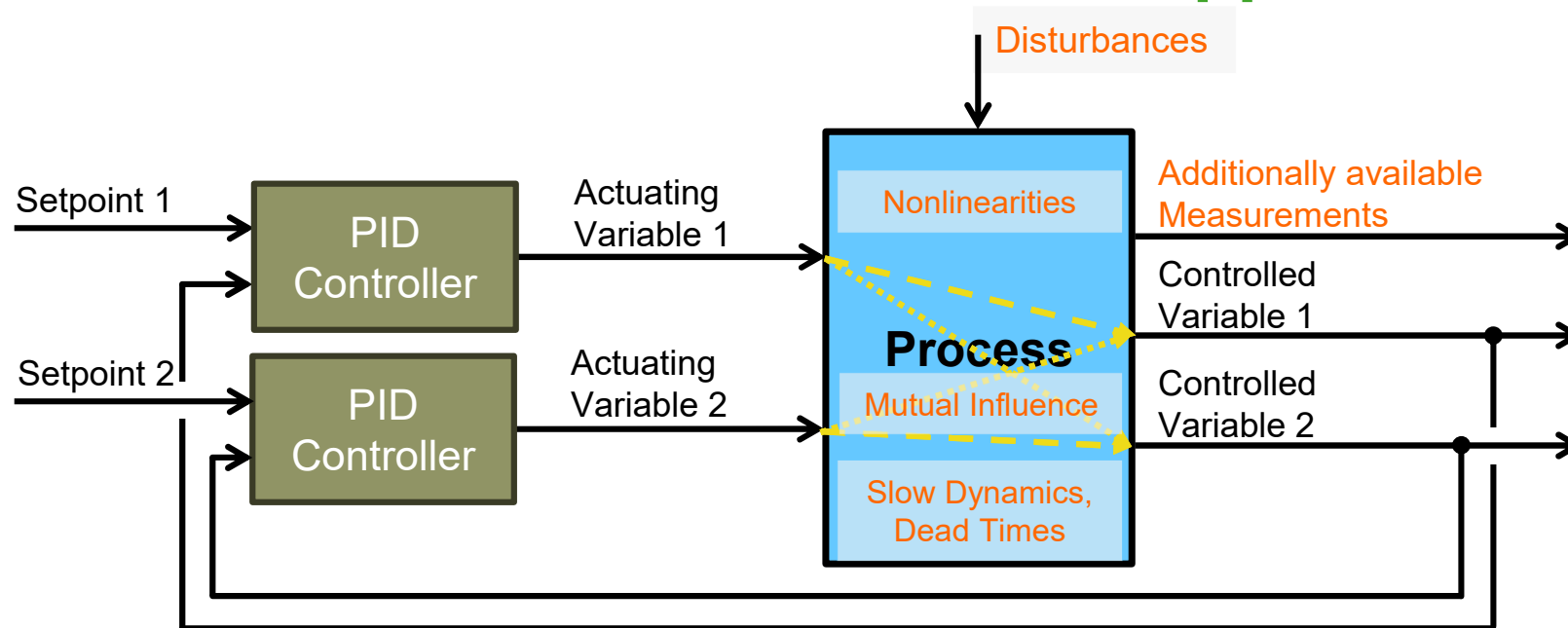
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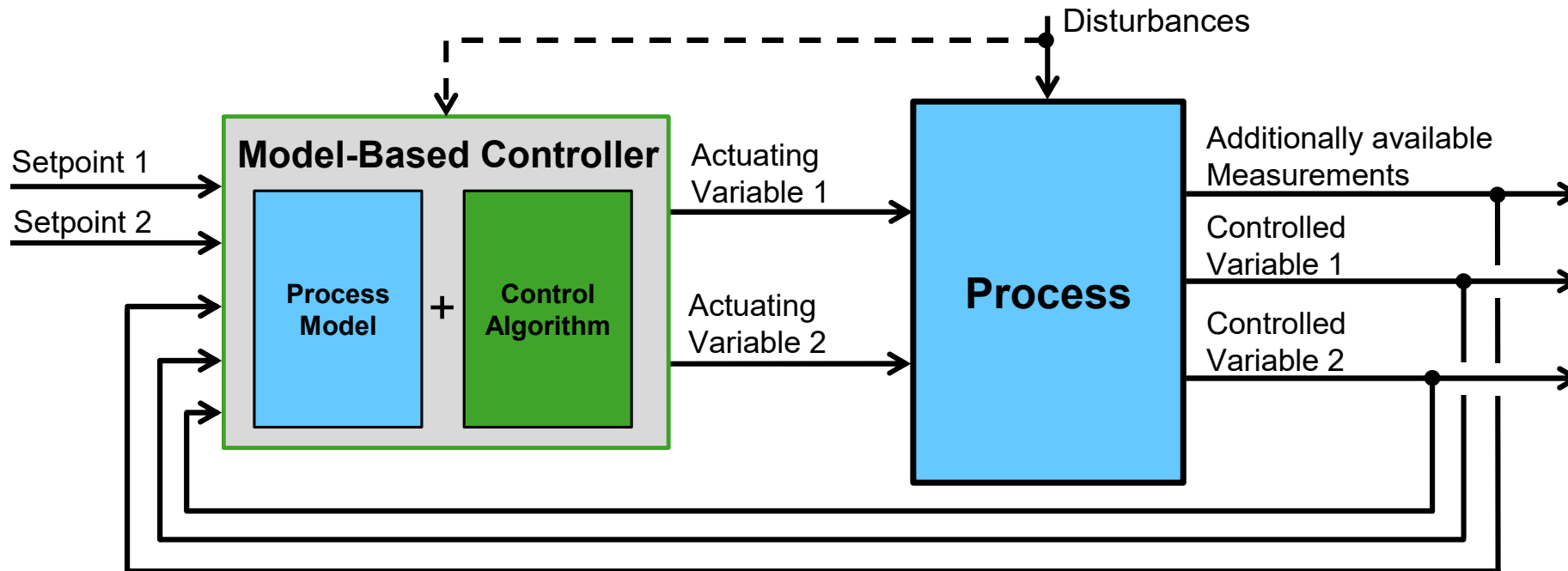
Process Control – The Standard PID Approach



- + Low **implementation effort**
- + Requires only **limited process understanding**

- No dedicated **disturbance rejection**
- Control loops **mutually influence** each other
- No consideration of **process nonlinearities**
- **Limited load modulation capability** for processes with slow dynamics and significant dead times
- No use of **additional process information** from available measurements

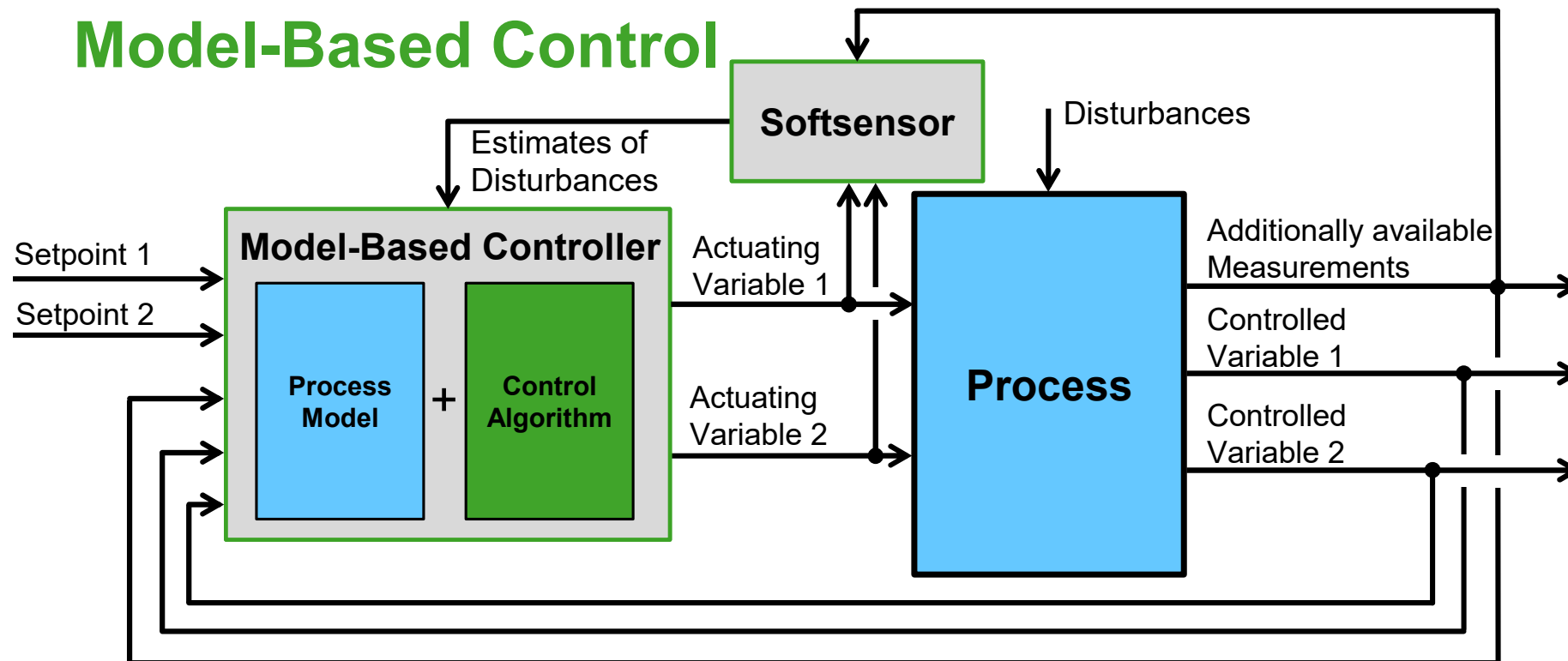
Model-Based Control



- + **Explicit consideration of the process dynamics**
(nonlinearities, dead times, cross-couplings between different actuating variables)
- + Utilisation of **additionally available measurements**
- + Active **disturbance rejection**
- + Improved **load modulation capability**
- Increased **implementation effort**
- Requires **deeper process understanding**



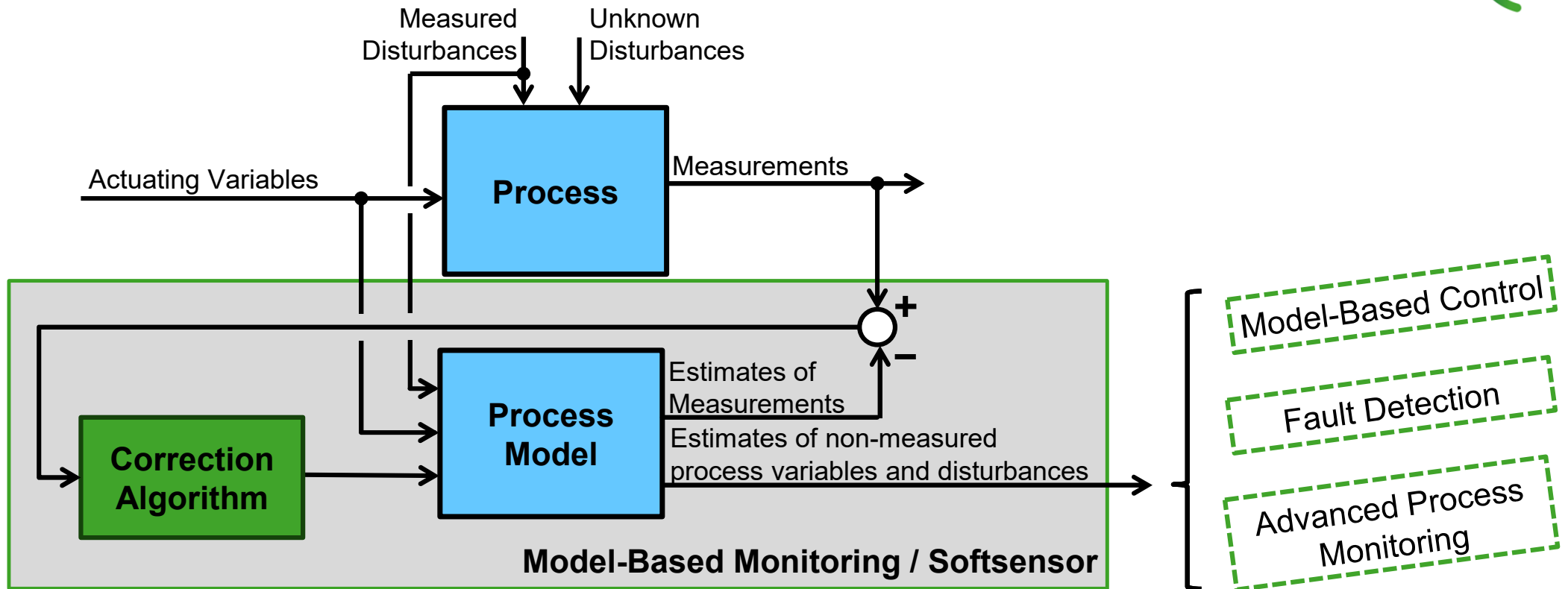
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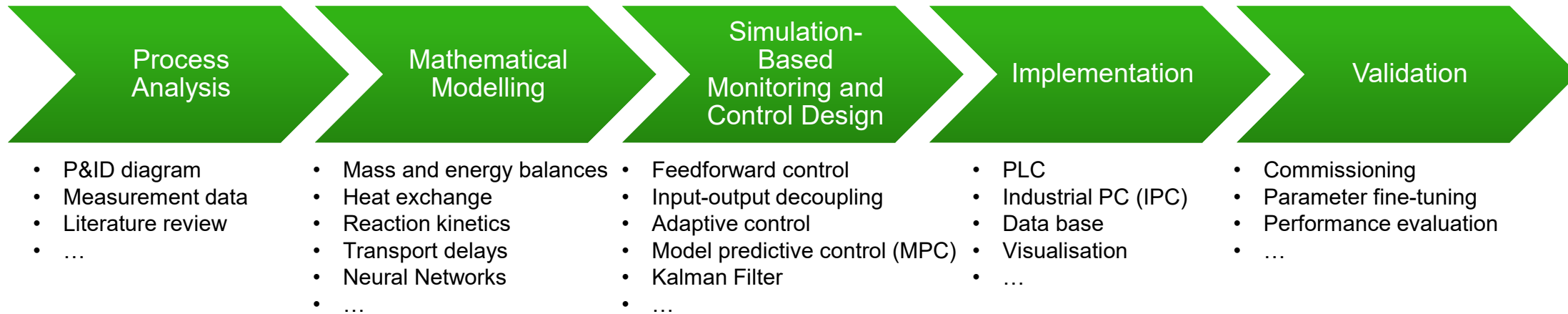
Model-Based Monitoring (Softsensor)



Online-estimation of important **process variables** and **unknown disturbances**

- Application of a **tailored process model**
- Design of an **algorithm for model correction** based on the deviation between measured and estimated variables

Methodology and Technologies



Thermal technologies:

- Solar thermal systems
- Heat pumps
- Drying processes

Thermochemical technologies:

- Pyrolysis
- Gasification
- Combustion

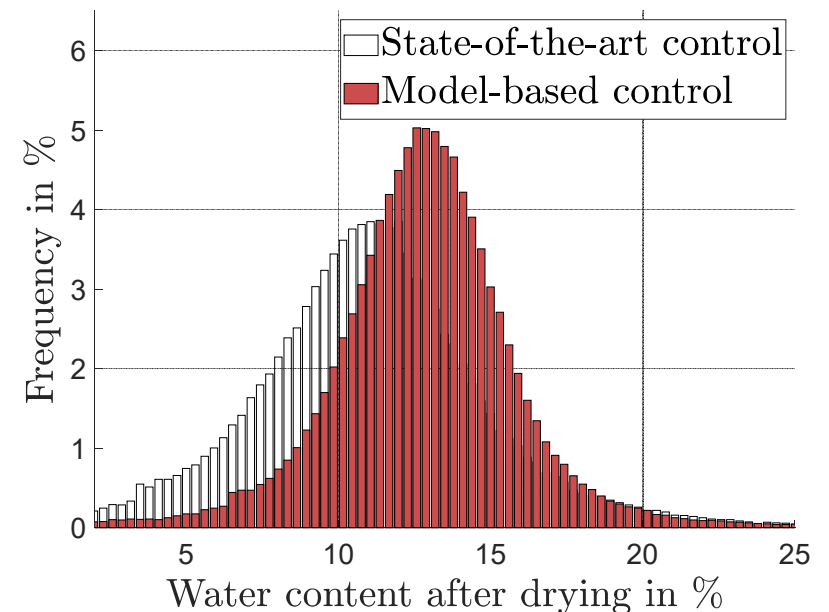
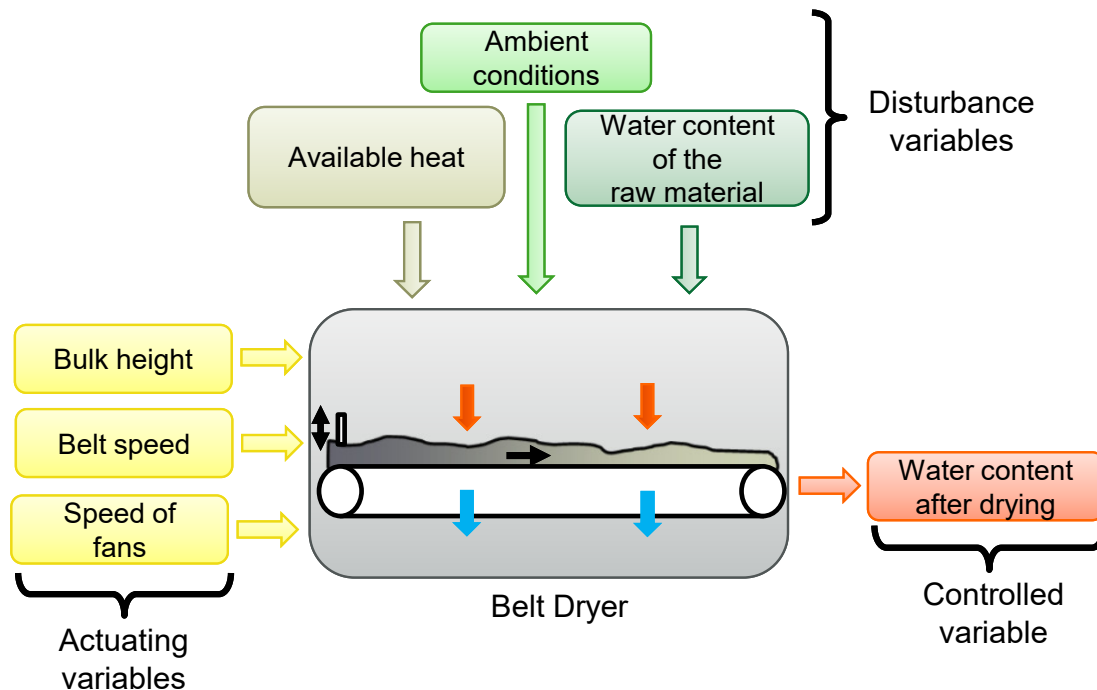
Other technologies:

- Hydraulic systems
- Biotechnological processes
- Flow batteries



Example 1

Control of the Water Content in a Sawdust Drying Process

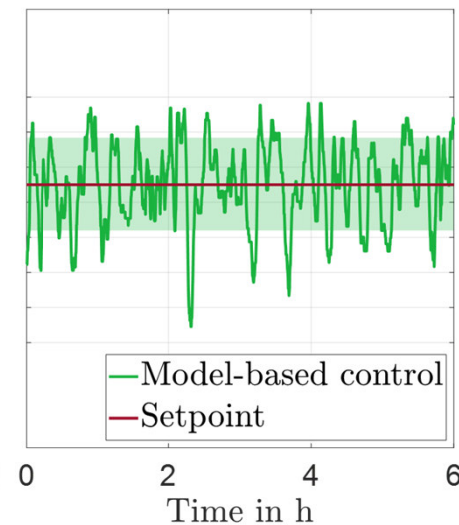
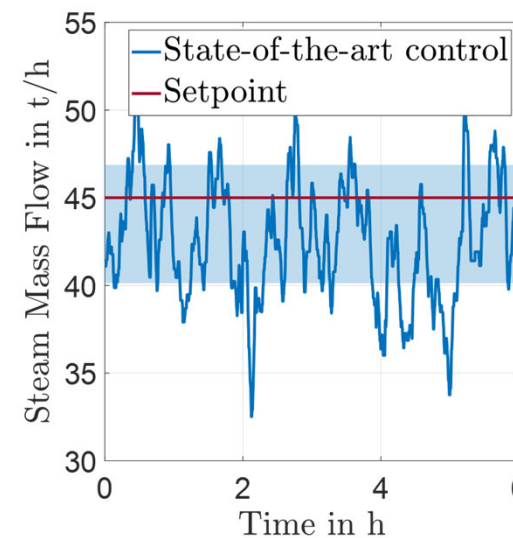
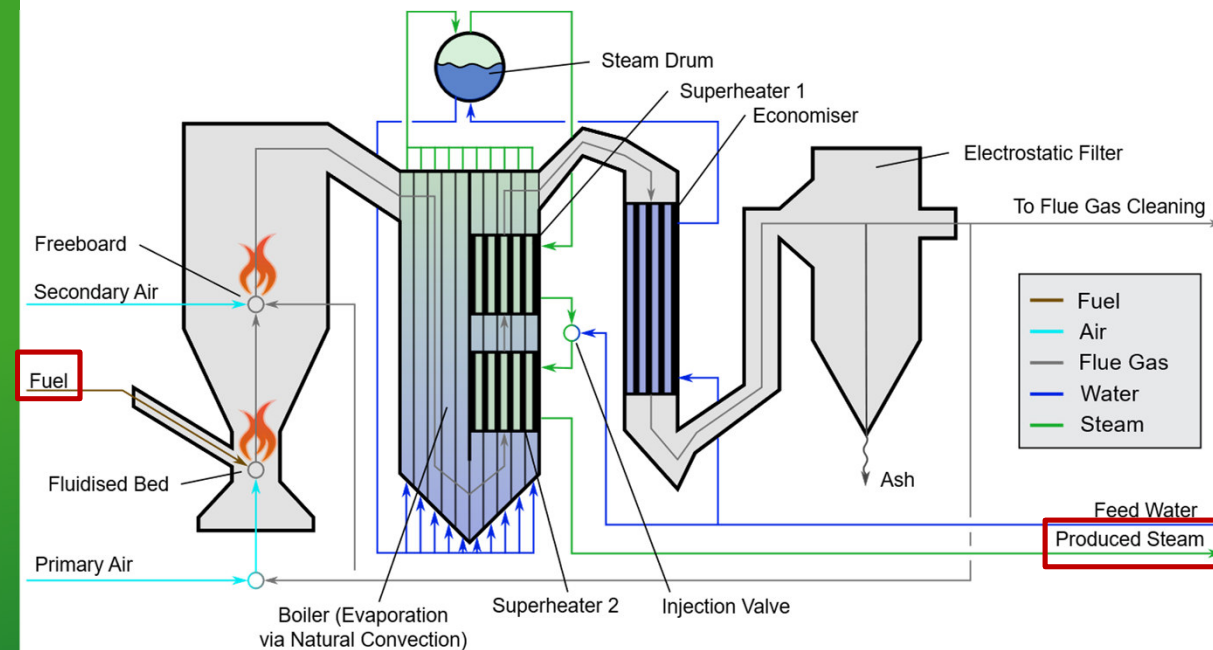


- Reduction in water content fluctuations **by 25%** (standard deviation)
- Possibility to **increase the average water content after drying by 0.5 %pt** whilst maintaining pellet quality
- Average **efficiency gain of 2.42%**
- Significantly **increased material throughput**
- Reduced need for **manual operator intervention**
- Annual **CO₂ savings of 220 t**



Example 2

Power Control of a 38 MW Fluidized-Bed Waste Incineration

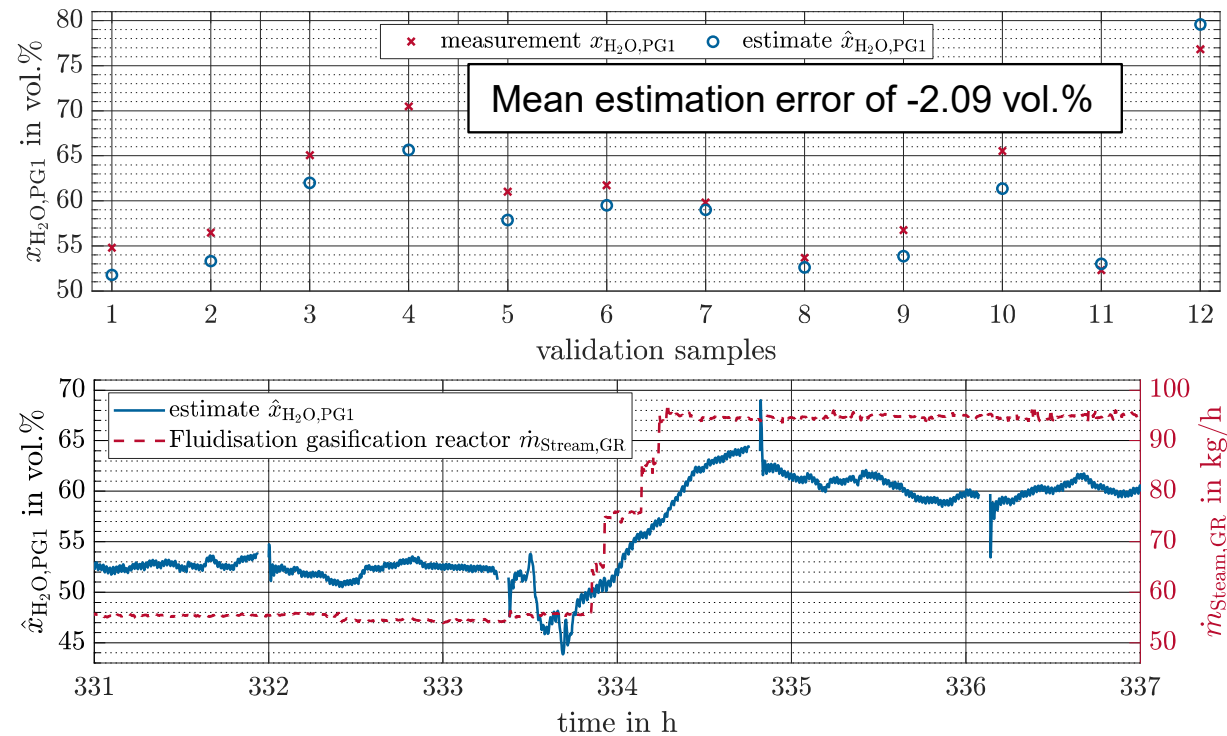
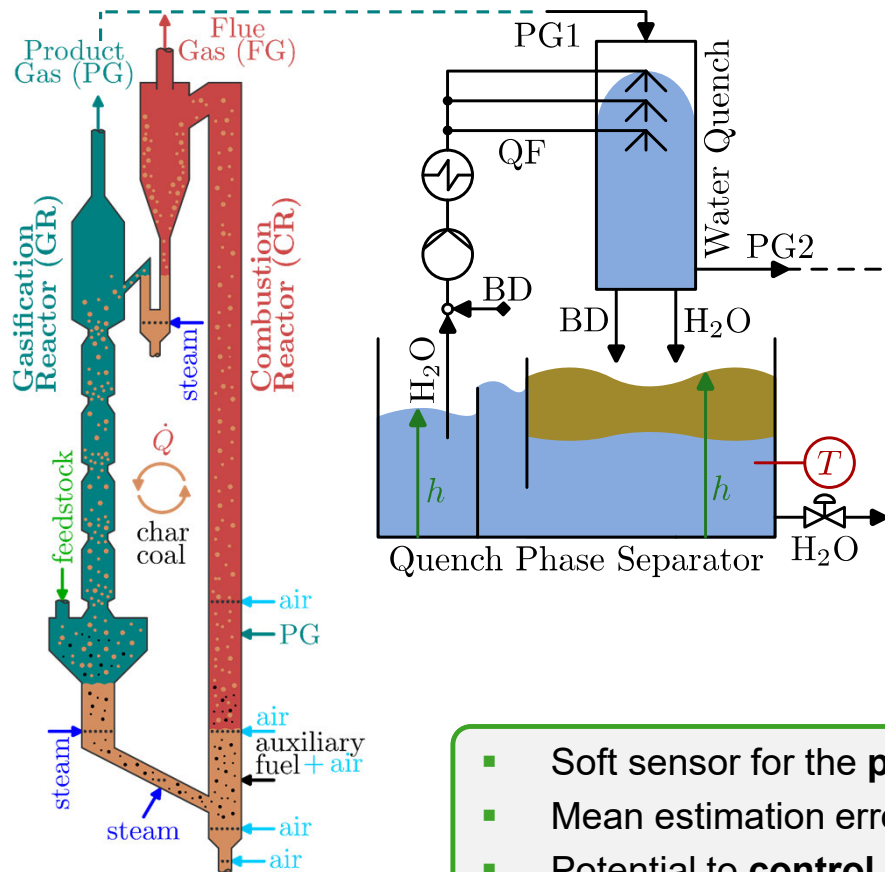


- Utilisation of a **soft sensor for the flue gas mass flow** for control purposes
- Improved **stability** of the process:
 - Reduction in **steam mass flow fluctuations by 23 %**
 - Reduction in **reactor head temperature fluctuations by 34 %**



Example 3

Monitoring of the Product Gas Quality in an aDFB Steam Gasifier



- Soft sensor for the **product gas water content**
- Mean estimation error of **-2.09 vol.%**
- Potential to **control KPIs** (e.g. Steam2Fuel / Steam2Carbon / Water Conversion Rate)
- Potential to **increase overall plant efficiency** by reducing excess steam input



Summary & Conclusion

- Model-based monitoring and control can contribute to:
 - Increase **process efficiency & process stability** in the presence of disturbances
 - Enable process operation **closer to critical limits**
 - Obtain **deeper insights** into the process state & **detect faults**
 - Improve **load modulation capability**
 - Reduce need for **manual operator intervention**
 - (Typically) **limited model accuracy**:
 - Manageable **model complexity** (parametrization, implementation, computational effort)
 - **Stochastic** parts in process dynamics
 - Uncertain **measurements**
- Focus on **most relevant effects**
 - Application of **robust monitoring & control methods**

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