

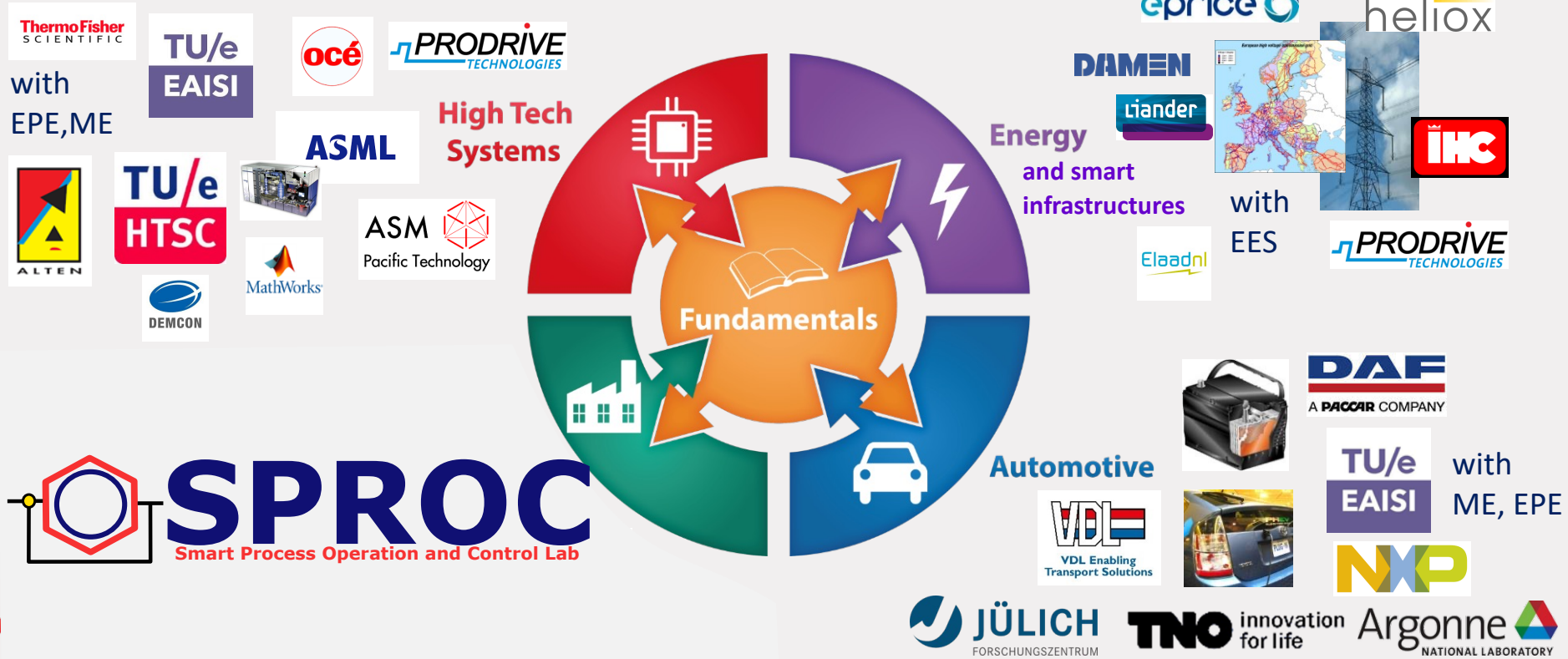


Revolutionizing Process Control: Innovations and Future Trends in Model Predictive Control

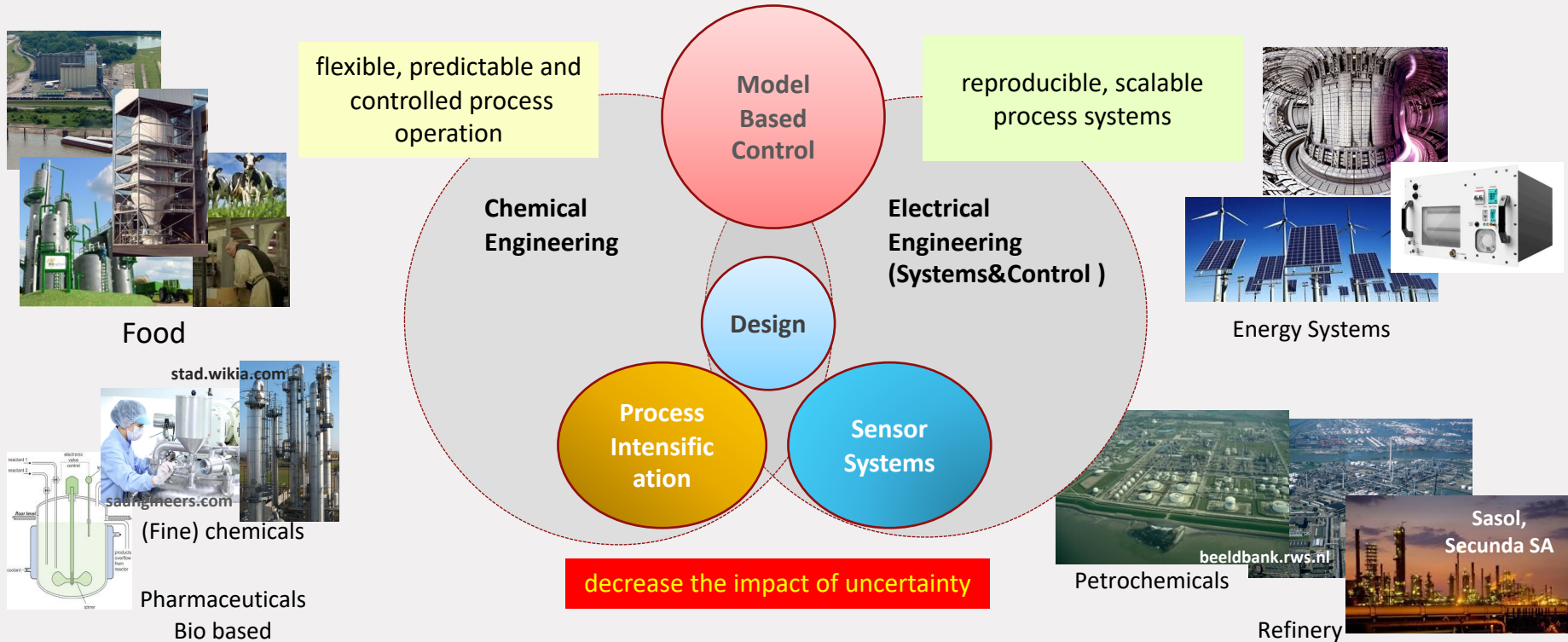
Control Systems Group, Electrical Engineering Department

Leyla Özkan

EE-Control Systems Group



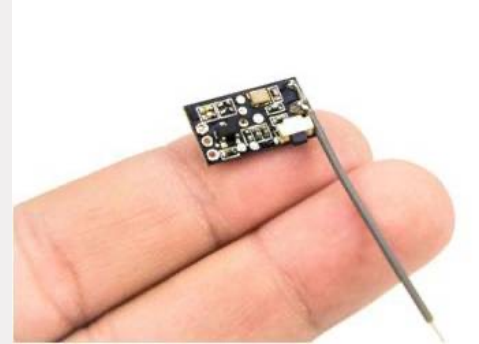
What Does SPROC Do?



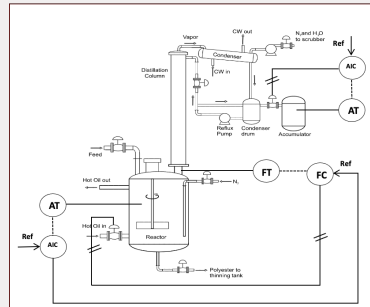
Control Challenges in Process Systems



~100 years



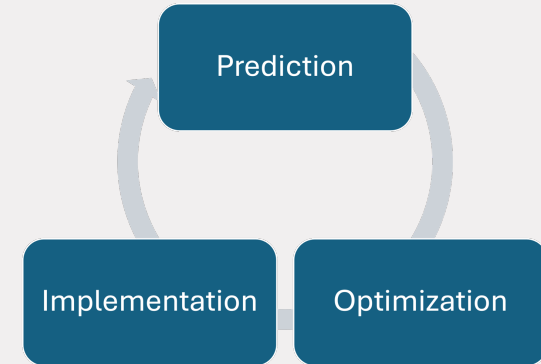
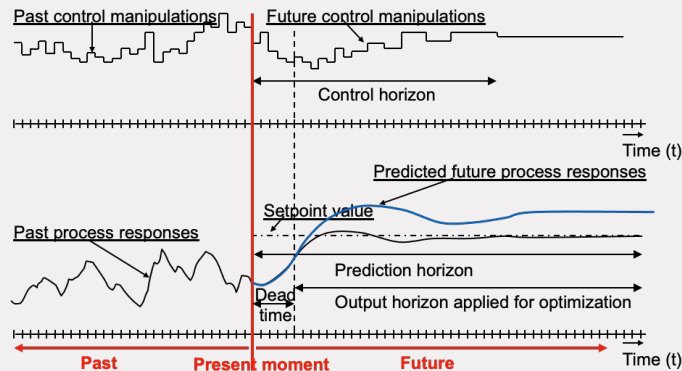
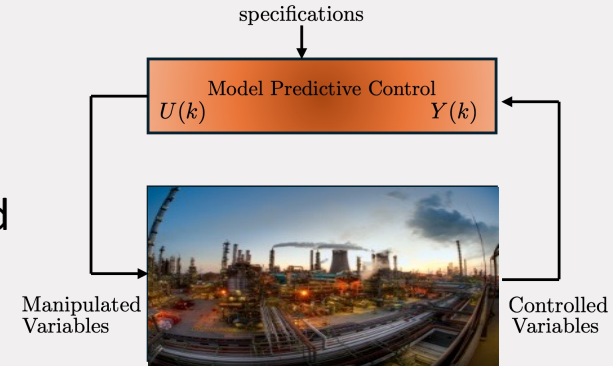
Fundamentally many chemical engineering processes have changed little from the dye industry of the 1900's,
Prof. Kevin Roberts, University of Leeds



An example: Control of a Reactive Batch Distillation Column[7]

Model Predictive Control-An Introduction

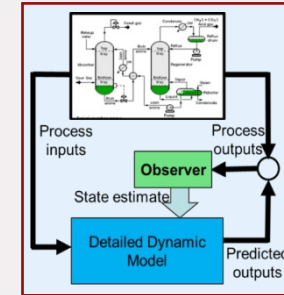
- Multivariable control strategy
- Accepted technology in petrochemicals
- Process Constraints are explicitly addressed



Model Predictive Control-Current Situation

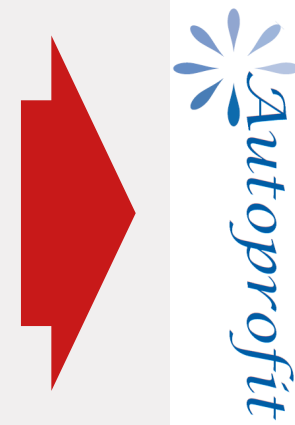
Observations:

- Model-based applications have a high potential for operation both on-line as well as off-line.
- Online use of models is still limited.



Why this contradiction?

- Total Cost of ownership is significant (TCOO)
- Complexity and expertise required
- Lifetime performance is limited due to lack of (automated) maintenance

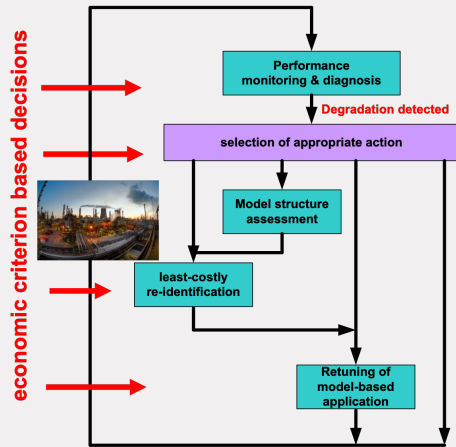


Autoprofit

Advanced Autonomous Model-Based Operation of Industrial Process Systems

Goal of the project:

Improved lifetime performance of model-based applications by autonomous cost-efficient maintenance and Reduce total cost of Ownership of the system



Autonomous maintenance for linear model-based operation

Developments focused on:

- Performance Diagnostics
- Autonomous testing:
- Autonomous MPC tuning:
- Extension to non-linear systems

Extensive testing under practical circumstances



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SASOL reaching new frontiers

Autoprofit Test Case:

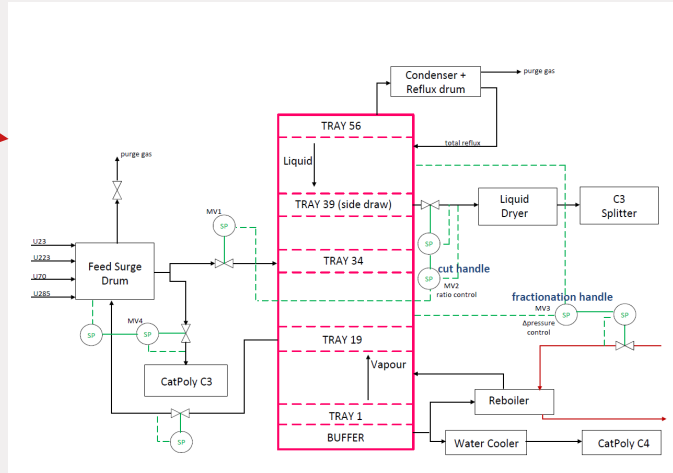
Fischer Tropsch Depropaniser plant at Sasol, SA



Objective: Maximize the side-draw product (C_3s) while maintaining the quality (no impurities such as C_4s)

Primary MVs	Primary CVs
Feed-to-Side draw ratio	Side draw composition
Delta-pressure	Column bottom's temperature

total reflux 56-tray tower with a side draw section above tray 38.

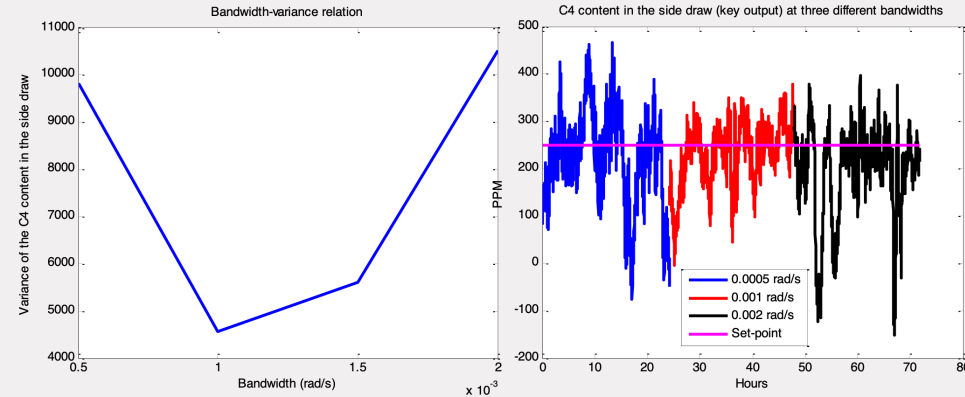


Autoprofit Test Case Campaign

Performed experiments:

1. Initial open loop identification
2. MPC implemented
3. Performance drop introduced
4. Re-identification and detuning tested

Optimal Tuning Experiment

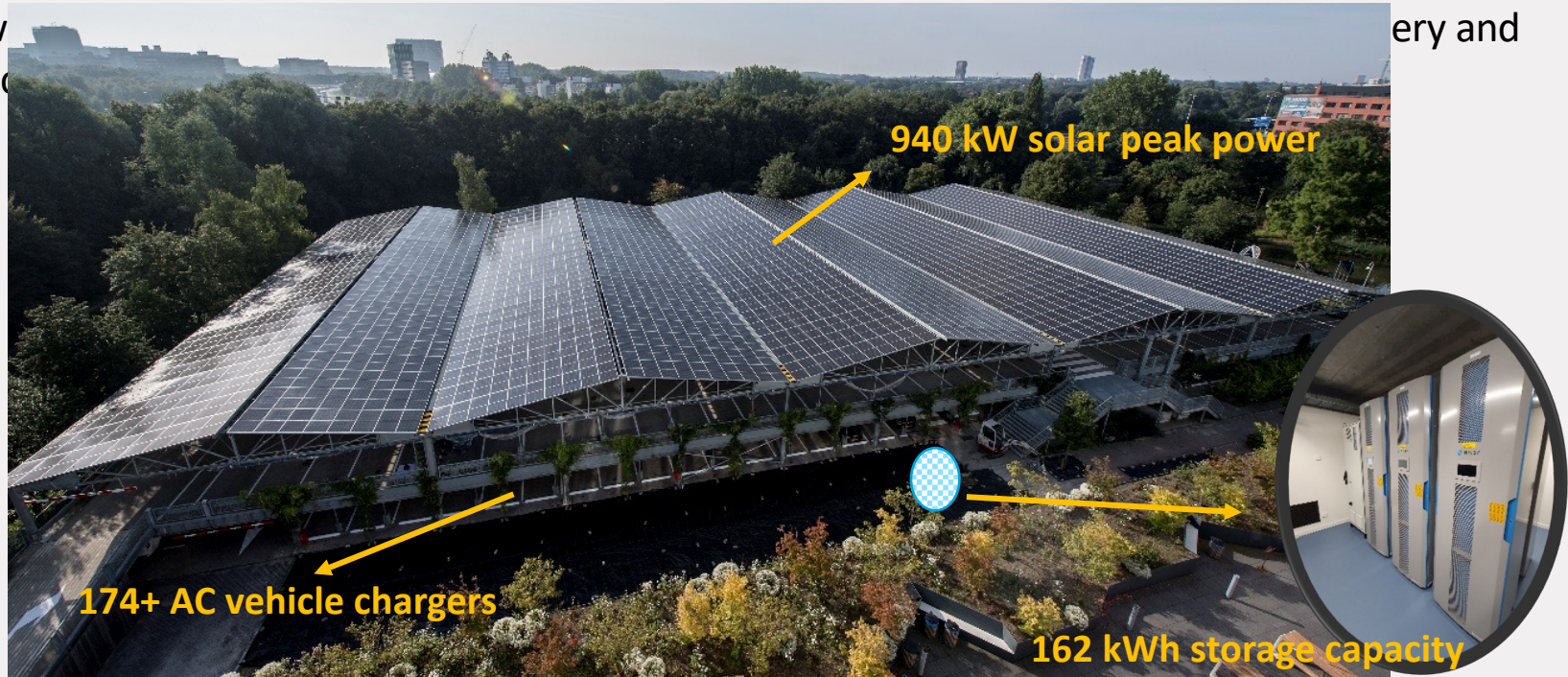


Final Evaluation : **Excellent**

MPC of EV Charging Stations in Grid Connected Microgrid

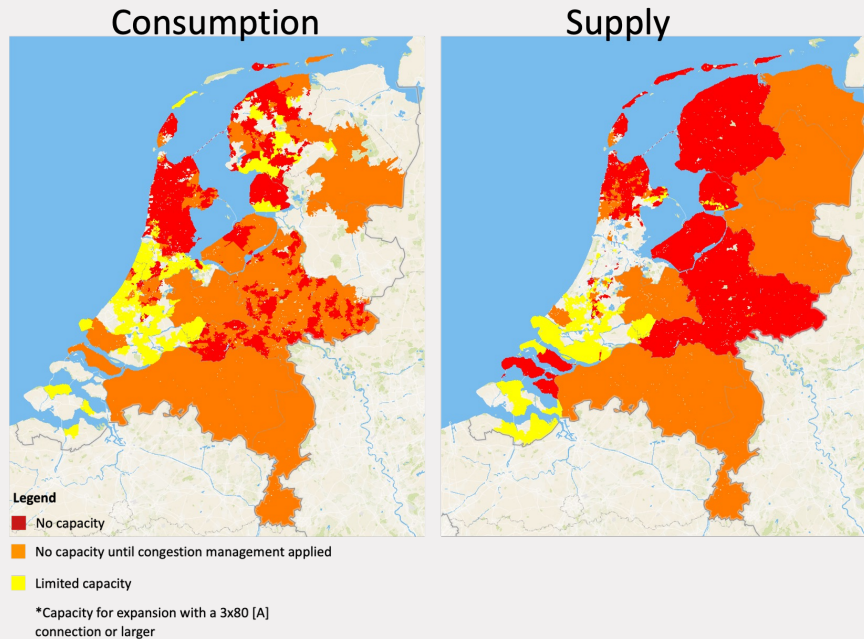
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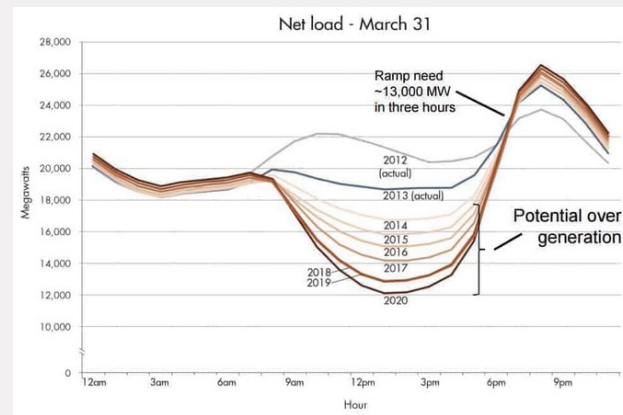


MPC of Ev Charging Stations in Grid Connected Microgrid

Problem: Mismatch renewable power supply and power demand



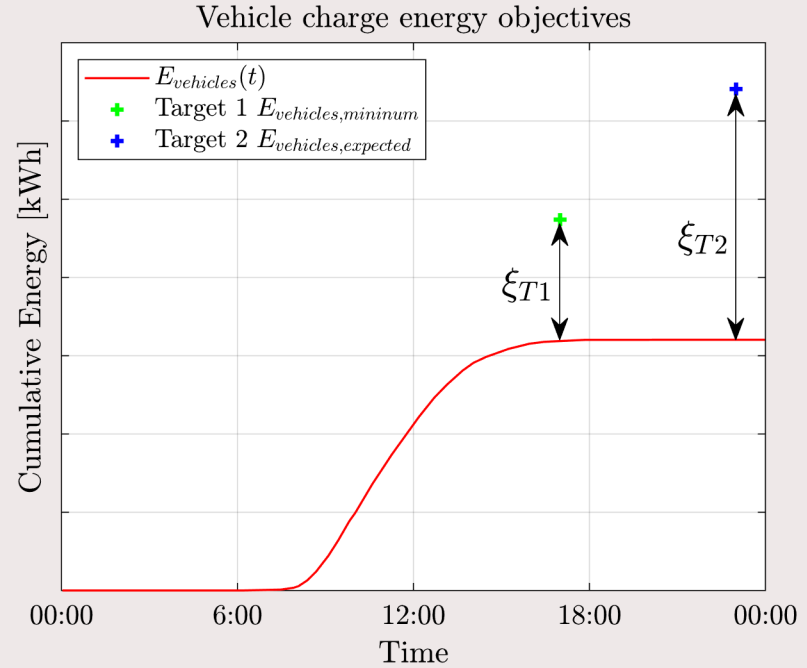
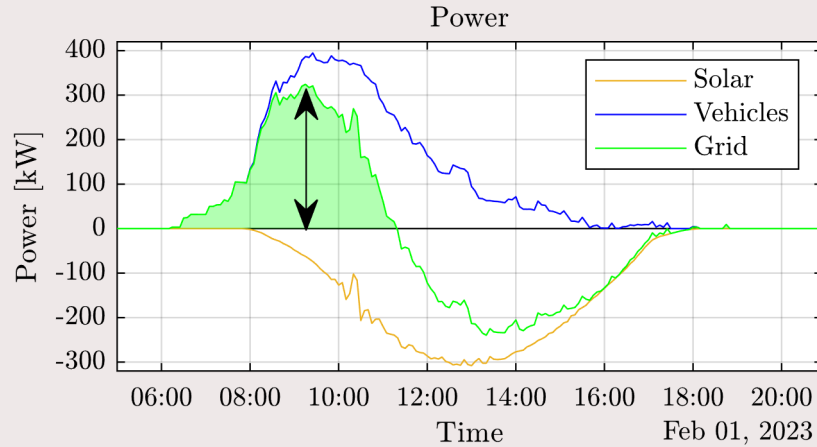
Source: Netbeheer Nederland 17-03-2023 [6]



Source: California ISO

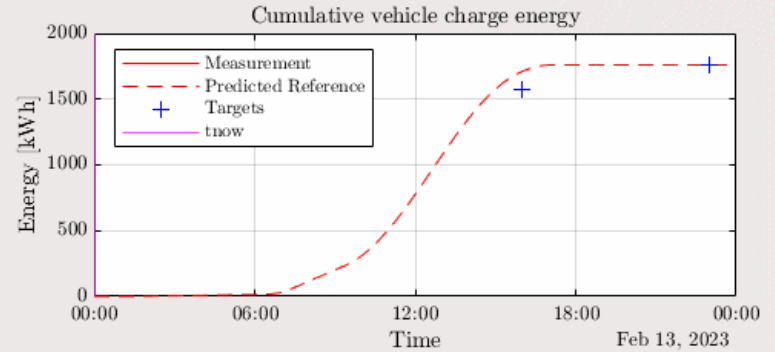
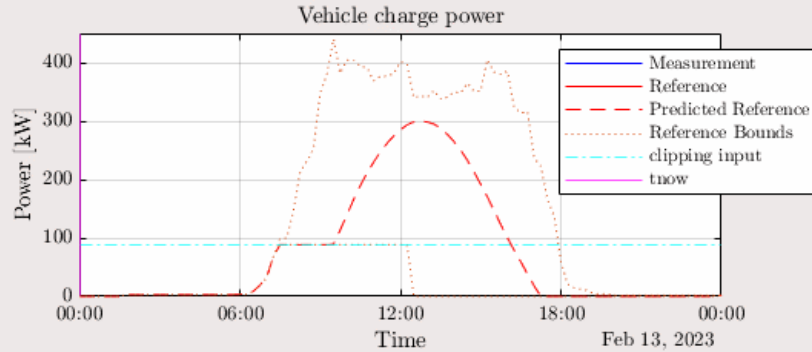
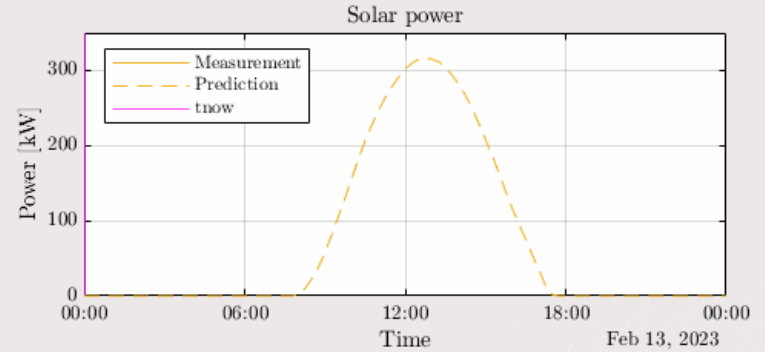
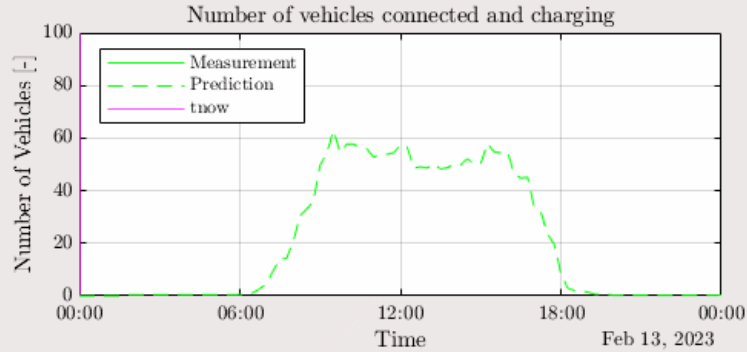
MPC Objective

1. Maximize self sufficiency
2. Minimize peaks
3. Minimize deviation energy targets: ξ_{T1} , ξ_{T2}



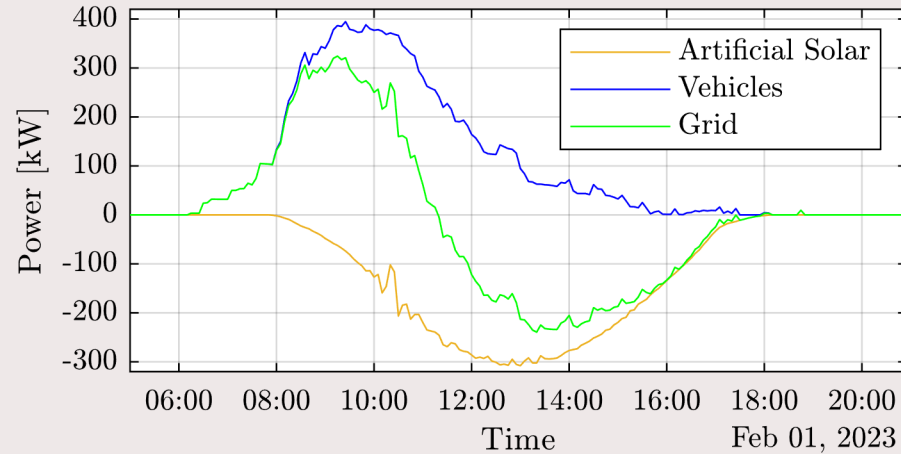
Results single day

Time:
00:00

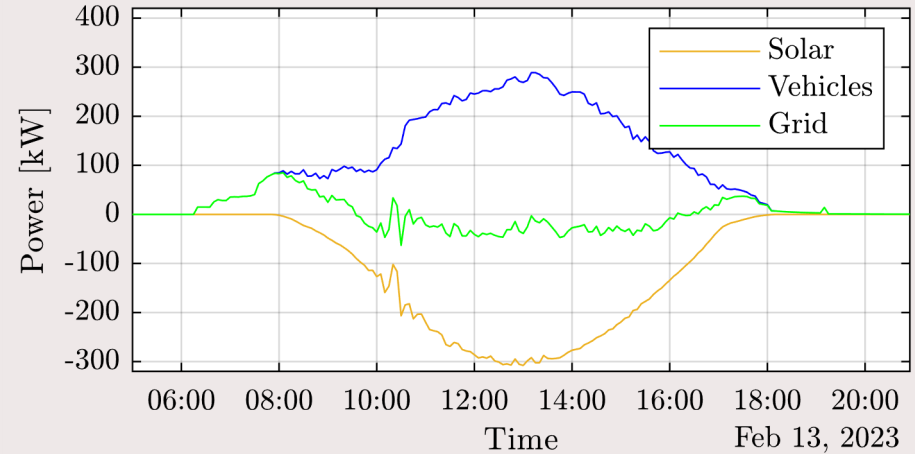


Results single day: Comparison [2/2]

Power controller not operational



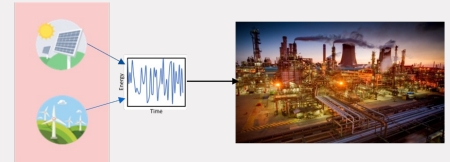
Power controller operational



	01-02-2023: not operational	13-02-2023: operational	Difference
Self sufficiency	47.8 %	88.2 %	+40.4 %
Peak power	324 kW	85 kW	-74 %
Charge energy	23.1	21.1	-8.6%

The Next Industrial Revolution

- Industry 4.0 / Digitization
 - Smart use of Data /Sensors/Prior Knowledge
 - Data and product flows across company borders
 - Fully automated, continuously monitored for control, optimization
- Electrification / Circularity/Green Transition of Process Industry
 - New chemistry, new energy source, new feedstock
 - Tightly integrated physical network
 - Dynamics becomes important
- Integration of the (process) industrial operations in the (electric) power grid
 - Use of available flexibility for balancing and congestion mitigation
 - Connection to the heat network



Future Directions

- Data Driven Control

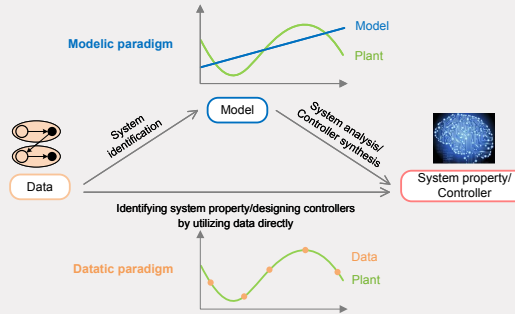


Figure taken from [5]

- Large Scale Optimization
 - Computation load
 - Uncertain uncertainties

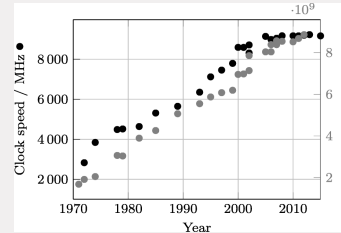


Figure taken from [6]

- Human-Automation Interaction
 - Technology should speak a natural language to the operator

Final Remarks

- Model Predictive Control will be even more popular due to
 - Flexibility in its formulation
 - Ability to contribute to efficiency of system
- Wider usability of the technology in process industry is needed.
 - Reducing the complexity of the modeling and tuning

We all think of tomorrow but there is also the day after tomorrow.

Acknowledgments:

Autoprofit:

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EV Charging

Jobert Ludlage

Bram Hermans

Shalika Walker (Kropman)

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