Are Complex Energy System Models More Accurate?

An Intra-Model Comparison of Power System Optimization Models

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FCN | Future Energy Consumer Needs and Behavior

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Motivation

„All models are wrong, but some are useful.“
(George Box)

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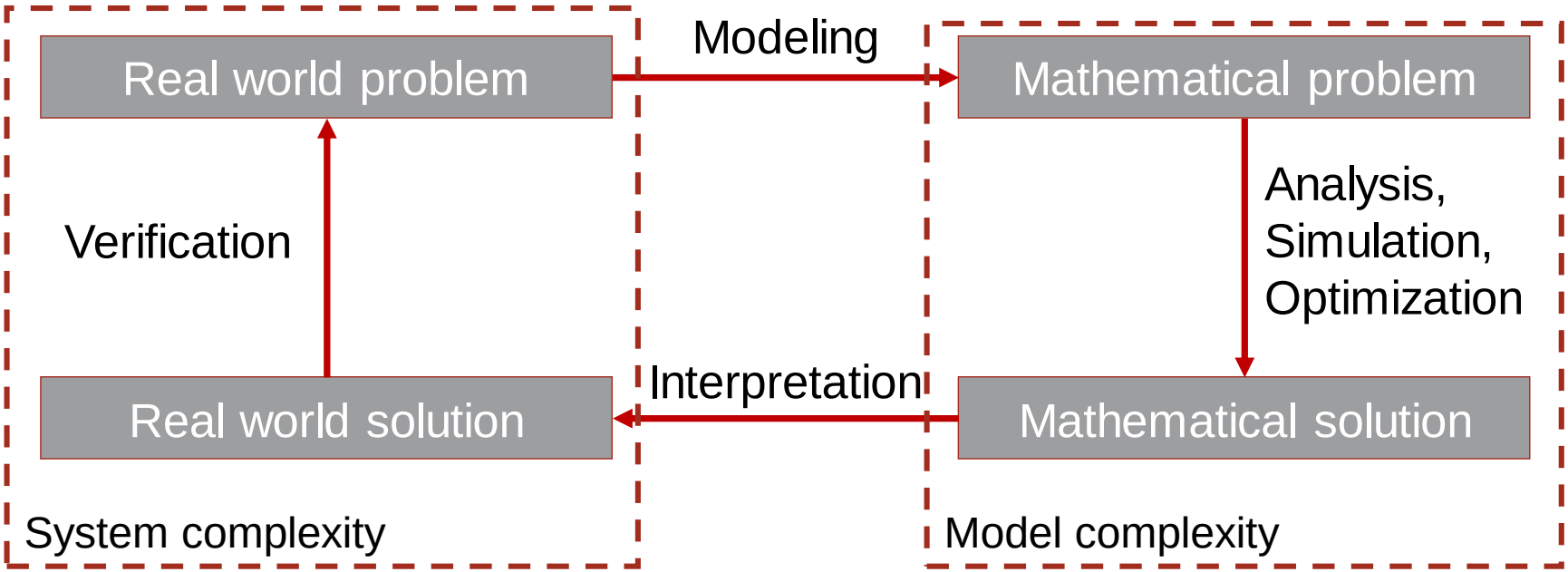
The linkage between system complexity and model complexity



Drivers of complexity in energy systems

- Nonlinearities, discrete decisions, path dependency, uncertainties, ...

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Trends leading to more complex energy system optimization models

(1) Energy systems become more complex and **(2) computer and data science** make impressive advancements

(1): Liberalization, **decentralization** and **volatile generation**

- Energy system models become **broader in scope**, have a **higher spatial,** and a **higher temporal resolution**

(2): Advancements in **computer capacities**, **optimization solvers** and **data sciences**

- Operation of such complex models becomes possible

Are complex models more „useful“?

What degree of complexity is necessary?

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Evaluating the trade-off between complexity and accuracy for individual components

Studies focusing on **individual components** compare **different implementations** by their respective **complexity and accuracy**

Various **complexity reduction techniques** are applied to individual components:

- Linearization
- Technological simplification
- Reformulation
- Time series aggregation (e.g. typical days, resolution change)
- Technical unit aggregation (unit clustering)
- Decomposition (within the model)

Our approach: Relaxing the ceteris paribus condition and vary multiple system component implementations

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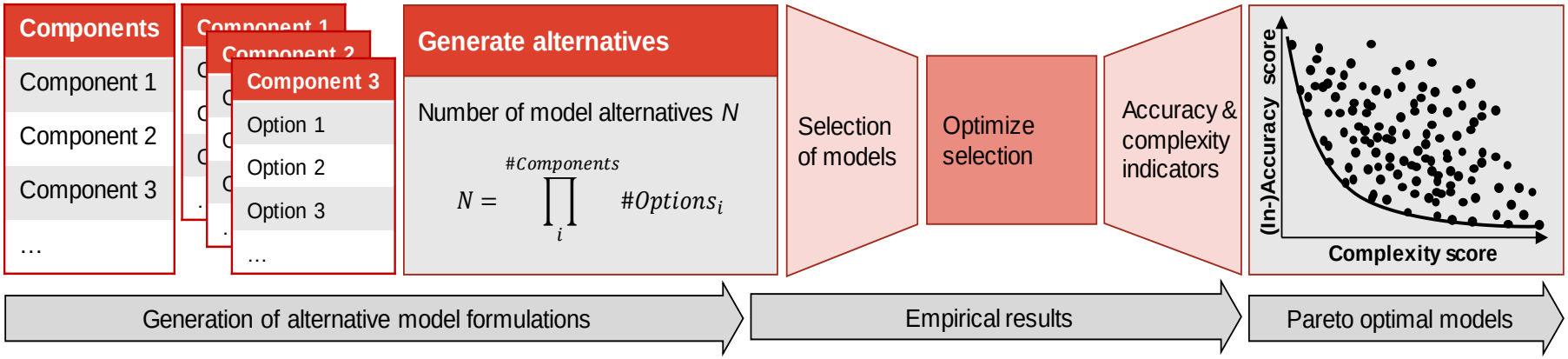
Research Questions & Framework

(1) Are complex power system models more accurate?
(2) What are the complexity and accuracy drivers in power system optimization models?



Scores / Indicators	
Complexity:	• Solving time • Model size as a proxy for Memory usage
(In-)accuracy:	• Deviation from benchmark objective function value (benchmark: setting with maximum degree of detail)

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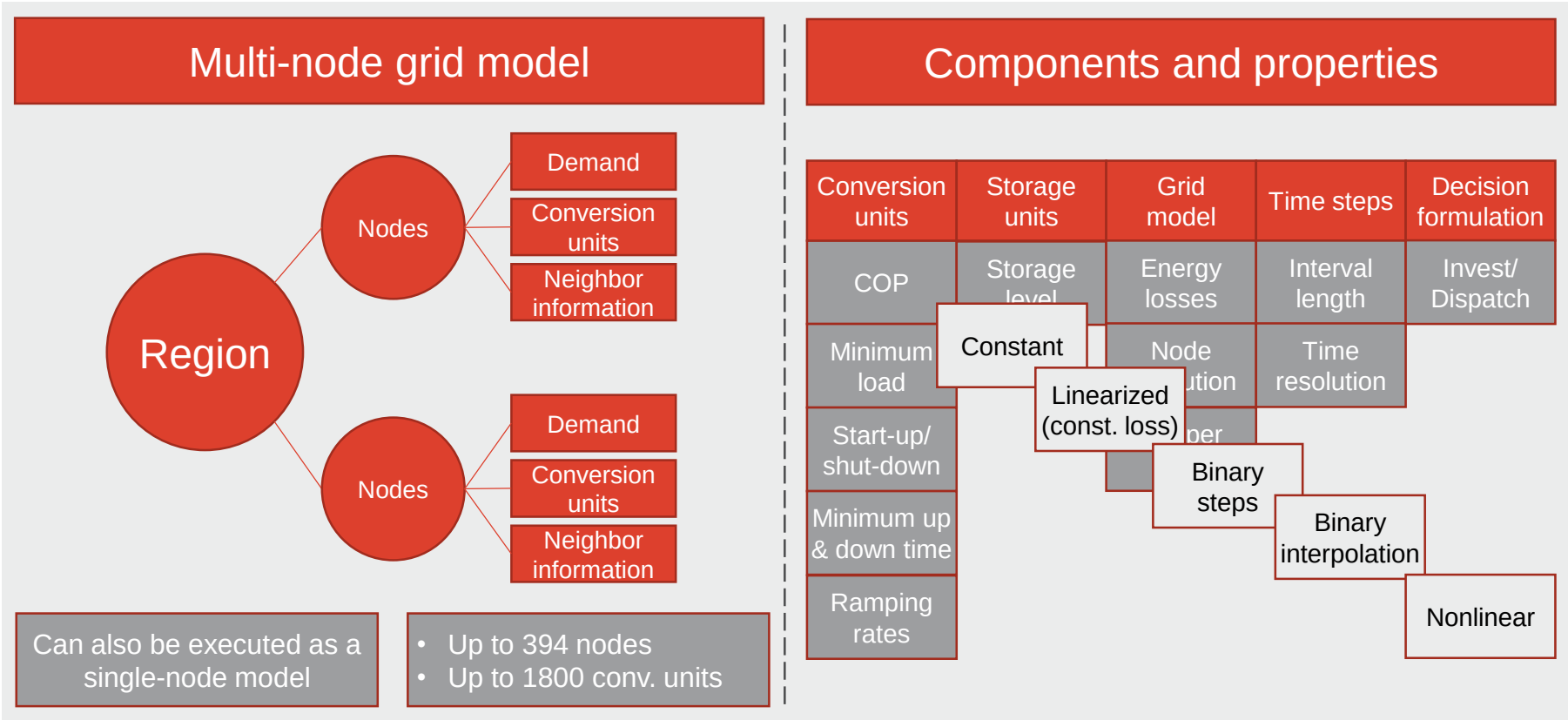
Power system optimization model & components

Multi-node power system optimization model of the German power supply system



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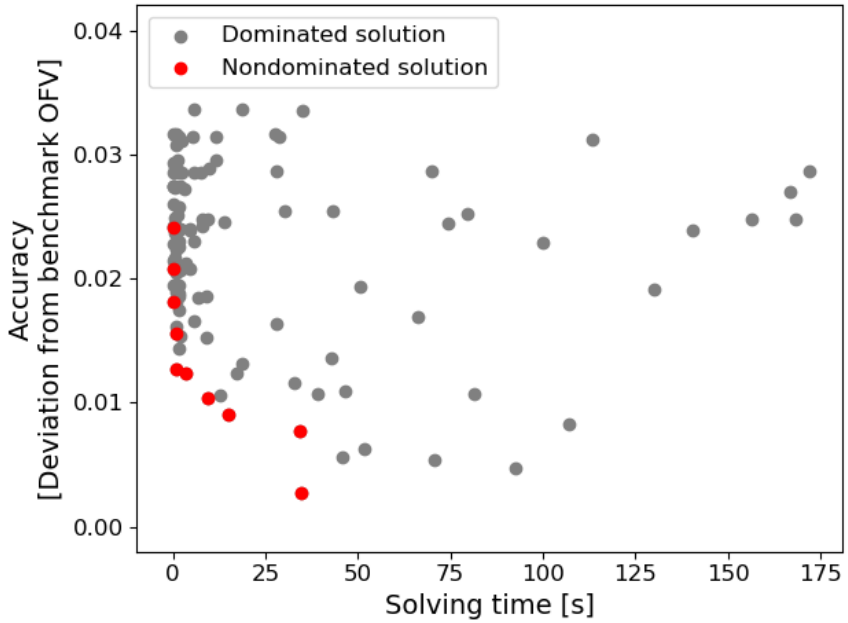
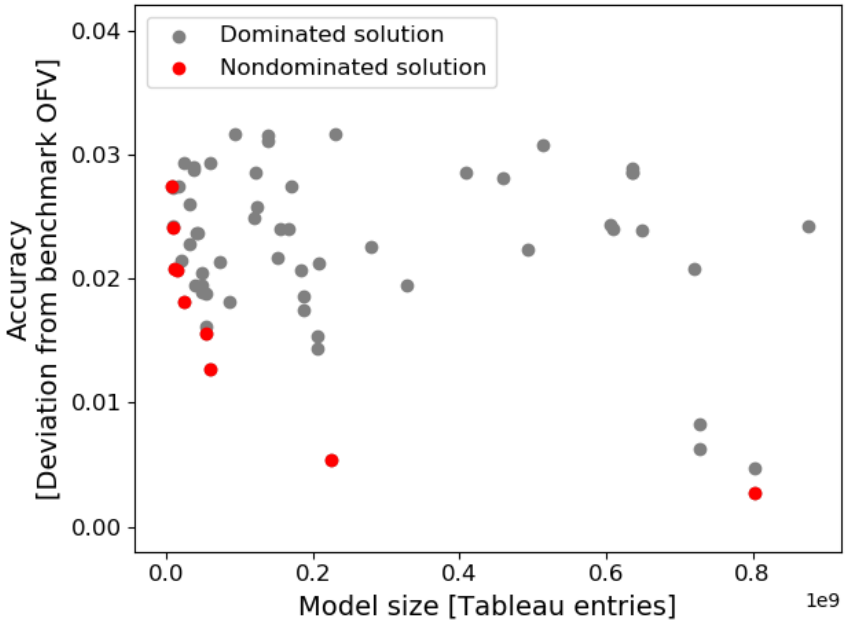
Pareto optimal model formulations for the (dispatch) power system optimization model

Solving time



Model size



- **Pareto frontier** identifies efficient model configurations
- **Marginal utility** (Increase in accuracy) decreases with additional complexity
- **High degree of operational detail** is common among most Pareto optimal model formulations

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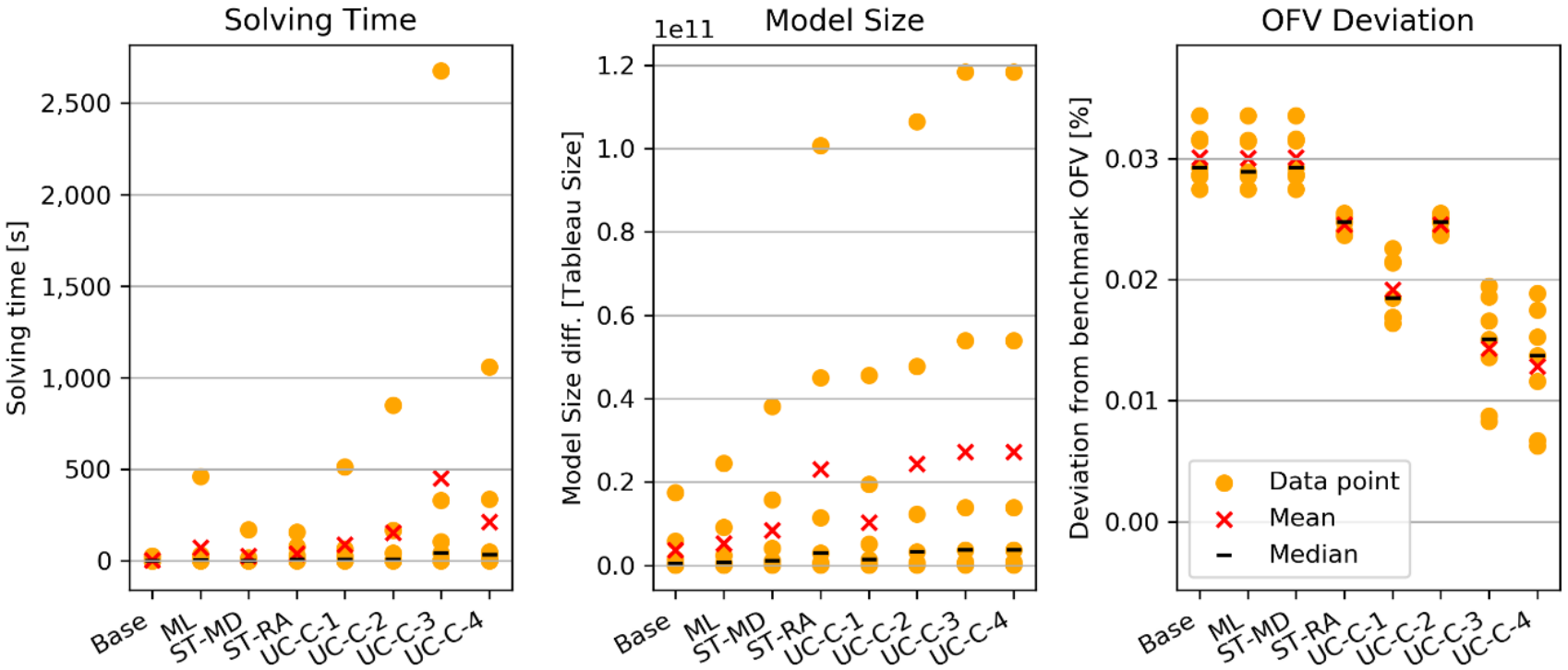
Complexity and accuracy drivers in power system optimization models

Example: Mutually evaluated constraints for operational detail:



- Accuracy driver: Multiple detailed operational constraints
- Complexity driver: Multiple dynamics constraints

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Conclusion & Outlook

Are complex power system optimization models more accurate?

- Yes, but: The **most accurate models are also the most complex** ones but the **marginal utility of additional complexity decreases**, leading to e.g. most of the Pareto optimal models being below 1.2% of the maximum solving time observed
- The Pareto frontier defines a **clear distinction** between preferable and non-preferable model formulation
- The **level of operational detail** drives the accuracy and the model size in dispatch models while multiple dynamics are the main driver regarding solving time

- The range of complexity levels discovered is large - showing the **potential for using computational resources** more efficiently
- The effort for implementing modular models and generating the data basis is extensive – calling for **generally accessible best practices**

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Thank you for your attention!

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