## Summer School on "Modelling, Simulation and Optimization for Energy Networks"

### *Programm:*

**<u>Wednesday, June 8th, 2022</u>**

**3.00 pm**: Falk Hante (HU Berlin)
*"Introduction to Mathematical Modelling, Simulation and Optimization using the Example of Gas Networks"*

**3.45 pm:** Frauke Liers (FAU Erlangen-Nürnberg)
*"Introduction to Robust Optimization"*

**4.30 pm:** Holger Heitsch (WIAS Berlin)
*"An algorithmic approach for solving optimization problems with probabilistic/robust (probust) constraints"*

Discussion with the Speakers (15min)

**<u>Thursday, June 9th, 2022</u>**

**10.00 am:** Falk Hante (HU Berlin)
*"Introduction to Optimal Control"*

**11:00 am:** Michael Schuster (FAU Erlangen-Nürnberg)
*"Probabilistic Constrained Optimization on Gas Networks"*

Discussion with the Speakers (15min)

**12:00 am - 1:00 pm:** Break

**1.00 pm:** Olivier Huber (WIAS Berlin)
*"Nash Equilibrium Problems"*

**1.45 pm:** Rico Raber (TU Berlin)
*"Packing under convex quadratic constraints"*

Discussion with the Speakers (15min)

**3.00 pm – 3.15 pm:** Break

**3.15 pm: Industrial Talk** by Maxime Grangereau (EDF, Électricité de France)
*"Upcoming challenges in the upcoming (electrical) energy system"*

Discussion with the Speakers (15min)

**4.30 pm:** Falk Hante (HU Berlin), Frauke Liers (FAU Erlangen-Nürnberg)
*“Closing“*

## *Abstracts:*

**Holger Heitsch** (WIAS Berlin)

*"An algorithmic approach for solving optimization problems with probabilistic/robust (probust) constraints"*

*Presented is an adaptive grid refinement algorithm to solve probabilistic optimization problems with infinitely many random constraints. Using a bilevel approach, inequalities that provide most information not in a geometric but in a probabilistic sense are aggregated iteratively. For this conceptual idea convergence can be proven and an adapted implementable algorithm is presented. The efficiency of the approach is shown for a water reservoir problem with joint probabilistic filling level constraints.*

**Michael Schuster** (FAU Erlangen-Nürnberg)

*"Probabilistic Constrained Optimization on Gas Networks"*

*Uncertainty often plays an important role in gas transport and probabilistic constraints are an excellent modeling tool to obtain controls and other quantities that are robust against perturbations in e.g., the boundary data. We consider both, a stationary and a dynamic gas transport model with uncertain boundary data on networks. We provide an efficient way to compute the probability that random boundary data is feasible. In this context feasible means that the pressure corresponding to the random boundary data meets some box constraints at the network junctions. Further we consider and analyze optimization problems with probabilistic constraints in the stationary and the dynamic setting. The probabilities are computed using the spheric radial decomposition and a kernel density estimator approach. Last we compare the solutions of the probabilistic constrained optimization problems with the solutions of the corresponding deterministic problems.*

*References*

*[1] M. Schuster, E. Strauch, M. Gugat and J. Lang (2021) Probabilistic Constrained Optimization on Flow Networks, Optim. Eng. (2021), https://doi.org/10.1007/s11081-021-09619-x.*

*[2] M. Schuster (2021) Nodal Control and Probabilistic Constrained Optimization using the Example of Gas Networks, Dissertation, FAU Erlangen-Nürnberg, Germany, 2021, https://opus4.kobv.de/opus4-trr154/frontdoor/index/index/docId/410.*

**Olivier Huber** (WIAS Berlin)

*"Nash Equilibrium Problems"*

*Motivated by the current evolution of energy markets, we consider a stylized gas market featuring Cournot competition. This is modeled as a Generalized Nash equilibrium problem where each producer looks to maximize their profit by transporting and selling gas. The time and space evolution of the gas flow obeys a system of PDE, which is a shared constraint for all players. To allow for economical interpretation of a solution to this game, we focus on the solution concept of variational equilibrium (VE). Under appropriate regularity and convexity assumptions, any VE also satisfies a variational inequality. This enables us to show the existence of a VE. We use this model to investigate the linepacking phenomenon, which is the use of the network as a temporary storage device. In particular, we highlight how additional linepacking ability is used and who benefits from it.*

**Rico Raber** (TU Berlin)

*"Packing under convex quadratic constraints"*

*We consider a general class of binary packing problems with multiple convex quadratic knapsack constraints. We present three constant-factor approximation algorithms based upon three different algorithmic techniques:*

*(1) a rounding technique tailored to a convex relaxation in conjunction with a non-convex relaxation;*

*(2) a greedy strategy;*

*and*

*(3) a randomized rounding method.*

*The practical performance is tested by a computational study of the empirical approximation of these algorithms for problem instances arising in the context of real-world gas transport networks.*

**Industrial Talk** by **Maxime Grangereau** (EDF, Électricité de France)

*"Upcoming challenges in the upcoming (electrical) energy system"*

*With the rising share of decentralized energy production systems on electricity networks, the paradigm for optimizing the electrical energy system is changing a lot. From a centralized control paradigm, with low short-term uncertainty, it is evolving towards a decentralized system, with multiple actors interacting through market, while the short term uncertainty becomes important due to the intermittency of the production by solar panels and wind turbines. This new paradigm requires the development of new mathematical methods in order to adjust the demand and control local flexibilities in order to stabilize the electrical system. We present a variety of these techniques (decomposition, stochastic control, mean-field games and control...) in the first part of the talk. In the second part of the talk, we present modelling challenges faced by electricity network operators, caused by local renewable sources, which create randomness, two-sided flows in power grids and local congestions in grid operations. We present several modelling approaches allowing to handle uncertainty, as well as convexification techniques (relaxations based on Semi-Definite Programming/Second-Order Cone Programming) of the constraints arising from the physical laws of electricity networks, in an effort to trade-off tractability, precision and performance.*