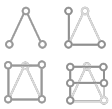
VAME 2024

Variational Analysis and Applications
for Modeling of Energy Exchange

Universität Trier



ALGORITHMIC
OPTIMIZATION

May 13 & 14, 2024

General Information

Venue

Bischöfliches Priesterseminar Trier
Jesuitenstraße 13
Trier, 54290

Organizing Committee

Laura Sokolowski
Martin Schmidt

Please do not hesitate to ask if you have any questions!

We gratefully acknowledge the support of

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Monday, May 13

9:00 – 9:30	Registration
9:30 – 10:00	Welcome (vice president Prof. Dr. Torsten Mattern)

Session #1 (Chair: Gregor Zöttl)

10:00 – 10:30	Rossana Riccardi *Transition in electricity market: a stochastic bilevel program with Contracts for Differences*
10:30 – 11:00	Giorgia Oggioni *Economic viability of new generation and storage units in a renewable-dominated power system: a bilevel approach*
11:00 – 11:30	Coffee break

Session #2 (Chair: Didier Aussel)

11:30 – 12:00	Wim Van Ackooij *A study of differentiability of probability functions involving star-shaped data*
12:00 – 12:30	Oliver Stein *A branch-and-bound algorithm for non-convex Nash equilibrium problems*
12:30 – 13:30	Lunch

Session #3 (Chair: David Salas)

14:00 – 14:30	Simone Sagratella *Addressing Hierarchical Jointly-Convex Generalized Nash Equilibrium Problems with Nonsmooth Payoffs*
14:30 – 15:00	René Henrion *Chance constraints in energy management and aspects of nonsmoothness*
15:00 – 15:30	Claudia Sagastizábl *Chance-constrained Stochastic Dynamic Dual Programming for Long-term Generation Planning of Hydro-thermal Systems with Increasing Shares of Distributed Generation*
15:30 – 16:00	Frauke Liers *Robust Gas Network Operation via an Outer Approximation Framework for Mixed-Integer Nonlinear Robust Optimization*
16:00 – 16:30	Coffee break

Session #4 (Chair: Rossana Riccardi)

16:30 – 17:00	Mel Devine *The interactions between demand- and supply-side green investment decisions in an oligopolistic market*
17:00 – 17:30	Steven Gabriel *Equilibrium Modeling in Natural Gas Markets: A Theoretical Analysis and a Case Study for Brazil*
17:30 – 18:00	Johannes Thürauf *Adjustable Robust Network Design for Energy Networks*
20:00	Wine Tasting & Conference Dinner (“Wirtshaus Zur Glocke”; Glockenstraße 12, 54290 Trier)

Tuesday, May 14

Session #5 (Chair: Giorgia Oggioni)

9:30 – 10:00 Luce Brotcorne
Optimal Optimal Electric Vehicle Charging with Dynamic Pricing

10:00 – 10:30 Jalal Kazempour
Electric Vehicles Bidding in Nordic Flexibility Markets: A Distributionally Robust Chance-Constrained Program

10:30 – 11:00 Coffee break

Session # 6 (Chair: Lorenzo Lampariello)

11:00 – 11:30 John Cotrina
Remarks on projected solutions for generalized Nash equilibrium problems

11:30 – 12:00 Anton Svensson
Lower semicontinuity of intersections of set-valued maps and applications on bilevel games

12:00 – 13:30 Lunch

Session #7 (Chair: Martine Labbé)

13:30 – 14:00 Ramteen Sioshansi
Comparing Profit-Maximizing Offer Behavior of Generators in Centrally Versus Self-Committed Wholesale Electricity Markets

14:00 – 14:30 Afzal Siddiqui
Transmission Planning in an Imperfectly Competitive Power Sector with Environmental Externalities

14:30 – 15:00 Salvador Pineda
Tight Big-Ms for Optimal Transmission Switching

Luce Brotcorne

Optimal Electric Vehicle Charging with Dynamic Pricing (Miguel F. Anjos, Luce Brotcorne and Gaël Guillot)

We consider a provider of electric vehicle charging stations that operates a network of charging stations and use time varying pricing to maximize profit and reduce the impact on the electric grid. We propose a bilevel model with a single leader and multiple disjoint followers. The customers (followers) makes decisions independently from each the other. The provider (leader) sets the prices for each station at each time slot, and ensures there is enough energy to charge. The charging choice of each customer is represented by a combination of a preference list of (station, time) pairs and a reserve price. The proposed model takes thus into accounts for the heterogeneity of customers with respect to price sensitivity and charging preferences. We define a single level reformulation based on the reformulation for the rank pricing problem. Numerical results put into highlight the efficiency of the new reformulation and the impact of the model on the grid peaks.

John Cotrina

Remarks on projected solutions for generalized Nash equilibrium problems

In this talk, we focus on the concept of projected solutions for generalized Nash equilibrium problems. We show that projected solutions correspond to classical Nash equilibria of an auxiliary generalized Nash equilibrium problem obtained by adding a new player.

Mel Devine

The interactions between demand- and supply-side green investment decisions in an oligopolistic market (Mel T. Devine, Valentin Bertsch)

To meet carbon reduction targets, there will need to be investment in a range of different green technologies in electricity markets across the world. For instance, investment in wind energy, solar PV, and battery storage. In this work, we consider what the optimal investment mix for these technologies will be from the perspective of both generating firms and consumers. To do so, we develop a game theory optimisation problem where several generating firms maximise their profits while various consumer groups minimise their demand. All players modelled make hourly operational decisions in addition to long-term investment decisions. The generating firms may exert market power. That is, they may strategically choose they generation decisions so as to increase the market price and thus enhance their profits. The model takes the form of a stochastic Mixed Complementarity Problem and is solved using a Benders Decomposition Algorithm. The uncertainty of wind (both onshore and offshore) and solar PV are the sources of the model's stochasticity. We apply the model to a case study of the Irish electricity system in 2030, which is envisaged to have a significant presence of renewable sources. We consider the optimal investment mix when market power is both present and absent from the market. Previous similar work either neglected investment decisions or market power. We observe that the presence of market power increases electricity prices which leads to increased generating firms' profits and consumer costs. It also leads to increased investment in renewable technologies and battery storage, which leads to reduced carbon emissions. Furthermore, we consider the effect a Feed-in-Premium (FiP) has on renewable investment and observe a counter-intuitive result whereby the absence of a FiP leads to less investment in renewables from generation companies but, consequently, increased investment in renewables from consumers.

Steven Gabriel

Equilibrium Modeling in Natural Gas Markets: A Theoretical Analysis and a Case Study for Brazil

We present an abstract view of natural gas markets to offer a theoretical discussion on the existence and prove uniqueness of equilibrium solutions. In the abstract model, each player solves a separate profit-maximization optimization problem, the optimality conditions of which can be concatenated together along with market-clearing conditions to give rise to a mixed complementarity problem. The equilibrium-based approach features a general framework that allows for the analysis of a convex combination of price-taking and price-making strategies for producers with a particular Cournot coefficient. As a new motivation for such an analysis, we apply the model to a gas market in transition as is the case in Brazil, which has undergone significant regulatory changes aimed at making it more open and competitive. By demonstrating a sensitivity analysis of market competition on an illustrative Brazilian gas network, we offer new insights to competitive natural gas market modeling.

René Henrion

Chance constraints in energy management and aspects of nonsmoothness

Chance constraints have been introduced as a model of operations research some seventy years ago. They allow robust decision making in the presence of uncertain constraints. Feasibility is enforced at a given probability according to the distribution of randomness. Prominent classical applications in energy management were devoted, for instance, to the optimal control of hydro reservoirs. In recent years, the focus has shifted from traditional finite-dimensional problems of nonlinear optimization to more complicated structures like hierarchical optimization or PDE constrained risk averse optimisation. The talk addresses applications of chance constraints to capacity maximization in gas networks, to probabilistic islanding of minigrids, and to power and gas market models in the presence of uncertain demand. As a particular challenge, the aspect of nonsmoothness is discussed.

Jalal Kazempour

Electric Vehicles Bidding in Nordic Flexibility Markets: A Distributionally Robust Chance-Constrained Program

We will present a distributionally robust chance-constrained model that enables the aggregators of electric vehicles to place informed reserve bids in the Nordic flexibility markets, in particular frequency containment reserve for disturbances (FCR-D) markets. Using real data from Denmark, we will show the synergy effect among vehicles, and challenge the current practice of the Danish TSO on the pre-qualification of demand-side assets bidding in such markets.

Frauke Liers

Robust Gas Network Operation via an Outer Approximation Framework for Mixed-Integer Nonlinear Robust Optimization

In this talk, we present an algorithm for convex mixed-integer nonlinear robust optimization where a key feature is that the method does not rely on a specific structure of the inner worst-case (adversarial) problem and allows the latter to be non-convex. A major challenge of such a general nonlinear setting is ensuring robust protection, as this calls for a global solution of the nonconvex adversarial problem. Our method achieves this up to a tolerance, by requiring worst-case evaluations only up to a certain precision. The necessary assumptions can for example be met by approximating a non-convex adversarial via piecewise relaxations and solving the resulting problem up to any requested error as a mixed-integer linear problem.

In our approach, we model a robust optimization problem as a nonsmooth mixed-integer nonlinear problem and tackle it by outer approximation that requires only inexact function values and subgradients. To deal with the arising nonlinear subproblems, we present a novel adaptive bundle method and extend it to generate cutting planes that are valid up to a known precision. We obtain finite convergence of the method.

We study the gas transport problem under uncertainties in demand and physical parameters on realistic instances and provide computational results demonstrating the efficiency of our method. This is joint work with Daniela Bernhard (FAU), Martina Kuchlbauer (UTN) and Michael Stingl (FAU).

Giorgia Oggioni

Economic viability of new generation and storage units in a renewable-dominated power system: a bilevel approach (Miguel Carrión, Ruth Domínguez, Giorgia Oggioni, Rafael Zárate-Miñano)

The economic viability of electricity markets is essential for attracting the investments needed to ensure both the security of energy supply and the clean energy transition. Electricity prices should allow for the cost recovery. However, the increasing renewable-based capacity with almost zero operating costs significantly reduces pool prices at certain hours. Therefore, the economic income of new power and storage plants may be much smaller than expected if the current installation rate of new renewable units is maintained or increased. This may discourage investments leading to possible reliability problems of the power system. In this work, we propose a stochastic bilevel programming model in which a certain level of renewable energy penetration and the cost recovery of investments in new generation and storage units are enforced. In the upper-level problem, the market operator minimizes the total investment costs, considering the limits on investment decisions, the maximum non-renewable production, the units' technical constraints, and the cost recovery constraint. The lower-level problem simulates the energy and reserve capacity market clearing processes. The analysis is carried out using real data and considering different sensitivity analyses.

Salvador Pineda

Tight Big-Ms for Optimal Transmission Switching

This work addresses the Optimal Transmission Switching (OTS) problem in electricity networks, which aims to find an optimal power grid topology that minimizes system operation costs while satisfying physical and operational constraints. Existing methods typically convert the OTS problem into a Mixed-Integer Linear Program (MILP) using big-M constants. However, the computational performance of these approaches relies significantly on the tightness of these big-Ms. In this paper, we propose an iterative tightening strategy to strengthen the big-Ms by efficiently solving a series of bounding problems that account for the economics of the OTS objective function through an upper-bound on the generating cost. We also discuss how the performance of the proposed tightening strategy is enhanced if reduced line capacities are considered. Using the 118-bus test system we demonstrate that the proposed methodology outperforms existing approaches, offering tighter bounds and significantly reducing the computational burden of the OTS problem.

Rossana Riccardi

Transition in electricity market: a stochastic bilevel program with Contracts for Differences

(Ruth Dominguez, Giorgia Oggioni, Rossana Riccardi, Carlos Ruiz Mora)

In this work, we propose a stochastic bilevel programming problem in which regulators auction off contracts for differences (CfD) for wind technologies. The market regulator seeks to minimize the costs of derivative contracts while trying to finance expansion projects up to a certain production capacity. In this context, the wind producers have to decide how much capacity to trade through CfD contracts and how much in the spot markets. Thus, producers offer a bid price for installing new capacity through the CfD contract. Then, the regulator clears the bids and assigns the wind capacity accepted to be covered by the CfD contracts. In addition, we model the case in which the wind producer owns an energy storage (battery) that is connected to the wind farm and allows to counteract the variability of the wind power. The analysis is carried out on the Spanish electricity market and different sensitivity analyses on how to determine the reference price (hour-by-hour day-ahead (DA) price, DA price over a longer period, including intraday and/or balancing prices) and on different sizes of the battery are conducted.

Claudia Sagastizábal

Chance-constrained Stochastic Dynamic Dual Programming for Long-term Generation Planning of Hydro-thermal Systems with Increasing Shares of Distributed Generation
(Williams López, Claudia Sagastizábal, André Luiz Diniz)

Since distributed generation technologies emerged to reduce carbon-intensive sources of electric energy, their share in the energy balance has grown consistently, most notably in the last decade. Distributed generation lessens the environmental impact, but it also makes the system load more volatile. For hydro-thermal systems like Brazil's, this means that not only inflows but also a share of electricity consumption becomes stochastic data. We propose a chance-constrained approach for the long term generation planning problem with demand uncertainty. The distribution function is based on estimates of distributed generation future growth. Thanks to a suitable mathematical reformulation, the new model continues to be solvable by stochastic dual dynamic programming. Results on real data show the impact of the increasing penetration of distributed generation in the mix. Higher shares of distributed generation need more back-up conventional sources, highlighting the need of properly balancing sustainability with idle capacity issues.

Simone Sagratella

Addressing Hierarchical Jointly-Convex Generalized Nash Equilibrium Problems with Nonsmooth Payoffs

We consider a Generalized Nash Equilibrium Problem whose joint feasible region is implicitly defined as the solution set of another Nash game. This structure arises e.g. in multi-portfolio selection contexts, whenever agents interact at different hierarchical levels. We consider nonsmooth terms in all players' objectives, to promote, for example, sparsity in the solution. Under standard assumptions, we show that the equilibrium problems we deal with have a nonempty solution set and turn out to be jointly convex. To compute variational equilibria, we devise first-order projection Tikhonov-like methods whose convergence properties are studied. We provide complexity bounds and we equip our analysis with numerical tests using real-world financial datasets.

Afzal Siddiqui

Transmission Planning in an Imperfectly Competitive Power Sector with Environmental Externalities

Policymakers face the challenge of integrating intermittent output from variable renewable energy (VRE). Even in a well-functioning power sector with flexible generation, producers' incentives may not align with society's welfare-maximisation objective. At the same time, political pressure can obstruct policymakers from pricing damage from CO2 emissions according to its social costs. In facilitating decarbonisation, transmission planning will have to adapt to such economic and environmental distortions. Using a Stackelberg model of the Nordic power sector, we find that a first-best transmission-expansion plan involves better resource sharing between zones, which actually reduces the need for some VRE adoption. Next, we allow for departures from perfect competition and identify an extended transmission-expansion plan under market power by nuclear plants. By contrast, temporal arbitrage by hydro reservoirs does not necessitate transmission expansion beyond that of perfect competition because it incentivises sufficient VRE adoption using existing lines. Meanwhile, incomplete CO2 pricing under perfect competition requires a transmission plan that matches hydro-rich zones with sites for VRE adoption. However, since incomplete CO2 pricing leaves fossil-fuelled generation economically viable, it reduces the leverage of strategic producers, thereby catalysing less (more) extensive transmission expansion under market power by nuclear (hydro) plants.

Ramteen Sioshansi

Comparing Profit-Maximizing Offer Behavior of Generators in Centrally Versus Self-Committed Wholesale Electricity Markets

We study the incentive properties of the two primary approaches to incorporating unit-commitment decisions in wholesale electricity markets. One approach is centralized unit commitment, wherein generating firms provide complex multi-part offers that specify their non-convex fixed and variable operating costs. The second approach is self-commitment, whereby firms determine unit-commitment decisions for their generating units individually and submit simple offers for the provision of energy. We find that the profit of the profit-maximizing firm does not differ significantly between the two market designs but that system costs can be higher under a self-committed design.

Oliver Stein

A branch-and-bound algorithm for non-convex Nash equilibrium problems

We present the first spatial branch-and-bound method for the computation of the set of all epsilon-Nash equilibria of continuous box-constrained non-convex Nash equilibrium problems with an approximation guarantee. Thereby, the existence of epsilon-Nash equilibria is not assumed, but the algorithm is also able to detect their absence. After a brief introduction to branch-and-bound ideas in global optimization, we explain appropriate discarding and fathoming techniques for Nash equilibrium problems, formulate convergence results for the proposed algorithm, and report our computational experience.

Anton Svensson

Lower semicontinuity of intersections of set-valued maps and applications on bilevel games

We discuss about the lower semicontinuity of set-valued maps, which is a crucial concept in parametric optimization and game theory. The focus is on the intersection of set-valued maps and the preservation of lower semicontinuity under this operation. We present new results based on some minimal properties that ensure the lower semicontinuity of the intersection with other lower semicontinuous maps. Additionally, the lower semicontinuity of the intersection of an infinite family of set-valued maps is considered. We provide an example to illustrate the application of this concept in bilevel games.

Johannes Thürauf

Adjustable Robust Network Design for Energy Networks

We study network design problems for nonlinear and nonconvex flow models under demand uncertainties. To this end, we apply the concept of adjustable robust optimization to compute a network design that admits a feasible transport for all, possibly infinitely many, demand scenarios within a given uncertainty set. For solving the corresponding adjustable robust mixed-integer nonlinear optimization problem, we show that a given network design is robust feasible, i.e., it admits a feasible transport for all demand uncertainties, if and only if a finite number of worst-case demand scenarios can be routed through the network. We compute these worst-case scenarios by solving polynomially many nonlinear optimization problems. Embedding this result for robust feasibility in an adversarial approach leads to an exact algorithm that computes an optimal robust network design in a finite number of iterations. Since all of the results are valid for general potential-based flows, the approach can be applied to different energy networks such as gas, hydrogen, or lossless DC power flow networks. We finally demonstrate the applicability of the method by computing robust gas networks that are protected from future demand fluctuations.

Wim Van Ackooij

A study of differentiability of probability functions involving star-shaped data

(Co-Authors : Pedro Pérez-Aros, Claudia Soto, René Henrion)

Motivated by an example from control wherein the dynamics are driven by uncertainty and a given “here-and-now” control, we define a feasible trajectory as one achieving the target with high probability. The resulting probability function measures the probabilistic contents of a “star-shaped” set. In this talk we will investigate several implications for the probability function and notably discuss under what assumptions some degree of differentiability can be expected.