Transregio-CRC 154 on Mathematical Modelling, Simulation and Optimization Using the Example of Gas Networks invites applications for PhD positions

The consortium of the Transregio-CRC 154, see www.trr154.fau.de, is seeking highly motivated and qualified students that are looking for obtaining a PhD degree in applied mathematics. Once recruited, you will perform research in a highly relevant research area in applied mathematics that is centered around the "turnaround in energy policy", in particular in the context of gas networks. The main aim of the Transregio-CRC is to provide certified novel answers to mathematical challenges arising in this context, based on mathematical modeling, simulation, and optimization. In order to achieve these goals new paradigms in the integration of these disciplines and, in particular, in the interplay between integer and nonlinear programming in the context of stochastic data have to be established and brought to bear.

The TRR154 is financed by the German Science Foundation, the second funding phase lasts from July 1st, 2018, until June 30th, 2022. The TRR154 project descriptions and other details are contained in the corresponding attachment.

The call for applications is open until June 22nd, 2018. The deadline might be extended until all positions are filled. We especially encourage applications by female candidates.

Who can apply?

You are eligible to apply for a position within the TRR 154, if

- you either hold or are about to obtain a M.Sc. degree by the starting date of the PhD project, in one of the following areas: Mathematics, Computer Science, or in a closely related field
- you are proficient in the English language
- knowledge of the German language is not a must.

What can you expect from a position in the TRR 154?

Once recruited, we will offer:

- The possibility to perform research with us in mathematical modelling, simulation and optimization in a highly innovative and active research area in applied mathematics.
- Remuneration is at E 13 TV-L (75%), according to the German public service salary scale).
- Apart from the individual research project, your research program will include trans-regional summer and winter schools, regular lectures and block courses given by guest researchers as well as lecture series that at each site are specifically designed for the main research fields of the TRR 154.
- You will be assigned two mentors that are PIs in the TRR 154 who will guide you through your PhD research project.
- We aim at an equal representation of women and men at all levels. At each of the member sites, gender equality offices are at the TRR's disposal that offer different services for its university members. Furthermore, the TRR 154 has financial resources with which it finances equal opportunity measures, for example courses that increase the career chances of young female researchers. The TRR also finances measures for improving the compatibility of work and family life, which includes contingents of child care places, emergency and holiday care for children

and care-dependent relatives. Further details can be found at https://trr154.fau.de/index.php/en/gender-mainstreaming.

How can you apply?

With a **single** application, you may apply for more than one fellowship within the TRR 154 (maximum 10), in order of preference.

You will need to provide us with the following documents:

a) Application form (see attachment)
b) Letter of motivation (max. 1 page)
c) Copies of degree and academic transcripts (with grades and rankings)
d) Brief summary of Master's thesis (max. 1 page)
e) Short CV including letter/s of recommendation and publication list (if any)

All the above-mentioned documents **must** be collected in a single pdf file and have to be uploaded on EasyChair on

https://easychair.org/conferences/?conf=trr154-2018

after creating an account on easychair.org.
Please include your data for “author 1” and tick the “corresponding author” box.
As title and as abstract, please choose “Application for TRR 154”.
As keywords, please give the same ranking of the TRR 154 subprojects you apply to as you have given in the application form.
We will only consider applications if they are uploaded there.

What happens after you have applied?

We will come back to you soon after the application deadline is over. Shortlisted candidates will be invited for an interview (traveling to each partner's site may not be necessary). Winners will be announced as soon as possible. Applications received after the deadline might still be considered if the corresponding positions have not been filled yet.

A summary of the subprojects is given below:

A01: Global Methods for stationary and instationary gas transport

Marc Pfetsch, Stefan Ulbrich (TU Darmstadt)

The goal of this project is to develop methods for the global solution of optimization problems subject to ODE or PDE constraints and integer decisions. One the one hand this should be performed for instationary gas flow and on the other hand for topology planing problems. The key issue is the development of good lower and upper bounds for the solutions and an adequate handling of the integer decisions.

A02: Analysis und consistent numerical approximation of optimization problems for hyperbolic PDE models of gas networks

Stefan Ulbrich (TU Darmstadt)

We consider the analysis and consistent numerical discretization of optimization problems for transient hyperbolic PDE models of gas networks with state constraints. We plan to analyze the convergence of numerical approximations and the corresponding sensitivities and adjoints for optimization problems governed by systems of hyperbolic balance laws on networks with continuous and switching controls. Moreover, the sensitivity and adjoint calculus developed in the first phase shall be extended to more general BV solutions on networks.

A03: Mixed integer-continuous dynamical systems with partial differential equations

Falk Hante (FAU Erlangen-Nürnberg)

The aim of the project is the development of control theory for mixed integer-continuous (hybrid) dynamical systems comprising partial differential equations. Based on regularity and sensitivity results obtained in the first funding period the project now designs and investigates receding horizon methods that are able to take decisions based on optimality principles for the control of such systems also under uncertainties for example being applicable for the control of a gas network by valves in non-stationary situations.

A05: Decomposition methods for mixed-integer optimal control

Günter Leugering, Alexander Martin, Martin Schmidt (FAU Erlangen-Nürnberg)

In order to achieve a holistic MINLP solution for optimization problems constrained by the semilinear Euler equations in gas networks, we extend the decomposition methods of the first funding period by a time-domain decomposition on the continuous level that allows for an iterative “space-time” (on subgraph as well as time intervals) decomposition adapted to the complexity of the problem and to the capabilities of current MINLP techniques for the time-discrete problem in order to handle time-expanded MINLPs via block-structured methods, whereby MIP-relaxation techniques will play an important role.

A07: Combinatorial network flow methods for instationary gas flows and gas market problems

Max Klimm (HU Berlin), Marc Pfetsch (TU Darmstadt), Martin Skutella (TU Berlin)

The project studies the optimization of the capacity usage of gas networks with efficient network flow methods. Based on structural insights and algorithms for the computation of instationary flows in time-expanded networks, new (approximation) algorithms for the robust and online-optimization of gas networks are devised. Finally, the allocation of the network capacities in incentive-compatible auctions is studied.

B01: Adaptive Dynamic Multiscale Approaches

Pia Domschke (TU Darmstadt), Jens Lang (TU Darmstadt)

The focus of this project is the application of a dynamic multiscale approach for the description of the stochastic behaviour of practically relevant output values with respect to randomized parameters in compressible, instationary Euler equations on network structures (uncertainty quantification), for the construction of reduced order models and for an adaptive multilevel optimization. For this, adaptive stochastic collocation methods with multilevel-like algorithms for variance reduction will be used.

B02: Multicriteria optimization subject to equilibrium constraints at the example of gas markets

Michael Hintermüller (WIAS Berlin)

The objective is to provide a mathematical description of markets that are coupled with physical processes for investigating economic questions regarding the behavior of market participants or optimal capacity utilization of the transport network. The main focus lies on analyzing generalized Nash equilibrium problems that include the physical processes as well as state- and control-constraints, the efficient numerical treatment of such problems and consideration of agents that are risk-averse against uncertainties in various parameters of the mathematical model.

B03: Controlled coupling of mixed integer-continuous port-Hamiltonian network models

Volker Mehrmann (TU Berlin)

The goal of the project is to develop a new methodology for the coupling of mathematical models with strongly different modeling accuracy and different scales in a network. It is planned to use a system theoretic approach as models of port-Hamiltonian (pH) systems of differential-algebraic equations. A second topic is the data-based construction of pH surrogate models, e.g., for compressor stations, that can be implemented in the model hierarchy, as well as the structured incorporation of hybrid model components, such as valves. The third topic is the development of structure preserving model reduction methods for the network components as well as the whole network, including appropriate error estimates.

B04: Chance constraints in gas market models

René Henrion (WIAS Berlin)

The project is devoted to the consideration of uncertainties in gas transport, mostly random loads, via chance constraints. These allow one to find optimal and robust decisions in the sense of probability. The focus of future research will be on embedding of such constraints into equilibrium problems (MPECs). Doing so, one may complete gas market models by a component taking into account robust load satisfaction. This requires both a theoretical analysis of structure and the development of appropriate algorithms.

B05: Stochastic Optimization in Gas Transport

Rüdiger Schultz (Uni Duisburg-Essen)

The aim of the project is in the extension of results from Phase 1 on characterizing nomination validity in computationally feasible fashion for strongly meshed gas networks under stochastic uncertainty. To this end, recent results from symbolic computation (comprehensive Gröbner systems) are employed. Moreover, approaches to risk averse optimization in stochastic gas networks with network constraints and different market models, for instance, with or without nodal pricing will be developed.

B06: Robust Optimization of Gas Networks

Frauke Liers, Michael Stingl (FAU Erlangen-Nürnberg)

The focus of this research project consists in modelling of robust optimization problems in gas networks, their theoretical analysis, as well as the development of appropriate solution approaches. Building upon the results of the first funding phase for the stationary setting, decomposition approaches will be developed for the resulting two-stage robust optimization problems with uncertainties in the demands as well as in the physical parameters. The decomposition approach envisaged here enables a generalization towards the instationary case and coupled robust-stochastic optimization tasks. Market aspects will be integrated via welfare optimization in the nodal price system.

B07: MIP techniques for equilibrium models with integer constraints

Alexander Martin, Lars Schewe (FAU Erlangen-Nürnberg)

In this subproject we will develop techniques to solve equilibrium problems with integer constraints using MIP techniques. To this end, we will consider first mixed-integer linear, then mixed-integer nonlinear problems as subproblems. To solve the resulting problems we will study both complete descriptions as also generalized KKT theorems for mixed-integer nonlinear optimization problems.

B08: Multilevel mixed-integer nonlinear optimization for gas markets

Veronika Grimm, Martin Schmidt (FAU Erlangen-Nürnberg)

The main goal of this project is the development of mathematical methods for the solution of multilevel, mixed-integer, and nonlinear optimization models for gas markets. To this end, the focus is on a genuine four-level model of the entry-exit system that can be reformulated as a Bilevel model. The mathematical and algorithmic insights shall then be used to characterize market solutions in the entry-exit system and to compare them to system optima. Particular attention is paid to booking prices for entry or exit capacity.

B09: Strategic Booking Decisions in the Entry-Exit-System

Alexandra Schwartz (TU Darmstadt), Gregor Zöttl (FAU Erlangen-Nürnberg)

The goal of the project is to develop methods for analyzing strategic interaction in gas markets based on multi-level optimization models. We formulate the strategic interaction resulting from firms' booking and nomination decisions as an equilibrium problem with equilibrium constraints (EPEC). Exploiting from the specific mathematical structure of the considered problem we derive analytic results regarding existence and uniqueness of solutions of the resulting EPEC and develop suitable algorithms to determine the equilibria of the considered market games. Based on the theoretical and algorithmic results we assess the impact of strategic interaction on booking prices and market outcomes and determine how those results change for different market structures and market designs.

C02: Numerical analysis and simulation of overdetermined DAEs in the context of optimization of transient compressor control in gas networks

Caren Tischendorf (HU Berlin)

Aim of this project is the combination of simulation and optimization, with special focus on the control of transient compressors, the admissibility of pressures and mass flows and with the aim to overcome problems concerning the simulation due to the opening and closing of valves. As methodical way we pursue an approach of the form 1. discretize in space 2. optimize 3. discretize in time. The focus rests on new approaches for the time discretization of the resulting DAE by a least-squares collocation method that has regularizing properties and is robust with respect to switching structures.

C03: Nodal control and the turnpike phenomenon

Martin Gugat (FAU Erlangen-Nürnberg), Rüdiger Schultz (Uni Duisburg-Essen)

Turnpike results provide connections between the solutions of transient and the corresponding stationary optimal control problems that are often used as models in the control of gas transport networks. In this way turnpike results give a theoretical foundation for the approximation of transient optimal controls by the solutions of stationary optimal control problems that have a simpler structure. Turnpike studies can also be considered as investigations of the structure of the transient optimal controls. In the best case the stationary optimal controls approximate the transient optimal controls exponentially fast.

C04: Galerkin methods for the simulation, calibration, and control of partial differential equations on networks

Herbert Egger (TU Darmstadt), Michael Hintermüller (WIAS Berlin)

The main goal of this subproject is the systematic numerical approximation of systems of partial differential equations on networks, which arise in the modeling of gas transport. The focus lies on new kinds of Galerkin methods which, due to their variational structure, allow an efficient treatment of corresponding problems on a higher level, e.g., the calibration and optimal control of gas networks.

Z03: Central tasks of the Collaborative Research Centre

Alexander Martin (FAU Erlangen-Nürnberg)

A general manager will take care of the following organisational tasks within the TRR 154: Coordination and organisation of the international conference *Mathematics of Gas Transport* in 2020 and 2022, presentations of the TRR 154 at scientific conferences, maintenance of the website trr154.fau.de, support for the TRR 154 Scientific Advisory Board and international guests, coordination and organization of public relations tasks, support in organising the TRR meetings, coordination of the creation of a web game about controlling gas networks, assistance in the organisation of the Integrated Graduate College, support of the TRR 154 Gender Equality Team, support for the creation and maintenance of the test instances generated in the subprojects.