POEMA

H2020-MSCA-ITN-2018

Polynomial Optimization, Efficiency through Moments and Algebra

PERSONAL CAREER DEVELOPMENT PLAN

Project	
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Introduction

The Personal Career Development Plan (PCDP) describes both near and long term objectives of the fellow, to reflect on their progress, plan their future development, and take actions to realize their plans. The document must be completed and updated every 12 month by the fellow and his/her advisor. It will be monitored yearly by the Educational Committee who will also provide the feedback assessment results of the training programme on the occasion of the yearly meeting. Major deviations from the plan should be reported to the Educational Committee.

1 Individual Research Plan

1.1 Host Institution

Artelys

1.2 PhD Advisor(s)

Doctoral advisor: Bernard Mourrain

Main supervisor at Artelys: Michaël Gabay

1.3 PhD Thesis Supervisor Committee (if applicable)

1.4 Short overall project description

The student will investigate Polynomial Optimization techniques as well as Optimal Power Flow problems.

He will understand how a power system works, what an Optimal Power Flow problem is and what models are best in order to optimize the operations of power systems (especially with respect to transmission and distribution networks).

He will design new models for state estimation and optimization of Power Systems. Especially, he will make use of Polynomial Optimization techniques in order to build strong relaxations for optimal power flow problems. Especially, he will understand the state of the art with respect to SOCP and SDP relaxations and build new tractable and strong relaxation schemes.

He will implement new general and/or specific optimization algorithms in order to tackle these problems and experiment them within and versus existing algorithms in the commercial solver Artelys Knitro.

1.5 First secondment

CNRS (Toulouse, France) working with Professor D. Henrion

1.6 Second secondment

Tilburg University (Tilburg, The Netherlands) working with Professor E. de Klerk

2 Research Outputs, Dissemination and Mobility

2.1 Research results

We focus on the development of polynomial formulations of the Optimal Power Flow problem that are tractable for large scale networks. In particular, with relaxations yielding global solutions or strong lower bounds.

Variations on the Optimal Power Flow problem are considered and, thus, research results cover the following topics:

1) Efficient global optimization of classical Optimal Power Flow instances via Moment-based relaxations: Formulation of new convex relaxations for this problem has been achieved. However, the lower bounds yielded by these relaxations are not as tight as desired. This work generated insights for improvement of Moment-based relaxations using different sparsity-exploiting techniques to those presented in the literature; the ongoing research focuses in this promising direction.

2) Inclusion of discrete control devices such as transformers and shunt elements into the Optimal Power Flow model and solution via nonlinear mixed-integer formulations: Development of nonlinear mixed-integer models to solve this problem; heuristics used in the solution yield results comparable with those of state-of-the-art techniques but with a reduction of computational time. Thus, we next consider partial and/or total convexification of our models get better solutions.

3) Optimization techniques for power networks reconfiguration after a failure in the network should occur (N-1 security constraints). As a result of last period's research and experience working with the Optimal Power Flow problem, we will as a next step, apply and evaluate the techniques on a real-world application from Artelys. This project is expected to result in the efficient implementation of a mixed-integer model that allows to find suboptimal feasible solutions in the least computational time possible.

2.2 Research publications

We focus on the Optimal Power Flow problem which is both a quadratic polynomial program and a power network optimization problem. Hence, publications of research results are interesting for both the polynomial and power network optimization communities.

Although no publication has been made yet, once our partial results are refined, we aim for presentation of our results in an electrical engineering conference and publication of papers in applied mathematics journals.

2.3 Dissemination and networking

(15/01/2020-17/01/2020) 1st POEMA workshop - Research introductive workshop on Polynomial Optimization and Moments (to be attended on January 15th), Department of Mathematics and Computer Science, Florence, Italy.

(27/05/2020-16/09/2020) POEMA first learning week - Mathematical Foundations of convex and polynomial optimization Fachbereich Mathematik und Statistik
Universität Konstanz, Konstanz, Germany.

(15/10/2020) POEMA ESR DAY. Series of online seminars aimed to foster collaboration among the ESR researchers.

(20/10/2020-11/12/2020) 2nd POEMA workshop - Foundations of Polynomial Optimization , Fachbereich Mathematik und Statistik
Universität Konstanz, Konstanz, Germany.

(29/01/2021-17/02/2021) 3rd POEMA workshop – Current research panorama in mathematical programming and global optimization.

(Summer-Autumn 2021) First Secondment at CNRS with Prof. Didier Henrion.

2.4 Software, Data, other

Common use of Julia programming language has allowed us to interact with other members of the project and integrate their packages, such as MomentTools or PolynomialMomentOptimization, to our work. For instance, adding power network optimization problems to POEMA's database.

We have implemented our models using JuMP to interface with Knitro and Mosek solvers. In particular, Knitro solver is used for nonlinear mixed-integer programs while Mosek solver is used to solve convex programs.

New models arising in the research may require of specialized solvers for efficient computation. In particular, low-rank SDP solvers will be an important tool for optimization of large-scale networks. This generates the opportunity to collaborate with other researchers in the network that are working in the development of this kind of solvers.

3 Personal Training Plan

3.1 Scientific training courses

Scientific training will mainly consider courses offered by Université Côte d'Azur on topics related to: Numerical Optimization, Power Systems Analysis, Operations Research, Linear Algebra and Numerical Programming.

Training in polynomial optimization has been received from the POEMA network. At this point, two workshops and one learning week have been attended. Third workshop is to be attended soon.

3.2 Complementary training courses

Conferences, workshops and schools on continuous optimization, mixed-integer nonlinear programming, polynomial optimization and power networks optimization.

3.3 Professional skill development

- Collaboration with optimization experts, numerical engineers and power system experts: collaboration with Next project team at Artelys.
- Presentation of results in seminars, in English or in French: first presentation of first year's research results has taken place within Artelys premises.
- Discussion of technical issues of Power Systems optimization among specialists in the context of the seminars of related projects at Artelys.

4 Personal Career Development

4.1 Plan for the next period

Development of new convex relaxations for the Optimal Power Flow problem that are based on moment relaxations and are applicable to large-scale network optimization when the sparsity of the network is exploited.

Development of algorithms for efficient design of N-1 security constrained power networks. In particular, switch manipulation for network reconfiguration after a failure occurs. Limited scope to radial power networks will allow to study some specializations for efficient computation on networks with this particular topology.

Expansion on the research topics and applications motivated by my first secondment at CNRS.

In particular, the experience of the first year will allow us to focus on concrete well-defined objectives and problems. General knowledge of Optimal Power Flow problems will allow us to focus on particular applications. For instance, handling of N-1 security constraints.

Cooperation within the Consortium will be motivated. The secondments will be of special interest in order to generate opportunities of collaboration with other members of the project. Application and/or adaptation of solution techniques developed for other applications outside the Optimal Power Flow problem can be explored in order to improve our results. At the same time, our solution techniques can be of interest for other members dealing with similar optimization problems. Thus, team effort will be of relevance for the progress of the project.

Collaboration with other colleagues at Artelys will be motivated as well. Immediate action considers tackling of Optimal Power Flow problems with discrete control devices, but this area of action could be extended in the near future.

4.2 Career objectives (Postdoctoral project, …)

- To gain expertise on the optimization of power system networks.
- To develop sufficient mathematical modeling skills during the PhD in order to be able to continue working with real-world problems in the future and keep working at Artelys.