PhD position on Polynomial Optimization Techniques for Energy Network Operation and Design

This PhD position is funded by the Marie Skłodowska-Curie program of European Union through the innovative training network (ITN) POEMA on polynomial optimization.

More information and applications at https://easychair.org/cfp/POEMA-19-22

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Artelys is an international company based in France (HQ), with offices in Brussels (Belgium), Chicago (US) and Montréal (Canada). Artelys is specialized in optimization, decision-making and modeling. Relying on their high level of expertise in quantitative methods, Artelys' consultants deliver efficient solutions to complex business problems. They provide services to numerous industries: Energy & Environment, Logistics & Transportation, Telecommunications, Finance, Defense, etc.

Artelys offers a wide variety of services, including software solutions (optimization solvers, business specific solutions & specific software developments), consulting, project management assistance, training, etc. For instance, Artelys develops **Knitro**, a state-of-the-art nonlinear optimization solver, and also the Artelys Crystal software suite which addresses specific business problems (especially in the energy sector and planning) including optimization and visualization tools.

The company was founded with an ambition to provide sound quantitative analysis for daily business decisions and its reputation and growth rely on a number of key values such as competence and experience, commitment to deliver and client satisfaction.

Keywords: combinatorial optimization, nonlinear optimization, mixed integer programming, optimal power flow.

Scientific context

Energy network optimization problems are a challenging class of nonlinear optimization programs for existing optimization solvers. A good example is the Optimal Power Flow (OPF) problem [1], which consists in computing the best operating point of a power network and is critically important for the safe and efficient operation of electric power systems. This problem is becoming even more crucial (and complex) with the increasing integration of renewable energy sources and distributed storage. The nonlinear optimization solver **Artelys Knitro** [2] is highly efficient at tackling such nonlinear problems. Other industrially relevant problems appear in the optimal management and design of water, oil and gas networks [3] [4].

Recently, promising approaches have been proposed for solving the Alternating Current OPF problems in transmission networks by means of Sum-Of-Squares (SOS) relaxations [5], SOS techniques provide a global optimum of the network optimization problem along with a global optimality certificate, which is more valuable from

the perspective of a Transmission System Operator. Other methods based on conic optimization have been explored by academic researchers in the case of transmission and distribution networks.

Yet, these problems are still difficult to solve to (global) optimality when integrating all of the desired parameters. For instance, the AC optimal transmission-switching problem involves mixed-integer constraints and can be turned into a mixed-integer SOCP. Network design and transmission expansion planning problems typically involve binary variables. This class of problems is handled by means of Branch-and-Bound algorithms, in which convex or linear relaxations are solved for every node.

In the case of optimal power flow problems, it has been observed that piecewise linear relaxations may fail at providing good performance. Therefore, the use of polynomial relaxations for deriving strong lower bounds is a promising research direction.

PHD OBJECTIVES

The main expected result during this thesis is developing novel practical algorithms based on polynomial relaxations for solving mixed-integer nonlinear programs arising in power systems optimization.

As part of a young and dynamic high-level R&D IT team, your mission will be to:

- Design and develop various decision support functions and optimization models
- For a given problem, enumerate, prototype and compare various resolution methods (exact or approximate, relaxations, branch-and-bound, branch-and-cut, mixed integer variables, complementarities, constraint programming, etc.)
- Design and implement the chosen solutions, with a strong requirement for reliability and numerical efficiency
- Integrate and test these features into the nonlinear optimization solver Artelys Knitro

PLANNED SECONDMENTS

The candidate will have research stays (secondments) at CNRS (Toulouse, France), working with D. Henrion, and at Tilburg University (Tilburg, The Netherlands), working with E. de Klerk.

CONDITIONS FOR APPLICATION

- Have — at the date of recruitment — a **Master's degree in Computer Science, Mathematics or Engineering** (or any equivalent diploma).
- Should have — at the date of recruitment — **less than 4 years of a research career**, and not have a doctoral degree. The 4 years are measured from the date when they obtained the degree which would

formally entitle them to embark on a PhD, either in the country where the degree was obtained or in the country where the PhD is provided.

- Trans-national mobility: The applicant — at the date of recruitment — **should not have resided in the country where the research training takes place for more than 12 months in the 3 years immediately prior to recruitment**, and not have carried out their main activity (work, studies, etc.) in that country. For refugees under the Geneva Convention (1951 Refugee Convention and the 1967 Protocol), the refugee procedure (i.e. before refugee status is conferred) will not be counted as 'period of residence/activity in the country of the beneficiary'.
- Be able to communicate fluently in English (speaking and writing). Oral interview with the prospective advisor may be required.

REQUIRED SKILLS

Ideal candidates must have a master degree in computer science and/or applied mathematics. You should have a solid background in Operations Research. You are curious and enthusiast to exploit your computer development skills and your knowledge of optimization research.
Operational on various contexts and real issues. Rigorous and passionate, you show initiative and imagination and already have an ease in programming in programming and scientific languages (C/C++, Python, R, Julia).

During this thesis, you will be brought to develop your skills in:

- Linear, nonlinear and polynomial optimization
- Combinatorial optimization
- Power systems modeling and optimization
- Software development and programming
- Versioning, Integration (Git, Jenkins, Maven)

The candidate should be fluent in English. Knowledge of French is an asset.

PROCEDURES FOR APPLICATION

All candidates must apply via https://easychair.org/cfp/POEMA-19-22

The applications closing date is **March 15, 2019**.

Interviews will be conducted in Paris and remotely in April/May 2019.

The start of this position will be in autumn 2019 and will last 3 years maximum.

References

[1] H. L. Steven, Convex relaxation of optimal power flow., IEE Transactions on Control of Network Systems, 2014.

[2] "Artelys Knitro," [Online]. Available: https://www.artelys.com/en/optimization-tools/knitro.

[3] L. W. M. Kevin E. Lansey, "Optimization model for water distribution system design," *Journal of Hydraulic Engineering,* vol. 115, 1989.

[4] G. E. S. E. J.Durrer, "Optimization of Petroleum and Natural Gas Production—A Survey," *INFORMS Management Science,* 1977.

[5] C. Josz, J. Maeght, P. Panciatici and J. C. Gilbert, "Application of the Moment-SOS Approach to Global Optimization of the OPF Problem," *IEEE Transactions on Power Systems,* pp. 463 - 470, 2014 .