PGMO-IROE umbrella project OGRE 2016-1749H Optimization, Games and Renewable Energy 2016-2017

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Abstract

The transformation of energy systems is accelerating. Local initiatives are blossoming, with the drop in renewable energy costs and the impulse of decentralized actors (individuals, collectivities). Managing an energy system with myriads of decentralized sources (wind, sun) and actors is becoming more and more challenging.

The OGRE project stands as an umbrella project that welcomes companion PGMO projects related to centralized versus decentralized management of energy systems. The OGRE project is a PGMO-IROE Project funded by Programme Gaspard Monge pour l'Optimisation et la recherche opérationnelle (PGMO), Électricité de France (EDF) et Fondation Mathématique Jacques Hadamard (FMJH) for the years 2016 and 2017.

`http://cermics.enpc.fr/~delara/PROJECTS/PGMO_OGRE_2016/PGMO_OGRE_2016_web/`

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1.1 Summary

The transformation of energy systems is accelerating. Local initiatives are blossoming, with the drop in renewable energy costs and the impulse of decentralized actors (individuals, collectivities). Managing an energy system with myriads of decentralized sources (wind, sun) and actors is becoming more and more challenging.

The PGMO has launched several projects which, directly or indirectly, touch the subject of the role of optimization and game theory, in the new energy landscape. The 2016 PGMO call for projects has attracted new proposals that touch related issues: bi-level optimization, smart-grids, etc. When relevant, the sponsor EDF encourages projects to work together, to give more impact to the PGMO outputs.

This is why we propose OGRE — Optimization, Games and Renewable Energy — as an umbrella project that welcomes companion projects (ongoing and new), related to centralized versus decentralized management of energy systems. Each companion project preserves its financial and scientific autonomy. The OGRE project will coordinate the research programs of the companion projects by organizing joint meetings and by providing a common report. The common OGRE report has made limited progress in one year. However, the OGRE project has made possible the holding of four meetings with scientific exchanges.

Keywords: Optimization, games, renewable energy, energy transition, decentralization

1.2 Companion projects

Summaries of the following companion projects can be found in §A.

- Logiciels pour l'optimisation des réseaux intelligents (LORI) — Michel De Lara (Cermics, École des Ponts ParisTech)
- Paris-London network on stochastics and optimization in renewable energy — Teemu Pennanen (King's College, London) and Jean-Philippe Chancelier (Cermics, École des Ponts ParisTech)
- Centralized versus decentralized energy management in a stochastic framework (LASON2) — Bernardo Pagnoncelli (Universidad Adolfo Ibañez) and Michel De Lara (Cermics, École des Ponts ParisTech)
- Managing risk in a multi-agent energy market — Vincent Leclère (Cermics, École des Ponts ParisTech)
- Decentralized control for renewable integration in smart-grids — Ana Busic (Inria, Dyogene)

- Design and pricing of electricity services in a competitive environment — Luce Brotcorne (INRIA Lille Nord Europe, Inocs)
- Multi-leader-follower approach for energy pricing problems: competitive interactions producers/aggregators and producers/smart grid operators — Didier Aussel (Université de Perpignan)
- Smart cities with efficient coupled energy transport management — Yezekael Hayel (Université d'Avignon)
- Decentralised optimization and smart-grids — El Ghazali Talbi (Polytech'Lille - Université Lille 1)
- Partitionnement connexe équicoloré des smartgrids — M. Grappe

2 The OGRE outputs

2.1 OGRE meetings

Monday 29 August 2016

Participants: Laetitia Andrieu (EDF R& D), Sebastien Lepaul (EDF R& D), Olivier Beaude (EDF R& D), Nadia Oudjane (EDF R& D), Yezekael Hayel (Université d'Avignon), Didier Aussel (Université de Perpignan), Luce Brotcorne (Inria), Pierre Carpentier (Ensta), Jean-Philippe Chancelier (ENPC), Vincent Leclère (ENPC), Michel De Lara (ENPC)

Roundtable followed by discussion on organization. Summary of decisions:

- If possible, have a description of all companion projects (initial project as submitted to PGMO? website?).
- Have one day meetings every two months, with the morning dedicated to OGRE coordination, and the afternoon reserved for work within companion projects.
- Ask the PGMO Days organizers for two streams of 1h30 each, so that OGRE would have 3 hours for 6 talks.

Survey, by Michel De Lara, of the second chapter of the OGRE report

PGMO Days Wednesday 9 November 2016

The following speakers have agreed to give a talk under an OGRE stream.

- Didier Aussel. *Multi-leader-follower-games: a state of art of applications to energy problems and of their (global vs local) reformulations*
- Luce Brotcorne. *Energy Pricing Problems for Demand Side and Revenue Management* slides

- Michel De Lara. *Charting optimization problems with multiple agents and information* slides
- Olivier Beaude and Yezekael Hayel. *Efficient Coupled Energy-Transport Management for Smart Cities* slides
- Bernardo Pagnoncelli. *Microgrid Energy Management with Renewables and Storage* slides
- El-Ghazali Talbi. *A Multiobjective Evolutionary Algorithm for Household Appliances Scheduling* slides

OGRE invited session program

Thursday 2 February 2017

Location: EDF Lab, Saclay

Morning (9h30–12h30).

- Roundtable: P. Carpentier (ENSTA), J.-P. Chancelier (ENPC), M. De Lara (ENPC), M. Lacroix (LIPN), E. Traversi (LIPN), D. Aussel (Université de Perpignan), Y. Hayel (Université d'Avignon), A. Busic (INRIA), G. Doukopoulos (EDF), S. Lepaul (EDF), A. Lenoir (EDF), O. Beaude (EDF)
- Presentation of the last version of the OGRE report (Benjamin Heymann, Michel De Lara). Ultimately, we expect to produce a printed book with the OGRE report material.
- Différentiation des fournisseurs en concurrence dans un modèle biniveau où les suiveurs doivent être flexibles (Sébastien Lepaul)
- A bilevel providers-consumers competition model (Olivier Beaude)
- Game Theory with Information: Research Agenda with the Witsenhausen Intrinsic Model (Benjamin Heymann, Michel De Lara)

Afternoon (14h00–17h00). Working session

Monday 29 May 2017

Location: Room Opale 1AB01, EDF Lab, Saclay

Afternoon (14h30–18h00).

- Roundtable:
- Presentation of the last version of the OGRE report (Michel De Lara)
- Complexity results for smartgrid partitioning (Roland Grappe)
- Blockchain-based markets for local renewable energy balancing (David Menga and José Horta)

Tuesday 30 May 2017

Host OGRE session inside the SESO 2017 International Thematic Week "Smart Energy and Stochastic Optimization"

Location: ENSTA ParisTech, Palaiseau, France

2.2 OGRE report

Link to the OGRE report:
`http://cermics.enpc.fr/~delara/PROJECTS/PGMO_OGRE_2016/OGRE_report.pdf`

The OGRE report is made of two main parts.

- The first part contains three chapters.
  - The first chapter presents how EDF perceives the new playground of energy systems, with its different actors; it underlines some new management problems that EDF faces. This first chapter is finished.
  - The second chapter provides the concepts needed to enlighten the mathematical structure of the new management problems: agents, information, criteria; then, it delineates corresponding classes of optimization and of game problems. This second chapter is well advanced but not finished. Daniel Kadnikov's PhD thesis at Cermics will build upon this framework.
  - The third chapter should describe common models and problems, destined to be instances for the methods developed by the academic community. This third chapter has not been written.
- The second part of the report is made of a series of case studies, organized in chapters: local agents; big producer managing local agents; big producer and local agents in competition. These chapters will be made of the contributions of the OGRE companion projects. This second part of the report has not been written.

2.3 OGRE panoply of models and problems

We expect that the OGRE researchers will build, in common, a panoply of models and problems that are destined to be common instances for the methods developed by each companion project.

A Summaries of the Companion projects

A.1 Logiciels pour l'optimisation des réseaux intelligents (LORI) — Michel De Lara

The world's energy landscape is changing fast. Three key drivers are remolding power systems: renewable energies penetration (intermittent and highly variable), expansion of markets and of new players, deployment of telecommunication technology and smart meters. These changes put to the front stochastic and decentralized optimization as an adapted formalism. Even if methods, algorithms and softwares have been developed for a long time, they are less common in practical applications than their deterministic counterparts. The LORI project – Logiciels pour l'Optimisation des Réseaux Intelligents – aims at making academics and companies closer in working together on the development of stochastic and decentralized optimization methods, algorithms and softwares (dedicated toolboxes, including modelers and solvers).

A.2 Paris-London network on stochastics and optimization in renewable energy — Teemu Pennanen and Jean-Philippe Chancelier

The operation of power production and trading is challenged by renewable energies penetration, which stresses physical and market risk factors. Specific approaches and tools are required. The PALON project aims at initiating collaboration between researchers, in Paris (PA) and London (LON), who represent a unique combination of mathematical, computational and financial expertise. They have identified common interest and complementary skills in stochastic modeling and optimization of renewable energy systems within modern electricity markets. Thanks to two workshops, the PALON project will clarify which mathematical models and computational tools are to be developed for future long term research.

A.3 Centralized versus decentralized energy management in a stochastic framework (LASON2) — Bernardo Pagnoncelli and Michel De Lara

The classical energy management optimization framework considers that a central planner decides how to efficiently dispatch energy to consumers, in a centralized fashion. Due to the recent growth of alternative and renewable energy sources, new relevant actors have appeared

in the context of smart grids. Such new actors (for generation, storage, demand response) challenge the classical generation model in which a central planner is the sole decision maker. As a consequence, we propose to explore new models and methodologies in order to achieve optimal operation of emerging decentralized energy systems.

A.4 Managing risk in a multi-agent energy market — Vincent Leclère

The project aims at studying how a risk-averse public decision maker can design a market in a way such that the competitive equilibrium minimizes the utility of the decision maker. More precisely, a recent paper by M.Ferris, A.Philpott and R.Wets has shown that a competitive equilibrium of risk-averse agents in a certain market is equivalent to a global risk-averse minimization problem with specific risk measure. We propose to take the reverse road. We consider a risk averse global problem with given risk-measure and decompose the problem in subproblems through Lagrangian price-decomposition. We want to deduce from the decomposition the adequate market design.

A.5 Decentralized control for renewable integration in smart-grids — Ana Busic

A.6 Design and pricing of electricity services in a competitive environment — Luce Brotcorne

The aim of the project is to solve a joint pricing and design problem of energy services in a competitive environment for residential demand side management. More precisely, the objective is twofold: generate revenue for an energy provider and encourage the customers to individually and voluntarily reduce their consumption at peak periods. A bilevel approach is considered to take explicitly into account the strategic behaviour of consumers into the optimization process. The robustess of the bilevel problem with respect to the demand will be studied. Solution algorithms will be developped to solve a mixed integer bilinear bilinear bilevel and an Equilibrium problem with equilibrium constraints

A.7 Multi-leader-follower approach for energy pricing problems: competitive interactions producers/aggregators and producers/smart grid operators — Didier Aussel

The aim of this project is to realize a deep analysis of the equilibrium offer/demand in a decentralized context of power systems. Indeed, the emergence on the power system of local actors and renewable energy lead to new framework of decentralized optimization problems. By considering three different aspects of the interactions between local actor/aggregators and main producers/sellers, we intend to evaluate the influence of such new exchanges processes

on the steering/flexibility of the demand and the market prices. This analysis will be based on multi-leader-follower game theory.

A.8 Smart cities with efficient coupled energy transport management — Yezekael Hayel

We aim at jointly studying two problems which are usually independent: transportation and electrical networks. In the context of smart cities, the question addressed is the following: could both problems become inter-dependent? On the one hand, the traffic assignment problem in the transportation network with Electric Vehicles (EV) should consider both (road) congestion effect and energy need for the travel. On the other hand, in the electrical network, electricity prices depend on the demand, that typically itself depends on the aggregate energy need of EVs. It is now clear that energy consumed by driving is directly linked with travel time, and thus with congestion. In turn, both problems are naturally coupled. Both problems can be modeled with bi-level optimization: at the top level is the transportation / electrical network operator — deciding respectively road toll or electricity pricing - and at the bottom level the EVs — choosing a route and a charging profile. This collaborative project brings methodologies and expertise of academic researchers for coupling two bi-level problems and also of EDF researcher-engineers for studying the practical interest of coupling driving and charging decisions (smart cities).

A.9 Decentralised optimization and smart-grids — El Ghazali Talbi

With the smart grid revolution, house energy consumption will play a significant role in the energy system. Home users are indeed responsible for a significant portion of the world's energy needs portion, but are totally inelastic with respect to the market (i.e. the energy demand does not follow the price of the energy itself). Thus, the whole energy generation and distribution system performance can be improved by optimizing the house energy management. Those problems are concerned by multiple objectives such as cost and users' comfort, and multiple decision makers such as end-users and energy operators. We propose a home automation system that can monitor appliance scheduling in order to simultaneously optimize the total energy cost and the customer satisfaction.

A.10 Partitionnement connexe équicoloré des smartgrids — M. Grappe

Nous vivons aujourd'hui une époque cruciale de l'évolution du secteur électrique : l'émergence des énergies renouvelables se combine à l'arrivée de composants dits "intelligents" transformant le réseau électrique en "smart grid". À terme, celle-ci sera constituée d'un ensemble de sous-réseaux ou "microgrids" pouvant se connecter ou se déconnecter en temps réel du réseau principal. L'objectif de chaque "microgrid" sera alors de tendre vers l'autonomie en

satisfaisant la demande énergétique de ses consommateurs à l'aide de sites de production qui lui seront propres.

Dans ce projet, nous nous intéressons aux problèmes d'optimisation combinatoire liés au découpage futur de la "smart grid" en "microgrids". En particulier, nous souhaitons étudier l'impact du concept d'autonomie sur les problèmes de partitionnement et d'augmentation de graphes.