PGMO-IROE Project LASON2 2014-1604H Centralized versus Decentralized Energy Management in a Stochastic Setting

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February 29, 2016

Abstract

The LASON2 project seeks to foster research on Centralized and Decentralized Energy Management in a Stochastic Setting, with the purpose to tackle smart grid issues. The LASON2 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 2014 and 2015.

Link: `http://cermics.enpc.fr/~delara/PGMO_LASON2_2014/PGMO_LASON2_2014/`

1 The LASON2 project

The Latin American Stochastic Optimization Network (LASON) was formed in 2012 to apply for a PGMO project covering energy applications using stochastic programming, stochastic control, and dynamic programming techniques. The goals of the group were to animate a network of researchers in Chile and France, with similar interests, to study and understand the relevant problems faced by EDF and to attract EDF researchers to collaborate with our team. LASON won two PGMO projects and, after two meetings (January 2013 and December 2013), the group matured and accomplished the goals that were initially proposed.

As a consequence, we have decided to apply to an IROE project with the incorporation of EDF researchers Anes Dallagi and Sandrine Charousset. In the meetings and throughout the year 2013, LASON members have been discussing with EDF researchers the most relevant problems in energy management and how the expertise of the team could be used to address these problems.

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Motivated by two EDF reports by Yassine Ameur (advised by Pierre Carpentier and Sandrine Charousset) and Alex Ringeval (advised by Michel De Lara and Sandrine Charousset), that were extensively discussed within the LASON group, the classes of problems we want to handle are related to the challenges posed by the emergence of new local actors in the context of smart grids. More specifically, the recent appearance of small (but relevant) local generators and consumers, which form what we will refer to as Smart Decision Centers (SDC), challenges the classical generation model in which a central planner is the sole decision maker and relevant actor.

New mechanisms of communication between the central planner and SDCs will need to be designed, and, in order to operate the system efficiently, new mathematical formulations have to be developed. Moreover, SDCs are extremely diverse: some have solar panels, wind energy, batteries to store energy, or a combination of those. Hence, assessing the impact of each SDC requires appropriate modeling of their characteristics. What are the objectives of each player? How do they respond to signals (e.g. price changes) set by the regulation authority? How can we capture the uncertainties such as demand, wind generation and prices, in order to construct a useful model?

We believe that the collaboration with a group outside France (and Europe) is fruitful and enriching since it allows the transfer of expertise and a fresh and different view to a very relevant problem faced by EDF. LASON is applying for 2-year IROE project (LASON2) to study the change in paradigm from centralized to decentralized energy systems. There are two parallel problems that the group plan to study. We now describe each of those problems and a yearly plan for each one:

Problem I — Mechanism design

Year 1: Comprehension of the problem and study different mechanisms to model the relationship between the central planner and the local generators. Propose mathematical formulations for the problem, run simulation models that test different mechanisms and different signals that can be sent by the regulation authority.

Year 2: Propose efficient algorithms to solve the resulting problems and integrate the models with part II of the project.

Problem II — Managing and optimizing local generators

Year 1: Comprehend the specifics of each type of SDC. Start designing mathematical formulations for the SDC problem. Develop more sophisticated formulations for SDCs, discuss the different objectives such as cost, environmental goals, reliability of the network, welfare of the population served by the SDC.

Year 2: Develop simulation and optimization algorithms to solve the SDC problem, and integrate the findings with the models in part I of the project.

2 Workshops

2.1 Chile workshop, Santiago, Wednesday 17 — Tuesday 18, January 2015

In December the 17th and the 18th, 2014, the French researchers Michel De Lara, Pierre Carpentier and Jean-Philippe Chancelier visited Adolfo Ibáñez University in Santiago, Chile. We discussed problems related to mechanism design (what was called problem I in the original IROE application) and to managing and optimizing local generators (problem II).

Our goal was to start designing simple mathematical formulations for those problems. The first one is an energy management problem in a decision unit. A decision unit is a small-scale unit of energy generation, storage and loads that can function autonomously. The decision unit is connected to the centralized system, from which it consumes energy when needed, and can sell the excess that was generated, when it is convenient. Decision units can also be connected between themselves. The whole system forms a micro-grid if its size is not too large (micro). We arrived at a simple formulation of a small photovoltaic decision unit with batteries as storage connected to the main power grid.

The second problem we consider is a demand response formulation in which a utility has to decide on incentives towards clients, so that they shed and shift demand. Demand response consists in inducing changes in the pattern of energy use by consumers in response to changes in the way energy is charged. We plan to analyze a problem with two agents and two objectives, one for the utility company and another for the client. In the utility problem, the unknowns are the non-moveable utilities demand and the spot market prices. In the client's problem, the compensation offered by the utility company is the unknown input parameter. We are currently studying an iterative algorithm that solves both problems and update the unknowns at each step, until convergence is achieved. We have written down both formulations and, in the second year (2015), we plan to add more realistic features to those problems, such as increasing the grid size, including uncertainties, and managing risk.

2.2 French workshop, Paris, Monday 22 — Friday 26, June 2015

Between June 22nd and the 26th, 2015, the researchers Bernardo Pagnonceli, Tito Homem-de-Mello and Rodrigo Carrasco went from Chile to France for the SESO meeting, organized by Michel De Lara, Pierre Carpentier and Jean-Philippe Chancelier.

- Bernardo Pagnoncelli gave a talk entitled "Microgrid Energy Management with Renewables and Storage", presenting a model that includes solar panels and batteries in a micro grid setting.

- Michel De Lara gave a talk entitled "Single and multi agent optimization, game theory", to provide a framework for centralized and decentralized optimization.

- Valentin Foucher (student at École Polytechnique) gave a talk entitled "Optimal control and sizing of a combined heat and power generator", presenting the work he did during

his internships in France and in Chile.

- Pierre Carpentier gave a talk entitled "Decentralized energy management: two examples", where he compared centralized and decentralized optimization on two examples.

In addition to the discussion that took place during the SESO workshop, in the last day of the event the Chilean and French teams, together with EDF researchers Riadh Zorgati and Sandrine Charrouset, discussed current problems faced by EDF. As a result of the discussion a three-level model was outlined, comprising high, medium and low voltage networks. In the model, the users of the low voltage network can exchange energy with the medium voltage consumers, and energy exchanges are governed by flow equations. The objective is to minimize costs, including transmission costs since the presence of local generators significantly decreases the need for the use of long transmission lines.

2.3 Chile workshop, Santiago, Monday 18 — Tuesday 19, January 2016

`Workshop program: http://cermics.enpc.fr/~delara/PGMO_LASON2_2014/workshop_UAI_2016.pdf`