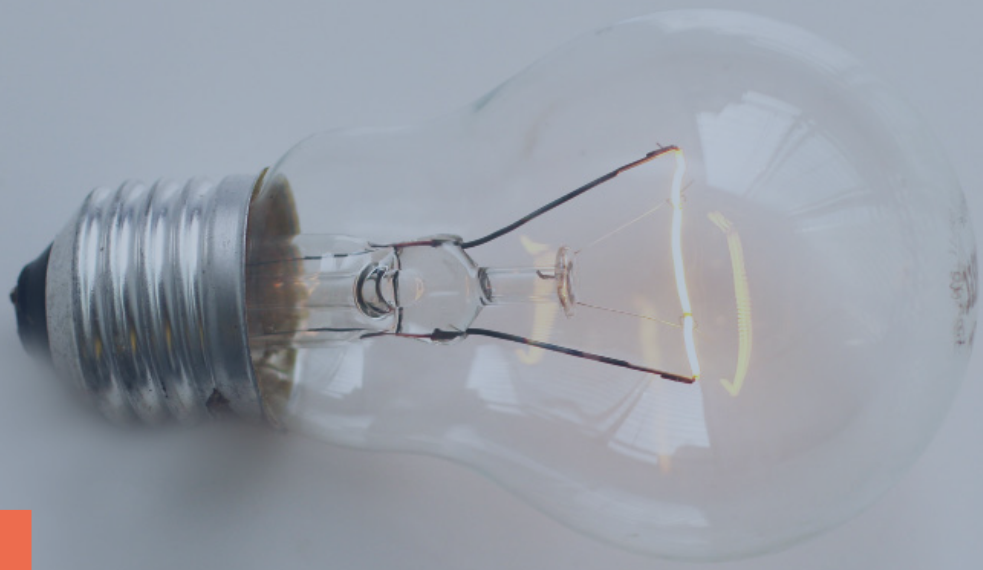
WORKSHOP

ENERGY DAY



December 7 - 8 2020

Day 1

Morning Session

11.15 - 11.30: Welcome by Anthony Papavasiliou (CORE, UCLouvain)

11:30 - 12:30: Keynote presentation

Andreas Tirez, CREG

Fundamentals of market functioning: the role of a price signals and how to come to good price signals in power markets

An important reason to liberalise energy markets and introduce competition, and more generally other goods and services, is the presence of information asymmetry. Even if there would be a benevolent and competent bureaucracy, it cannot possibly know all the relevant information that is needed to make good decisions.
To avoid central planning by bureaucratic institutions, the European Union has chosen to liberalise energy markets. Market prices are viewed as the aggregation of all the relevant and distributed information into one single parameter on which all market players can react. Consequently, for a power market to function efficiently it needs market prices that are aggregating the information on the actual available generation, demand and transmission capacities.
This presentation will focus on the currently distorted price signal in the day ahead power market in the Central-West European region, and more specifically in the context of extensive re-dispatching. The presentation will be based on a recent study by the Belgian federal energy regulator CREG.

Afternoon Session

14:00 - 17:00: Machine and Reinforcement Learning Problems in Electricity Markets

Moderator: Gilles Bertrand (CORE/UCLouvain)

14.00 - 15.20: **Wolf Berwouts, N-SIDE**

Using reinforcement learning to perform topology optimisation

Finding the optimal topology for a transmission network is a complex problem which is in practice solved by highly experienced system operators, backed by approximations and heuristic methods. Elia & N-SIDE research the application of reinforcement learning in a practical innovation project in an attempt to make the decisions faster and better, avoiding unnecessary congestion & redispatch actions. By letting a neural network train itself on a digital twin of the Elia network, together with thousands of hours of training scenarios, it can learn what optimal actions to take in each situation. Such actions could be the disconnection of lines, splitting of substations, or even acting on the maintenance plan. The ultimate goal is to provide the operators with a tool that can support them in taking these topology decisions in their day-to-day tasks.

Anthony Papavasiliou, CORE/UCLouvain
A Modeling Framework for Analyzing European Balancing Markets

The European balancing market is undergoing radical transformation through numerous market design initiatives. These initiatives aim at improving geographical coordination among European transmission system operators, and better positioning the European system for integrating renewable resources through short-term operational efficiency and long-term investment in flexible resources. However, the European design is characterized by a missing market for real-time reserve capacity, that has been inherited from a failure to recognize the central role of real-time operations as the spot market of the electric power industry. This missing market undermines the valuation of reserve capacity, and the back-propagation of price signals to forward reserve markets that can support investment in reserves. The goal of the present paper is to develop a methodology that exposes the implications of this missing market. The methodology relies on analytical insights that can be derived under an assumption of price-taking behavior. These insights are validated by a simulation model which represents the European balancing market as a Markov Decision Process. The simulation model is used for validating the analytical insights and testing the ability of various balancing market design options to back-propagate the real-time value of reserve to forward reserve markets.

15.20 - 15.40: Break

15.40 - 17.00: **Olivier Martin, ENGIE**
Algorithmic Trading on German Intraday Power Markets

The German intraday market exhibits several characteristics that make it particularly well suited to the development of automated trading and optimization strategies. Firstly, it is a highly physical market, with very little speculation. Price movements are often the result of measurable fundamentals, the volumes involved are relatively low and there are many players. On the other hand, there are numerous factors that can trigger large intraday price movements, including: changing weather forecasts, unscheduled unavailability of generation units, the status of the transmission grid, the flexibility of generating facilities, and so on. It is sometimes difficult to assess the impact a specific event will have because there are so many factors at play and because those factors are interdependent. We will present a machine-learning based approach to identify market conditions in which the price differs significantly from its expected value, and illustrate how an automated trading strategy may exploit these situations.

Gilles Bertrand, CORE/UCLouvain
Adaptive trading in the Continuous Intraday Market using Reinforcement Learning

The increasing integration of renewable resources in electricity markets has increased the need for producers to correct their trading position close to real time in order to avoid volatile real-time prices. The closest option to delivery time in European markets is to trade in the continuous intraday market. This market is therefore an attractive trading outlet for assets that target at extracting value from their flexibility. Trading in this market is challenging due to the multistage nature of the problem, its high uncertainty and the fact that decisions need to be reached rapidly, in order to lock in profitable trades. We model the trading problem of a storage unit in the Markov Decision Process framework. We present an approach based on policy function approximation for tackling the problem. We provide relevant parameters for defining our policy, and demonstrate the effectiveness of our approach by comparing it to the rolling intrinsic policy on real historical data. Our proposed approach outperforms the rolling intrinsic policy, which
is commonly employed in practice for storage units, by increasing profitability by 17.8% on out-of-sample testing for a storage with perfect round-trip efficiency and by 13.6% for a storage unit with a round-trip efficiency of 81%.

Day 2

Morning Session

09:30 - 12.30 **Mobilizing distributed demand-side flexibility through advanced analytics**
Moderator: Yuting Mou (CORE/UCLouvain,VITO)

09:30 - 10.50 **Dimitrios Papadaskalopoulos, Imperial College London and NTUA**
Distributed optimisation, game-theoretic and reinforcement learning approaches for investigating the impacts of demand flexibility in emerging electricity markets

The ongoing decarbonization of electricity systems drives constantly increasing interest around the role and value of demand-side flexibility. However, the realisation of its potential in the deregulated market framework constitutes a non-trivial task which cannot be effectively addressed through traditional analytical models, considering the complex challenges associated with a) the scalability and privacy limitations of centralised coordination approaches, b) the strategic behaviour of large producers and retailers, and c) the emergence of local energy markets and peer-to-peer energy trading. This talk will present new modelling approaches to address the above challenges, founded on distributed optimisation, game theory, and deep reinforcement learning principles.

Leonardo Meeus, Vlerick School of Business and Florence School of Regulation
The Future of Electricity Markets with Distribution Network Constraints

Net-zero-carbon targets are expected to accelerate the ongoing electrification in industry, transport, and heating and cooling of buildings. Several impact studies have estimated that this will require billions of euros of investments in distribution networks. Some of these network investments can be avoided or delayed by making use of the flexibility that will be increasingly available in distribution networks. This flexibility can come from demand, generation, and storage. It will be too expensive to avoid distribution network constraints by reinforcing the network. We will need to manage the new grid users or new technologies installed by existing users well. This talk discusses the future of electricity markets with distribution network constraints.

10.50 - 11.10: Break

11.10 - 12.30: **Dimitri Tomanos, Imperial College London and NTUA**
Integration of Flexibility Mechanisms into Decentralized Systems Energy Production Sizing Optimization Problem

Prosumer is an advanced simulation and optimization tool developed by Engie Impact. The tool helps ENGIE entities implementing the new strategy of ENGIE to be the leader of the zero-carbon transition. Prosumer helps to harmonize climate change imperatives with business profitability, by designing the investment strategy of a zero-carbon journey. Prosumer designs the optimal configuration of a decentralized system minimizing its total cost of ownership. The focus of the tool is on strategic assessment of distributed energy projects (focus on pre-feasibility studies). The tool plans, at different territory levels: industrial parks, campuses, eco-districts, regions, the optimal sizing and dispatching of all physical assets and provides key indicators of the resulting techno-economic performance (Return on investment, Levelized cost of Energy, etc.), Environmental footprint/Avoided CO2 emissions, etc. The focus of the presentation will be on the recent implementation of different flexibility mechanisms and the results achieved on some illustrative use cases.

Yuting Mou, VITO
Comparison of Priority Service and Multilevel Demand Subscription for Mobilizing Residential Demand Response

Priority service and multilevel demand subscription have been proposed as two alternative methods for the mobilization of residential demand response. Whereas priority service relies on the differentiation and non-linear pricing of electricity according to reliability, multilevel demand subscription further differentiates electricity service according to duration. The increased complexity of multilevel demand subscription for residential consumers promises increased operational efficiency, as it permits a finer differentiation of consumer classes by the utility. This paper proposes a framework for quantifying this effect. We propose a modeling approach for designing multilevel demand subscription menus, and evaluate their performance in a system with utility-scale renewable supply, residential renewable supply, and residential storage. We compare priority service to multilevel demand subscription, and discuss the implications on operational efficiency and consumer expenditures for electricity service.

Afternoon Session

14.00 - 17.00: Algorithmic and Market Design Topics in T&D Coordination and Local Energy Markets
Moderator: Ilyès Mezghani (CORE/UCLouvain)

14.00 - 15.20 : **Ibrahim Abada, ENGIE Impact**
Distributed optimisation, game-theoretic and reinforcement learning approaches for investigating the impacts of demand flexibility in emerging electricity markets

In 2019, the European Commission finalized a legal framework for «Citizens» and «Renewable Energy Communities», paving the way for their deployment. While the benefits of such communities have been discussed, there is increasing concern that inadequate grid tariffs may lead to excess adoption of such business models. Furthermore, snowball effects may be observed following the effects these communities have on grid tariffs. We show that restraining the study to a simple financial analysis is far from satisfactory. Therefore, we use the framework of cooperative game theory to take account of the ability of communities to share gains between members. The interaction between energy communities and the distribution system operator then results in a non-cooperative equilibrium. We provide mathematical formulations and intuitions of such effects, and carry out realistic numerical applications where communities can invest jointly in solar panels and batteries. We show that such a snowball effect may be observed, but its magnitude and its welfare effects will depend on the grid tariff structure that is implemented, leading to possible over-investments in photo-voltaic panels. In particular, we find that setting a fixed grid tariff strongly mitigates such over-investments.

Ilyès Mezghani, CORE/UCLouvain
Models and Algorithms for Clearing Integrated T&D Markets with ACOPF and Non-Convex Offers

With the proliferation of renewable energy resources, the electrical grid, particularly the distribution network, becomes increasingly relevant to model, since production and consumption are not split in two different regions of the network anymore. Consequently, dispatch decisions and pricing, while maintaining feasibility and fairness among participants, are challenging features to ensure in this context. Also, the market allows for complex bid structures which makes the decision even more complicated.
This presentation provides a detailed modeling of the real-time market clearing problem which results in a mixed-integer non-linear problem. The clearing platform that we propose implements a method based on a mix of relaxations and exact solutions of the optimal power flow.

15.20 - 15.40: Break

15.40 - 17.00: **Burak Kocuk, Sabanci University**
An Analysis of the Multi-Period Optimal Power Flow Problem with Electric Vehicles under Emission Considerations

In this talk, we present a new formulation for the multi-period optimal power flow (MOPF) problem with electric vehicles (EV) under emission considerations. We integrate three different real data sets, household electricity consumption, marginal emission factors, and EV driving profiles, into the proposed formulation. We present a systematic solution approach based on second-order cone programming (SOCP) to find globally optimal solutions of the MOPF problem. Our computational experiments on test cases with up to 2000 buses demonstrate that the proposed approach leads to approximately globally optimal solutions with significant emission savings and reductions in cost through coordinated charging of EVs.

Ignacio Aravena, Lawrence Livermore National Laboratory
Solving realistic security-constrained optimal power flow problems: lessons learned from ARPA-E Grid Optimization Competition Challenge 1

In this talk we present the lessons learned in preparing and participating in the ARPA-E Grid Optimization (GO) Competition Challenge 1. We describe the GO Competition's official formulation of the security-constrained AC optimal power flow problem, emphasizing its most challenging features. We present our nonlinear approximation of the coupling constraints between base case and contingencies – that took the form of complementarity constraints in the original formulation – and our crashing procedure to ensure feasibility of our final solutions. Then, we outline our decomposition approach for large-scale instances, which consists of a pre-screening for impactful contingencies, soft bubble constraints for transmission contingencies and differentiable convex approximations for recourse contingency terms, incorporated to the base case as contingencies are incrementally evaluated. We present our high-performance computing implementation of the decomposition approach which features state-of-the-art computational optimization, advanced (primal-dual) interior point warm start of both base case and contingency subproblems, and distributed-memory asynchronous (lock free) parallelism. We detail our multiple levels of exception handling for subproblem evaluation, especially important for effective contingency evaluation, as we learned that contingency subproblems can be numerically challenging for nonlinear programming solvers.
We present a summary of our experimental results throughout the competition and studying how our developments were impacting our overall performance. Finally, we describe directions for further research that we believe will be the most impactful in improving current capabilities for handling these problems effectively in practice.

Organizer:
Anthony Papavasiliou, LIDAM/CORE, UCLouvain
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