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Support Vector Machines for decision support in electricity markets' strategic bidding

Tiago Pinto [a,*], Tiago M. Sousa [a], Isabel Praça [a], Zita Vale [a], Hugo Morais [b]

[a] GECAD – Knowledge Engineering and Decision Support Research Center, Polytechnic of Porto (IPP), R. Dr. António Bernardino de Almeida, 431, 4200-072 Porto, Portugal

[b] Automation and Control Group, Department of Electrical Engineering, Denmark Technical University (DTU), Elektrovej, Bld 326, 2800 Lyngby, Denmark

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ABSTRACT

Energy systems worldwide are complex and challenging environments. Multi-agent based simulation platforms are increasing at a high rate, as they show to be a good option to study many issues related to these systems, as well as the involved players at act in this domain. In this scope the authors' research group has developed a multi-agent system: Multi-Agent System for Competitive Electricity Markets (MASCEM), which simulates the electricity markets environment. MASCEM is integrated with Adaptive Learning Strategic Bidding System (ALBidS) that works as a decision support system for market players. The ALBidS system allows MASCEM market negotiating players to take the best possible advantages from the market context. This paper presents the application of a Support Vector Machines (SVM) based approach to provide decision support to electricity market players. This strategy is tested and validated by being included in ALBidS and then compared with the application of an Artificial Neural Network (ANN), originating promising results: an effective electricity market price forecast in a fast execution time. The proposed approach is tested and validated using real electricity markets data from MIBEL – Iberian market operator.

1. Introduction

The study of the operation of electricity markets has become increasingly important in recent years as a result of the challenges that the restructuring of these markets originated, this restructuring has increased the competitiveness of the market, but also its complexity. The increasing complexity and unpredictability, consequently, increase the difficulty in decision making. The bodies involved are then forced to rethink their behavior and market strategies [1], which makes it essential to use tools that allow the study and different market mechanisms and the relationships between the participating entities [2].

Regulators and players have an interest in predicting market behavior; regulators to test regulations before they are implemented, and detect market inefficiencies, the market players to realize market behavior in order to optimize their profits. The need to understand these mechanisms and how the interactions between the players affect the market has contributed to the increased use of simulation tools. Multi-agent software is particularly directed to the analysis of dynamic and adaptive systems with complex interactions among stakeholders. Several modeling tools for the study of electricity markets have emerged. Some relevant examples are Electricity Market Complex Adaptive System (EMCAS) [3], Agent-based Modeling of Electricity Systems (AMES) [4], Genoa Artificial Power Exchange (GAPEX) [5], and Multi-Agent System for Competitive Electricity Markets (MASCEM) [6,7].

Although some studies have emerged, confirming the applicability of simulation tools to study these markets, particularly using multi-agent systems, these tools present a common limitation: the lack of adaptive learning capabilities that enable them to provide effective support to the decisions of market entities. Current tools are directed to the study of market mechanisms and interactions among participants, but are not suitable for supporting the decision of the players' negotiators in obtaining higher profits in energy transactions.

These limitations highlight the need to develop adaptive tools, which enable strong support for market players. These tools will enhance the improvement of the results of these players. Being adaptable to different market circumstances and contexts of negotiation, intelligent tools can get realistic and appropriate suggestions for players' actions so that they can direct their behavior in search of the best possible results.

With a view to eliminating this gap, the Adaptive Learning strategic Bidding System (ALBidS) [7,8] has been developed. ALBidS is based on multi-agent technology, assembling several

* Corresponding author. Tel.: +351 22 8340500; fax: +351 22 8321159.
E-mail address: tmcfp@isep.ipp.pt (T. Pinto).
URL: http://www.gecad.isep.ipp.pt (T. Pinto).

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different strategic approaches to act in the electricity market. The ALBidS system is integrated with the MASCEM simulator, a system that models the environment of electricity market and the interactions between the major participating organizations, both in negotiation and management.

The competitive nature of electricity markets, which translates to constant and rapid changes in this environment, also require an endless search for new methods of artificial intelligence, adaptive learning and decision support, enabling systems like ALBidS adequate adaptation at all times. The nature of these new approaches should reflect an increasing effectiveness in forecasts in the shortest time possible execution.

Support Vector Machines (SVM) [9] is a technique for classification and data forecasting (closely related to Artificial Neural Networks (ANN) [10]), which, by its characteristics, offers some guarantees to grant ALBidS with the required specifications: good predictive power in short execution time. SVMs have been used in many areas, such as pattern recognition, image recognition, classification and regression analysis, text categorization, medical science, weather forecast, energy prices, and many other applications [11,12].

This paper presents the development of an SVM based methodology for electricity markets' participation and its integration in the ALBidS system [8]. The main goal of the proposed SVM approach is to provide a bid suggestion for market participation, based on the electricity market price forecast. The forecasted price is used as a basis for an operational strategy of agents participating in the electricity market. The strategic action proposal provided by the SVM approach can be used by ALBidS as a suggestion for the action that should be performed by the supported electricity market negotiating player. The integration of the proposed SVM methodology with the MAS model of ALBidS provides an innovative approach, taking full advantage on the complementarily of the several artificial intelligence (AI) approaches that compose ALBidS with the best features of SVM: high quality results in a very short execution time. The interconnection with ALBidS and MASCEM [6] allows the testing and validation of the proposed strategy in a realistic electricity market simulation environment, using real data from the Iberian power market – MIBEL [13].

After this introductory section, Section 2 presents an overview of the MASCEM simulator and of ALBidS decision support system. Section 3 presents the proposed SVM based approach for decision support in an electricity market environment. Section 4 shows the experimental results of the proposed methodology, comparing them to the performance of other forecasting methodologies, under three distinct perspectives: (i) comparison of forecasting capabilities; (ii) execution times; (iii) results when used as decision support for electricity markets participation. Finally, Section 5 presents the most relevant conclusions of this work.

2. MASCEM and ALBidS overview

MASCEM [6,7] is a multi-agent system that models the most important players that take part in electricity markets, collecting data in the medium and long term to support the decisions of these agents according to their characteristics and objectives, thus allowing better understanding of the mechanisms and behaviors that are common to this type of markets. The MASCEM simulator uses several approaches and learning techniques for modeling and supporting market actors in their decisions. Fig. 1 shows the main features of the MASCEM simulator.

The simulator is directed to the study of various types of markets, including the day-ahead spot market, balancing markets, forwards markets, and bilateral contracts. MASCEM allows defining the simulation settings and market scenarios to simulate, including the definition of the characteristics of buyers and sellers

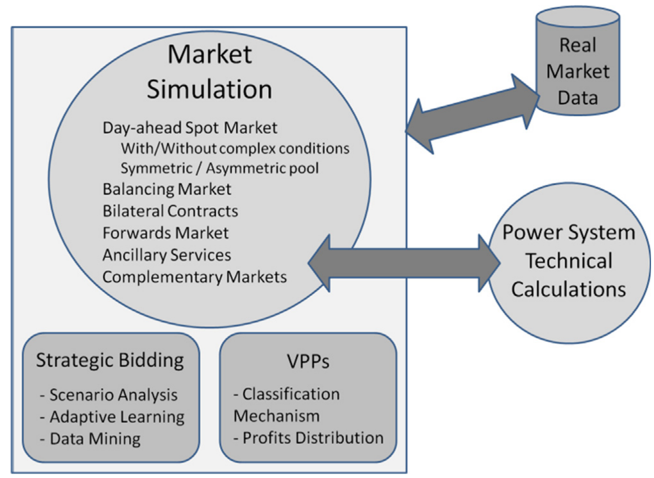

Fig. 1. Key features of MASCEM [14].

and their number. These scenarios are supported by real data from several electricity market operators [13], which provides a realistic representation of such markets.

After the simulations it is possible to analyze the amounts of energy transacted by each agent, the respective market prices, and the obtained profits/costs in each period.

One advantage of MASCEM, being a simulator of electricity markets, is to allow the study of multiple models for different market types, and to be able to achieve results with high accuracy, facilitating the drawing of conclusions on the future uncertain environment of power systems.

The user can perform several simulations, such as studying the same exact market or the same scenario negotiations as often as needed to draw the necessary conclusions, or using several different scenarios for testing. It is also possible to change the settings for each buyer or seller agent, and create the trading scenarios, and analyse their results under different circumstances.

To help in the analysis of results, MASCEM comes accompanied with a series of graphs that are generated during each negotiation process, so that the results of the agents, whether sellers or buyers, can be tracked. Configuration files are generated for each agent and simulation; these files can also be used to repeat the simulations or to execute close variations in order to compare results.

Adaptive Learning strategic Bidding System (ALBidS) [7,8] is a multi-agent system, which integrated with MASCEM. ALBidS uses adaptive learning to make MASCEM agents capable of analyzing negotiation contexts, such as the types of markets in which they are inserted, economic and weather conditions, the type of day (e.g. business, weekend, or holiday) and the trading period (e.g. peak or off-peak).

Thus, agents can adapt to any market automatically, being prepared for unexpected changes in electricity markets, managing to change their strategy of buying or selling through this system. For this, ALBidS uses Reinforcement Learning Algorithms (RLA) to choose the strategy that best fits each specific context. Fig. 2 shows the interconnection between MASCEM and ALBidS.

From Fig. 2 it is visible that interactions between MASCEM and ALBidS are performed through the Main Agent. Electricity market negotiating agents, such as buyers and sellers, which request the decision support of ALBidS, ask the Main Agent for action suggestions. The Main Agent, which is the top entity in ALBidS, sends the requests to the Strategy Agents, which are responsible for executing the different strategies based on different approaches and techniques. Once all Strategy Agents finish the execution of their action strategies, they send their specific action suggestions to the