AiD-EM: Adaptive Decision Support for Electricity Markets Negotiations

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Abstract

This paper presents the Adaptive Decision Support for Electricity Markets Negotiations (AiD-EM) system. AiD-EM is a multi-agent system that provides decision support to market players by incorporating multiple sub-(agent-based) systems, directed to the decision support of specific problems. These sub-systems make use of different artificial intelligence methodologies, such as machine learning and evolutionary computing, to enable players adaptation in the planning phase and in actual negotiations in auction-based markets and bilateral negotiations. AiD-EM demonstration is enabled by its connection to MASCEM (Multi-Agent Simulator of Competitive Electricity Markets).

1 Introduction

Worldwide electricity markets are strongly affected by the increasing use of renewable energy sources. This increase has been stimulated by new energy policies that result from the growing concerns regarding the scarcity of fossil fuels and their environmental impact. Consequently, huge investments have been made in the power and energy sector. However, the large-scale integration of fluctuating renewable sources in power systems, such as wind and sun, poses several constraints that limit not only the production reliability but also its use [Odeh *et al*., 2018].

The large-scale integration of renewable energy sources has led to a restructuring of the power and energy sector. This restructuring process resulted in a deep change in the operation of competitive electricity markets. These markets aim at ensuring increased and fair competition giving electricity buyers more options and pushing players to increase their efficiency, thus enabling electricity prices decrease. The electricity markets' restructuring process brought out, however, several challenges itself, demanding the transformation of the conceptual models that have previously dominated this sector. The restructuring made the market more competitive, but also more complex, placing new challenges to the participants. The growing complexity and unpredictability of the markets' evolution consequently increases the difficulty of decision making, which is exacerbated by the increasing number of new market types that are continuously being implemented to deal with the new challenges that keep on emerging. Therefore, the intervenient entities forced to rethink their behaviour and market strategies to cope with this constantly changing environment [Ringler *et al*., 2016].

So that these entities can deal with the new challenges, the use of decision support tools becomes crucial. The need for understanding the market mechanisms and how the involved players' interaction affects the outcomes of markets has contributed to the emergence of a large number of simulation tools. Multi-agent-based software is the most widely adopted solution as this paradigm is particularly suitable to analyse dynamic and adaptive systems with complex interactions among its elements, such as electricity markets. Current software tools allow studying different electricity market mechanisms and analysing the relationships between market entities; however, they are not prepared to provide suitable decision support to the negotiation process of electricity market players [Niu, *et al*., 2018].

This gap motivates the development of Adaptive Decision Support for Electricity Markets Negotiations (AiD-EM), which arises with the purpose of providing solutions that enable electricity market players to take the best possible outcomes out of each market context. AiD-EM is an enhanced multi-agent-based decision support system developed in JADE. AiD-EM includes a Portfolio Optimization methodology, which decides in which market opportunities should market players negotiate at each moment. The actual negotiation process in each market is supported by specific decision support systems, directed to different types of negotiation. The participation in auction-based markets is supported by the Adaptive Learning strategic Bidding System (ALBidS) [Pinto *et al*., 2014]. This decision support system includes a large number of distinct market participation strategies, and learns which should be used in each context in order to provide the best expected response. Negotiations by means of bilateral contracts are assisted by the Decision Support for Energy Contracts Negotiation (DECON) system, which includes methodologies to analyse competitor players' negotiation profiles enabling the adaptation of the adopted negotiation strategies and tactics. All methodologies are supported by a context analysis methodology, which allows analysing and identifying different contexts of negotiation, thus enabling a contextual adaptation of the diverse learning processes.

2 Proposed Approach

Figure 1 shows the global structure of the AiD-EM multi-agent decision support system, including the representation of its main components.

The AiD-EM system includes the AiD-EM Manager agent, as illustrated in Figure 1, which acts as the central entity of the system, providing the connection with the MASCEM electricity market simulator [Santos *et al*. 2016]. The AiD-EM Manager agent executes a Portfolio Optimization, which defines the amount of power that the supported player should buy or sell in each available market opportunity at each time and according to each context. The expected prices in each market are obtained from several forecasting methods [Pang *et al*., 2018]. The AiD-EM Manager agent also optimizes the performance of the system by distributing the AiD-EM agents by the available machines, and by executing the Efficiency/Effectiveness (2E) balance management mechanism, which defines the amount of time that each of the integrated decision support systems is allowed to use in its execution, depending on the purpose of each simulation and on the user's requirements regarding the expected balance between the achieved quality of results and the execution time of the simulation.

Considering the defined amount of power to be transacted in each market, specific decision support systems are used to provide action suggestions for the supported player to perform in each distinct market type. ALBidS [Pinto *et al*., 2014] is directed to the decision support for negotiations in auction based markets and includes several different methodologies to provide alternative action suggestions. The used approaches range from game theory [Chan and Ortiz, 2018] to the combination of different algorithms using the metalearning concept [Grau-Moya *et al*., 2018] among many others. The approach chosen as the players' actual action is selected by the employment of Reinforcement Learning Algorithms (RLA), which for each different situation, simulation circumstances and context, decide which proposed action is the one with higher possibility of achieving the most success. ALBidS is equipped with its own 2E balance management mechanism, which defines which strategies should be executed at each time, considering the requirements of the AiD-EM 2E management, the execution time of each strategy and the quality of' results.

The decision support for bilateral contract negotiations is assured by DECON, which considers two main components: *(i)* decision support for the pre-negotiation stage, and *(ii)* decision support for the actual negotiation process. The pre-negotiation step aims at identifying the ideal competitor(s) that should be approached so that the undertaken negotiations can provide as much benefit as possible for the supported player. The expected limits and target prices of each envisaged competitor are also predicted with the purpose of enhancing the decision support for the negotiations. The actual negotiations are supported by a set of different tactics that follow different strategies. Different combinations of tactics are supported, allowing the supported player to change its tactic strategically in response to the behaviour of the opponent(s) and to the current context. The initial choice and dynamic change of the most appropriate strategies and tactics to use against each opponent is based on a learning approach, considering the analysis and definition of competitor players' profiles.

The context awareness of the system is provided by a context analysis mechanism [Pinto *et al*., 2015]. The context analysis considers several relevant factors that influence players' negotiating environment, thus allowing market participation strategies to be adapted and used accordingly to each different negotiation context.

The significance of the introduced decision support methodologies can only be assessed by means of realistic electricity market simulations. The connection with MASCEM plays an essential role in this context. Using the Realistic Scenario Generator (RealScen) [Silva *et al*., 2016], which uses real electricity market data, extracted in real time from the websites of several market operators, it is possible to recreate the electricity markets' reality in a controlled simulation environment in MASCEM. Realistic simulation scenarios of several European electricity markets are used to test and validate the proposed methodologies.

3 Conclusions

This paper presents and demonstrates AiD-EM, a multi-agent decision support system that helps electricity market players in their negotiations.

The demonstration of this system includes the execution of its several components, namely the portfolio optimization, DECON and ALBidS systems and their validation in realistic simulations using MASCEM.

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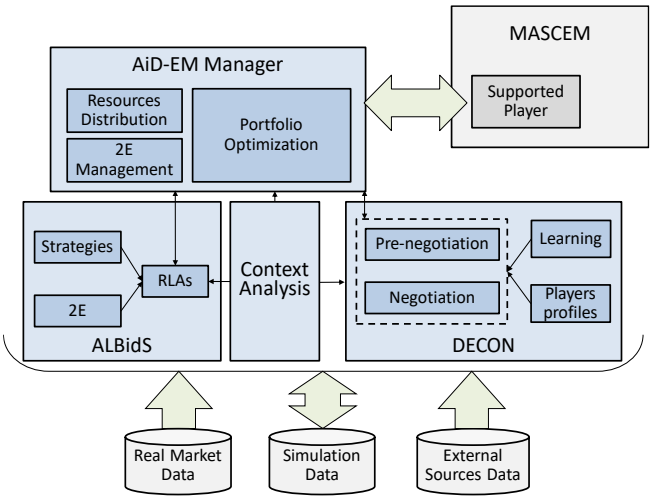

Figure 1. AiD-EM overview

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