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Negotiation context analysis in electricity markets

Tiago Pinto*, Zita Vale [1], Tiago M. Sousa, Isabel Praça

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

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ABSTRACT

Contextualization is critical in every decision making process. Adequate responses to problems depend not only on the variables with direct influence on the outcomes, but also on a correct contextualization of the problem regarding the surrounding environment. Electricity markets are dynamic environments with increasing complexity, potentiated by the last decades' restructuring process. Dealing with the growing complexity and competitiveness in this sector brought the need for using decision support tools. A solid example is MASCEM (Multi-Agent Simulator of Competitive Electricity Markets), whose players' decisions are supported by another multiagent system – ALBidS (Adaptive Learning strategic Bidding System). ALBidS uses artificial intelligence techniques to endow market players with adaptive learning capabilities that allow them to achieve the best possible results in market negotiations. This paper studies the influence of context awareness in the decision making process of agents acting in electricity markets. A context analysis mechanism is proposed, considering important characteristics of each negotiation period, so that negotiating agents can adapt their acting strategies to different contexts. The main conclusion is that context-dependant responses improve the decision making process. Suiting actions to different contexts allows adapting the behaviour of negotiating entities to different circumstances, resulting in profitable outcomes.

1. Introduction

The EM (electricity markets) restructuring has been changing the EM paradigm over the last two decades. The privatization of previously state owned companies, the deregulation of privately owned systems, and the internationalization of companies, are some examples of the transformations that have been applied [1]. Nowadays EM operate in more complex and reliable models. However, EM are still restricted to the participation of large players. Thus, the increased use of DG (distributed generation), mainly based on RES (renewable energy sources) of intermittent nature, hardly contributes to the efficiency of the system. Moreover, they are still supported by governmental stimulus [2].

The reduction of fossil fuels' environmental impact, risk and high prices, potentiates the investment of the power industry in renewable based power generation and EM organization. These two key fronts of investment have the additional objective of making the sector more efficient through competitiveness [3]. Despite the favourable scenario for DG growth, there are important aspects to consider of both economic and technical nature. To take advantage of an intensive use of DG, issues such as the dispatch ability, the participation of small producers in the markets and the high cost of maintenance must be solved [2,3].

The problem of DG growth and integration into EM is being addressed by a wide range of different approaches all around the world; however, during the last years some common solutions are globally being adopted. EM are evolving to RM (regional markets) and some to continental scale, supporting transactions of huge amounts of electrical energy and enabling the efficient use of renewable based generation in places where it exceeds the local needs. A reference case of this evolution is the European EM. The majority of European countries have joined together into common market operators, resulting in joint regional EM composed of several countries. The types of markets in which players can participate differs in each region, under each operator, however, the market mechanisms are evolving towards a uniform architecture, in order to accommodate a Continental level EM – the Pan-European EM [4].

Since February 2006, seven regional markets were launched: Central-West (EPEXSPOT [5]), Northern (Nord Pool [6]), UK and

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

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Ireland, Central-South (GME [7]), South-West (Iberian Market Operator - MIBEL [8]), Central East and Baltic. The merging process between these operators is the ultimate goal, and is currently being prepared [4]. The transformation of National EM into Regional and Continental EM is evidenced by other examples, such as the U.S. EM [9–11], and the Brazilian EM [12]. These markets, although not representing a Continent as a whole, can be considered as Continental EM due to these countries' size. The management and operation of these markets is an important example for the emerging ones. EM put a new emphasis on the economic dimension of the problem. However, the basic infrastructure, namely the power system network has a real physical nature, with specific limitations [5–12]. The introduction of EM has shown the fragility of power systems infrastructures to operate in a competitive context. Several severe incidents, including blackouts, occurred (e.g. the 14th August 2003 Blackout in the US, and the 4th October 2006 quasi-blackout affecting nine European countries and some African nations as well).

A globally adopted solution is approaching the electricity network as a series of subsystems [13], giving birth to the concept of microgrid [14,15]. Experimental implementations of microgrids are arising all around the world [14,16], considering the management of local generation, loads, and storage systems, as independent from the main system, although connected with the main grid through a connection bus, or even working as an isolated system (in islanded mode). The intelligent management of these smaller electricity grids has been evolving and potentiating the implementation of SG (Smart Grids) as an upcoming reality [13,16,17]. There are several approaches regarding SG management and practical implementations [14–17], and the results are promising, ensuring that it is just a matter of time until this reality is implemented in a global scale as a core part of the electrical grids all around the world.

Due to the constant evolution of the EM environment, and the change in the operation and participation in EM, it becomes essential for professionals in the area to completely understand the markets' principles, and how to evaluate their investments in such a competitive environment. The usage of simulation tools, with the purpose of taking the best possible results out of each market context for each participating entity, has grown with the need for understanding those mechanisms and how the involved players' interaction affects the outcomes of the markets. To analyse complex interactions in dynamic and adaptive systems, multi-agent based systems are particularly well suitable. AMES (Agent-based Modelling of Electricity Systems) [18], EMCAS (Electricity Market Complex Adaptive System) [19], and MASCEM (Multi-Agent Simulator of Competitive Electricity Markets) [20–24] are examples of some of the relevant tools that have emerged to study restructured wholesale power markets.

EM simulators must be able to cope with the dynamic reality of the rapid evolution of EM and adapt to the new models and rules of the market, in order to provide players adequate tools to adapt themselves to the changing environment. This brings an increasing need to consider the concept of context awareness. Taking into account the influence that the characteristics of each negotiation moment has on the negotiation process itself, players can adapt their actions in order to best fulfil their needs.

This paper proposes a new context analysis mechanism, with the aim of providing adaptive capabilities to decision support systems directed to the enhancement of EM negotiating players. The proposed context analysis mechanism considers several relevant factors that influence players' negotiation environment. The correct understanding of each market characteristics [5–12], such as the negotiation mechanisms; the usual market prices that are practiced in each market in different situations; the influence of different players' participation in the negotiation process; the external environmental factors, such as wind surplus or shortage [25,26]; and the perception regarding different types of days, which lead to different market negotiating results, e.g. the difference between business days and weekends; are variables that have huge importance for players to be able to adapt their actions. Hence, the proposed methodology has the goal of analysing the negotiation context in order to distinguish days and periods with similar characteristics, so that market participation strategies can be adapted and used accordingly to each context; i.e. the proposed methodology is not a market strategy itself, it is rather a model that enables complementing existing market strategies so that their use can be optimized by deciding when and how to employ different market strategies, depending on each different context that each day and period fits in.

After this introductory section, section 2 presents an overview of simulation tools in the scope of EM, including a brief state of the art regarding the most relevant EM simulators that can be found in the literature, and a description of MASCEM and ALBidS (Adaptive Learning strategic Bidding System) [21,24,27], the two systems in which the proposed context analysis mechanism is integrated, and which support the testing and validation of the proposed methodology. Section 3 presents the description of the proposed context analysis mechanism, and section 4 depicts some simulation results regarding the participation of EM players in the MIBEL, EPEX and Nord Pool, using the support of ALBidS equipped with the proposed context analysis features. Finally, section 5 presents the most relevant conclusions and future work.

2. Electricity markets simulation

Electricity Markets are not only a new reality but an evolving one as the involved players and rules change at a relatively high rate [3]. The emergence of a diversity of new players (e.g. aggregators) and new ways of participating in the market (distributed energy resources and demand side are gaining a more active role) are signs of this [3,28]. Restructured electricity markets are sequential open-ended games with multiple participants trading electric power. Market players and regulators are very interested in foreseeing market behaviour: regulators to test rules before they are implemented and to detect market inefficiencies; market players to understand market's behaviour and operate in order to maximize their profits. These necessities turned electricity markets into an attractive domain for developers of software tools. Simulation and artificial intelligence techniques may be very helpful under this context.

2.1. Electricity market simulators

Electricity market simulators must be able to cope with this evolving complex dynamic reality and provide electricity market players with adequate tools to adapt themselves to the new reality, gaining experience to act in the frame of a changing economic, financial, and regulatory environment. With a multiagent simulation tool the model may be easily enlarged and future evolution of markets may be accomplished. Multiagent simulation combined with other artificial intelligence techniques may result in sophisticated tools, namely in what concerns players modelling and simulation, strategic bidding and decision-support [21,24,29,30]. For example, consumers' role has significantly changed in this competitive context, making load analysis, consumer profiling and consumer classification very important [31]. The data generated during simulations and by real electricity markets operation can be used for knowledge discovery and machine learning, using data mining techniques [21,31], in order to provide electricity markets