Decision Support System for the Negotiation of Bilateral Contracts in Electricity Markets

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Abstract. The use of Decision Support Systems (DSS) in the field of Electricity Markets (EM) is essential to provide strategic support to its players. EM are constantly changing, dynamic environments, with many entities which give them a particularly complex nature. There are several simulators for this purpose, including Bilateral Contracting. However, a gap is noticeable in the pre-negotiation phase of energy transactions, particularly in gathering information on opposing negotiators. This paper presents an overview of existing tools for decision support to the Bilateral Contracting in EM, and proposes a new tool that addresses the identified gap, using concepts related to automated negotiation, game theory and data mining.

Keywords: Automated Negotiation, Bilateral Contracts, Data Mining, Decision Support Systems, Electricity Markets, Game Theory

1 Introduction

Since the beginning of the 21st century, the EM have undergone a profound restructuring, proceeding to its liberalization. Therefore, EM became more competitive, but also more complex, resulting in increased unpredictability[1].

Nowadays, new challenges arise regarding the increasing usage of energy from renewable sources. The European Union (EU) has defined a set of policies and standards that contribute to the large-scale implementation of distributed generation, in order to encourage and increase the use of this type of energy. An example would be the "20-20-20" program [2]. However, the usage of this energy type introduces a new source of unpredictability in the sector, due to its intermittent nature. As such, the unpredictability and risk in the EM are increasingly

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higher, considering the great complexity of the interaction between its participating entities and the large number of associated variables, which hinder the decision-making process. In this context, EM simulation proves to be a great tool for decision support, through the study of the inherent mechanisms of these markets as well as the relations between the entities (players), by analysing their profiles, behaviours and strategies [3]. Although there are several EM simulators, few are the ones that provide support for negotiation among players.

This paper intends to address the identified gap, aiming to propose a solution that allows participating agents to obtain the best possible results, considering their objectives. As such, it's considered a Decision Support System (DSS) for bilateral contracts, including methodologies for the pre-negotiation phase, particularly in the profile analysis of opposing negotiators. This way, it allows adaptability of the negotiation strategies, which together with a contextual analysis, gives the capability to analyse and identify different contexts of negotiation.

This paper is divided into five sections: Bilateral Contracts in Electricity Markets, Multi-Agent Simulators as Decision Support Systems in Electricity Markets, Proposal, Experimental Findings and Conclusions.

2 Bilateral Contracts in Electricity Markets

EM are constantly evolving and adapting. Currently, most countries have their own market or participate in regional markets, together with neighbouring countries [4]. EM are composed of several market types [5, 6], based on three different models, which are (I) day-ahead spot, (II) intra-day, both usually auction based, and (III) bilateral contracts models.

In the scope of EM, bilateral contracts are long-term contracts established between two entities, buyer and seller, for energy transaction, without the involvement of a third entity. The transaction is usually carried out several weeks or months after the contract is made [7] and usually has the following specifications: start and end dates and times; Price per hour (€/MWh) and amount of energy (MW), variable throughout the contract and, finally, a range of hours relative to the delivery of the contract. Players can use customized long-term contracts, trading ”over the counter” and electronic trading to conduct bilateral transactions [8]. There are four types of bilateral contracts: the first type are Forward Contracts, that consist in energy exchange between a buyer and a seller for a future date, for the price negotiated at that moment; the second type are Future Contracts, which are similar to Forward Contracts except that they are managed by a third party responsible for ensuring compliance with the agreement; the third type are Option Contracts, that are similar to the Forward and Future contracts with the difference that the two entities only guarantee a buy/sell option; the last one are Contracts for Difference, that allows entities concerned to protect themselves from the energy price change between the date of establishment of the agreement and the agreed date of exchange.

With the exception of Contracts for Difference, this type of negotiation allows players to control the price at which they will transact energy, in contrast to what happens in spot markets, due to the proposals' instability. In establishing a Forward or Future contract, players are committing themselves to transact energy for a given price at a future time, with the risk of making a transaction at a lower price than the expected and lose competitive power. Option Contracts or Contracts for Difference can avoid this risk. The first allows the player to choose not to go through with the exchange while the second ensures that the transaction is carried out at the market price. However, the first option also has the risk of not guaranteeing whether or not the other party will exercise their option to exchange and the second option does not allow better prices than the market. This way, it is possible to understand the risk associated with the negotiation of bilateral contracts and the need that players have of tools that help them reduce this risk and even optimize their profits.

3 Multi-Agent Simulators as Decision Support Systems in Electricity Markets

The vast majority of EM simulators are focused only on market analysis and are void of mechanisms that allow their users to get support for direct negotiation. Particularly with bilateral contracts, there are gaps in decision support systems, namely in obtaining information about the opposing party [9]. This leads to an urgent need to acquire new methods that support the decision process, such as the definition of suitable models, choice of the best candidates to close the deal, analysis of the previous transactions of these candidates and strategies to employ to get the best deal possible. One of the main advantages of using MAS for the implementation of these simulators is that they have software agents that, by definition, interact with each other autonomously in order to meet an objective [10].

Table 1. Phases of Automated Negotiation problems (Adapted from [9])

Group	Component or Dimension
Preliminaries	– Social conflict (detection and exploration) – Negotiating parties (number of parties)
Pre-Negotiation	– Structuring of personal information (definition and execution of key pre-negotiation tasks) – Analysis of the opponents – Protocol and selection of the initial strategy
Actual Negotiation	– Exchange of offers and feedback information – Argumentation (threats, promises, etc.) – Learning (in negotiation) – Dynamic strategic choice (new strategies) – Impasse resolution
Renegotiation	– Analysis and improvement of the final agreement

In the literature, it is possible to find references to systems that allow the simulation of bilateral contracts in the context of EM. Some examples are The Electricity Market Complex Adaptive System (EMCAS) [11], The Multi-Agent Negotiation and Risk Management in Electricity Markets (MAN-REM) [9] and The General Environment for Negotiation with Intelligent Multi-purpose Usage Simulation (GENIUS) [12]. These simulators are based on phased negotiation approaches, following the ideology of automated negotiation (see Table 1), namely in the definition of the pre-negotiation, actual negotiation and analysis of the results in order to adjust future proposals. However, these simulators do not respond to the problem already identified, that is, in the pre-negotiation phase, a detailed study of the characteristics of possible opponents does not occur, in order to perceive which are best suited to their objectives and which negotiation strategies should be used with each one of them, in order to close the best possible deal.

4 Proposal

This DSS focused on the Pre-Negotiation phase, joining the Preliminary and Pre-Negotiation phases of automated negotiation. This union simplifies the system given the proximity of the two phases, being joined in most models. The DSS is intended to support an agent who intends to transact energy with other agents through bilateral contracts. The agent supported by this system may be any type of entity interested in transactions within the electricity markets. The agent will use the system whenever it pretends to enter new bilateral contracts and wish to guarantee the maximum possible gain. When an agent pretends to enter into a bilateral contract market, it can find more than one competitor. Weighted competitor choice is very important when maximizing profits. Moreover, this decision does not necessarily fall on the competitor who can offer the best proposals. The competitor's ability to comply with the agreement is a very important factor. The fulfilment of agreements, however promising they may be, with competitors who fail to do their part ends up being a great waste of time for the agent and compromising his management.

For decision support in this stage of negotiation, the system uses a scenario analysis method based on game theory. The outputs of this method are the choice of the most favourable competitors, the distribution of the amount of energy, to be negotiated with each of the selected competitors, which guarantees greater profit, and the price that each competitor is expected to show.

As can be seen in Fig.1, the proposed method is composed of three parts: Scenarios Definition, Possible Actions Definition and Decision Process. The Scenarios Definition consists in the specification of the different negotiation scenarios that the supported agent can find. The results of the potential competitors in the past are analysed and, by means of forecast algorithms, the prices of the competitors, for different amounts of energy, are forecast. When there is not enough history to make forecasts, an estimation process is necessary. The Possible Actions Definition are the generation of all alternative actions that the supported

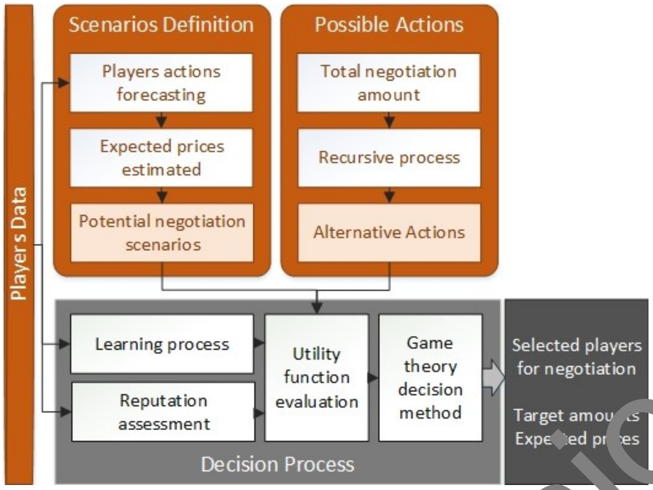

Fig. 1. Diagram of proposed methodology

agent can take. The total energy to be negotiated with each competitor is determined through a recursive process to exploit all possibilities. The last part, Decision Process, is composed by the choice of competitors to negotiate with, the respective amounts of energy and the expected prices. For this purpose, a game theory approach is used to evaluate the potential outcome of each scenario-action combination through a utility function. The appraisal also considers the reputation of each competitor and also uses a learning process, which allows to know which scenarios are more likely to occur in each context.

Concerning the user's interaction with the system, a graphical interface is available, allowing the user to enter his objectives and his possible competitors, obtaining the ideal solution (the quantities to be negotiated with certain competitors and the expected prices) coupled with an explanation of the results.

5 Experimental Findings

This section presents a case study that allows the evaluation of the proposed tool's operation. In order to facilitate the analysis of results, it's considered a simple scenario in which the supported player intends to buy 10 MW in a week-day context. In order to obtain decision support on the opponents to negotiate, and corresponding quantities, the supported player indicates the 5 players that it can negotiate with. From his point of view, the calculation of each opponent's reputation should have as much importance to his personal opinion as the social opinion. The social opinion itself will be calculated giving the same weight to the supported group's members' opinion, as well as the group of each target player. The decision method to be used is the Most Probable, which selects the action with the highest utility of the most probable scenario, determined by the learning module. Finally, regarding the risk value, several tests will be carried out in order to perceive its impact.

In the first stage, a forecast is performed to obtain the price that each opponent may propose, considering their contracts history. In case of unsufficient data to forecast the price for a given quantity, a value is estimated, considering the price forecasts for the other quantities. Fig. 2 shows the forecast results.

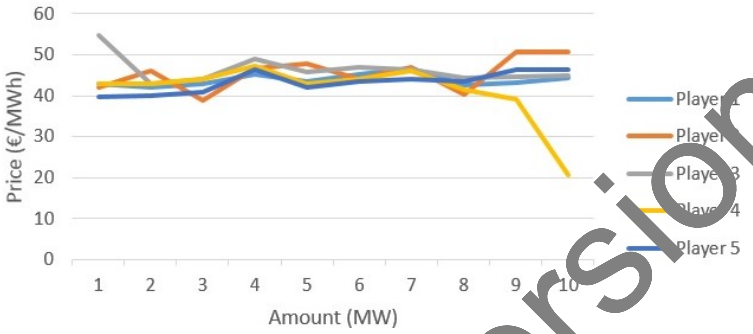

Fig. 2. Opponents expected price per energy amount

Supported by the data in the application's database, it was possible to forecast the expected prices for all quantities for all opponents, with the exception of the 10 MW quantity. The estimation made for this quantity shows prices close to those presented in the remaining amounts of energy, except for the estimated price for Player 4. In this case, there is a deviation from his normal behaviour due to forecasts of quantities exceeding 10 MW, which presented a significant downward trend. Taking into account the results of the forecast phase, Player 4 presents the best selling price, precisely for the amount of energy that the supported player intends to acquire. However, the final decision will also depend on each opponent's reputation (see Table 2).

Table 2. Reputation of the opponents

Player ID	1	2	3	4	5
Reputation	0.275	0.575	0.125	0.325	0.425

As it can be seen in Table 2, the player with the highest reputation is Player 2, followed by Player 5 and then Player 4 (player with the best selling price). Depending on the player's propensity to risk, reputation may not favour Player 4 against Players 2 and 5 who, despite not having such attractive sales prices, are more secure due to their reputation. To determine the best choice the supported player can take, all possible actions are generated and the utility value of each one is calculated. The range of possible actions are the maximum number of different power distributions by the various opponents, from trading 10MW with only one player, to trading the same amount, but divided by several players (Example: 6MW with one player and 1MW with each of the remaining). The actions' utility value combines the reputation of the players to trade in that action, with the economic advantage it can bring to the supported player. The two components' weight varies depending on the supported player's risk propensity. The risk value ranges from 0 to 1 where 0 is the minimum risk and only the reputation component is considered and 1 is the maximum risk, where only the economic component is considered. The number of possible distributions of 10MW per 5 players is 1001, a very high number, considering the amount of energy and possible opponents in question. Through the Most Probable decision method, it was possible to obtain the negotiation recommendations presented in Fig. 3, for different risk levels.

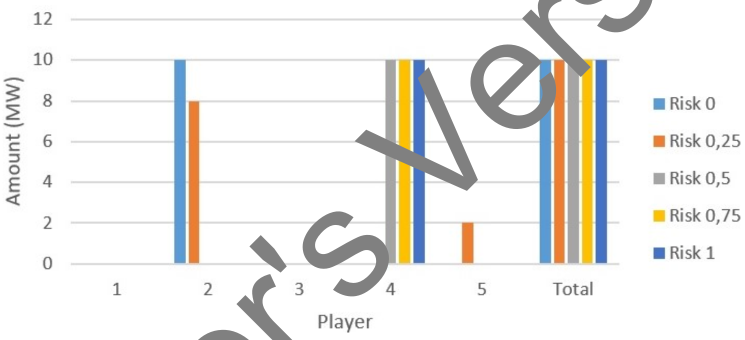

Fig. 3. Actions for different risks

Figure 3 shows that in case of risk 0, that is, each action is evaluated only by the reputation of the players involved, it's recommended to transact all the energy with Player 2, the player with the highest reputation. By increasing the risk to 0.25, it's no longer advisable to negotiate all power with Player 2. The supported player should only transact 8MW with Player 2 and 2MW with Player 5 (second highest reputation). In this case, some security is abandoned in favour of a more economically advantageous transaction. This is followed by a case where the risk value is 0.5, where the reputational component is as important as the economic component. In this case, since Player 4 has a superior advantage in the economic component than Players 2 and 5 in the reputation component, he's selected to transact the 10MW. Being Player 4 in advantage, the risk increase, favouring the economic component, will keep the recommendation in his favour.

Through this case study it is possible to perceive the advantages that a player, intending to make bilateral contracts, may have when using this decision support system. The system presents the expected results according to the supported player's expectations and presents the best solution in the middle of a very high number of possible actions in a large number of scenarios that would otherwise be practically impossible to achieve.

6 Conclusions

The paper presents a state of art for bilateral contracting in EM as well as acknowledgement of automated negotiation as the main strategy for modelling this type of simulators. It was concluded that the simulators seek to follow the automated negotiation phases, but present weaknesses in not exploring the information of the opposing traders in the pre-negotiation. Thus, a DSS that proposes a solution to the identified problem is presented, which uses data mining techniques and game theory to select the players with whom they intend to negotiate, fulfilling their requirements. A study was performed in order to demonstrate the advantages of the tool for the decision maker.

As future work, alternative approaches to the Possible Actions phase will be considered, to present an higher performance while keeping the quality of results.

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