# Negotiating Hour-Wise Tariffs in Multi-Agent Electricity Markets

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**Abstract.** Electricity markets (EMs) are a constantly evolving reality, since both market players and market rules are constantly changing. Two major market models have been considered: pools and bilateral transactions. Pool prices tend to change quickly and variations are usually highly unpredictable. In this way, market participants can enter into bilateral contracts to hedge against pool price volatility. This article addresses the issues associated with the negotiation of forward bilateral contracts. It presents the key features of a negotiation model for software agents and describes a case study involving a 24-rate tariff.

## 1 Introduction

The electrical power industry was traditionally heavily regulated with a lack of market-price mechanisms. Owing to new regulations, it has evolved into a distributed and competitive industry in which market forces drive electricity prices. Electricity markets (EMs) are not only a new reality but also an evolving one, since both market players and market rules are constantly changing (e. g., the emergence of aggregators).

Two key objectives of EMs are ensuring a secure and efficient operation and decreasing the cost of electricity utilization. To achieve these goals, two major market models have been considered [14]: pools and bilateral contracts. A pool is a market place where electricity-generating companies submit production bids and corresponding market-prices, and consumer companies submit consumption bids. A market operator uses a market-clearing tool, typically a standard uniform auction, to set market prices. Bilateral contracts are negotiable agreements between two parties to exchange electric power under a set of specified conditions, such as price, volume, time of delivery, and duration. Market participants set the terms and conditions of agreements independent of the market operator. They often enter into bilateral contracts to hedge against pool price volatility.

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Practically speaking, opening up electrical energy production to competition is an important tool to improve the efficiency of the electricity industry and therefore to benefit energy customers. Competitive forces can drive companies to innovate and operate in more efficient and economic ways. Innovation can lead to lower prices and better uses of energy resources. However, the analysis of important EMs yields the main observation that they are still far from liberalized. Today there is still a lack of both theoretical and practical understanding and important challenges are still waiting to be addressed more thoroughly. Chief among these are the additional complexities to coordinate technical and economic issues, and the technical difficulties to understand EMs internal dynamics. Stated simply, tariffs do not reflect the pressure of competition.

Multi-agent systems (MAS) are essentially loosely coupled networks of software agents that interact to solve problems that are beyond the individual capabilities of each agent. MAS can deal with complex dynamic interactions and support both Artificial Intelligence (AI) techniques and numerical algorithms. A multi-agent approach in which software agents are capable of flexible autonomous action in order to meet their design objectives is an ideal fit to the naturally distributed domain of a deregulated electricity market. Accordingly, an ongoing study is looking at using software agents with negotiation competence to help manage the complexity of electricity markets towards ensuring long-term capacity sustainability. Specifically, the overall goal of this work is to develop an EM simulator enabling market participants to:

1. negotiate the terms of bilateral contracts, reach (near) Pareto-optimal agreements, and unilaterally de-commit from contracts by paying decommitment penalties;
2. consider dynamic pricing tariffs by pursuing strategies for promoting demand response;
3. manage a portfolio of customers, taking into account trade-offs between the risk and return of bilateral contracts;
4. ally into beneficial coalitions to achieve more powerful negotiation positions, and thus negotiate better tariffs.

This paper is devoted to forward bilateral contracts in electricity markets. It presents the key features of a negotiation model for software agents and describes a case study on forward bilateral contracts—a retailer agent (a seller) and an industrial customer agent (a buyer) negotiate a 24-rate tariff.

This paper builds on our previous work in the area of bilateral contracting in multi-agent electricity markets [4–7]. In particular, it extends the case study presented in [8, 9], by considering a 24-rate tariff and a different set of negotiation strategies. The remainder of the paper is structured as follows. Section 2 presents bilateral contracting in deregulated electricity markets. Section 3 presents the key features of a negotiation model for agents. Section 4 presents a case study on forward bilateral contracts. Finally, concluding remarks are presented in section 5.

## 2 Bilateral Contracting in Electricity Markets

A bilateral transaction involves only two parties: a buyer and a seller. Depending on the amount of time available and the quantities to be traded, buyers and sellers will resort to the following forms of bilateral trading [2]:

1. *Customized long-term contracts.* These contracts usually involve the sale of large amounts of power (hundreds or thousands of MW) over long periods of time (several months to years). The terms and conditions of the negotiated agreements are set independent of the market operator—although this operator should verify that sufficient transmission capacity exists to complete the transactions and maintain transmission security. The key advantage of these contracts is flexibility, since their terms and conditions are negotiated privately to meet the needs and objectives of both parties. Their disadvantages stem from the cost of negotiation and the risk of the creditworthiness of counterparties.
2. *Trading "over the counter".* These transactions involve smaller amounts of energy to be delivered according to a standard profile, i.e., a standardized definition of how much energy should be delivered during different periods of the day. This form of trading has a much lower cost and is used by producers and consumers to refine their position as delivery time approaches.
3. *Electronic trading.* Market participants can submit offers to buy energy, or bids to sell energy, directly in a computerized marketplace. When a new bid is submitted, the software checks to see if there is a matching offer for the bid's period of delivery. In positive case, a deal is automatically struck and the price and quantity are displayed to all participants. If no match is found, the new bid is added to the list of outstanding bids and remains there until either a matching offer is made, the bid is withdrawn, or it lapses because the market closes for that period. This form of trading often takes place in the minutes and seconds before the closing of the market as generators and retailers fine-tune their position ahead of the delivery period.

## 3 Two-Party Negotiation

Negotiation, like other forms of social interaction, often proceeds through several distinct phases, notably [3]:

- *a beginning or initiation phase*: focuses on preliminaries to bargaining and is marked by each party's efforts to acknowledge a dispute and to posture for positions;
- *a middle or problem-solving phase*: seeks a solution for a dispute and is characterized by extensive interpersonal interaction toward a mutually acceptable agreement;
- *an ending or resolution phase*: centers on building commitment and implementing a final agreement.

This section presents the key features of a negotiation model for bilateral contracting in electricity markets, focusing on the operational and strategic process of preparing and planning for negotiation and the central process of moving toward agreement.[1] Let $\mathcal{A}=\{a_1, a_2\}$ be the set of autonomous agents (negotiating parties). Both the number of agents and their identity are fixed and known to all the participants. Let $\mathcal{I}=\{x_1, \ldots, x_n\}$ be the negotiating agenda—the set of issues to be deliberated during negotiation. Let $\mathcal{D}=\{D_1, \ldots, D_n\}$ be the set of issue domains. For each issue $x_k$, the range of acceptable values is represented by the interval $D_k=[min_k, max_k]$.

### 3.1 Pre-negotiation

Negotiators who carefully prepare and plan will make efforts to perform a number of activities, including:

1. prioritizing the issues;
2. defining the limits and targets;
3. selecting an appropriate protocol;
4. specifying the preferences.

Prioritization involves deciding which issues are most important and which are least important. Target setting involves defining two key points for each issue at stake in negotiation:

1. the *resistance point* or *limit*: the point where every negotiator decides to stop the negotiation rather than to continue, because any settlement beyond this point is not minimally acceptable;
2. the *target point* or *level of aspiration*: the point where every negotiator realistically expects to achieve a settlement.

The negotiation protocol is an alternating offers protocol [10]. Two agents or players bargain over the division of the surplus of $n \geq 2$ distinct issues. The players determine an allocation of the issues by alternately submitting proposals at times in $\mathcal{T} = \{1, 2, \ldots\}$. This means that one proposal is made per time period $t \in \mathcal{T}$, with an agent, say $a_i \in \mathcal{A}$, offering in odd periods $\{1, 3, \ldots\}$, and the other agent $a_j \in \mathcal{A}$ offering in even periods $\{2, 4, \ldots\}$. The agents have the ability to unilaterally opt out of the negotiation when responding to a proposal.

Negotiation starts with $a_i$ submitting a proposal $p^1_{i\to j}$ to $a_j$ in period $t=1$. The agent $a_j$ receives $p^1_{i\to j}$ and can either accept it (`Yes`), reject it and opt out of the negotiation (`Opt`), or reject it and continue bargaining (`No`). In the first two cases the negotiation ends. Specifically, if $p^1_{i\to j}$ is accepted, negotiation ends successfully. Conversely, if $p^1_{i\to j}$ is rejected and $a_j$ decides to opt out, negotiation terminates with no agreement. In the last case, negotiation proceeds to the next time period $t=2$, in which $a_j$ makes a counter-proposal $p^2_{j\to i}$. The tasks just described are then repeated.

[1] This section builds on and updates the material presented in [6, 7, 9].

**Definition 1 (Proposal).** *Let $\mathcal{A}$ be the set of negotiating agents and $\mathcal{I}$ the set of issues at stake in negotiation. Let $\mathcal{T}$ be the set of time periods. A proposal $p^t_{i\rightarrow j}$ submitted by an agent $a_i \in \mathcal{A}$ to an agent $a_j \in \mathcal{A}$ in period $t \in \mathcal{T}$ is a vector of issue values:*

$$p^t_{i\rightarrow j} = (v_1, \ldots, v_n)$$

*where $v_k$, $k=1,\ldots,n$, is a value of an issue $x_k \in \mathcal{I}$.*

**Definition 2 (Agreement, Possible Agreements).** *An agreement is a proposal accepted by all the negotiating agents in $\mathcal{A}$. The set of possible agreements is:*

$$\mathcal{S} = \{(v_1, \ldots, v_n) \in \mathbb{R}^n : \ v_k \in D_k, \ \textit{for } k = 1, \ldots, n\}$$

*where $v_k$ is a value of an issue $x_k \in \mathcal{I}$.*

Negotiators should express their own preferences to rate and compare incoming offers and counter-offers. Let $\mathcal{I} = \{x_1, \ldots, x_n\}$ be the agenda and $\mathcal{D} = \{D_1, \ldots, D_n\}$ the set of issue domains. We consider that each agent $a_i \in \mathcal{A}$ has a continuous utility function: $U_i : \{D_1 \times \ldots \times D_n\} \cup \{\texttt{Opt}, \texttt{Disagreement}\} \rightarrow \mathbb{R}$. The outcome `Opt` is interpreted as one of the agents opting out of the negotiation in a given period of time. Perpetual disagreement is denoted by `Disagreement`.

Now, the additive model is probably the most widely used in multi-issue negotiation: the parties assign numerical values to the different levels on each issue and add them to get an entire offer evaluation [13]. This model is simple and intuitive, and therefore well suited to the purposes of this work.

**Definition 3 (Multi-Issue Utility Function).** *Let $\mathcal{A} = \{a_1, a_2\}$ be the set of negotiating agents and $\mathcal{I} = \{x_1, \ldots, x_n\}$ the negotiating agenda. The utility function $U_i$ of an agent $a_i \in \mathcal{A}$ to rate offers and counter-offers takes the form:*

$$U_i(x_1, \ldots, x_n) = \sum_{k=1}^{n} w_k \, V_k(x_k)$$

*where:*

**(i)** *$w_k$ is the weight of $a_i$ for an issue $x_k \in \mathcal{I}$;*
**(ii)** *$V_k(x_k)$ is the (marginal) utility function of $a_i$ for $x_k$, i.e., the function that gives the score $a_i$ assigns to a value of an issue $x_k$.*

Negotiation may end with either agreement or no agreement. The resistance points or limits play a key role in reaching agreement when the parties have the ability to unilaterally opt out of the negotiation—they define the worst agreement for a given party which is still better than opting out. For each agent $a_i \in \mathcal{A}$, we will denote this agreement by $\hat{s}_i \in \mathcal{S}$. Hence, $\hat{s}_i$ will be the least-acceptable agreement for $a_i$, i.e., the worst (but still acceptable) agreement for $a_i$. The set of all agreements that are preferred by $a_i$ to opting out will be denoted by $S_i$.

**Definition 4 (Least-acceptable Agreement, Acceptable Agreements).** *The least-acceptable agreement for an agent* $a_i \in \mathcal{A}$ *is defined as:* $\hat{s}_i = (lim_1, \ldots, lim_n)$*, where* $lim_k$*,* $k = 1, \ldots, n$*, is the limit of* $a_i$ *for an issue* $x_k \in \mathcal{I}$*. The set of acceptable agreements for* $a_i$ *is:*

$$S_i = \{s\colon\, s \in \mathcal{S},\; U_i(s) \geq U_i(\hat{s}_i)\}$$

*where* $U_i(\hat{s}_i)$ *is the utility of* $\hat{s}_i$ *for* $a_i$*.*

### 3.2 Actual Negotiation

The negotiation protocol defines the states (e.g., accepting a proposal), the valid actions of the agents in particular states (e.g., which messages can be sent by whom, to whom, at what stage), and the events that cause states to change (e.g., proposal accepted). It marks branching points at which agents have to make decisions according to their strategies. Concession making strategies have attracted much attention in negotiation research and this article is restricted to them.

**Concession Making Strategies.** Concession making involves reducing negotiators' demands to (partially) accommodate the opponent. This behaviour can take several forms and some representative examples are now presented. Negotiators sometimes start with ambitious demands, well in excess of limits and aspirations, and concede slowly. *High demands and slow concessions* are often motivated by concern about position loss and image loss [11]. Also, there are two main reactions to the other party's demands and concessions [12]: matching and mismatching. *Matching* occurs when negotiators demand more if their opponents demands are larger or concede more rapidly the faster the opponent concedes. *Mismatching* occurs when negotiators demand more if their opponents demands are smaller or concede more rapidly the slower the opponent concedes.

If mismatching is found at the beginning of negotiation and matching in the middle, a reasonable behaviour for convincing the other party to concede is to start with a *high level of demand* and then to *concede regularly*. Such a "reformed sinner" behaviour is often more effective than a behaviour involving a moderate initial demand and a few additional concessions.

Clearly, bargainers generally view the world differently—they are not identical in their interests and preferences. In particular, they frequently have different strengths of preference for the issues at stake—they place greater emphasis on some key issues and make significant efforts to resolve them favorably. Hence, they concede more often on less important or low-priority issues. *Low-priority concession making* involves changes of proposals in which larger concessions are made on low-priority than on high-priority issues [11].

A formal definition of a negotiation strategy that models some the aforementioned forms of concession making follows (see also [7]). For a given time period $t > 1$ of negotiation, the strategy specifies the concession tactics to be used in preparing counter-offers. It also states whether bargaining should continue or terminate.

**Definition 5 (Concession Strategy).** *Let $\mathcal{A}$ be the set of negotiating agents, $\mathcal{I}$ the negotiating agenda, $\mathcal{T}$ the set of time periods, and $\mathcal{S}$ the set of possible agreements. Let $a_i \in \mathcal{A}$ be a negotiating agent and $T_i$ its set of tactics. Let $a_j \in \mathcal{A}$ be the other negotiating agent and $p^{t-1}_{j\to i}$ the offer that $a_j$ has just proposed to $a_i$ in period $t-1$. A concession strategy $C_i : \mathcal{T} \to \mathcal{S} \cup \{\texttt{Yes}, \texttt{No}, \texttt{Opt}\}$ for $a_i$ is a function with the following general form:*

$$C_i = \begin{cases} \textit{apply } Y_i \textit{ and prepare } p^t_{i\to j} & \\ \textit{if} \triangle U_i \geq 0 \textit{ accept } p^{t-1}_{j\to i} \textit{ else reject,} & \textit{if } a_j \textit{'s turn and } U_i(p^{t-1}_{j\to i}) \geq U_i(\hat{s}_i) \\ \textit{reject } p^{t-1}_{j\to i} \textit{ and quit,} & \textit{if } a_j \textit{'s turn and } U_i(p^{t-1}_{j\to i}) < U_i(\hat{s}_i) \\ \textit{offer compromise } p^t_{i\to j}, & \textit{if } a_i \textit{'s turn (time period } t) \end{cases}$$

*where:*

**(i)** *for each issue $x_k \in \mathcal{I}$, $Y_i$ is a concession tactic (see below);*
**(ii)** *$p^t_{i\to j}$ is the offer of $a_i$ for period $t$ of negotiation;*
**(iii)** $\triangle U_i = U_i(p^{t-1}_{j\to i}) - U_i(p^t_{i\to j})$;
**(iv)** *$U_i(\hat{s}_i)$ is the utility of the least-acceptable agreement for $a_i$, i.e., the worst (but still acceptable) agreement for $a_i$.*

**Concession Tactics.** These tactics are functions that model the concessions to be made throughout negotiation. A formal definition of a generic concession tactic follows (see also [7]).

**Definition 6 (Concession Tactic).** *Let $\mathcal{A} = \{a_1, a_2\}$ be the set of negotiating agents, $\mathcal{I} = \{x_1, \ldots, x_n\}$ the negotiating agenda, and $\mathcal{D} = \{D_1, \ldots, D_n\}$ the set of issue domains. A concession tactic $Y_i : D_k \times [0,1] \to D_k$ of an agent $a_i \in \mathcal{A}$ for an issue $x_k \in \mathcal{I}$ is a function with the following general form:*

$$Y_i(x_k, f_k) = x_k - f_k(x_k - lim_k)$$

*where:*

**(i)** *$f_k \in [0,1]$ is the concession factor of $a_i$ for $x_k$;*
**(ii)** *$lim_k$ is the limit of $a_i$ for $x_k$.*

The following three levels of concession magnitude are commonly discussed in the negotiation literature [3]: large, substantial, and small. To this we would add two other levels: null and complete. Accordingly, we consider the following five concession tactics.

1. *stalemate*: models a null concession on an issue $x_k$ at stake;
2. *tough*: models a small concession on $x_k$;
3. *moderate*: models a substantial concession on $x_k$;
4. *soft*: models a large concession on $x_k$;
5. *accommodate*: models a complete concession on $x_k$.

Now, concession tactics can generate new values for each issue at stake by considering specific criteria. Typical criteria include the time elapsed since the beginning of negotiation, the quantity of resources available, the previous behavior of the opponent, and the total concession made on each issue throughout negotiation (see, e.g., [1, 4]). In this work, we also consider the quantity of energy traded in a given period of the day. Consider a wise tariff involving $m \in [1, 24]$ periods. Let $a_i \in \mathcal{A}$ be a negotiating agent and $E$ the amount of energy that $a_i$ is willing to trade in a specific period. We model the concession factor $f$ of $a_i$ by the following family of exponential functions [7]:

$$f(E) = exp^{-\beta \, \frac{E}{E_T}}$$

where:

**(i)** $\beta \in \mathbb{R}^+$ is a parameter;
**(ii)** $E_T$ is the total amount of energy that $a_i$ is willing to trade in a day.

## 4 Negotiating Hour-Wise Tariffs: A Case Study

David Colburn, CEO of N2K Power—a retailer agent—and Tom Britton, executive at SCO Corporation—a customer agent—negotiate a 24-rate tariff in a multi-agent electricity market.[2] Table 1 shows the initial offers and the price limits for the two agents. Some values were selected by looking up to real trading prices associated with a pool market in an attempt to approximate the case study to the real-world. In particular, market reference prices were obtained by analysing the Iberian Electricity Market.[3] The minimum seller prices—that is, the limits—were then set to these reference prices. Also, some energy quantities were based on consumer load profiles provided by the New York State Electric & Gas.[4]

Negotiation involves an iterative exchange of offers and counter-offers. The negotiation strategies are the following:

- Starting reasonable and conceding moderately (SRCM): negotiators adopt a realistic opening position and make substantial concessions during negotiation;
- Low-priority concession making (LPCM): negotiators yield basically on low-priority issues throughout negotiation;
- Energy dependent concession making (EDCM): negotiators concede strategically throughout negotiation, by considering the amount or quantity of energy traded in each period of the day;
- Conceder [1]: negotiators make large concessions at the beginning of negotiation and low concessions near a deadline; they quickly go to their resistance points;

[2] As stated earlier, this section extends the case study presented in [8, 9].
[3] `www.mibel.com`
[4] `www.nyseg.com`

**Table 1.** Initial offers and price limits for the negotiating parties

| | Consumer | | | Retailler | |
|---|---|---|---|---|---|
| Hour | Price (€/MWh) | Limit (€/MWh) | Energy (MWh) | Price (€/MWh) | Limit (€/MWh) |
| 1 | 42.26 | 54.69 | 6.28 | 57.18 | 47.23 |
| 2 | 32.85 | 42.52 | 6.03 | 44.45 | 36.72 |
| 3 | 31.49 | 40.76 | 5.90 | 42.61 | 35.20 |
| 4 | 31.45 | 40.70 | 5.86 | 42.55 | 35.15 |
| 5 | 31.15 | 40.32 | 6.00 | 42.15 | 34.82 |
| 6 | 31.45 | 40.70 | 6.30 | 42.55 | 35.15 |
| 7 | 38.36 | 49.64 | 7.34 | 51.90 | 42.87 |
| 8 | 45.51 | 58.89 | 8.97 | 61.57 | 50.86 |
| 9 | 43.52 | 56.32 | 10.30 | 58.88 | 48.64 |
| 10 | 45.51 | 58.89 | 11.09 | 61.57 | 50.86 |
| 11 | 47.44 | 61.39 | 11.50 | 64.18 | 53.02 |
| 12 | 45.51 | 58.89 | 11.79 | 61.57 | 50.86 |
| 13 | 45.56 | 58.96 | 11.50 | 61.64 | 50.92 |
| 14 | 45.51 | 58.89 | 11.44 | 61.57 | 50.86 |
| 15 | 42.54 | 55.06 | 11.21 | 57.56 | 47.55 |
| 16 | 41.65 | 53.90 | 10.75 | 56.35 | 46.55 |
| 17 | 34.31 | 44.41 | 9.99 | 46.43 | 38.35 |
| 18 | 32.47 | 42.02 | 9.29 | 43.93 | 36.29 |
| 19 | 31.08 | 40.23 | 8.86 | 42.06 | 34.74 |
| 20 | 34.00 | 44.00 | 8.76 | 46.00 | 38.00 |
| 21 | 42.26 | 54.69 | 8.65 | 57.18 | 47.23 |
| 22 | 45.22 | 58.52 | 8.02 | 61.18 | 50.54 |
| 23 | 45.31 | 58.63 | 7.27 | 61.30 | 50.64 |
| 24 | 43.03 | 55.68 | 6.75 | 58.21 | 48.09 |

**Table 2.** Benefit of agents in the final agreement: (Consumer; Retailer) pairs

| | SRCM | LPCM | EDCM | Conceder | Boulware | TFT |
|---|---|---|---|---|---|---|
| SRCM | (0.55; 0.45) | (0.54; 0.47) | (0.47; 0.54) | (0.90; 0.10) | (0.39; 0.61) | (0.68; 0.32) |
| LPCM | (0.75; 0.27) | (0.77; 0.24) | (0.64; 0.38) | (1.00; 0.01) | (0.53; 0.50) | (0.69; 0.33) |
| EDCM | (0.54; 0.50) | (0.54; 0.50) | (0.47; 0.57) | (0.85; 0.19) | (0.47; 0.57) | (0.62; 0.42) |
| Conceder | (0.11; 0.89) | (0.09; 0.93) | (0.08; 0.92) | (0.60; 0.40) | (0.03; 0.97) | (0.73; 0.28) |
| Boulware | (0.63; 0.37) | (0.62; 0.38) | (0.55; 0.41) | (0.93; 0.07) | (0.34; 0.63) | (0.63; 0.37) |
| TFT | (0.63; 0.37) | (0.57; 0.44) | (0.52; 0.52) | (0.62; 0.40) | (0.59; 0.43) | (0.55; 0.50) |

- Boulware [1]: negotiators maintain the offered values until the time is almost exhausted, whereupon they concede up to the reservation values;
- Tit-For-Tat (TFT) [1]: agents reproduce, in percentage terms, the behavior that their opponent performed $\alpha > 1$ received proposals ago;

We have taken up the possible pairs of strategies, one at a time, and examined their impact on the negotiation outcome. The main response measure was the joint benefit provided by the final agreement, i.e., the sum of the two agents benefits in the final agreement. Table 2 shows the results. The following strategies yielded superior outcomes for both agents:

1. Low-priority concession making (LPCM);
2. Energy dependent concession making (EDCM).

It is important to note, however, that these are *initial* (and *partial*) results in a specific bargaining scenario. There is a need to conduct extensive experiments to evaluate the effect of the aforementioned strategies on both the outcome of negotiation and the convergence of the negotiation process.

## 5 Conclusion

This paper has presented the key features of a model for software agents that handles two-party and multi-issue negotiation. The paper has also described a case study on forward bilateral contracts. Results from a multi-agent retail market have shown that both low-priority concession making and energy dependent concession making strategies lead to superior outcomes.

## References


1. Faratin, P., Sierra, C., Jennings, N.: Negotiation Decision Functions for Autonomous Agents. Robotics and Autonomous Systems 24, 59–182 (1998)
2. Kirschen, D., Strbac, G.: Fundamentals of Power System Economics. Wiley, Chichester (2004)
3. Lewicki, R., Barry, B., Saunders, D.: Negotiation. McGraw Hill, New York (2010)
4. Lopes, F., Mamede, N., Novais, A.Q., Coelho, H.: A Negotiation Model for Autonomous Computational Agents: Formal Description and Empirical Evaluation. Journal of Intelligent & Fuzzy Systems 12, 195–212 (2002)
5. Lopes, F., Mamede, N., Novais, A.Q., Coelho, H.: Negotiation Strategies for Autonomous Computational Agents. In: ECAI 2004, pp. 38–42. IOS Press (2004)
6. Lopes, F., Novais, A.Q., Coelho, H.: Bilateral Negotiation in a Multi-Agent Energy Market. In: Huang, D.-S., Jo, K.-H., Lee, H.-H., Kang, H.-J., Bevilacqua, V. (eds.) ICIC 2009. LNCS, vol. 5754, pp. 655–664. Springer, Heidelberg (2009)
7. Lopes, F., Coelho, H.: Concession Strategies for Negotiating Bilateral Contracts in Multi-agent Electricity Markets. In: IATEM 2012 Workshop and DEXA 2012 Event, pp. 321–325. IEEE Computer Society Press (2012)
8. Lopes, F., Rodrigues, T., Sousa, J.: Negotiating Bilateral Contracts in a Multi-agent Electricity Market: A Case Study. In: IATEM 2012 Workshop and DEXA 2012 Event, pp. 326–330. IEEE Computer Society Press (2012)
9. Lopes, F., Algarvio, H., Coelho, H.: Bilateral Contracting in Multi-agent Electricity Markets: Negotiation Strategies and a Case Study. In: International Conference on the European Energy Market (EEM 2013). IEEE Computer Society Press (2013)
10. Osborne, M., Rubinstein, A.: Bargaining and Markets. Academic Press, London (1990)
11. Pruitt, D.: Negotiation Behavior. Academic Press, New York (1981)
12. Pruitt, D., Carnevale, P.: Negotiation in Social Conflict. Open University Press, Philadelphia (1993)
13. Raiffa, H.: The Art and Science of Negotiation. Harvard University Press, Cambridge (1982)
14. Shahidehpour, M., Yamin, H., Li, Z.: Market Operations in Electric Power Systems. John Wiley & Sons, Chichester (2002)