Paper accepted for presentation at 2009 IEEE Bucharest Power Tech Conference, June 28th - July 2nd, Bucharest, Romania

Bilateral Negotiation of Energy Contracts from the Buyer Perspective

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Abstract-- **In this study is presented a decision support model considering the perspective of a buyer who needs evaluating a basic set of contractual conditions. The approach recognizes that a potential new contract under negotiation introduces two main risks: One is related to the insufficiency of load supply (ILS) to end users. Other risk is related with the volatility of the short term spot prices used as a reference for defining the contractual price. Both of these risks are estimated based on the Monte Carlo method and payment minimization. Important characteristics of bilateral contracts like, the necessary modulation to compensate seasonal load variations and the flexibility margins are considered in the model. In case the risks levels are not acceptable, the model makes possible to evaluate a review in the previous conditions in a responsive manner. Results show that with this tool, agents have important information about the negotiated offers being able to clearly define margins of negotiation. These margins are based on the relationships between levels of risk and contractual conditions. The proposed tool is easy to implement and gives a strong support in the decision making process during negotiation of bilateral energy contracts.**

***Index Terms*--Bilateral Contracts, Risk Management, Monte Carlo Simulation, Contractual Conditions.**

I. INTRODUCTION

In electricity markets, during negotiation of long term energy bilateral contracts, agents need to consider contractual conditions involving risks due to the uncertainty of several aspects in the trading process [1] – [4]. The study presented here analyzes the perspective of buyer agents like generation companies (gencos), distribution companies (discos), retailers, or big consumers. As buyers, these agents have specific needs and risks during the negotiation process. Gencos can play the role of buyers of bilateral energy contracts for the purpose of protecting themselves against energy unavailability or for the purpose of making a good deal by buying a bilateral contract at low price. In the case of discos, they want to supply energy to end users without being exposed to unfavorable spot prices and/or being exposed to suffer penalties imposed by the regulator in case of causing energy shortages [5]. In the case of retailers, their objective is to buy energy contracts at low prices and sell energy at higher prices for making profits. They need to balance their financial situation assuming the market risks due to the impossibility of storing large amounts of energy [6]. Big consumers are concerned with supplying their energy needs by negotiating better conditions than the ones offered by discos. Because of their specific characteristics, independent big buyers can directly negotiate contractual conditions with producers (gencos) for implementing bilateral contracts. During negotiation they should study the possible unfavorable exposition to the spot price and financial penalties for not fully supply the end users load during the contractual period [5].

Considering a set of negotiation conditions, the suggested model estimates if the conditions are convenient taking into account the level of risk involved. From the buyer perspective, the suggested model gives information for a clear assessment of the convenience of offered conditions like the size of the contract, price, monthly modulation and flexibility in an annual basis. Moreover, the suggested approach estimates the level of risk of not fully supplying the required energy to end users, which is called here as risk of insufficiency of load supply (*ILS*), in case of energy shortage during the contractual period. Note that with this estimative of the *ILS* risk, the buyer can try to fully supply their load with only bilateral contracts as could be requested by the regulator. Additionally, the model estimates the level of risk of unfavorable spot prices during the annual period of the contract based on annual forecast prices derived from statistical analysis of historical records.

The process of determining risks levels takes into consideration the optimization of the buyer portfolio. This optimization consists in minimizing payments by selecting the best offers in the spot market given the flexibility margin offered by bilateral contracts. Several important studies have been presented in the literature on this subject [7] – [9]. The model proposed here besides solving the portfolio optimization problem also combines a statistical procedure for the purpose of obtaining risk levels associated with the implementation of the potential new contract.

In section II is presented the mathematical formulation of the buyer portfolio optimization model used here. In section III is presented the structure of the support decision tool. In section IV, the contractual conditions from the buyer perspective like seasonal modulation and flexibility are mathematically formulated. In section V is presented the model used for simulating the main random variables. In section VI is presented a statistical analysis in order to obtain risk measures. In section VII and VIII numerical examples and conclusions are presented .

This work is financially supported by the Coordenação de Aperfeiçoamento de Pessoal de Nivel Superior - CAPES.

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II. BUYER PORTFOLIO OPTIMIZATION

The buyer portfolio optimization problem consists of determining the best purchase strategy within a contractual period defining the required energy amounts in each interval of the period in order to minimize agent's payments. Considering a contractual price of a new contract and having a spot price forecast based on statistical records, the buyer has several alternatives to meet their own load consumption along the contractual period. In an annual contractual horizon, the buyer minimizes their payments by adjusting the seasonal modulation of the new contract as showed in Figure 1 for three contracts.

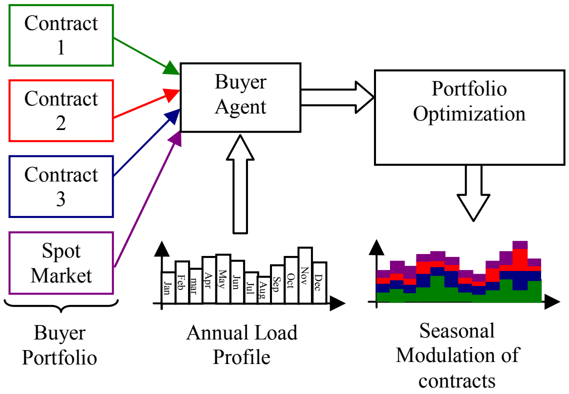

Fig. 1: Optimal seasonal modulation of buyer portfolio.

In this figure if the buyer already has two old contracts supplying part of their load, he or she wants to adjust the seasonal modulation of the third new contract before offering a negotiation condition to the seller. This optimal adjustment depends on the estimative of their load profile and price forecast in the spot market during the contractual period. These uncertainties are introduced in the buyer portfolio management model in order to also evaluate the corresponding risks.

The optimization function of the buyer is the payment minimization of energy purchases during the contractual period. Since, for instance, in the case of discos the revenues coming from selling energy to end users are normally supervised by the regulator through fixed rates and considering that eventual energy sold in the spot market can be modeled as negative payments, the buyer optimization problem considered here is the minimization of payments instead of the maximization of profit.

The annual buyer payment (ABP) in \$/year is

$$ABP = C^{BCC} - T^{spot} + C^{pen}. \tag{1}$$

Where, C^{BCC} is the total annual payment of contracts that can be written as the summation of monthly energy amounts purchased at the corresponding contractual price, π_i. This summation includes the offer of the new contract under negotiation. Therefore, C^{BCC} (\$/year) can be written as,

$$C^{BCC} = \sum_{m}^{12}\sum_{i=1}^{nc} C_{i,m}^{BCC} = \sum_{m=1}^{12}\sum_{i=1}^{nc} E_{i,m}^{BCC} \cdot \pi_i. \tag{2}$$

Where, $E_{i,m}^{BCC}$ is the monthly level of energy bought at month m through contract i considering that the buyer has a total of nc contracts. The possible participation on the spot market is represented through transactions, T^{spot} (\$/year), as defined in (3).

$$T^{spot} = \sum_{m=1}^{12} E_m^{spot} \cdot \lambda_m \tag{3}$$

Where λ_m is the average spot price at month m. The monthly negotiated energy in the spot market is the difference between the purchased energy through bilateral contracts and the forecasted level of consumption (from the EX-ANTE buyer perspective), ED_m^{for}, or the difference between the purchased energy through bilateral contracts and the measured level of consumption (from the EX-POST regulator point of view), ED_m^{ver}, as shown in (4).

$$E_m^{spot} = \sum_{i=1}^{nc} E_{i,m}^{BCC} - ED_m^{ver} \tag{4}$$

The short term transactions can be written in terms of monthly levels as shown in (5) by substituting (4) in (3).

$$T^{spot} = \sum_{m=1}^{12}\left(\sum_{i=1}^{nc} E_{i,m}^{BCC} - ED_m^{ver}\right)\cdot \lambda_m \tag{5}$$

Observe that if $T^{spot} > 0$ then the buyer has a revenue because of the possibility to sell energy (reducing total payments), whereas if $T^{spot}<0$ the buyer has an expenditure because of the need to purchase energy in the short term market. The self energy produced by the buyer can be consider in this model as another purchased contract, $E_{i,m}^{BCC}$, in (5).

From the regulator point of view, energy buyers like Discos should fully supply end users at all moments through their bilateral contracts or transactions in the spot market. In case of insufficiency of load supply (*ILS*) to end users, the regulator imposes penalties that can follow the rule given in (6).

$$C^{pen} = \begin{cases} 0, & ILS \le 0 \\ \dfrac{ILS}{12}\cdot \lambda^{pen}, & ILS > 0 \end{cases} \tag{6}$$

Where, λ^{pen} is a reference price fixed by the regulator and *ILS* is defined as shown in (7).

$$ILS = \sum_{m=1}^{12}\left(ED_m^{ver} - \sum_{i=1}^{nc} E_{i,m}^{BCC}\right) \tag{7}$$

From the Disco perspective, it is not possible to know exactly the load at each interval in the contractual period in the future, for this reason, is necessary estimating the load profile. This means that from the buyer perspective the negotiation depends on forecasts of several factors in the contractual period (or ex-ante assessment) whereas from the regulator point of view the role is verifying in an annual basis the past operation based on measurements (or ex-post or after the fact assessment), as illustrated on Figure 2.

Because of their position, the buyer should consider the load to be supplied during the contractual period with a random behavior. Modeling this random behavior of the load can be done in several ways. In section IV is presented a simple procedure to model a random load behavior following an expected load profile ($\mathbf{ED^{for}}$) based on historical records.

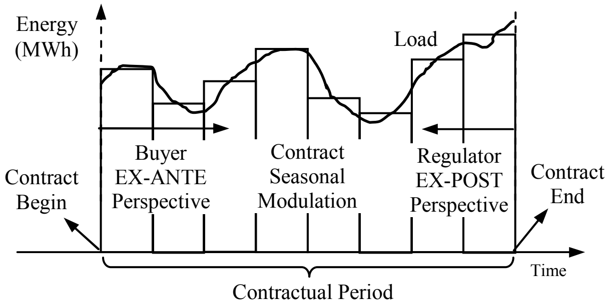

Fig. 2. Buyer and Regulator perspectives

Substituting (2), (5) and (6) in (1), the annual buyer payment is,

$$ABP = \sum_{m=1}^{12} \left[\begin{array}{l} ED_m^{ver} \cdot \left(\lambda_m + \dfrac{\lambda^{pen}}{12} \right) + \dots \\ \dots + \displaystyle\sum_{i=1}^{nc} E_{i,m}^{BCC} \cdot \left(\pi_i - \lambda_m - \dfrac{\lambda^{pen}}{12} \right) \end{array} \right] \qquad (8)$$

Defining $\lambda_m^* \overset{\Delta}{=} \lambda_m + \dfrac{\lambda^{pen}}{12}$ and inserting in (8), *ABP* can be expressed as follows,

$$ABP = \sum_{m=1}^{12} \left[ED_m^{ver} \cdot \lambda_m^* + \sum_{i=1}^{nc} \underbrace{E_{i,m}^{BCC} \cdot \left(\pi_i - \lambda_m^* \right)}_{\text{Oportunity Cost}} \right] \qquad (9)$$

The last term in (9) is the opportunity cost for not participating in the spot market and instead paying π_i for the energy amount, $E_{i,m}^{BCC}$. The buyer portfolio optimization consists in minimizing (9) having as a decision variable the seasonal modulation of the potential new contract *i*, $E_{i,m}^{BCC}$, as showed in the optimization problem described by (10) - (12).

$$Minimize \ \{ABP\} \qquad (10)$$

Subject to the following constraints:

- The negotiated annual amount of energy must be supplied.

$$E_i^{BCC} = \sum_{m=1}^{12} E_{i,m}^{BCC} \qquad (11)$$

- Monthly levels have a margin of variation dictated by the flexibility condition, ϕ_i.

$$E_{i,m}^{min} = E_{i,m}(1-\phi_i) \le E_{i,m}^{BCC} \le E_{i,m}(1+\phi_i) = E_{i,m}^{m\acute{a}x} \qquad (12)$$

Where $E_{i,m}$ are the energy levels corresponding to a required predefined modulation (which can be flat, proportional to $\mathbf{ED^{for}}$, or any other). The limits in (12) depend on the contractual condition of flexibility which is subject to negotiation. For instance, in Brazil the maximum allowed flexibility (ϕ_i) by the regulator is ±15%. The previous optimization depends on uncertain parameters like spot prices and load consumption along the contractual period. Because of this, a Monte Carlo procedure is used as described in the next section. The optimization problem (10) – (12) can be used by the buyer to evaluate a new contract and associated risks of *ILS* and negative spot exposition. The way these risks are estimated considering the previous optimization problem and how to use this information for supporting the negotiation of a new contract is the main contribution of this paper. The procedure is described in the following sections.

III. BILATERAL CONTRACT NEGOTIATION TOOL FROM BUYERS PERSPECTIVE

Figure 3 presents the structure of the decision support tool. The initial required input consists of contractual conditions like annual energy blocks, associated contractual prices, seasonal modulation and flexibility margin. Other required input data are the self-defined risk tolerance level, a set of samples of energy consumption and a set of samples of spot prices. The sets of samples are used for applying the Monte Carlo method.

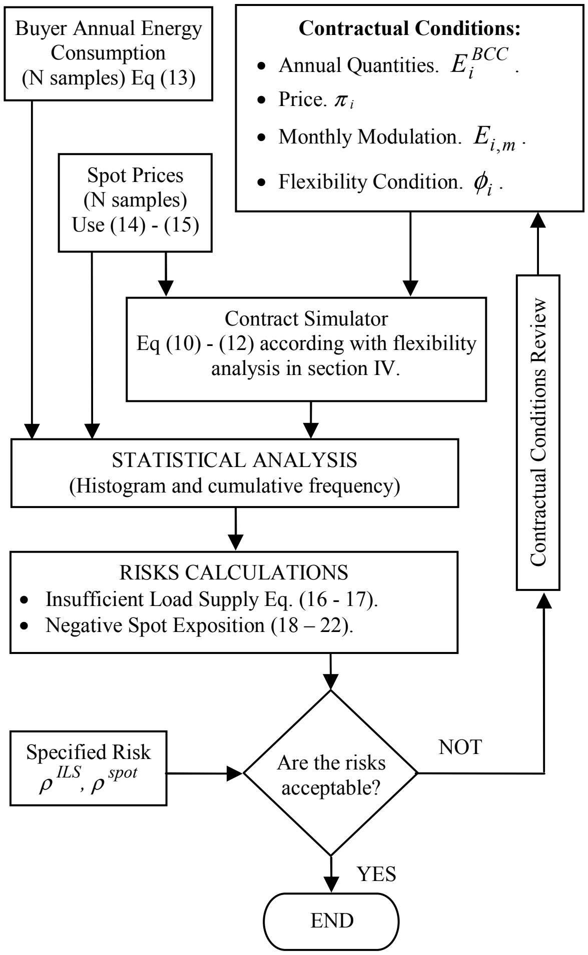

Fig. 3: Structure of the Bilateral Contract Negotiation support tool.

The contractual initial conditions and samples of variables are introduced in the contract simulator for producing a set of samples which allows obtaining risks levels through a further statistical process. The contract simulator is able to consider two types of possible flexibility margin definitions: mandatory and optional. If the risks levels are unacceptable, modifications of contractual conditions should be suggested to the seller for the purpose of reaching an agreement. New contractual conditions can be easily evaluated by using the information already processed in previous rounds. Each part of the decision support tool is described in the following sections.

IV. CHARACTERISTICS OF SEASONAL MODULATION AND FLEXIBILITY CONDITION

The definition of monthly levels of contracts is a condition subject to negotiation or not. In general, because of the inelasticity of the load the buyer determines the monthly levels according to the load profile ($\mathbf{ED}^{\mathbf{for}}$) along the contractual period. In the model presented here, only the buyer establishes the condition of seasonal modulation. Nevertheless, the model is able to consider the case when the regulator allows implementing a contract where the seller determines the contract modulation. In this case, the contract modulation does not follow a load profile but instead a different monthly modulation driven by operational and financial purposes [4].

Electricity markets consider two possibilities for exercising the flexibility margin condition in bilateral contracts. One way is considering a mandatory flexibility and the other is considering an optional flexibility.

A. Mandatory Flexibility

The margin defined by the flexibility is estimated based on load records and allows the future compensation of unexpected load variations. These unplanned variations can happened, for instance, when a set of consumers decide to be supplied from other disco or decide to be independent consumers negotiating directly with producers (or vice-versa, if new consumers are supplied by the buyer). With mandatory flexibility the buyer can only use the margin provided by the flexibility to follow their load as closer as possible. It is called mandatory flexibility because it is the only rule allowed by the regulator for using the flexibility margin. The possibility of using this margin for the purpose of obtaining revenues by trading in the spot market is not allowed. According to this use of the flexibility margin, the aggregated monthly allocated levels of energy do not necessarily match with the annual contractual size. It is left to the last annual contract month to compensate the aggregate imbalance. This imbalance is priced at the corresponding spot price of the last month.

B. Optional flexibility

In this kind of flexibility, the margin defined by ϕ_i is used by the buyer depending on the favorable forecasted opportunities presented in the spot market along the contractual period. The buyer uses the margin to optimize their exposition in the short term market by solving the problem (10) – (12). The buyer can simulates the impact on ABP due to flexibility contractual offers adjusting the limits in (12). In case the buyer has other contracts with the same type of optional flexibility, the problem (10) – (12) is used to optimize the portfolio of contracts inside the corresponding margins.

This study is focused on the use of optional flexibility because it is the more widely used in electricity markets.

V. MODELS FOR GENERATING RANDOM VARIABLES

The decision support model allows incorporating any probability density function (*pdf*) for the purpose of generating samples of random variables like spot prices and loads along the contractual period. These samples are necessary in order to use the Monte Carlo procedure suggested here. Agents can select the *pdf* that better represent the statistical behavior of the random variable under consideration. Among several ways of generating random samples for load and spot prices, it is adopted a formulation using a normal *pdf* as described next. In the case of generating load samples, the energy demand supplied by the buyer, $\mathbf{ED}^{\mathbf{ver}}$, is a random vector obtained by (13).

$$\mathbf{ED}^{\mathbf{ver}} = (1+\sigma_t \cdot r_n)\cdot \mathbf{ED}^{\mathbf{for}} \tag{13}$$

This vector is obtained from a typical load profile vector, $\mathbf{ED}^{\mathbf{for}}$, which is available in historic records. Both vectors have dimension equal to the number of months of the contractual period. r_n is a random number whose normal *pdf* has mean equal to zero and standard deviation equal to one. σ_t represents the associated uncertainty at time interval t in the load forecast that varies between pessimistic and optimistic expected scenarios.

Because the samples created by (13) are based on typical load profiles, they keep a degree of inter-temporal correlation between them. This is not the case of the spot prices which normally are quite volatile and because of this the inter-temporal influences between samples do not follow a defined pattern. Thus, model (13) is not used in this case. The spot price samples in each month are generated according to (14).

$$\lambda_m = \lambda_m^{avg} + \sigma \cdot r_n \tag{14}$$

Where λ_m^{avg} is the monthly average spot price obtained from historic records; r_n is a random number whose normal *pdf* has mean equal to zero and standard deviation equal to one; σ is the standard deviation of the spot price *pdf*, which follows the approximation showed in (15).

$$\sigma = \left(\lambda_m^{\max} - \lambda_m^{\min}\right)/2 \tag{15}$$

Where, $\lambda_m^{\max}$ and is the maximum expected spot price (pessimistic scenario) and $\lambda_m^{\min}$ is the minimum expected spot price (optimistic scenario) in month m. Observe that monthly price samples are generated based on the historic average and the standard deviations that considers the possible short term spot price volatility. For this reason weekly or hourly price samples are not explicitly used. According with this model, the monthly resolution is a reasonable approximation in a long term horizon in power systems with predominant hydro generation because of the dynamic of the hydrological regime. However, if it is consider necessary, the procedure is able to work with a higher resolution of samples.

The strategy followed for producing the set of samples through (13) - (15) is a possibility of modeling the random behavior of the spot prices and load consumption which is used in the structure presented in Figure 3. However, depending on the buyer case, other more suitable models can be incorporated in the decision support tool. In the following sections is presented the risks calculations based on the Monte Carlo simulation.

VI. STATISTICAL ANALYSIS AND RISK CALCULATION

A. *Risk of Insufficiency of Load Supply*

According to the definition of *ILS* in (6), the risk of insufficiency of load supply, Ψ^{ILS} , is defined as the probability of *ILS* becomes positive as shown in (16).

$$\Psi^{ILS} = \text{Prob}\{0 < ILS\} \tag{16}$$

The buyer can also self-define the degree of tolerance accepted in relation to this risk, ρ_{ILS} . In this case the risk is as shown in (17).

$$\Psi^{ILS} = \text{Prob}\{\rho_{ILS} < ILS\} \tag{17}$$

B. *Risk of Unfavorable Spot Exposition*

The buyer exposition in month *m* in the short term market due to the presence of contract *i* is defined as shown in (18) and represents the monthly opportunity cost of contract *i*.

$$\varepsilon_{i,m}^{spot} = E_m^{spot} \cdot (\lambda_m - \pi_i) \tag{18}$$

Where, E_m^{spot} is obtained according to (4). Because $\varepsilon_{i,m}^{spot}$ in (18) can assume positive and negative values depending on E_m^{spot} and price differences, four situations are possible along the contractual period due to the volatility of prices and uncertainty of the load as presented in table I.

TABLE I: SPOT EXPOSITION OF A BUYER

	$\varepsilon_{i,m}^{spot}$	
	$E^{spot} < 0$ (need to purchase)	**$E^{spot} > 0$ (need to sell)**
$\lambda_m < \pi_i$	Positive	Negative
$\lambda_m > \pi_i$	Negative	Positive

If $E_m^{spot} < 0$ and $\lambda_m < \pi_i$, the buyer should purchase energy in the spot market to compensate the deficit at a price lower than the contractual price. Therefore, in this case the exposition is positive. If $E_m^{spot} < 0$ and $\lambda_m > \pi_i$, the buyer should purchase energy from the spot market to compensate the deficit at a higher price than the contractual price. Therefore, in this case the exposition is negative. If $E_m^{spot} > 0$ and $\lambda_m < \pi_i$, then the buyer should sell energy in the spot market at a lower price than the contractual price. This situation is unfavorable because energy is purchased at a higher price and the surplus is sold at a lower price. In this case the exposition in the spot market is negative. If $E_m^{spot} > 0$ and $\lambda_m > \pi_i$, the buyer can sell the energy surplus in the spot market at a higher price than the contractual price. In this case the spot exposition is positive.

The annual buyer exposition in the spot market caused by the potential new contract *i* is obtained by (19).

$$\varepsilon_i^{spot} = \sum_{m=1}^{12} \varepsilon_{i,m}^{spot} \tag{19}$$

The risk of unfavorable spot exposition caused by the presence of the new contract *i* is obtained by using (20).

$$\Psi_i^{spot} = \text{Prob}\{\varepsilon_i^{spot} < 0\} \tag{20}$$

Considering the effect on the spot exposition of other existent contracts, $\varepsilon^{spot} = \sum_{i=1}^{nc} \varepsilon_i^{spot}$; the risk of unfavorable spot exposition is,

$$\Psi^{spot} = \text{Prob}\{\varepsilon^{spot} < 0\}. \tag{21}$$

The buyer can self-define a measure of tolerance to such risk, ρ^{spot}. In this case, the risk is defined as shown in (22).

$$\Psi^{spot} = \text{Prob}\{\varepsilon^{spot} < \rho^{spot}\} \tag{22}$$

VII. NUMERICAL EXAMPLE

In this Example, we studied a case of a Distribution company located in the southwest region of Brazil whose energy demand has a forecasted growing rate of 4.5%. In Figure 4 is showed the forecasted load curve of the energy amounts required by the buyer for the next 4 years. The estimated degree of uncertainty of the forecasted load level is also shown in the figure.

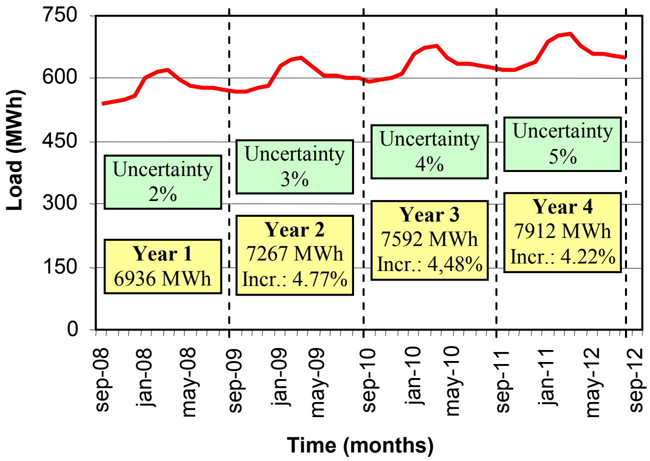

Fig. 4. Disco Load forecast for the next 4 years.

Initial conditions of the negotiation process are described in Table II and consider optional flexibility. Seasonal modulation values in this table correspond to the same values showed in Figure 4.

As described in Figure 3, in order to apply the Monte Carlo Method (considering as random variables the load and spot prices), two sets of one thousand samples of load levels and spot prices are produced by using (13) and (23) (see appendix). Each sample is used for simulating the contract implementation by using (10) - (12) and obtaining as a result a sample of the annual monthly amounts that minimize payments. For each of these results, the *ILS* level and ε^{spot} are calculated by using (7) and (19). After considering all samples of load and spot prices in (10) – (12), one thousand of samples of *ILS* and ε^{spot} are available. These sets of samples are statistically analyzed for obtaining the risks levels of Ψ^{ILS} and Ψ^{spot} by using (17) and (22). The obtained risks levels are compared with the self-defined risks tolerances which in this case are $\Psi^{ILS}=\Psi^{spot}=10\%$.

TABLE II. INITIAL CONTRACTUAL CONDITIONS – SEASONAL MODULATION, CONTRACTUAL PRICE AND FLEXIBILITY

Month	Year			
	1	2	3	4
September	540,6	566,7	593,6	619,5
October	543,6	569,9	596,8	622,9
November	549,2	575,7	602,9	629,3
December	557,6	584,5	612,2	639,0
January	602,5	631,0	658,5	685,9
February	615,9	645,1	673,2	701,2
March	622,3	651,8	680,2	708,4
April	595,6	623,9	651,0	678,1
May	580,7	608,2	634,7	661,1
June	579,7	607,2	633,6	659,9
July	575,6	602,9	629,2	655,3
August	572,6	599,7	625,8	651,8
TOTAL	6936,0	7266,6	7591,9	7912,3
Initial contractual Price (R\$/MWh)		160		
Initial Flexibility		5%		

Table III shows the risks levels obtained in the first year considering several different contractual conditions. This table is divided in three blocks. Each block corresponds to a negotiation observation. By using the block on the left side of the table is possible to estimate the size of the contract in the first year. As can be observed, increasing the size of the contract reduces the risk levels, Ψ^{ILS} . Therefore, for obtaining Ψ^{ILS}<10% the size of the contract should be greater than 6980 MWh. As a consequence, the buyer decides that the more convenient size to purchase is 6990 MWh. The block on the middle of the table gives information to the buyer for estimating the contractual price, given the contractual conditions of size and flexibility. As can be seen in this block, the reduction of the contractual price also reduces the risk level, Ψ^{spot} (risk levels of Ψ^{ILS} remain almost constant). The buyer can choose a contractual price not higher than 360 \$/MWh for ensuring a risk level lower than 12% considering the current conditions of size and flexibility.

The block on the right shows risks levels for several flexibility margins while holding fixed the size and the contractual price. In this case the buyer is considering the possibility of submitting a contractual price offer of 300 \$/MWh. Results show that the reduction of flexibility margins increases the risk levels of Ψ^{spot} (risk levels of Ψ^{ILS} remain almost constant). Therefore, if the self-defined tolerance is not superior to 10%, the buyer can only accept flexibilities offers higher than 4%. As a negotiation strategy, the buyer should start the negotiation suggesting offers with wide margins of flexibility and in the next negotiation rounds progressively reducing for the purpose of making feasible to reach a deal. Supposing that agents agree with a flexibility margin of 2% (which is exactly the forecasted load uncertainty in the first year) but still with the possibility of re-negotiating the contractual price. Table IV shows the new negotiation evaluation considering several contractual prices keeping fixed the flexibility condition in 2% and the size of the contract. In this table is observed that if the seller reduces the contractual price below 180 \$/MWh, the buyer can accept the deal because the risks levels are tolerated.

TABLE III: RISKS LEVELS OBTAINED CONSIDERING SEVERAL CONTRACTUAL CONDITIONS

$\pi = 160\ \mathrm{R\$/MWh}$,			E^{BCC}= 6990 ,			E^{BCC}= 6990 ,		
Flexibility = ±5 %			Flexibility = ±5 %			$\pi = 300\ \mathrm{R\$/MWh}$,		
E^{BCC}	Ψ^{ILS}	Ψ^{spot}	π	Ψ^{ILS}	Ψ^{spot}	Flex	Ψ^{ILS}	Ψ^{spot}
7000	5,4	0,5	390	9,8	13	7%	8,9	1,3
6995	6,5	0,7	**360**	7,9	**12**	6%	8,4	2,9
6980	**12,9**	0,5	330	8,8	6,7	5%	7,3	5,4
6965	24,2	0	300	9,5	5,9	**4%**	7,8	**10**
6950	35,7	0,1	220	8,7	1,4	3%	10,1	17,4
6936	51,1	0	130	8,3	0,2	2%	9,1	31,5
6900	82,3	0	100	7,5	0,1	1%	9,3	59,6
6800	100	0	80	8,5	0	0%	10,6	83

TABLE IV: RISK LEVELS OBTAINED CONSIDERING SEVERAL CONTRACTUAL PRICES FOR A FIXED CONTRACT SIZE AND FLEXIBILITY

E^{BCC}= 6990, Flexibilidade = ±2 %								
π	240	220	200	**180**	160	140	120	100
Ψ^{ILS}	8,6	7,8	7,7	8,2	9,6	10,1	7,9	9
Ψ^{spot}	21,1	17,3	12,8	**10,8**	5,9	5,4	1,9	0,7

TABLE V: CONTRACTUAL CONDITION LIMITS FOR NEGOTIATION

Year	1	2	3	4
Load [MWh]	6936	7267	7592	7912
E^{BCC} [MWh]	6990	7350	7700	8060
Price [R\$/MWh]	180	180	160	185
Flexibility [%]	±2	±3	±4	±5

Table V shows the resulting contractual conditions during the entire contractual period obtained by following the same procedure as described before. As can be seen, the obtained annual contracted quantities are greater than the annual expected quantities. This is because of the need of reducing the risk levels of *ILS* to a self-defined tolerance level considering the increasing uncertainty along the contractual period. The flexibility margin also affects the negotiation. A wide margin is convenient for the buyer but it is not for the seller. The buyer can reduce the negative spot exposition and therefore increase the possibility of obtaining revenues in the spot market. The inconvenience for the seller is the increase in volatility of supplying the contract and the reduction of revenues in the spot market.

VIII. CONCLUSION

A decision support tool designed for buyer agents during negotiation of bilateral energy contracts is presented. The suggested model considers the characteristics of bilateral contractual conditions and the minimization of the buyer payments. Due to the fact that the negotiation of long term bilateral contracts involves uncertainty in prices and load, it is necessary to estimate the levels of risks involved. Since these variables are uncertain along the contractual period, a procedure involving a Monte Carlo simulation and a payment minimization allows obtaining levels of risks. The risks involved during negotiation are the risk of not fully supply end users through bilateral contracts and the risk of unfavorable exposition in the short term market due to the possible buyer participation for compensating the load. The contractual conditions analyzed are the size of the contract, price and delivery conditions like seasonal modulation and flexibility margin. The proposed tool is straightforward to implement and produce tables and cumulative probability curves based on statistic analysis allowing to clearly evaluating seller offers by observing the buyer risk levels. Numerical results show that the buyer can analyze several contractual conditions in different orders establishing margins of negotiation in each contractual condition based on the determination of risks levels. The seller counter offers can be analyzed in a responsive manner. Results also show that optional flexibility normally allows negotiation margins between agents involved in the negotiation of a new energy contract.

IX. APPENDIX

Load samples are obtained by (13) assuming σ=2% in the first year and incrementing this uncertainty by 1% in the following next years as showed in Figure 4. Samples of spot prices are produced through a random procedure showed in (23).

$$\lambda_m = R_{\exp}\left(R_{gamma}(k;\theta)\right) \tag{23}$$

This procedure is based in a Southwest Brazilian region spot price *pdf* approximation. R_{exp} is a random generator number with exponential *pdf* whose scale parameter is generated by function R_{gamma} which is another random generator number with gamma *pdf* (with scale factor θ=75.35 and form factor k=2) [10]. The approximation in (23) was obtained following the procedure in [11] which is based on the simulation of numerous operative scenarios as recommended in [12]. These scenarios include hydrological inflows, total energy demand, unit availability and fuel prices. The statistical behavior of samples generated through (23) follows a typical Pareto *pdf* [13] – [14] which is a suitable approximation for representing the historical behavior of spot prices of the Southwest Brazilian region.

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