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Editores
José Boaventura Cunha
Manuel Cordeiro
Sérgio Leitão

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Production Support-System on Liberalized Market Environment

Filipe Azevedo and Zita A. Vale
GECAD - Knowledge Engineering and Decision Support Research Group
Rua Dr. António Bernardino de Almeida, 431 - 4200-072 Porto (Portugal)
phone:+351 22 8340500, fax:+351 22 8321159
e-mail: fazevedo@dee.isep.ipp.pt; zav@dee.isep.ipp.pt

Abstract

The restructuration and liberalization processes of power systems are a constant all over the world. However, those processes due to the specific characteristics of the "product" electricity create uncertainty and new risks that doesn't exist when power systems were vertically integrated. Those changes, origin the necessity of tools that allow the participants of the electricity markets to practice the hedge against the volatility of the System Marginal Price. In that sense, we present in this paper a Mean Variance Optimization Method trying to give a response to the necessities of the electricity markets participants. This optimization method was applied on an example presented in this paper. We conclude that, the Optimization Method presented in this paper, could be useful to producers and also to others participants.

Introduction

The separation between product – energy – and service – transport and distribution – is the fundamental characteristic of the recent deregulation of the electric sector. This deregulation, associated to the liberalization on an unbundled system, allows the free competition in sectors of activity traditionally monopolist. Facing the new reality, the participants of electricity markets must deal with new challenges but also with new risks (Azevedo, 2003). The volatility of electric energy price in spot markets is, among the risks in a liberalized market, the one that poses major concerns to the agents of the electric market and, in particular, to the producers.

This characteristic, lead the agents of those markets to search for hedging tools (Tanlapco, 2002) that allow them to turn their results more predictable. Responding to that necessity was created, in mature markets, the derivatives markets which negotiate contracts with underlying active the electric energy. Derivatives markets negotiate forward, futures and options contracts (Hull, 1993). To deal with those types of contracts, the participants of the electric markets need decision support tools (Wagner, 2003) that allow them to decide which contracts to establish for a certain programming period considering a certain objective function.

So, in the present paper, was developed a decision support system that allow the producers to decide what type of contracts to establish for a certain programming period. Was admitted in this paper that those entities could only establish contracts that comprises the physical delivery.

Problem Formulation

In the optimization method presented in this paper was admitted that, all energy previously negotiated by the producer has the same delivery price and that the producer leave a margin of production equal to a certain percentage teta (θ) of the maximum capacity plus the energy negotiated in the options that comprise the supply of energy that he will use to satisfy the energy previously negotiated. This margin of production is very important because, if long-call and short-put options weren't exercised, producer has to decide if he produce that energy or if he buy it in the spot market if the incremental costs is lower than the SMP.

The model developed in this paper is based on a maximization of the Mean Variance of the profit (π) for a certain programming period i. However, the expected value of the return is calculated for a set of scenarios S and the variance is calculated for a set of scenarios T, where $T \subset S$. This assumption allows the producer to eliminate the risk associated to a wrong scenarios prediction.

The optimization problem formulation that pretend to maximize a Mean Variance function is given by,

$$\max_i \; U_i = E_i(\pi) - \frac{\delta}{2} \times Var_i(\pi) \tag{1}$$

$$st. \; e_{ig}^{\min} \leq e_{ig} \leq e_{ig}^{\max} \tag{2}$$

$$e_i^P + e_i^{LS} + e_i^{LF} + e_i^{LC} + e_i^{SP} = E_i \tag{3}$$

$$e_i^{SS} + e_i^{SF} + e_i^{SC} + e_i^{LP} \leq e_{ig}^{\max} \times (1-\theta) - (e_{ij}^{LC} + e_{ij}^{SP}) \tag{4}$$

$$e_{ig} = e_i^P + e_i^{SS} + e_i^{SF} + e_i^{SC} + e_i^{LP} \tag{5}$$

$$E_i(\pi) \geq 0 \tag{6}$$

Where,

$$\pi = r_{ij}^P + r_{ij}^{SS} + r_{ij}^{LS} + r_{ij}^{SF} + r_{ij}^{LF} + r_{ij}^{SC} + r_{ij}^{LC} + r_{ij}^{SP} + r_{ij}^{LP} - C(e_{ig}) \tag{7}$$

And,

π	represents the profit, in €, for period i
$E_i(\pi)$	represents the expected profit, in €, for the programming period i and is calculated for the scenarios $S_i=\{s_{i1},\ldots,s_{in}\}$ with probability $p_{is}=\{p_{is1},\ldots,p_{isn}\}$
$Var_i(\pi)$	represents the variance, in €, of the profit for the programming period i. These variance is calculated for a set of scenarios $T_i=\{t_{i1},\ldots,t_{im}\}$ and $T \subset S$
δ	represents the risk aversion factor of the producer
e_{ig}	represents the energy generated, in MWh, for the period programming i
$e_{ig}^{\min}$	represents the minimum energy, in MWh, that generators can produce
$e_{ig}^{\max}$	represents the maximum energy, in MWh, that generators can produce
θ	represents the security reserve, in %, of the $e_{ig}^{\max}$ for the generator
$C_i(e_{ig})$	represents the production costs, in €, of the energy e_{ig} for the programming period i

Study Case

In this example, we pretend to calculate the optimal quantity of energy to produce and to buy in spot, forward or options contracts, to satisfy the quantity of energy previously negotiated for a certain programming period i. We pretend also to calculate the optimal excess energy capacity to sell in spot, forward or options contracts for the same programming period i. Was admitted that the period i has the characteristics indicated in Table 1.

Table 1: Characteristics of the programming period i.

Duration (h)	1
Energy previously negotiated (MWh)	40
SMP scenario 1 (€/MWh; probability)	(22; 0.7)
SMP scenario 2 (€/MWh; probability)	(15; 0.3)

The characteristics of the options contracts negotiated, with delivery date coincident with the programming period i, are presented in Table 2.

Table 2: Characteristics of options contracts for the period i.

	Quantity/Contract (MWh)	Exercise Price (€/MWh)	Premium (€/MWh)
Long Call	2.16	20.00	1.72
Short Put	2.00	17.40	2.06
Short Call	3.02	19.30	2.32
Long Put	1.97	18.00	2.58

Characteristics of forward contracts negotiated with delivery date coincident with the programming period i, are presented in Table 3.

Table 3: Characteristics of forward contracts for the period i.

Delivery Price (€/MWh)	21.02
Quantity/Contract (MWh)	2.50

The production cost function considered is equal to,

$$C(P_g) = 5 + 1.5 \times P_g + 0.1 \times P_g^2$$

with Pg in MW, C in €, P_g^{max}=100 MW and P_g^{min} =5 MW.
And was admitted that the producer previously negotiate to supply 40 MWh at the fixed price of 17.50 €/MWh. The risk aversion factor (δ) used was equal to one, the security reserve (θ) used was 5% and was used an interval T = [13,…,28].

Results

The results for the considered study case are presented in Table 4 and 5.

Table 4: Optimal energy to produce and to contract to satisfy the energy previously negotiated.

Self Production (MWh)	29.315
Long Spot Position (MWh)	0.685
Long Forward Position (N.º of Contracts)	4
Long Call Position (N.º of Contracts)	0
Short Put Position (N.º of Contracts)	0

Table 5: Optimal energy quantities of the excess production capacity to negotiate.

Short Spot Position (MWh)	0.507
Short Forward Position (N.º of Contracts)	21
Short Call Position (N.º of Contracts)	4
Long Put Position (N.º of Contracts)	0

In Fig. 1 - (a) is represented the optimal allocation contracts to supply the energy previously negotiated and the production excess capacity that the producer should sell.

In Fig. 2 – (b) is represented the producer profit for the scenarios interval T=[13,…..,28].

Analyzing Fig. 2 – (b), we can see that the producer profit is stable for the T interval.

To solve this optimization problem and, due to its complexity, were used genetics algorithms.

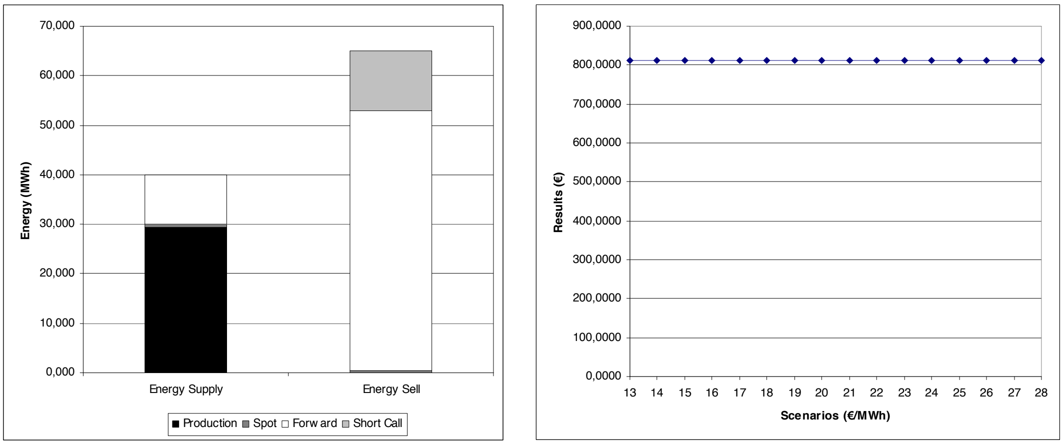

Fig. 1: (a): Optimal contract allocation; (b): Producer results for the interval T

Conclusions

All over the world, the restructuration and liberalization processes of the electric sector have been very popular all over the world. However, electricity markets aren't like the traditional markets due to the specific characteristics of "product" negotiated – the electric energy. One of the characteristics of the electricity markets that take more concerns to their participants is the volatility of the System Marginal Price (SMP). In order to turn those markets more liquid and to allow their participants to practice the hedge was created, in mature markets, the derivatives markets, which introduce a set of tools (contracts) that allow the electric participants to protect them against the volatility of the SMP.

In this work we present a Mean Variance optimization method that allows the participants of electricity markets and in particular the producers, to practice the hedge against the volatility of the System Marginal Price, using forward and options contracts.

Given the difficulties that the participants of the electricity markets deal, the optimization problem here presented could be useful to help them to find the optimal portfolio allocation and to manage, of a simple way, the risk associated to the volatility of the SMP.

Due to the complexity of this problem, to find the optimal solution genetics algorithms seems to be a good choice, however, it is necessary to study more it's behavior in problems of this nature.

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