Short-Term Trading for a Wind-PV Power Producer in an Electricity Market

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Abstract — **This paper deals with the problem of coordinated trading of wind and photovoltaic systems in order to find the optimal bid to submit in a pool-based electricity market. The coordination of wind and photovoltaic systems presents uncertainties not only due to electricity market prices, but also with wind and photovoltaic power forecast. Electricity markets are characterized by financial penalties in case of deficit or excess of generation. So, the aim o this work is to reduce these financial penalties and maximize the expected profit of the power producer. The problem is formulated as a stochastic linear programming problem. The proposed approach is validated with real data of pool-based electricity market of Iberian Peninsula.**

Keywords: Coordinated bidding strategy; day-ahead market; stochastic linear programming; wind-PV power system.

I. INTRODUCTION

Fossil fuels are characterized not only by being a scare source of energy, but also by energy conversion with negative impact on the habitat due to anthropogenic emission [1]. As consequence, renewable energy sources can play an important role in the electricity production of many countries and therefore reduce CO_2 emissions.

Wind power and photovoltaic power are the most promising technologies among the renewable energy sources. However, power producers exploiting these energy sources have to face the uncertainty on the availability of wind and photovoltaic power. A management of a fossil fuelled conventional power plant implies face the uncertainty on electricity prices in a day-ahead electricity market. While for a management of wind and photovoltaic plants there is an augmentation in uncertainty, due to not only electricity prices but also the availability of wind and photovoltaic power, respectively.

A power producer in a day-ahead electricity market has to submit their bids at the previous day for the 24 hours of the next day. The closing of the day-ahead electricity market defines power and price for the physical delivery contracts. However, the remuneration depends on the conformity achieved on the level of the physical delivery with the accepted value of the bid presented at the closing of the market. If it is revealed an absence of conformity, economic penalization for imbalances is due to happen.

A point of view about wind power standing alone is the non-capability of the technology on providing for constant load due to the uncertainty on values of the wind speed during operation [2]. Typically, a wind power system has more availability of the wind energy source at night and particular in the winter time. A point of view about photovoltaic power system standing alone is the non-capability of the technology providing for a continuous source of energy due to low availability of the source of energy in no sun periods or in winter time. The merging of these points of view bring up a line of enquire about if wind power coordinated with PV power has a better economic revenue for bidding in a day-ahead electricity market. This revenue seems to be likely to happen, because of the mismatch of the non-capabilities from one power system technology to other. In addition, coordinated operation to overcome the uncertain of renewable energy sources impact has been recommended to deal with the eventual imbalance cost [3]. Different approaches were presented to deal with wind power and photovoltaic power uncertainties, including the combined use of these technologies with energy storage [4] and stochastic linear programming [5,6].

under malfunctions.

II. PROBLEM FORMULATION

In addition to uncertainty on market prices, a wind-PV power producer is plagued by uncertainty established by the availability of its sources. If there is a non-null difference in hour t between the physical delivering of energy and the bids accepted at the closing of the day-ahead market the producer incurs in an imbalance. At each time period there is a positive imbalance price ratio, , and a negative imbalance price ratio, . For period t a power producer of a k unit operating uncoordinated has a profit as follows,

$$PR_t^k = \lambda_t P_t^k + (\lambda_t r_t^+ \Delta_t^{k+} - \lambda_t r_t^- \Delta_t^{k-}), \qquad (1)$$

The first term represents the expected profit from selling the production P_t^k at a day-ahead market price λ_t. The term in brackets is the imbalance income from the balancing mechanism, for positive deviation Δ_t^{k+} or negative deviation Δ_t^{k-}.

The objective function of the proposed approach for the coordination of wind and PV power, using a stochastic linear programming approach is given as follows, follows,

$$\sum_{\omega=1}^{\Omega}\sum_{t=1}^{T}\pi_{\omega}(\lambda_{t\omega}P_t + \lambda_{t\omega}r^{+}_{t\omega}\Delta^{+}_{t\omega} - \lambda_{t\omega}r^{-}_{t\omega}\Delta^{-}_{t\omega}), \qquad (2)$$

The uncertainties for the wind-PV power producer such as wind power, PV power and market prices are assumed to be stochastic processes and modeled via a set of scenarios Ω. In (2), each scenario ω is weighted by the probability of occurrence π_{ω}. The objective function is subject to,

$$0 \le P_t \le P^{W\max} + P^{PV\max}, \forall t, \qquad (3)$$

In (3), the upper bound on the bid is set to be equal to the sum of the capacity of wind and PV systems.

III. CASE STUDY

The case study is based on a wind system and PV system deployed in the Iberian Peninsula, having 100 MW and 50 MW of rated powers, respectively. The energy traded by the uncoordinated configurations is shown in Figure 1.

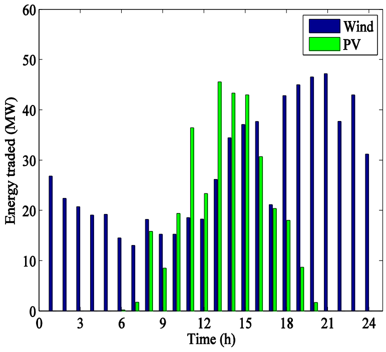

Fig. 1. Energy traded: uncoordinated.

The energy traded by the coordinated configurations is shown in Figure 2.

Figure 1 and Figure 2 shows that there are periods in which coordinated option is better than uncoordinated usually at periods of high day-ahead market prices. The expected profit and CPU time is shown in Table 1.

TABLE 1
EXPECTED PROFIT AND CPU TIME

	Expected profit (€)	CPU (s)
Wind power	49 189.47	5.54
PV power	19 082.38	5.18
Total uncoordinated	68 271.85	-
Total coordinated	68 603.83	17.18

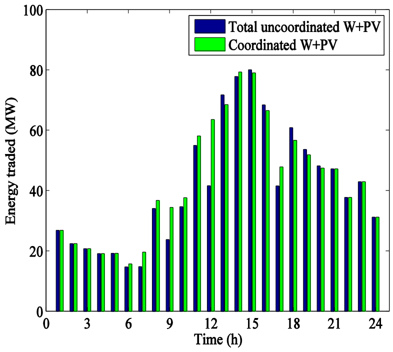

Fig. 2. Energy traded: coordinated.

Table 1 shows the increase on expected profit from the uncoordinated configuration to the coordinated configuration. This increase is due to the fact that the coordinated configuration can absorb more generation volatility.

III. CONCLUSION

Stochastic linear programming is a suitable approach to address the uncertainties by a set of scenarios. The aggregation is envisaged as favorable one when the mismatch due to the wind and PV powers is partial disable by one to another.

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