Wind-Thermal Production in a Day-Ahead Electricity Market

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Abstract — **This paper presents a stochastic mixed-integer linear programming approach for solving the self-scheduling problem of a price-taker thermal and wind power producer taking part in a pool-based electricity market. Uncertainty on electricity price and wind power is considered through a set of scenarios. Numerical results from a case study are presented to illustrate the performance of the proposed approach.**

Keywords: Bilateral contracts, day-ahead market, stochastic programming, wind-thermal production.

I. INTRODUCTION

Renewable energy sources play an important role in the need for clean energy in a sustainable society [1,2]. Renewable energy can partly replace fossil fuels, avowing anthropogenic gas emissions. Energy conversion from renewable energy has been supported by policies, providing incentive or subsidy for exploitation [2]. These polices have pushed the integration of renewable energy forward, but by an extra-market approach. The approach involves, for instances, legislative directives, feed-in tariffs, favorable penalty pricing and grid right of entry, and survives at reserved integration level. But as integration of renewable energy increases the approach is expected to be untenable [3]. Sooner or later, a wind power producer (WPP) has to face competition in a day-ahead electricity market. For instances, in Portugal, a WPP is paid by a feed-in tariff under the condition of a limited amount of time or of energy delivered. Otherwise, the route is the day-ahead market or by bilateral contracting [3].

In a deregulated electricity market, the generation companies operate under a high competition degree due to the nodal variations of electricity prices [2] in order to obtain the best profit bidding in the day-ahead market [2-4]. For the wind power producers (WPP), wind power and the market-clearing electricity price uncertainties are to be addressed in order to know how much to produce in order to formulate realistic bids, because in case of excessive or moderate bids, other producers must reduce or increase production to fill the so-called deviation, implying penalties causing economic losses [2]. For thermal power producers, only market-clearing electricity price uncertainties have to be addressed.

This paper presents a formulation for GENCO owners of thermal plants and wind farms, which allows submitting electrical energy offers at the day-ahead market based on a profitable coordinated exploitation of wind power with thermal power.

II. PROBLEM FORMULATION

System imbalance is defined as a non-null difference on the trading, i.e., between physical delivered of energy and the value of energy on contract at the closing of the market. If there is an excess of delivered energy in the power system, the system imbalance is positive; otherwise, the system imbalance is negative. The imbalance is given by:

$$I_t = \lambda_t^D r_t^+ \Delta_t ,\ \Delta_t \geq 0 \quad I_t = \lambda_t^D r_t^- \Delta_t ,\ \Delta_t < 0 \qquad (1)$$

The exponential nature of a start-up cost of thermal units is modelled by an approximation of a non-decreasing stepwise function with a step is given by:

$$b_{\omega i t} \geq K_i^{\beta} \left(u_{\omega i t} - \sum_{r=1}^{\beta} u_{\omega i t-r} \right) \quad \forall\, \omega, \quad \forall\, i, \quad \forall\, t \qquad (2)$$

The expected revenue of the WTPP over the time horizon NT is given by the solution of the following mathematical programming problem with the objective function given by:

$$\sum_{\omega=1}^{N_\Omega} \sum_{t=1}^{N_T} \pi_\omega \left[\left(\lambda_{\omega t}^D P_{\omega t}^{offer} + \lambda_{\omega t}^D r_{\omega t}^+ \Delta_{\omega t}^+ - \lambda_{\omega t}^D r_{\omega t}^- \Delta_{\omega t}^- \right) - F_{\omega t}^T \right] \qquad (3)$$

III. CASE STUDY

The market data is to be used by a GENCO that owns both thermal and wind production. For the thermal generation are considered 8 units with a total installed capacity of 1440 MW and wind farm installed capacity is 360 MW. In a first step, we obtained the results for the described installed capacities and then we change the capacities first for the wind farm and then for the thermal units and investigate the gain variation of the coordinated approach versus the uncoordinated approach [2].

The energies traded for each scenario, with and without and with coordination, are shown in Figure 1 and in Figure 2.

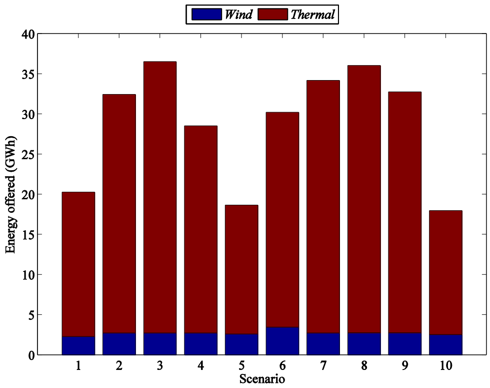

Figure 1 Energy traded without coordination.

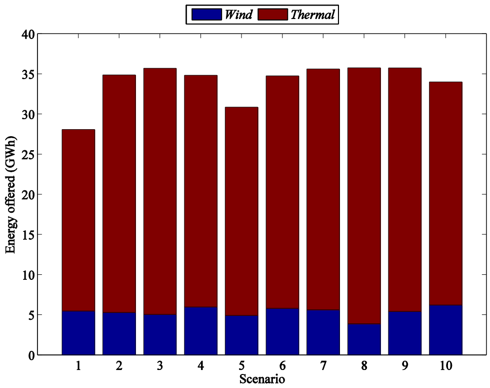

Figure 2 Energy traded with coordination.

IV. CONCLUSION

Stochastic programming is a proper approach to offering strategy and the self-scheduling problem of a price-taker wind power and thermal power producer is developed in this paper.

The coordinated offer of wind power with thermal power allows providing better results than the sum of the isolated offers. The stochastic programming is a suitable approach to address parameter uncertainty in modelling via scenarios.

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