Optimización estocástica para la gestión de la energía eólica en el Mercado Libre Brasileño
Stochastic optimization for the management of wind energy in the Brazilian Free Market

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***Resumen*[1]— Este estudio propone un modelo de optimización estocástica para la asignación de la energía en forma mensual por un año hacia adelante, teniendo en cuenta las características del mercado libre brasileño de energía y la velocidad del viento y la generación de energía de un parque eólico real en el noreste de Brasil. Como tratamos la previsión a largo plazo, los predictores climáticos están incorporados en la previsión de energía eólica, lo que representa una contribución a la Academia y el gobierno, en particular, en el contexto de planificación anual de energía. El modelo sugiere la asignación máxima de energía en la segunda mitad del año, ya que en Brasil la velocidad del viento es mucho mayor en este período**

***Palabras Clave*— Anomalía del Temperatura del Atlántico, el Mercado libre brasileño de energía, la asignación de energía, optimización estocástica, la simulación de la energía eólica.**

***Abstract* — This study proposes a stochastic optimization model for energy allocation on monthly basis for one year ahead, considering the Brazilian Energy Free Market characteristics and the wind speed and generation of a real wind farm in the Northeast of Brazil. As we deal with long forecast horizon, climates predictors are incorporate in the wind energy forecast, representing a contribution for the Academy and for the government, particularly, the annual energy-planning context. The model suggests maximum allocation of energy in the second semester of the year, because in Brazil the wind speed is much higher in this period.**

***Keywords*— Atlantic temperature anomaly, Brazilian energy free market, energy allocation, stochastic optimization, wind power simulation.**

1. INTRODUCTION

With the demand for renewable energy and policy incentives, we face a continuous increase of wind power penetration in power systems and the difficulties caused by the intermittent nature of wind energy, especially, the occurrences in system operations such as scheduling, dispatching, and market allocation of energy produced. Therefore, system operators, investors and researchers have drawn attention towards the state-of-the-art of wind speed and power forecasting methods.

In Brazil, wind power was introduced in the matrix in 2006, but only 2011 the source starts to gain penetration in the system with quite the entire energy sold in the regulated market. In November 2014, the total wind capacity installed in Brazil was 4,236 MW (3.2% of the Brazilian's energy capacity) and 10,416 MW were already authorized [1], this means only a third of total wind power capacity authorized was in fact explored. Most part of this energy is already sold in Regulated Auctions, but there still a part free for commercialization in the Energy Free Market (about 10% to 20%), which challenge for forecast methods able to support the commercial decisions of energy management.

Although there is a vast literature about wind speed and power forecast, the time horizons considered are hours or few days ahead, which is really important for system operation, but less important for commercialization in the Brazilian Free Market. In fact, in the Brazilian Free Market, the reference price is calculated per week, load level and region (there are four regions in the country: North, Northeast, South and Southeast) and most of the contracts are negotiated for month supply in the Forward Market [2]. These characteristics demand forecast of wind power and prices for some months ahead in order to optimize energy allocation and revenues, as, according to Dalben et al. [2], wind energy's negotiation in the Brazilian Free Market may not pay-off.

In this work, we report a stochastic optimization model for energy allocation in month basis, considering the Brazilian Energy Free Market characteristics, the wind speed and the generation of a real wind farm in Ceará, located in the Northeast of Brazil. There are few or even none study about the problem of wind farm management in moth basis, which is really important in Brazil and could be important in annual planning context in other countries. Besides, as climates factors are important for long forecast horizons, we analyze the impact of ENSO conditions and Atlantic´s temperature anomalies in the power time series, and decide to include the Atlantic South´s temperature anomaly in the

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