# Stochastic Optimization in Generation and Trading Planning

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## 1 Generation and Trading Planning

### 1.1 Motivation

In the process of the generation and trading planning, generation companies maximize the contribution margin, i.e. the difference of the revenues of energy trades and the costs for generating and purchasing electrical energy. The planning time horizon of this process covers a period of one month to one year. The complex planning task necessitates the application of computer-based tools [1]. Due to structural changes within the power industry, these tools have to be adapted continuously to the new conditions.

Nowadays these tools have to consider generation units, wholesale and reserve markets as well as fuel markets, limited transfer capacities and planning uncertainties.

### 1.2 Requirements for Planning Tools

Thermal power plants can be classified as single process units and combined-cycle gas turbines (CCGT), related to their different thermo-mechanical cycle. Each unit has to comply with technical restrictions like the minimum and maximum power output level, minimum up- and down-times as well as non-linear efficiency curves. Furthermore the accruing costs during start-up and normal operation have to be considered accordingly. Hydro power plants can be separated into storage and pump-storage as well as run-of-river power plants. Especially in mountainous regions hydro power plants are usually interconnected and characterized by interdependencies for the operation. The generation of electricity in hydro power plants is a non-linear function of the water flow and the hydraulic head.

Due to the deregulation of the electricity markets in Europe new power markets have been established. Electrical energy can be traded bilaterally (over-the-counter;

OTC) or at power exchanges. At the spot market electrical energy can be sold and purchased one day prior to delivery, whereas futures markets facilitate the trade of long-term contracts. The most liquid long-term products are base and peak which can be traded up to several years in advance. In addition, options on electrical energy provide opportunities of risk management in combination with futures.

Transmission system operators (TSO) have to procure reserve power in a tender to facilitate a secure network operation. For generation companies these newly established markets offer an alternative to wholesale markets. Hence, the decision has to be made whether to market the generation assets at the wholesale market or at markets for reserve.

Besides trading electrical energy, the trading of fuels, i.e. hard-coal and natural gas, gains in importance in the planning process of generation companies. Markets for hard-coal are already well established whereas the markets for natural gas emerge due to the recent deregulation of the gas sector. In analogy to the electricity markets spot and futures markets for gas emerge.

Driven by the Kyoto Protocol a reduction mechanism for greenhouse gas emissions has been established by means of a certificate trading approach. Fossil fuel fired power plants need to have sufficient allowances according to their emissions, which can be sold and purchased at the emission certificates market. Thus, the costs for the certificates have an influence on the specific fuel costs of a unit.

The interconnections between countries were originally not dimensioned for cross-border trading. The limited transfer capacities lead to restricted access to international markets. Hence, these limited capacities affect the generation and trading and have to be considered in the planning process.

The consideration of the components described above leads to a complex optimization problem. Because of the highly uncertain input data within the generation and trading planning, e.g. market prices and natural inflow of hydro power plants, stochastic optimization models and methods for risk management gain in importance.

The scenario analysis is an appropriate method to model these planning uncertainties in the generation and trading planning. The uncertainties are modeled by a scenario tree that starts with a deterministic root and then branches with increasing time to represent possible future developments [2].

In the following chapter an optimization model is presented that is designed as a planning toolbox in order to customize the model to a variety of present generation and trading planning tasks.

## 2 Optimization Model and Further Development

Considering the technical and economical properties of the system presented in section 1.2, the optimization problem that has to be solved is characterized by non-linearities, system and time spanning constraints as well as integer decisions. Therefore a multi-stage optimization model was developed to solve this problem with appropriate modeling accuracy. Fig. 1 gives an overview of the developed optimization toolbox.

In the optional first stage a linear approach determines the exchange schedule between different market areas with limited cross-border transfer capacities. Furthermore, this module can be used as a stand-alone tool to calculate the optimal