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AN AGENT-BASED MODEL TO ANALYSE THE LONG-TERM DEVELOPMENT OF THE GERMAN ELECTRICITY SYSTEM

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Overview

The German electricity sector has undergone considerable changes throughout the past few years. Main developments are the liberalisation of electricity markets and the European CO_2 emissions trading scheme that started in 2005. Under these circumstances electricity generating companies have to deal with new uncertainties like high volatile electricity and CO_2-certificate prices. The phase-out of nuclear power plants in Germany until 2020 and the fact that many coal and gas fired power plants will reach the end of their technical lifetime in the next years leads to a high investment need for new power plants. Do enough incentives for power plant investments exist? Will adequacy, the long-term security of electricity systems, be ensured in a liberalised power market? In this paper, we present an agent-based model for the long-term simulation of the German electricity market to analyse these questions.

Methods

Traditional energy system models are often based on a central optimization routine (Enzensberger, 2003). Although working quite well in regulated electricity markets, it is not clear whether these models are adequate to simulate liberalised markets with higher price risks, uncertainties and possibly different strategies of the market players. A promising and novel approach for the scientific analysis of dynamic systems is the field of agent-based simulation (Tesfatsion, 2002). Market players like electricity generating companies or operators of renewable energy plants are modelled as one ore more software units called agents. The behaviour of these agents can be specified freely.

An overview over some parts of the model (Genoese, 2005) is given in Fig. 1. In the short-term-perspective a daily auction is simulated, it is assumed that the whole electricity consumption is traded in a spot market. *Sellers* of electricity offer power plant capacities of their company (their *generators*), considering variable costs, restart costs and market power mark-ups in their bidding price. *Buyers* of electricity represent a non-elastic demand. Power plant capacities which are not sold in the daily auction can be offered to the balancing power market. The dispatch of power plants causes CO_2 emissions, for which certificates have to be held. These certificates can be traded at the certificate markets. The certificate prices have also an influence of the merit order curve of the *generators*.

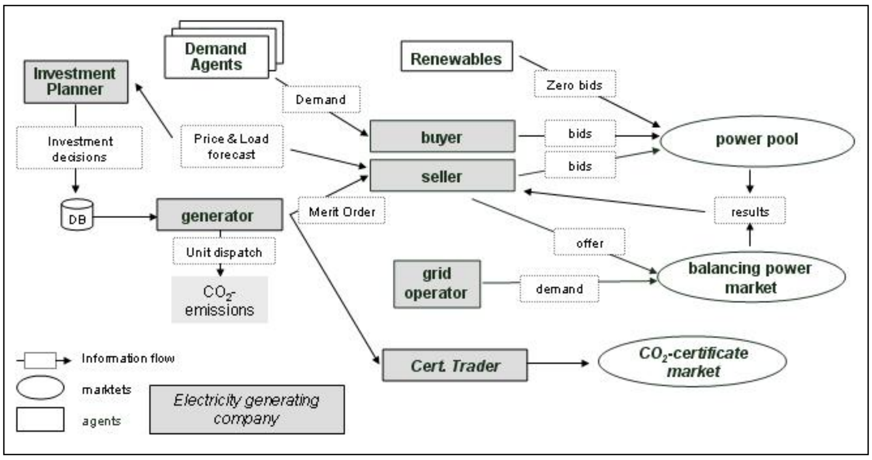


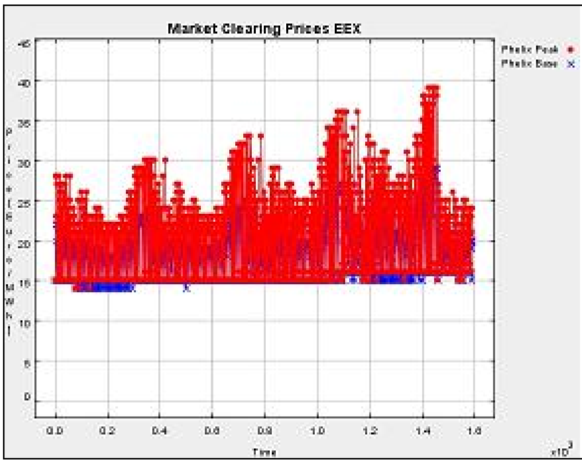
Fig. 1: Model structure

In the long-term perspective investment decisions of the *Investment Planner* are crucial. In former times, power plants with the best net present value were built. Under the new environment in liberalised power markets, plants are only built if enough profits can be earned. This might lead to the fact that power plants will not be built if electricity prices are too low even if there was a need in sense of a demand/supply perspective.

In theory, several ways of ensuring adequacy are known. According to (Oren, 2000) adequacy can be seen as long-term system security, as the ability of a system to meet aggregate power and energy requirement of all consumers at all times. In an ideal competitive market with continuously varying electricity prices payments to inframarginal generators should cover capacity costs. Direct Capacity Payments are another possibility for an incentive system for power plant investments. To determine the return on investment of plants, forecasts both of electricity and certificate prices have to be made, also actual electricity prices have to be taken into account. In our model, results of the daily auctions are reported to the agent *Investment Planner*, furthermore a price forecast has to be made, as shown in Fig. 1. In liberalised power markets, smaller and more flexible power plants, i.e. gas turbines, are likely to be preferred due to lower investments and faster amortisation. This reduces the risk of capital, but may result in a higher fuel price risk or in an availability risk. Modelling these kinds of risk preferences are a key advantage of agent-based approaches.

Results

In the short-term perspective, results of the daily auction show a quite good correlation with historic prices of the European Electricity Exchange (EEX 2005).



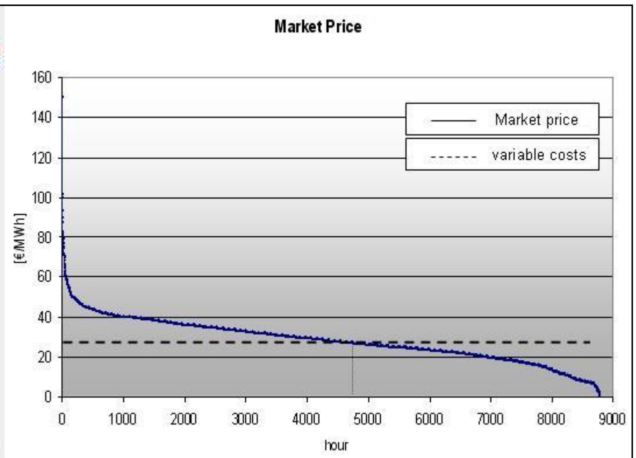


Fig. 2: Model results in the first five years

Fig. 3: profitable commitment of a power plant

In Fig. 2 the market prices of the PowerACE-model of the first five model years are shown (respectively the two indices PhelixBase and PhelixPeak). High price spikes are observable due to shut down of old power plants. This can be seen as investment incentive for new capacities. In Fig. 3, one decision rule for the investment planning is shown. A power plant unit is profitable, as long as the expected prices are higher than the variable costs of that unit. The area where the market price exceeds the variable costs is needed as contribution to cover the fixed costs of that plant. These fixed costs have to be covered during the life time of a power plant. In the paper and presentation a more detailed overview of the model will be given as well as first results of the capacity expansion decisions of the market players.

Conclusions

This paper presents a basic agent-based approach to simulate the development of the German electricity market. Agent-based modelling of short-term electricity markets has shown respectable results, this is also expected for long-term analysis. Up to now, only the German market is considered, a consideration of the European border countries is indispensable for further research, which is planned for the next steps. This model is currently being developed as part of research project (PowerACE) in Karlsruhe, funded by the Volkswagen Stiftung.