Coupling of Electricity and Gas Market Models

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***Abstract*— In the course of the German energy transition, the energy system is facing major transformations. In order to analyze and understand structural changes, system modeling is an appropriate approach to create an image of reality. Various models of the electricity and the gas market allow for an independent analysis of both systems. Due to the increasing importance of sector coupling technologies, a separate analysis of the two markets may no longer be sufficient. This paper deals with the difficulty of connecting electricity market models to gas market models while keeping the complexity of the resulting optimization problem low. Coupling points of the two models are identified and analyzed. Furthermore, in the methodology part, an iterative link between the two models is developed. In exemplary studies, the interaction between the two models is investigated for a lignite exit scenario in Germany.**

***Index Terms*—gas market, linear modeling, power market, sector coupling**

I. INTRODUCTION

Natural gas as a fossil energy carrier continues to be important across sectors due to low specific emissions, an existing infrastructure and the possibility of synthetic production. Regarding the electricity production sector, quickly adjustable gas power plants are able to deliver flexibility which is needed to maintain the security of supply. Furthermore, in future there may be an even closer coupling of the electricity sector and the gas sector. This results from the use of new technologies, such as power-to-gas, where electrical power is converted to gaseous fuels, as well as the more intensive use of gas power plants. Gas is often recognized as a natural partner for renewable energies.

For this reason, the combination of an electricity market model and a gas market model is analyzed in this paper. Both optimization models are based on a minimization of the overall economic costs. In section II both models are described separately. The methodology describes how the models are combined to interact with each other. Hereby, coupling points are identified and the input and output of both models is analyzed. Based on this analysis, a linkage of both models can be developed allowing them to interact. Finally, first exemplary investigations are carried out. A theoretical decommissioning of all lignite power plants is modeled. The resulting changed gas consumption leads to changed gas prices. In the end a conclusion of the methodology and the investigations is taken through.

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II. MODELS

A. Optimization models

The equations of the gas market and the electricity model are based on linear optimization, which is described in detail in standard works such as [1] or [2].

In general, both linear optimization problems have the structure

$$\begin{aligned} &C = min_x\ (f^T \cdot x) \\ &s.t.\ \ dlb \leq x \leq dub \\ &s.t.\ bl \leq A{\cdot}x \leq br. \end{aligned} \qquad (1)$$

C [€]:	Overall system costs
x [•]:	Vector of variables
f [€/•]:	Cost vector
dlb, dub:	Upper and lower bound of variables
A:	Matrix of constraints
bl, br [•]:	Left and right hand side of constraints

The goal of this optimization problem is a minimization of total system costs C. The set of variables, for which total system costs are minimized, is denoted in the vector x. Each element, x_i in the vector x, is consequently impacted by the cost vector f and the specific costs f_i. This minimization is subject to various restrictions. On the one hand, the elements in the resulting vector x can only accept numbers within the bounds dlb and dub. On the other hand, the constraints $x{\cdot}A$ have to be within the limits bl and br.

B. Energy System Model "ISAaR"

The model "ISAaR" ("Integrated simulation model for power plant dispatch planning and expansion planning with regionalization") is an energy system model which formulates a mathematical description of the energy system. It covers the electricity and heating sector and contains regional demands as well as production and storage units. In addition, the regional coupling of the electricity sector is taken into account by mapping the European transmission network.

The overall system costs, CO_2 emissions or the grid utilization can be used as an optimization goal. ISAaR can simulate both the power plant dispatch of existing plants as well as a cost optimal expansion plan for future components such as electricity storage units. For the consideration of future years, a forecast concerning the general conditions is