INTEGRATED POWER TRANSMISSION AND GENERATION EXPANSION PLANNING - A MODEL FORMULATION FOR GERMANY IN 2033

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Overview

In recent years Germany's federal government has announced ambitious objectives in the reduction of energy consumption, emissions and the use of fossil fuels as energy source. The power system has to adapt to new physical challenges in order to further increase infeeds from renewable energy sources (RES) and to achieve the targets mentioned in the Renewable Energy Sources Act. There is a general consensus about the need to expand the transmission grid in the short term and to maintain a flexible power plant fleet to balance the residual load. However, the current legal structure in Germany implies that primarily, generation capacities are placed rather uncoordinated and the transmission planning is undertaken secondarily. The transmission planning is conducted yearly elaborating the Grid Development Plan ("Netzentwicklungsplan", NEP) since 2012. This sequential approach is believed to cause economic inefficiencies. This paper therefore, aims to conduct a techno-economic analysis, where the transmission and generation expansion problem are solved simultaneously in an integrated mathematical optimization. The model formulated here is based on the DC load flow concept, minimizing annual overall costs consisting of operational and investment costs. In order to accelerate the solving process, the decomposable structure of the primary problem is exploited by dividing it into the investment and operational problem. Both problems are optimized separately by means of the Benders algorithm. Capacity expansions concerning the AC-grid, HVDC-connections, fossil-fuelled generation capacities, pumped storage facilities and exogenously RES are examined.

Methods

The applied method consists of a techno-economic anaylsis in which the German and surrounding countries' power system is mathematically modelled using the DC load flow concept. Moreover this model is extended and individually fitted according to the examination's object of inquiry and to account for several transmission and generation constraints. Since data is processed node sharp and with to-the-hour-accuracy the Benders decomposition and algorithm is applied in order to accelerate the processing speed. The model formulation and data is implemented and computed in GAMS (General Algebraic Modelling System). Furthermore several scenarios were designed, examined and juxtaposed.

Results

The results are:

- concrete capacity expansion plans for Germany's power system in the different scenarios, such as:
    - location and dimension of AC-grid expansions,
    - location and dimension of DC-connections as well as
    - technology type, location and dimension for expansion of conventional power plant capacities.

Furthermore are examined:

- the share in generation mix of different renewable energy sources,
- reductions of annual investment and operational cost for the power system and
- potential overinvestments in the capacity expansion plans currently pursued in Germany.

Conclusions

At present the transmission and generation capacity expansion planning in Germany is mainly executed by a central planner that only emphasizes on transmission expansion planning. Furthermore, the actual energy policy law allows power producers to place new generation facilities anywhere in the existing transmission grid regardless to welfare optimizing aspects. The current situation of power expansion in Germany is characterized by a sequential planning where the transmission follows the generation planning. The techno-economic analysis conducted here revealed investments enabling a better integration of a strongly increased installed capacity of RES, which lead to significant operational cost reductions of 34% in the future scenarios. Furthermore remarkable annual overinvestments of 1 billion € concerning the currently conducted generation expansion plans could be revealed.

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