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EFFECTS OF GERMAN WIND POWER GENERATION ON NORTH-WEST EUROPEAN NETWORK CONGESTION – A NUMERICAL ANALYSIS USING NODAL PRICING

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This paper models the impact of German offshore wind power generation on the North-West European electricity grid. German wind power capacities are mostly located in Northern parts of Germany while major demand centres are concentrated in the South. Due to power distribution through the entire European integrated network (UCTE grid) according to relative line impedances, Germany's neighbours to the North West, namely Benelux countries, are affected by unintended but inevitable cross-border flows congesting their grids. With the intended expansion of off shore wind capacities in the German North Sea, this problem is bound to aggravate. Based on different scenarios of German wind power expansion within the next decades, which were developed by DENA (German Energy Agency), we assess the impact of the integration of additional wind power capacities on the existing grid; we also take a look at the combined impact of German wind power production and Alpine hydropower production on the German grid.

Scientific analysis so far is scarce: DENA (2005) has made an assessment of the costs of wind power expansion to the year 2015, but only took into account the domestic situation. Leuthold et al. (2005) have studied the impact of a nodal pricing system on electricity flows from wind power within the German grid. Our paper extends the latter analysis beyond the German borders: we carry out economic simulations of relevant parts of the UCTE high voltage grid using GAMS software. By providing grid topology data (including line transmission capacities and line impedances) as well as demand and supply data, power flows within the grid are determined. Load flows are calculated within the DC load flow model (Schweppe, Caramanis, Tabors, Bohn, 1988, Stigler and Todem, 2005). Nodal reference demand is based on annual power demand per country which is assigned to provinces relative to provincial GDP. Demand curves are defined by reference demand and an assumed local demand elasticity of 0.25. Supply is constrained by generating capacities of power plants which charge constant marginal production costs for their energy output.

First of all, impacts on the existing grid under today's pricing systems (uniform price per country) are evaluated within a model comprising Germany, Benelux countries, Denmark and France, distinguishing three scenarios:

- no wind production in Germany (calm),
- only on shore wind production,
- on shore and off shore wind production (off shore capacity 8 and 13 GW respectively).

We then model a nodal pricing system as a welfare maximizing approach, assuming perfect markets without exercise of market power by players. The nodal pricing system allows for implicit pricing of line capacity sending price signals to consumers and producers. Due to line congestion caused by German wind power, we anticipate an arising price difference between Northern and Southern Germany. It is also expected that German wind power transmission produces negative externalities, namely congestion within the Benelux grid, also resulting in rising prices in this area with rising wind power production in Germany. In a third step, we include the Swiss and Austrian electricity markets in the model and simulate various seasonal scenarios represented by different combinations of wind and hydropower production levels.

We expect that the impact on German grid congestion will be worse in the winter scenario (high demand, low level of hydropower, high level of wind power production) than in the early summer scenario (moderate demand, high level of wind and hydropower production), as the reduced demand in the latter scenario can partly be supplied by hydropower capacities in the South, thus reducing the need to transport wind power through Germany.