Economic dispatch distortion due to changes in transmission pricing

Problem Overview

The EU aims to create the Internal electricity market on the continent by the end of 2014 [1]. This require different transmission pricing paradigm from the one being used now. The shift to a different pricing will affect economic dispatch and energy prices [2], [3], [4]. Energy prices are the main tool for assessing long-term investment decisions; energy prices disturbances affect energy market profitability and predictability. This can lead to the different investment moves from the ones foreseen now and other economic and social effects. Thus the transmission pricing effects on the economic dispatch need to be studied and described.

Proposed Model

The model simulates the European electricity transmission grid. The model includes 27 countries (27 EU countries excluding Malta and Cyprus but including Norway and Switzerland). Each country is presented as a single node. All consumption within one country is combined including energy losses on domestic power lines. The generation capacity is modeled by a set of standard generators, each generator representing one technology (e.g. Hydro Run-on-River, Solar PV, Nuclear, etc.).

Connections between countries are presented as single lines. Power losses are linearized.

Within one simulation prices for all 8760 hours of one year are computed. The prices are computed gradually by chunks of 24 hours.

Mathematically the model is a Mixed-Integer Linear Problem (MILP). The optimization goal is to minimize the cumulative generation and transmission cost:

$$\min_{i,t,ij,h}\left(\sum_{i,t,h} P^h_{i,t}\, C_{i,t} + \sum_{ij,h} P^h_{ij}\, C^h_{ij}\right), \qquad (1)$$

where $P^h_{i,t}$ as the energy produced in country i in hour h by a standard generator representing technology t, $C^h_{i,t}$ is the cost of energy MWh for this technology, which is computed as sum of fuel, CO_2 and variable O&M costs.

P^h_{ij} and C^h_{ij} are values of the cross-country energy transfers and prices of the energy transmission. The latter is computed according to the transmission pricing mechanism being tested during the given simulation.

Energy production is limited by generators minimum and maximum capacity:

$$P^{min}{}^h_{i,t} \le P^h_{i,t} \le P^{max}{}^h_{i,t}. \qquad (2)$$

The power plants fleet remains unchanged for every week (and thus $P^{min}{}^h_{i,t}$ and $P^{max}{}^h_{i,t}$). Power plants maintenance periods are considered. Forced outage times are randomly distributed.

Energy storages are simulated in a model as additional generators with minimal power being negative.

Rump up and rump down speeds limit power plants maneuverability:

$$P^h_{i,t} - P^{h-1}_{i,t} \le S^{up}_{i,t}, \qquad (3)$$

$$P^{h-1}_{i,t} - P^h_{i,t} \le S^{down}_{i,t}. \qquad (4)$$

Power flows are limited for every connection ij:

$$-P^{max}_{ij} \le P^h_{ij} \le P^{max}_{ij}. \qquad (5)$$

Reactive power and voltage limits are ignored in this model.

Energy is balanced in every country:

$$P^h_{i,t} - P_{C}{}^h_i = \sum_j P^h_{ij} + IE^h_i, \qquad (6)$$

where IE_i^h is the sum of import and export for the country i with neighboring countries outside of the EU (Russia, Turkey, Morocco and others).

Electricity price is computed as a dual variable to the above equation.

Expected Results

The model for assessing energy prices dependency on transmission pricing is created, populated with data and will be calibrated.

The simulation result will show how different transmission pricing schemes can affect economic dispatch in Europe and how it can influence long-term investment decisions. The tested pricing methodologies will be compared between each other and the most appealing one (if possible) will be identified.

The effects of the transmission pricing schemes will be described.

References

[1] ENTSO-e, "Annual Report 2011," 2011.

[2] PJM, "A Survey of Transmission Cost Allocation Issues , Methods and Practices," 2010.

[3] L. O. Camacho and I. J. Pérez-Arriaga, "An assessment of inter-TSO compensation algorithms in the Internal Electricity Market of the European Union," *International Journal of Electrical Power & Energy Systems*, vol. 29, no. 10, pp. 699–712, Dec. 2007.

[4] S. Stoft, *Power System Economics: Designing Markets for Electricity*. IEEE Press, 2002, p. 468.

Data sources: energy consumption and generating capacity data is taken from the ENTSO-E statistical yearbooks, IEA World Energy Outlook and Eurelectric Power statistics reports. Data on EU power interconnections and energy import and export volumes is taken from the ENTSO-E statistical yearbooks and adequacy forecasts. Data on energy prices and taxes is taken from the IEA Energy Prices and Taxes database.

The data is always taken for the last available year.