

National-strategic investment in European electricity transmission capacity

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(1) Overview

The decarbonisation of the European electricity sector, as envisaged in the EU Road Map 2050 (EC 2011), requires both a transformation of the generation portfolio as well as a significant expansion of the power transmission system. There are several recent studies that aim to determine the optimal investment plans for a decarbonised electricity sector (Fürsch, Nagl, and Lindenberger 2012; Tröster, Kuwahata, and Ackermann 2011): these use a pan-European welfare maximization approach, where all investment decisions are taken by a benevolent central planner (or, equivalently, by competitive market players).

These studies do not consider that transmission investment has a strong impact on national welfare. Network expansion is still a national prerogative, both regarding the planning and the funding. Beneficiaries of transmission investment may be in a different jurisdiction than those bearing the costs. National governments, regulators and/or Transmission System Operators (TSO) may be reluctant to invest if the benefits accrue elsewhere, unless an appropriate compensation mechanism is in place. Any analysis of the power market is particularly complicated due to the specific characteristics of electricity transmission: if one line between two zones is expanded, the changes in power flow patterns may adversely affect other TSOs. Our work combines the issue of a pan-European investment with national-strategic considerations. We use the term “*national-strategic*” to differentiate our work from other studies that treat generators as strategic players (Neuhoff et al. 2005; Schröder, Traber, and Kemfert 2013).

Egerer, Hirschhausen, and Kunz (2012) discuss the implications on supplier and consumer welfare for different topologies of the North and Baltic Sea offshore connectors. While some countries gain from upgrades in the network, others may also lose. The allocation of costs is therefore of paramount importance (Buijs and Belmans 2011). Theoretically, the right allocation of benefits and costs through side payments results in a grand coalition and in a system welfare optimal expansion on the European level. There is a string of scientific literature examining various allocation methods based on cooperative game theory (Gately 1974; Nylund 2013). Nylund and Egerer (abstract submitted to this conference) use an enumerative approach to determine Nash equilibria for a certain number of investment options using a stylized data set based on the region Germany, Austria, Switzerland, France and Italy. In contrast, our work aims to model the game between national regulators as multi-stage equilibrium model (or Equilibrium Problem under Equilibrium Constraints, EPEC).

(2) Methodology

We aim to model a Nash equilibrium between different national regulators aiming to maximize the welfare within their zone. This model is mathematically challenging: it is a two-level problem, where investment is decided on the upper level in a game between regulators, while the competitive power market forms the lower level. Congestion rents of TSOs are based on actual flows rather than financial transmission rights; these are included in the objective function of each national regulator. Since these are bilinear (product of the endogenous variables *line flow* and *price difference*), this is a non-convex integer two-level problem. We combine the approaches of disjunctive constraints (Gabriel and Leuthold 2010), strong duality (Ruiz and Conejo 2009) and integer-constrained complementarity problems (Gabriel et al. 2013) to derive and solve a convexified Mixed Integer Complementarity Problem.

(3) Results and Outlook

We apply this model to the same data set as used in Nylund and Egerer, and we obtain similar results. Given the mathematical difficulty of our approach, this is by no means guaranteed. We discuss potential extensions of our approach, which would not be feasible in a simple enumerative approach: first, the inclusion of an endogenous investment cost sharing allocation by a pan-European coordination agency (ACER) steering the equilibrium towards the social optimum, while guaranteeing incentive compatibility of all TSOs; second, an endogenous consideration of transmission fees to cover investment costs.

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