

# Generation capacity expansion analysis: open loop approximation of closed loop equilibria

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## Abstract-

In this paper we propose a methodology to approximate closed loop capacity equilibria using only open loop capacity equilibrium models. In the closed loop model, generation companies choose capacities that maximize their individual profit in the first stage while the second stage represents the conjectured price-response market equilibrium. In the open loop model, firms simultaneously choose capacities and quantities to maximize their individual profit, while each firm conjectures a price response to its output decisions. The closed loop equilibrium model is an equilibrium problem with equilibrium constraints, which belongs to a class of problems that is very hard to solve. The open loop equilibrium model is much easier to solve, however, it is also less realistic. With the approximation scheme proposed in this paper, we are able to solve the closed loop model reasonably well when market behavior is closer to oligopoly than to perfect competition by smartly employing open loop models which reduces the computational time by two orders of magnitude. We achieve this by transforming the open loop equilibrium problem into an equivalent convex quadratic optimization problem which can be solved efficiently. Finally, a case study is presented in order to validate the proposed approximation scheme.

**Index Terms-** Generation expansion planning, bilevel programming, equilibrium problem with equilibrium constraints (EPEC).

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