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The effectiveness of a strategic reserve in the presence of a high portfolio share of renewable energy sources

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ABSTRACT

To ensure sufficient investment in electricity generation capacity, mechanisms such as strategic reserves are being considered or already implemented. We analyze the effectiveness of a strategic reserve in the presence of a growing portfolio share of renewable energy sources (RES) with EMLab-Generation, an agent-based electricity market model. A strategic reserve can stabilize investment, but within limits. Uncertainty regarding future demand may cause the market to become instable, potentially leading to periods with very high electricity prices. In the presence of a large share of variable renewable energy sources, the reserve design should be adjusted or replaced by an alternative capacity mechanism.
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1. Introduction

We investigate the effectiveness of a strategic reserve with respect to incentivizing adequate generation investment in an electricity system with strong growth in the portfolio share of intermittent or variable renewable energy sources (RES). The increasing reliance on variable renewable electricity generation makes cost recovery more uncertain for thermal power plants in Europe. Their capacity is needed when the variable resources are not sufficiently available, but the number of hours per year that they operate declines when the share of renewable energy increases. In theory, this should not affect their business case as long as scarcity prices are allowed to rise high enough, but investment becomes riskier as their revenues come to depend increasingly on infrequent but high scarcity prices. When other causes of risk and uncertainty are taken into account, such as carbon-policy uncertainty, fuel-price uncertainty, and uncertain demand growth, there arises a legitimate concern that there will not be enough investment in thermal power generation capacity and that unprofitable thermal power plants might be decommissioned. In their paper on the decommissioning of power stations between 2001 and 2005, Wissen and Nicolosi (2007) contend that although much of the observed decommissioning was most likely due to other reasons, there is a possibility that some of these units would have remained operational in absence of growth of renewable energy (Sensfuß et al., 2008). Similarly, Nicolosi and Fürsch (2009) and Bushnell (2010) expect a lower share of base-load power plants in the supply mix over the long run. More recently, plants in the Netherlands are being mothballed due to a combination of excess capacity and shorter running hours due to the import of variable renewable energy from Germany (Straver, 2014).

In response to the rising share of renewables and the vulnerabilities of the electricity markets discussed in literature (Borenstein et al., 1995; Brown, 2001; De Vries and Hakvoort, 2003; De Vries, 2007; Joskow and Tirole, 2007; Joskow, 2008; Keppler, 2014; Pérez-Arriaga, 2001; Stoft, 2002; Woo et al., 2003), capacity mechanisms are being considered or already implemented in many countries (ACER, 2013; BMWi, 2015; Creti et al., 2012; DECC, 2014; Mastropietro et al., 2015; RTE, 2014; Spees et al., 2013). For our purposes, capacity mechanisms refer to policy instruments for ensuring adequate investment in generation capacity; in the European debate, they are also called capacity remuneration mechanisms. The impacts and the concerns regarding implementation of different capacity mechanisms have been discussed in depth in literature (Cramton et al., 2013; Finon, 2015, 2013; Meyer and Gore, 2015; Newbery and Grubb, 2014; Regulatory Assistance Project, 2013; Rodilla and Batlle, 2013, 2012). One such option is a strategic reserve (Cramton et al., 2013; Rodilla and Batlle, 2013), typically consisting of generators with high operating costs and/or demand-side resources that are contracted by the transmission system operator (TSO) and are dispatched when the market does not provide sufficient generation capacity. Conceptually, a strategic

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reserve may resemble operating reserves pricing (Stoft, 2002), depending on whether the decision to dispatch the reserve units on short notice as a function of the electricity price or some other variable. In Sweden, a strategic reserve was implemented to prevent old units from being decommissioned, despite their limited economic prospects. In southern Germany, a strategic reserve is currently used to allow the transmission system operator to purchase electricity from units that are more expensive than the market price, but that are locally needed due to network constraints. In this case, the reserve is used for congestion management.

The creation of a strategic reserve itself might not change the volume of available generation capacity, as it simply transfers the control of some power stations to the transmission system operator (TSO). The exception is if, by doing so, it prevents plant from being decommissioned. In case there is not enough available generation capacity, the TSO dispatches the strategic reserve at a price above the variable costs of the generation units. This will cause the average electricity price to increase and thus stimulate investment in generation capacity. The market design challenge, therefore, is to ensure that the dispatch price of the reserve provides an adequate investment incentive.

We analyze the effectiveness of a strategic reserve in providing reliability in the presence of a growing share of renewable energy supply in the supply mix. We also consider short-term and long-term effects on economic efficiency. We expand an existing agent-based model of electricity markets called EMLab-Generation (De Vries et al., 2013; Richstein et al., 2015a, 2015b, 2014). In the next section, we describe the fundamentals of designing and operating a strategic reserve. In Section 3, the EMLab-Generation agent-based model, the implementation of a strategic reserve in this model and calculation of the strategic reserve parameters are explained. Section 4 describes the scenarios used for our model runs. In Section 5, we present the results of our analysis of the effectiveness of a strategic reserve without and with a large share of renewable energy sources. We test it in a Monte Carlo-style analysis with uncertain demand growth rate and fuel-price developments. The indicators that we use in this analysis are described in detail in Section 5.1. The conclusions are summarized in Section 6.

2. Designing and operating a strategic reserve

2.1. Overview

We define a strategic reserve as a set of power plants and/or interruptible demand contracts that are controlled by the transmission system operator, to be deployed during shortages (De Vries, 2004; De Vries and Heijnen, 2006; Rodilla and Batlle, 2013). We analyze a strategic reserve that is dispatched when the market price exceeds a certain level. We do not consider alternative dispatch criteria, such as those based on the reserve margin (defined as the available generation capacity over the peak demand). In the basic strategic-reserve design, the system operator contracts electricity generation units with high operating costs (ideally, the last units in the merit order) and offers their electricity to the market at a price (P_{SR}), which is well above their variable cost (see Fig. 1). The pays the owners of these power plants their annual operations and maintenance costs. If the reserve capacity is dispatched, the operator pays the owners of these power plants their marginal cost of generation. Thus the operator pays all the reserve costs and keeps (most of) the profit when the reserve is dispatched. From the perspective of the operator, these profits should cover the fixed costs, but the operator takes the financial risk of keeping the reserve units available. In case the operator is unable to recover all its cost of contracting the reserve, the remaining costs are socialized (or spread across usage) as part of the network or system tariffs.

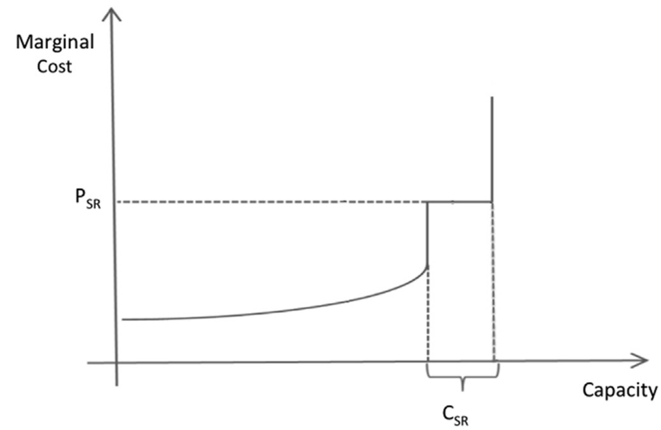

Fig. 1. Example of impact of strategic reserve on the supply curve (De Vries, 2004).

2.2. Reserve design

A strategic reserve with a price-based dispatch criterion, as analyzed here, withdraws a certain volume of generation capacity from the market and makes it available at a price that is (substantially) higher than its variable cost. This should stimulate investment in generation capacity as explained by Stoft (2002). The level of the reserve dispatch price (P_{SR}) is a key factor, as it effectively caps the market price (Stoft, 2002; De Vries and Heijnen, 2008). It therefore determines the strength of investment incentive, and, as a consequence, the total equilibrium volume of generation capacity and hence the level of generation adequacy. In principle, the reserve price P_{SR} should be determined such that the revenues earned by the power producers in the presence of the strategic reserve are equivalent to the revenues that they would have earned in an energy only market. In a perfect market, if the supply ratio[1] was optimal without the reserve, the reserve should lead to the same supply ratio. In case of market imperfections that cause insufficient investment, the reserve could provide compensation by raising generation companies' average revenues. The determination of an optimal supply ratio is beyond our paper's scope. In theory, it should follow from the minimization of social costs, but in practice it is often determined by the regulator. In our research, we focus on the effectiveness of a strategic reserve in providing reliability without and with a large share of renewable energy sources. A second criterion is the impact of the strategic reserve on economic efficiency.

The only time when the reserve price does not function as a maximum price is the rare occasion when the reserve is exhausted. Then the price may increase to the value of lost load if there are no more demand-side resources available. If the reserve functions well, it has attracted sufficient investment in generation capacity and is exhausted only under rare circumstances. As a result, generators lose some peak revenues. With a well-designed reserve, this loss is offset by the fact that the reserve increases the market price up to P_{SR} during other hours, namely when there is no absolute shortage but the reserve is needed to meet demand. The challenge is to design the reserve so it balances these two effects. Consequently, in a market with a strategic reserve, price spikes up to P_{SR}

[1] Supply ratio is defined as the ratio of available supply at peak over peak demand.

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