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Enhanced operational reserve as a tool for development of optimal energy mix

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ABSTRACT

The aim of this article is to present a novel capacity remuneration mechanism concept that differentiates the level of financial support according to the technology and parameters of the new power plants. New power plants that are to be constructed should guarantee the highest level of security of electricity supply and be consistent with actual energy policy carried out by a country. Thus, the proposed remuneration system is based on an 'operational reserve' system which is currently implemented in Poland. The proposed system distinguishes new power generating assets according to a total assessment based on three factors: type of technology (including emission benchmark), flexibility, and location (addressing issue of brown or green field investment and conditions of power system operation). Existing power plants are also subsidized by the proposed mechanism, however their remuneration is not based on their characteristics. The details of the proposed mechanism, a cost analysis, and a standardized evaluation procedure are described in the paper. The concept itself is universal and can be intruded in every power system that must overcome capacity problem.

1. Introduction

In recent years, the operation of power systems around the world has shown that energy-only markets are occasionally not efficient enough to maintain energy security (Batlle and Rodilla, 2010; Wen et al., 2004; Rodilla and Batlle, 2012; De Vries, 2007; Oren, 2000). This is at least partially because energy systems are increasingly losing reliability because of insufficient or inadequate generation installed.

- There has been a constant increase in RES market share; which, although from ecological point of view is very beneficial, may have a destructive influence on the system stability (Cepeda and Finon, 2013). Electricity production from solar and wind is highly erratic and does not necessarily correlate with demand. This problem can be overcome through the use of energy storage. The most common form of energy storage in areas where landform and water supplies allow, is a pumped-storage hydroelectricity that constitutes a backup for intermittent generation. Nevertheless, some countries have no potential to create enough PSH stations. In such cases, the reliable reserve for intermittent generation can only be covered by conventional units (Solomon et al., 2012). Because of the energy policies that require the further increase of the renewables in the energy mixes, in many countries the renewables are massively subsidized or have a priority in power supply. Since the operating schedule depends on the economic dispatch of power generating offers on the market, the conventional power plants (which cannot compete with subsidized RES) are forced to operate as peak units. In many cases the operation of those power units is limited to less than 20% of potential uptime (Joskow, 2006; Levin and Botterud, 2015). feasible to store energy on a large scale apart from pumped-hydro storage systems.
- Implementation of intraday and balancing markets with shorter periods of clearing prices.
- Introduction of smart grids in conjunction with local balancing areas and local markets: this most advanced idea assumes taking advantage on distributed generation, DSR and smart metering at the same time (Olek and Wierzbowski, 2014; Kubiak and Urbaniak, 2013).
- Removing price caps on the energy-only market (Hughes and Parece, 2002; Haas et al., 2014; Mauritzen, 2015): Higher prices in periods of scarcity would provide sufficient incentives to promote investment in new power plants; however, this could encourage generators to withdraw part of their capacity deliberately to increase the spot prices on the wholesale market. This phenomenon could be diminished if generating companies were obliged to make maintenance schedules. Still, the highly volatile prices will reduce investment attractiveness because of the augmented risk. (Clements et al., 2015; Weron, 2013; Tashpulatov, 2013).

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Nomenclature

APR	Available Power Reserve
BAT	Best Available Technology
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CRM	Capacity Remuneration Mechanism
DSR	Demand Side Response
EU ETS	EU Emission Trading System
EOPR	Enhanced Operational Power Reserve
ES	Energy Storage system
LCOE	Levelized Cost of Energy
O&M	Operation and Maintenance
ORM	Operational Reserve Mechanism
PSH	Pumped Storage Hydroelectricity
RES	Renewable Energy Sources
RRM	Required Reserve Margin
TSO	Transmission System Operator
WACC	Weighted Average Cost of Capital

If all of the aforementioned ideas could be introduced, the missing capacity problem would likely be solved. Unfortunately, most of them require long-term and expensive investments. The full introduction of smart grid and distributed generation can be a long-term perspective target. According to (Batlle and Rodilla, 2010), there are two ways of solving the missing capacity problem: do nothing and wait for the invisible hand of the market to start working (which is a hazardous assumption), or introduce a capacity remuneration mechanism. The arguments for limited efficiency of the energy only market according to standard market design are also presented in: (Batlle and Rodilla, 2010; Wen et al., 2004; Rodilla and Batlle, 2012; De Vries, 2007; Bidwell and Henney, 2004). Zones that have introduced such mechanisms, even with diverse outcomes, generally support the claim that these measures can improve the reliability of energy systems (Bhagwat et al., 2016).

1.1. Existing capacity mechanisms

There are five generally recognized types of capacity mechanisms (Batlle and Rodilla, 2010; De Vries, 2007; Mielczarski, 2000; Tennbakk et al., 2013; Meulman and Méray, 2012; Linklaters, 2014; Regulatory Comission, 2012):

- Capacity payments
- Strategic reserve
- Reliability option
- Capacity obligation (decentralized market)
- Capacity auction (centralized market)

1.1.1. Capacity payments (implemented in Spain, Portugal, Italy)

All or only allowed generation/DSR receives fixed remuneration in addition to direct market revenues from electricity production. The subsidy can be also allocated to planned generators and thus reduce the investment cost. The simplicity of this mechanism results from the method of allocation – the level of compensation is set by the central body and is equal for all the units proportionally to their capacity. This mechanism allows for different remuneration for new and existing capacity; however, it is not based on market rules and may result in pressure from power plant operators to increase capacity payments.

1.1.2. Strategic reserve (implemented in Sweden, Poland, Germany)

The authorized body establishes the required amount of capacity that needs to be available in the peak hours or in emergency situations in short notice (when the supply does not cover the demand). Those generators/DSR that constitute strategic reserve are usually withheld from the energy-only market but are compensated for maintaining a reserve power supply. This mechanism is beneficial for the old units but does not bring sufficient incentive to build new units. It may lead to the deliberate withholding of capacity from the energy market to receive capacity remuneration.

Strategic reserve and capacity payments primarily result in short-term benefits. Although they provide some incentives, including a fixed, predictable, long-term additional income, for potential investors the most visible effect is that they prevent old power plants (that nevertheless will have to be withdrawn in the near-term future) from decommissioning.

The last three options are more complicated, as they rely on market rules. The capacity obligation and capacity auction systems are currently the most promising solutions and are being implemented in very developed and problematic energy systems.

1.1.3. Reliability option (applied in New England and Columbia)

It is a financial instrument that allows purchasers and generators to sign a forward, long-term 'reliability contracts' through which they settle the fixed electricity price for established period. The strike price is strongly dependent on the marginal price on the energy market (thus this mechanism requires well-functioning energy-only wholesale market). When the market price for electricity surpasses the strike price, the contracted capacity providers must provide contracted power under threat of penalties. Their income is determined by the option market. Customers pay the option premium, but are not vulnerable to extremely high market prices. This mechanism is a strong incentive for generators to provide electricity in peak hours. Reliability mechanism has been implemented in many regions with different effects, but is

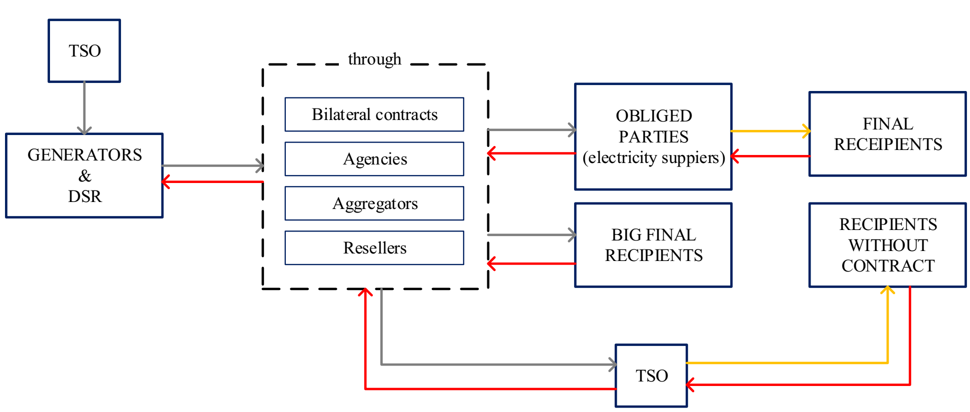

Fig. 1. Decentralized capacity market (dashed line - flow of certificates, dotted line - flow of payments).