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Capacity remuneration mechanisms: classification and experiences

ABSTRACT: Capacity remuneration mechanisms have been imposed globally in order to ensure capacity adequacy and prevent a sharp increase in electricity prices in the long-term. The main causes of their introduction are to provide financial support for companies to generate electricity or reduce consumption in peak demand and ensure sufficient incentives for potential investors. The paper aims to review the capacity remuneration mechanisms introduced in various countries. The following mechanisms are discussed: capacity payment, strategic reserve, reliability options, capacity obligations, and capacity auctions. The paper indicates the main advantages of mechanisms and key challenges related to their introduction and operation as well. The paper contributes to the existing literature by extending and updating the knowledge on the capacity remuneration mechanisms in various energy markets. The results indicate that the most complex schemes are market mechanisms. Regardless of the nature of the traded good (call options, certificates, capacity obligation), the second market structure must be introduced and managed. Consequently, the obligations are imposed on (i) the regulatory body (regulator or transmission system operator), generation companies (or demand-side response), trading companies, and consumers. The other challenge of the implementation of various CRMs is related to the transparent treatment of all technologies. All

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CRMs should be technologically neutral, but ultimately, some units are more favorable due to their greater impact on the reliability of the power system.

KEYWORDS: capacity remuneration mechanism, capacity market, capacity auction, strategic reserve, reliability options

Introduction

Capacity remuneration mechanisms (CRMs) have been imposed globally in order to ensure capacity adequacy and prevent the increase in electricity prices in the long-term. The main causes of their introduction are to provide financial support for companies to generate electricity (or reduce consumption) during peak demand and ensure sufficient incentives for potential investors.

The classification of the capacity remuneration mechanisms is shown in Figure 1. CRMs can be divided into two basic categories, i.e. (i) price-based and (ii) volume-based mechanisms. In price-based mechanisms, the regulatory body or the transmission system operator (TSO) sets the price for generation capacity in selected periods. The prices constitute the incentive for generation companies and potential investors to refurbish existing power plants or construct new ones. Therefore, price-based mechanisms provide direct financial support (KU Leuven Energy Institute 2013).

In the case of volume-based mechanisms, the regulatory body or the TSO determines the demand for capacity in given periods (e.g., years or quarters). They consider (i) the national and regional capacity demand, (ii) reserve margins, (iii) volume of generation capacity contracted in previous periods, (iv) capacity of interconnections, and other crucial parameters and forecasts. The price for generation capacity is usually set either based on market principles (merit order) or in bilateral contracts. The market-based CRMs are not usually intended to support given generation technologies.

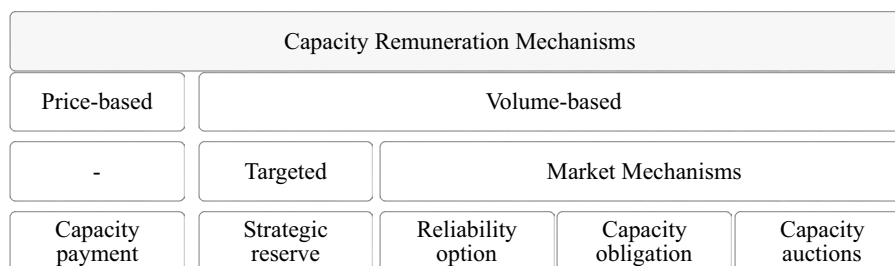


Fig. 1. Classification of capacity remuneration mechanisms

Source: own study based on (ACER 2013)

Rys. 1. Klasyfikacja mechanizmów wynagradzania zdolności wytwórczych

Capacity remuneration mechanisms and their main assumptions are widely discussed in the literature. Please refer to Briggs and Kleit (2013), Cramton et al. (2013), Kirschen and Strbac (2019), Spees et al. (2013) for further details on the fundamentals of the CRMs.

The paper aims to review capacity remuneration mechanisms introduced in various countries. The principles of their operation are discussed. The paper also indicates the main advantages of each mechanism, crucial challenges, and key disadvantages. The paper contributes to the existing literature by extending and updating the current state of the capacity remuneration mechanisms in energy markets.

The remainder of this paper is organized as follows. Sections 2–6 present the individual capacity remuneration mechanisms: capacity payment, strategic reserve, reliability options, capacity obligation, and capacity auctions. Section 7 concludes the paper.

1. Capacity payment

The capacity payment is a price-based capacity remuneration mechanism. The scheme of its operation is shown in Figure 2. The transmission system operator (TSO) or the regulator is responsible for ensuring the security of the power system. They acquire capacity obligation from generation companies, which receive payments in return. This mechanism operates in parallel to the electricity market. Consumers are charged with the cost of operation of the mechanisms as a fixed fee (directly or through trading companies).

The payment for generation companies should (i) partially cover the generation costs of existing power generation units and enable their maintenance in the power system, and (ii) be an incentive for potential investors to construct new units. This mechanism increases the generation capacity in the system and reduces the probability of black- or brown-out. Consequently, it ensures lower electricity prices because the volume of generation capacity allows one to meet peak demand in the system and determine the electricity price as a market clearing price.

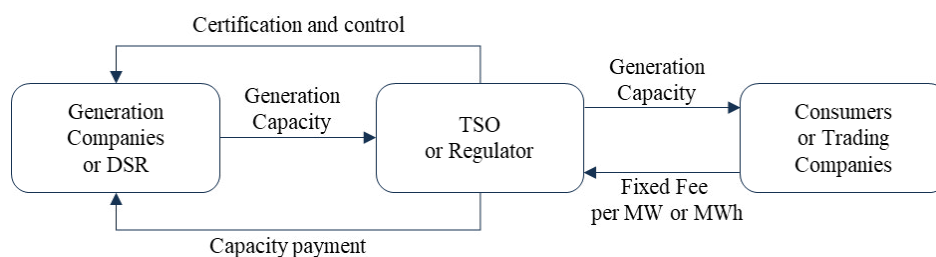


Fig. 2. Scheme of capacity payment

Source: own study based on (de Wachter and Buijs 2012; Zamasz 2019)

Rys. 2. Zasada działania mechanizmu płatności za moc

One of the key advantages of capacity payments is the simplicity of their introduction and withdrawal. The mechanism mitigates the investment risk of generation companies and stimulates new investments. However, regular financial support may result in the resignation of new solutions aimed at efficiency improvement. Moreover, it is usually difficult to adequately estimate the amount of capacity payments for particular generation technologies. Thermal power plants have a greater impact on system reliability than hydropower – the difference should be considered within a setting of financial support (Kirschen and Strbac 2004). The capacity payment mechanism is also exposed to regulatory risk because the regulatory body makes decisions about financial support. Finon and Roques (2013) point out that capacity payment does not also guarantee that the generation capacity in the power system will be equal to the forecasted power demand in the long-term.

Capacity payments have been implemented in, among others, Portugal (Ghazvini et al. 2019), Spain (Marques et al. 2019), Ireland (di Cosmo and Lynch 2016), Italy (Fraser and lo Passo 2003), Chile (Galetovic et al. 2015), and in some South American countries (Erbach 2017; Spees et al. 2013).

2. Strategic reserve

The scheme of the strategic reserve is illustrated in Figure 3. The volume of missing capacity in the power system is based on the forecast of power demand in a given period, performed by the regulator or TSO. In the next phase, in a tender or negotiations with generation companies, the regulator or TSO selects the generation companies. The selected units generate electricity only in peak demand, in accordance with the agreement with a regulatory body. Moreover, these units

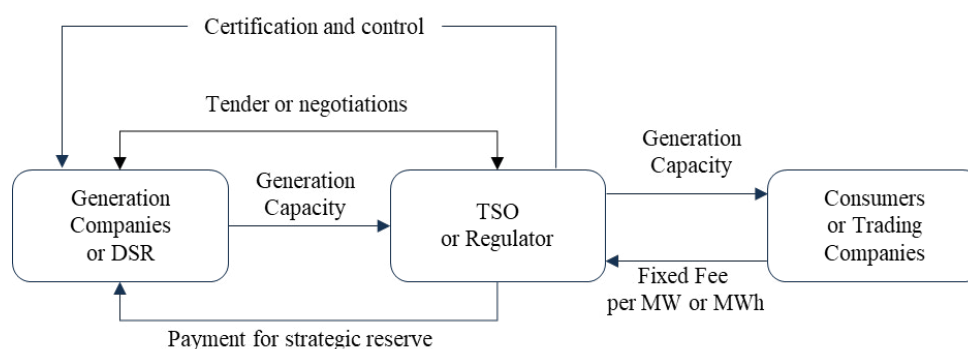


Fig. 3. Scheme of strategic reserve

Source: own study based on (de Wachter and Buijs 2012; Zamasz 2019)

Rys. 3. Zasada działania mechanizmu rezerwy strategicznej

cannot participate in the wholesale electricity market. The strategic reserve may operate in parallel to the energy market as a permanent solution or be a transitional element during the introduction of other capacity remuneration mechanisms.

The strategic reserve is the least costly CRM for consumers and the least complex one to implement in the power system compared to other mechanisms. This mechanism is also flexible – if sufficient incentives come from the market, the volume of the strategic reserve is maintained at a minimum level. Additionally, power generation companies have no difficulties in estimating the expected revenues – they are set in the bilateral agreements ahead. The disadvantages are mostly related to difficulties in estimating the fair price for auxiliary services by a regulatory body. A price that is incorrectly set (too low) is considered the price cap in the market and makes it difficult to make investments decisions. The regulatory body is also capable of targeting the support to selected technologies or locations.

The strategic reserve has been implemented in many European countries. It has been an integral part of the Finnish electricity market since 2006 (Ochoa and Gore 2015). The contracted generation units provide the service to the power system in peak demand. The volume of the strategic reserve was set by the regulator at 789 MW over the period of 2017–19 (Energiavirasto and Energimyndigheten 2017). This mechanism was also implemented in Sweden in 2003, where the volume of generation capacity was limited to 2 GW (Neuhoff et al. 2016). The strategic reserve also operates in Poland. The total generation capacity of the units providing the auxiliary service amounted to 830 MW in 2019 (PSE 2020).

In 2018, the European Commission approved the strategic reserve for Belgium and Germany. In Belgium, the mechanism is intended to ensure the security of supply in the case of nuclear power plants failures. The volume is determined by the TSO on the basis of the annual evaluation of the power system operation (Elia 2018). In Germany, the strategic reserve was implemented in order to ensure the continuous balancing of the power system. The volume of the contracted capacity amounts to 2 GW and is set for three two-year periods until 2025. A similar scheme has also been implemented in Norway (Finon et al. 2008), the Netherlands (Hölsgens 2019), and Austria (Thema Consulting Group 2013).

3. Reliability options

Reliability options are one of the market mechanisms. The scheme of their operation is shown in Figure 4. This mechanism is a call option, both physical and financial (Bidwell 2005). It means that the options are related to specific power generation units that must pay the penalty when they are not available (physical), and their operation is akin to traditional options (financial).

The regulator or TSO purchases call options at a market-clearing price (Vázquez et al. 2002). The number of purchased options is determined based on a forecast of power demand in the system and mimics the value of generation capacity that is fundamental to ensure capacity

adequacy. The strike price is set slightly above the marginal cost of the most expensive power generation unit in the system. Therefore, the reliability option mechanism guarantees a net income for power units equal to the strike price.

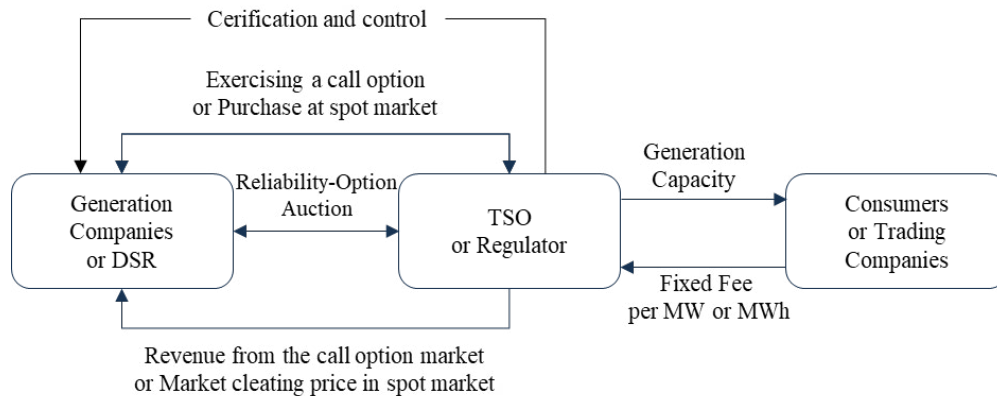


Fig. 4. Scheme of reliability option

Source: own study based on (de Wachter and Buijs 2012; Zamasz 2019)

Rys. 4. Zasada działania mechanizmu opcji na niezawodność

The mechanism operates as follows. When the market electricity price is lower than the strike prices, the power generation units obtain income that is equal to the product of the contracted capacity volume and the strike price. Otherwise (when the electricity price exceeds the strike price), power units have to pay the regulator or TSO the difference between the electricity price and the strike price. The reliability option mechanism provides an incentive to maximize the availability of power units by generation units during peak demand.

The reliability options transfer the responsibility for ensuring capacity adequacy in the power system from the regulator (or TSO) to generation companies. Moreover, this scheme results in decreasing the risk of price volatility in the electricity market.

However, the process of implementing this mechanism is complex, as it requires the introduction of the additional market (parallel to the electricity market), where call options are traded. A call option market is organized in a single buyer model – the regulator or the TSO acquires options from power companies on behalf of all customers. Another complex issue in this mechanism is setting the strike price, which should ensure stable electricity prices in the spot market and, concurrently, provide the investment incentives.

This mechanism was introduced for the first time in Colombia (Cramton and Stoft 2007). It currently operates in Ireland (SEM Committee 2016) and Italy, where it replaced the capacity payment mechanism (Mastropietro et al. 2018).

4. Capacity obligation

The capacity obligation mechanism operates as a decentralized capacity market. The scheme of its operation is presented in Figure 5. The regulator or the TSO issues capacity certificates to power companies (based on their generation capacity) and imposes an obligation on consumers and trading companies to purchase these certificates (usually based on their electricity consumption). The certificates are traded between generation companies (or DSRs) and consumers (or trading companies). The certification of power units is conducted three or four years ahead of the delivery period and every year thereafter.

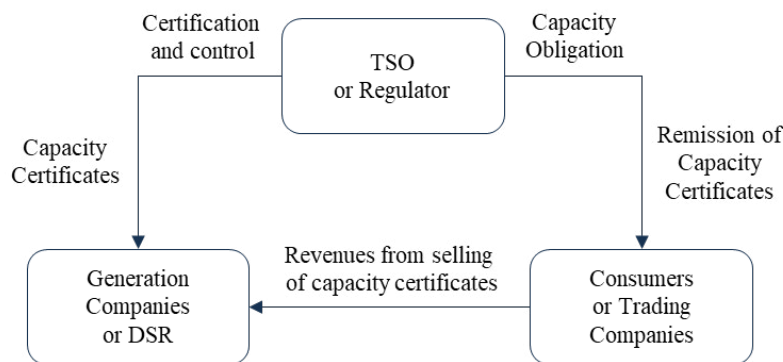


Fig. 5. Scheme of capacity obligation (decentralized capacity market)
 Source: own study based on (de Wachter and Buijs 2012; Zamasz 2019)

Rys. 5. Zasada działania mechanizmu zdecentralizowanego rynku mocy

Generation companies obtain revenues based on their actual availability at specified delivery periods (after considering the adjustment resulting from the fee for unavailability or delivery of a larger volume than specified in the certification). Consumers and trading companies are required to submit the purchased capacity certificates on the day of actual delivery. In the case of failure to comply with their obligation, they are obliged to pay a substitution fee.

As capacity obligations are established several years ahead of the delivery time, new investments are commissioned into the power system before the security of the energy supply is threatened. This mechanism usually encourages the demand side to participate in the market of capacity certificates. The obligation to fulfil capacity obligations (by purchasing an appropriate number of capacity certificates) is imposed on consumers and trading companies.

This capacity remuneration mechanism has a complex implementation, like other market CRMs. It requires the introduction of another market that operates in parallel to the electricity market. Moreover, there is a risk of excessively high revenues by the existing generating units.

The decentralized capacity markets were originally implemented in the United States of America by the following transmission system operators: CAISO (California Independent System Operator) and MISO (Midcontinent ISO).

In Europe, the decentralized capacity market was implemented in France in January 2017 (Lamoulié 2017). Every year, the volume of the capacity obligation is established for the generating units and DSRs that participate in the capacity market. Certificates are issued on this basis (one certificate corresponds to a capacity of 0.1 MW) and are traded between generation companies and consumers. The obligation to purchase certificates depends on the electricity consumption profile during the peak demand period. This period includes ten hours a day: from 7 am to 3 pm and from 6 pm to 8 pm in 10–15 days per year from November to March.

5. Capacity auctions

Capacity auctions are held in the capacity market. Figure 6 presents the general principles of operation of this mechanism. Power generation units, demand-side response units, or energy storages are among the market participants. The capacity obligation in a specific delivery period (e.g. year, quarter) is traded. Both existing and new units can participate in the capacity market. The power demand curve is set by a regulator or the TSO based on, among others, the forecasted demand, generation capacity in the system, and results of previous capacity auctions. The mechanism operates in a single-buyer model. The cost of the capacity market's operation is transferred to the consumers as a capacity fee.

The implementation of a centralized capacity market, similarly to other market mechanisms (i) reduces investment risk, (ii) increases the competitiveness of generating units and DSRs,

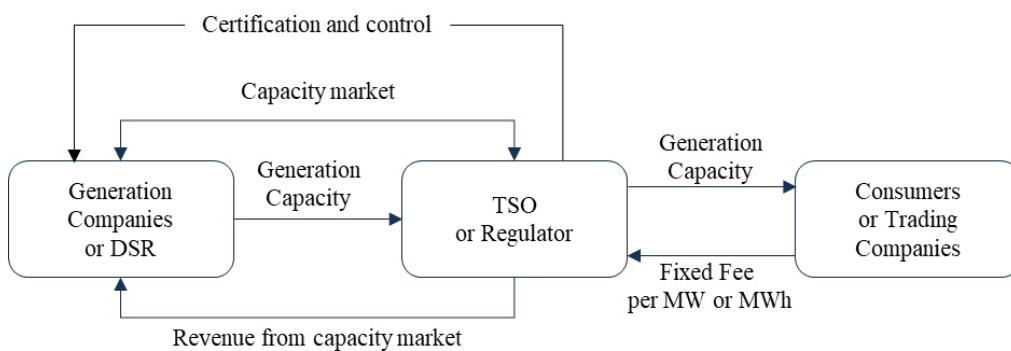


Fig. 6. Scheme of a centralized capacity market

Source: own study based on (de Wachter and Buijs 2012; Zamasz 2019)

Rys. 6. Zasada działania mechanizmu scentralizowanego rynku mocy

and (iii) enables reaching a rational compromise between the costs of maintaining adequate capacity in the system and electricity prices.

The feature that distinguishes this mechanism from the others is the centralized and obligatory capacity auction, usually carried out by the TSO. The mechanism is characterized by, among others, transparent prices, competitive conditions for participation in capacity auctions for new and existing power units, DSRs, energy storages, and foreign units. Additionally, capacity auctions provide a sufficient volume of generation capacity in the long-term because the agreement on the delivery can be signed for up to many years (max. 17 years in Poland).

Similar to the reliability options and decentralized capacity market, the introduction of a centralized capacity market is a complex process. The implementation of this system requires, among others, the power demand curve development, defining the delivery periods, and estimation of generation capacity necessary to meet the demand during the peak periods. Moreover, it requires the establishment of the competitive rules of market operation, monitoring and settlement of the primary and secondary markets. Consequently, the implementation of the two-commodity energy market requires the adoption of appropriate legal regulations, imposes new obligations and responsibilities on the TSO and regulatory bodies, and introduces new conditions to which enterprises participating in the capacity market are obliged to adapt.

The first centralized capacity markets were implemented in some parts of the United States of America in the late 1990s due to the liberalization of the electricity market. They have been implemented in the areas of the following transmission system operators: PJM (Bowring 2013; PJM 2019), NYISO (NYISO 2019), and ISO-NE (ISO New England 2014). The US experience shows that centralized capacity markets fulfil their basic ends, which were (i) ensuring the security of electricity supply and (ii) reducing periods of shortages in the power system. The mechanisms have also increased competition between generation units, DSRs, and units located in adjacent transmission systems. Adequate investment incentives in new generation capacities were also created, which replaced the generation units withdrawn due to age, technical conditions, or environmental regulations.

Among European countries, the United Kingdom was a pioneer in implementing a centralized capacity market (2014). The implementation of the capacity mechanism was a consequence of the increasing risk of periods of power shortages in the system. The growing problems of missing money, the lack of investment incentives for the construction of new generation units, and decommissioning of obsolete units, as well as the implemented climate policy confirmed that the electricity market did not meet its basic purposes. The capacity market in the UK is a single-buyer market where capacity is purchased by the transmission system operator. The TSO is also responsible for certifying existing and planned units in order to verify the potential volume of generation capacity in a given delivery period. The implemented capacity market model also enables trading in available capacity in the secondary market (Department for Business Energy & Industrial Strategy 2014).

In 2018, the capacity market was also implemented in Poland. It was designed along the lines of the British capacity market. The design and principles of the Polish capacity market are detailed specifically in (Benalcazar and Kamiński 2016; Benalcazar and Nalepka 2017; Komorowska et al. 2020; Komorowska and Kamiński 2019; Zamasz 2019).

Conclusions

The paper reviewed and discussed the current state of capacity remuneration mechanisms. The five widely introduced schemes were analyzed. The study embraced the designs of various CRMs, their pros and cons, and key challenges related to their practical operation.

The results indicate that the most complex mechanisms are market-based schemes. This is a consequence of the fact that a new market is introduced, maintained, and operated (parallel to the electricity market). Regardless of the nature of the traded good (call options, certificates, capacity obligation), the market structure must be imposed and managed. Consequently, the new obligations are imposed on (i) regulatory body, (ii) transmission system operator, (iii) generation companies (and DSRs), (iv) trading companies, and (v) consumers. It should also be noticed that the costs of the introduction of the new market, ensuring appropriate capacity, are transferred to consumers.

One of the key challenges of the implementation of CRMs is the fair treatment of all technologies. In theory, all CRMs should be technologically neutral. However, some technologies are more favorable due to their greater impact on the reliability of the power system. It should also be indicated that most CRMs are very sensitive to regulatory decisions. Developing conditions that would be equal for each technology pose a key challenge for designing and are a subject of discussion. Further research directions should investigate each CRM in the context of actually supported technologies and conclude their neutrality.

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Mechanizmy wynagradzania zdolności wytwórczych: klasyfikacja i doświadczenia

Streszczenie

Mechanizmy wynagradzania zdolności wytwórczych zostały wprowadzone na całym świecie w celu zapewnienia wystarczalności mocy wytwórczych i mitygacji ryzyka związanego z gwałtownym wzrostem cen energii elektrycznej w perspektywie długoterminowej. Głównymi przyczynami ich wprowadzenia jest zapewnienie wsparcia finansowego przedsiębiorstwom wytwórczym oraz jednostkom redukcji zapotrzebowania w szczytowym zapotrzebowaniu na moc oraz zapewnienie wystarczających zachęt dla potencjalnych inwestorów. Artykuł ma na celu przegląd mechanizmów wynagradzania mocy wytwórczych wprowadzonych w różnych krajach. Omówiono następujące mechanizmy: płatność za moc, rezerwę strategiczną, opcje na niezawodność, zobowiązania mocowe oraz aukcje mocy. W artykule wskazano główne zalety tych mechanizmów oraz kluczowe wyzwania związane z ich wdrażaniem i funkcjonowaniem. Artykuł wnosi wkład do istniejącej literatury poprzez poszerzenie i aktualizację wiedzy na temat mechanizmów wynagradzania mocy na różnych rynkach energii. Wyniki wskazują, że najbardziej złożonymi systemami są mechanizmy rynkowe. Niezależnie od charakteru towaru będącego przedmiotem obrotu (opcje, certyfikaty, obowiązek mocowy), konieczne jest wprowadzenie i zarządzanie drugim rynkiem. W konsekwencji, nakładane są nowe obowiązki na regulatora, operatora systemu przesyłowego, przedsiębiorstwa wytwórcze (lub

jednostki redukcji zapotrzebowania), przedsiębiorstwa obrotu i konsumentów. Kolejne wyzwanie stanowi transparentne i sprawiedliwe traktowanie wszystkich technologii. Teoretycznie wszystkich mechanizmy powinny być neutralne technologicznie, jednak ostatecznie niektóre jednostki są bardziej faworyzowane ze względu na ich większy wpływ na niezawodność systemu elektroenergetycznego.

SŁOWA KLUCZOWE: rynek mocy, mechanizmy wynagradzania zdolności wytwórczych, aukcje mocy, rezerwa strategiczna, opcje na niezawodność

