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A model-based analysis on the impact of explicit penalty schemes in capacity mechanisms

Paolo Mastropietro [a,*], Ignacio Herrero [a], Pablo Rodilla [a,b,c], Carlos Batlle [a,b,c]

[a] Institute for Research in Technology (IIT), Comillas Pontifical University, Sta. Cruz de Marcenado 26, Madrid, Spain
[b] MIT Energy Initiative, 77 Mass. Av., Cambridge, United States
[c] Florence School of Regulation, Florence, Italy

HIGHLIGHTS

- Capacity mechanisms aim at rewarding the real contribution to system reliability.
- Adding performance incentives as, e.g., financial penalties can improve effectiveness.
- We assess the potential impact of explicit penalties on the capacity auction outcomes.
- We develop a model to simulate the capacity auction to illustrate these impacts.
- We find that properly-designed penalty schemes for under-delivery can be beneficial.

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ABSTRACT

A major aim of Capacity Remuneration Mechanisms (CRMs) is to lead the power system expansion towards the level of security of supply that the regulator considers adequate. When introducing a capacity mechanism, therefore, regulators must ensure that the resulting mix will actually provide the firmness pursued, in such a way that both the generation and the demand resources awarded with the capacity remuneration actually perform as expected when the system needs them. In order to achieve this goal, some experts stressed the importance of including performance incentives in the CRM design. However, first capacity mechanisms (implemented mainly in the American continent) did not pay enough attention to this aspect. Two decades of operation have evidenced the need for performance incentives and these instruments are, at this writing, at the centre of the regulatory discussion.

On the basis of a model analysis, this article demonstrates how the introduction of properly designed explicit penalty schemes for under-delivery can positively impact the CRM outcomes, providing resources with effective incentives to maximise their reliability, discriminating against non-firm generation units, and therefore increasing the effectiveness of the mechanism in achieving its objectives.

1. Introduction

Due to the presence of several market imperfections, already analysed in detail in academic literature (among others, [1–4]), the vast majority of countries with a liberalised power sector have implemented or are in the process of implementing a Capacity Remuneration Mechanism (CRM). While widespread in the American continent since the very start of market implementation, CRMs are climbing regulatory agendas especially in Europe, due to, among other reasons, the impact of the regulatory-driven high penetration of intermittent renewable energy sources on the market incomes and investment decisions of other technologies [5–8].[1] The United Kingdom has recently held the first auction of its capacity market [12], Italy is accelerating on its reliability options mechanism [13], France will soon launch a CRM based on decentralised capacity obligations [14], while Germany is currently discussing about the possibility of encompassing a market-based capacity mechanism in the Energy Transition reform [15]. Excepting the French case, all these schemes are based on centralised long-term auctions for the procurement of some kind of reliability product. The same approach is followed in many power systems in the

* Corresponding author. Tel.: +34 91 542 2800x2740.
E-mail address: Paolo.Mastropietro@comillas.edu (P. Mastropietro).

[1] Despite this negative impact on investment decisions of conventional technologies, several authors also highlighted the pivotal role of renewable technologies in ensuring the security of supply in future electricity systems [9–11].

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United States and all those countries in Latin America which are still organised around market-based mechanisms, which, as stated, introduced CRMs during the last decades [16,17].

CRMs provide resources with an additional and more predictable remuneration with respect to the energy market, with the objective of hedging part of the long-term risk for new entrants and fostering investments. The goal of capacity mechanisms, however, is not merely to attract investments in new "nameplate" capacity, but to foster the installation of firm generation technologies that allow to actually enhance the security of electricity supply during real-time operation and to achieve the level of reliability established by the regulator. In exchange for an additional and predictable remuneration, resources taking part in the CRM are required to deliver the contracted contribution when the system most needs it, i.e., during scarcity conditions. However, designing the so-called reliability product that the regulator is willing to procure to actually achieve this objective has proven to be a major challenge [18].

A design element aimed at providing market agents with incentives to be available during scarcity conditions is an explicit penalty for under-delivery,[2] to be applied to those generators not fulfilling the CRM commitment. Penalty schemes (also termed performance incentives) were proposed by several authors working on the design of capacity mechanisms [19–21]. Nonetheless almost no CRM design did include effective and explicit penalties for underdelivery from the beginning. In Latin America, initial capacity payments remunerated a not-better-specified availability of generation facilities and actual performances had almost no role in the revenue flow. Long-term auctioning mechanisms later introduced corrected some of the flaws of these first schemes (see [22] for details), but did not put much emphasis on penalising underperformances either. In the capacity mechanisms implemented in the United States, a slightly stronger remuneration-performance correlation was gradually introduced. However, biases in the design of these penalties[3] hampered their effectiveness. This absence of properly-designed penalties has often resulted in costly CRMs that were not able to guarantee the level of reliability they were supposed to pursue.[4]

However, the situation is swiftly changing. At this writing, penalties and, more generally, performance incentives in CRMs are at the core of the regulatory debate. As largely discussed in recent US Federal Energy Regulatory Commission's dockets [24,25], ISO New England and PJM, two among the most relevant regional power systems in the United States, are reforming their capacity mechanisms following the so-called "pay-for-performance" principle. On the other side of the Atlantic, a specific working group established by the European Commission is focusing on the design of appropriate obligations and penalties [26], and CRMs implemented or under design in Member States already consider stringent penalty schemes. Nevertheless, many questions about performance incentives still need to be answered. How do they affect the generation mix installed in the system? Which is their impact on reliability, measured in terms of non-served energy? How do performance incentives, such as explicit penalties, affect the total cost of electricity supply? Is the higher cost in the capacity market offset (and outbalanced) by a reduction in the expenses related to non-served energy and energy market?

Despite the growing number of reports on this subject issued by relevant institutions working on the implementation of CRMs, no formal analysis of the problem is available in academic literature. The objective of this article is to fill this gap and to stress the ability of the explicit penalty in discriminating against non-firm energy units, providing existing plants with stronger incentives to improve their reliability and eventually leading to the entrance of new and more reliable generation plants. The research is developed on the basis of a simulation model that analyses and highlights the effect of the penalty scheme on the merit order of a CRM auction. This discussion benefits from and extends the seminal work of Vázquez et al. [19], who provided the theoretical basis of one specific kind of capacity mechanism, the reliability option contracts, which strongly inspired mechanisms implemented in different systems.[5] The mechanism, described in detail in the following section, is based on the centralised procurement of call options, which oblige the seller to return any positive difference between the spot price and a strike price, associated to a physical delivery, subject to an additional penalisation for underperformance. Vázquez et al. [19] also proposed a theoretical framework for the bid calculation to be expected from market agents in the auction. This article draws on such framework to provide a detailed discussion on the role of the explicit penalty through: (i) a theoretical analysis of the problem, focusing on the bids building methodology, and (ii) a two-stage model that simulates the auction itself and allows analysing case studies to confirm the outcomes of the theoretical analysis.

The paper is organised as follows. Section 2 describes the methodology used to face the problem. In the first subsection, the reliability option contracts mechanism is presented, together with the bid calculation methodology originally proposed. In the second subsection, the model used to simulate the auction mechanism is introduced and the theoretical analysis of the problem is developed. After that, Section 3 presents the outcomes of the simulation and provides an interpretation of the results. Finally, Section 4 draws conclusions and identifies potential policy implications.

2. Materials and methods

Prior to delving into the description of the methodology, it is worth starting with a caveat: the whole discussion is based on a centralised capacity auction for the so-called reliability option contracts, as originally defined by [19] a mechanism that is introduced just below. However, most of the results of the analysis presented in this article are valid also for other quantity-based CRM designs, procuring different reliability products or using alternative critical period indicators, i.e., the periods of time when CRM-resources have to actually deliver.

2.1. Reliability option contracts

The reliability option contract, consists of a combination of a financial call option with a high strike price to be backed by physical resources and an explicit penalty for non-delivery. It entitles the buyer of the option to receive from the seller any positive difference between the short-term market price p and the contract strike price s for each MW purchased under the contract. In exchange for that, the seller receives a premium fee F. From the generator point of view, selling an option means that it will receive an amount of money F in exchange for limiting to s the price it will obtain from selling its energy, therefore renouncing to the

[2] The distinction between an implicit and an explicit penalty is explained in the next section, after a detailed description of the reliability option principle is provided.

[3] Examples of these biased designs were too-low penalty rates or a methodology for the identification of scarcity conditions that resulted in almost no shortage events during the year.

[4] An analysis of international experience exceeds the scope of this article. However, examples of these regulatory issues were found, for example, in Colombia during the dry year that affected the country in 2009/2010 [23], or in PJM during the "polar vortex" event occurred in 2014 [24].

[5] The reliability option contracts mechanism is at the base of the capacity mechanisms implemented in Colombia (Firm Energy Obligations) and New England (Forward Capacity Market), and of the CRM currently under design in Italy [13].