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The case for auctioning transmission margins: the design of a competitive mechanism for access to the National Interconnected System in Brazil

Lucas Santos e Silva (UnB)
Maurício S. Bugarin (UnB and EPRG)

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The case for auctioning transmission margins: the design of a competitive mechanism for access to the National Interconnected System in Brazil

Lucas Santos e Silva [a, *], Mauricio Soares Bugarin [a]

[a] *Faculty of Administration, Economics, Accounting and Public Management, University of Brasília, Brasília, 70910-900, Brazil*

ABSTRACT

Recent transformations in the Brazilian Electricity Sector (BES) have ushered in a period marked by intense competition for transmission capacity within the National Interconnected System (NIS). This has brought attention to the inherent scarcity of transmission resources and revealed the inadequacy of the current queue criterion for allocating remaining margins in such a scenario. To address the country's new reality, this paper proposes adopting a competitive mechanism for granting access to the transmission grid—an alternative that employs a simple and transparent procedure, enhances allocative efficiency, and improves access dynamics. Specifically, our paper introduces the design of a Transmission Margin Auction (TMA) for the BES, a mechanism based on an open ascending format, where all the available capacity outlined in the National System Operator's (ONS) expansion plan is sequentially offered, and participants are granted the opportunity to compete at any preferred connection point of their choice.

Key Words: Mechanism design, Transmission margin auctions, Brazilian national interconnected system, Transmission network access, Grid access.

1. Introduction

The rapid expansion of renewable energy sources and the surge in applications for electricity generation licenses under Law No. 14,120 of 2021 have fundamentally reshaped access to the transmission system in the Brazilian Electricity Sector (BES). These developments triggered intense competition for transport capacity within the Brazilian National Interconnected System (NIS), revealing the scarcity of transmission resources and exposing the inadequacy of the current queue-based criterion for allocating remaining margins.

Recognizing the need of adopting a competitive mechanism for contracting transport capacity to address the sector's new reality (Schittekatte and Batlle, 2023), we propose an auction-based solution for granting access to the transmission system. While similar conceptual solutions have been discussed previously (Thema Consulting Group, 2020; Schittekatte and Batlle, 2023), this paper advances beyond basic propositions and theoretical discussions.[1] It presents a comprehensive, auction-theory-based proposal tailored to the specific context and characteristics of the BES, as well as its broader regulatory framework.

The primary outcome of our study is the design of a Transmission Margin Auction (TMA) for the BES. This new mechanism, based on an open ascending format (*ascending clock auction*), sequentially offers all available capacity outlined in the National System Operator's (ONS) expansion plan according to the years in the planning horizon and allows participants to compete at any preferred connection point of their choice. Notably, this research supported much of the Ministry of Mines and Energy's (MME) proposal outlined in Ministerial Ordinance No. 702/GM/MME (MME, 2022a) on November 1, 2022, and particularly in Ministerial Ordinance No. 716/GM/MME (MME, 2022d) on December 21, 2022, as well as its corresponding technical note (MME, 2022e).[2]

Given that grid access remains a significant challenge globally (Thema Consulting Group, 2020; Caspary et al., 2021; Clifford Chance, 2021; Gramlich et al., 2021), and considering the enduring preference in the electrical sector for variations of the "*First Come First Served*" method—despite its negative perspectives (Schittekatte and Batlle, 2023)—our analyses, results, and conclusions, though rooted in the Brazilian context, offer valuable insights for other countries facing similar struggles with transmission capacity allocation.

In addition to this introduction, the paper is organized as follows: Section 2 delves into the expansion of renewable sources in Brazil and the "race" for generation licenses following Law No. 14,120, shedding light on the origins and characteristics of the problem. Section 3 explains the rationale behind opting for a competitive mechanism to allocate NIS' transmission margins. Section 4 presents the principles that guided the design of the proposed mechanism, while Section 5 encompasses aspects and details related to its implementation. Finally, Section 6 presents the concluding remarks of the paper.

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* Corresponding author.
E-mail addresses: lucas28@gmail.com (Lucas Santos e Silva), bugarin.mauricio@gmail.com (Mauricio Soares Bugarin)

[1] Thema Consulting Group (2020) notes that "*thinking about auctions has never progressed beyond the initial concept stage*", while Schittekatte and Batlle (2023) highlight that "*auctions for granting network access are not a new idea, but it has not been generalized so far*".

[2] After undergoing the necessary detailing and formalization, the proposal advanced to Public Consultation. However, there have been no further developments since the country's government change.

2. The problem of access to the Brazilian National Interconnected System

The 2010s witnessed a significant surge in Brazilian renewable energy sources, notably in wind power generation (WPG) and photovoltaic solar generation (PSG), as depicted in Fig.1 and Fig. 2. In the same period, the rapid growth of Distributed Micro and Mini Generation (DMMG), particularly from photovoltaic solar sources, was also noteworthy, as illustrated in Fig.3.

As a result, by 2021, renewable sources accounted for 85% of the country's electricity matrix in terms of installed capacity, with photovoltaic solar, wind power, and distributed renewable self-production contributing to 20% of the total (EPE, 2022).

The pressing need for an energy transition, combined with Brazil's vast renewable potential and recent cost reductions in renewable energy sources (IRENA, 2022), has been a major driver of this surge in renewable generation. However, in the Brazilian case, this growth has been further accelerated by the implementation of subsidy and incentive policies.

The adoption of a net metering mechanism (Silva, 2021), along with state-level incentives through reductions in ICMS (the Brazilian value-added tax)[3], had a substantial impact on the expansion of DMMG. Regarding the growth of solar and wind generation, discounts on the transmission and distribution tariffs (TUST and TUSD, respectively), introduced by Law No. 13,360 of 2016 and Law No. 13,203 of 2015, were of great importance.[4]

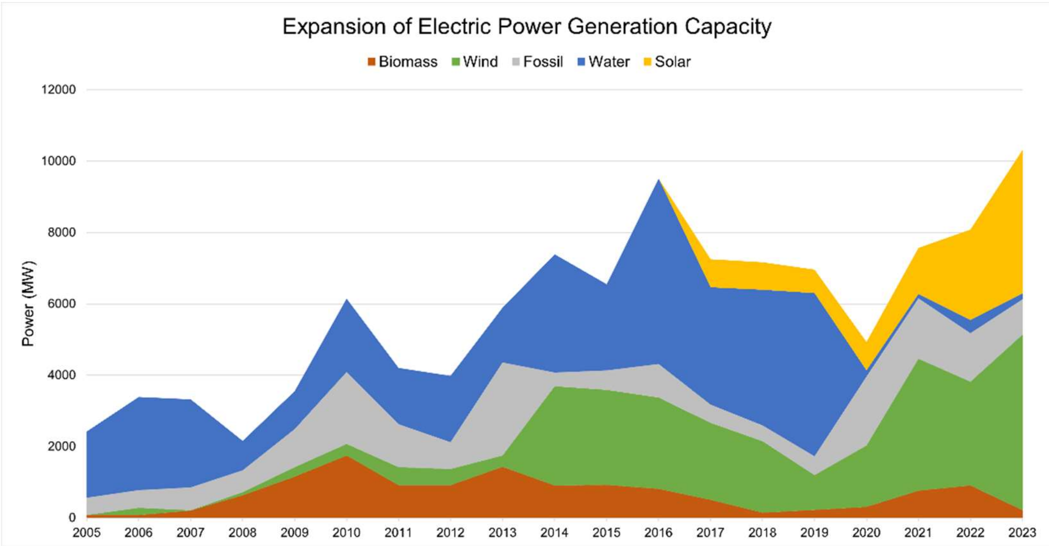

Fig.1. Brazilian yearly evolution of generation additions (2005-2023). Source: ANEEL, 2024a (adapted by the authors)

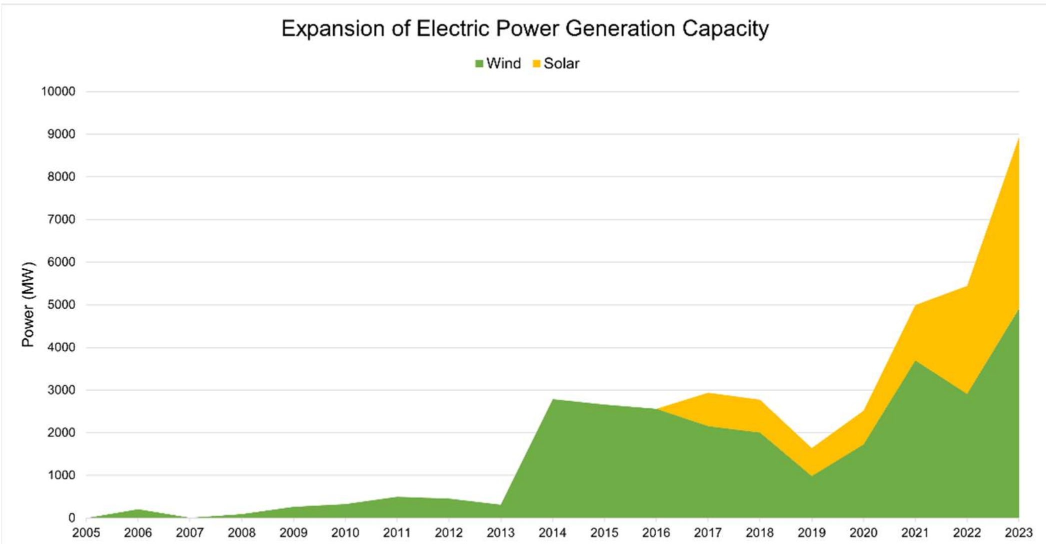

Fig. 2. Brazilian yearly evolution of generation additions: WPG and PSG (2005-2023). Source: ANEEL, 2024a (adapted by the authors)

[3] See, for example, Law No. 23,672, enacted in 2021, in the state of Minas Gerais.

[4] The laws stipulated that, for specific sources (including solar and wind generation) and under certain conditions, the Electric Energy National Agency (ANEEL) must contemplate reductions of no less than 50% in TUST and TUSD.

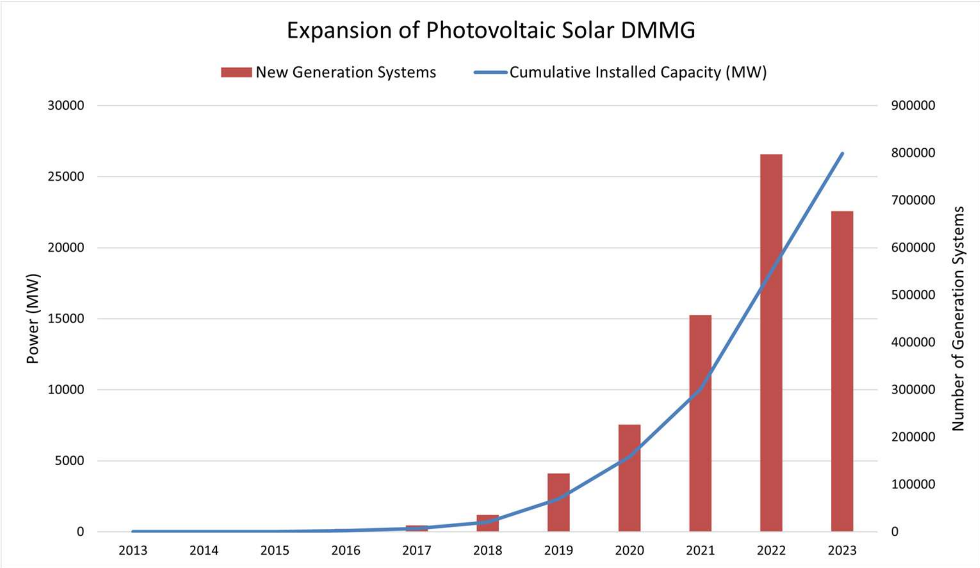

Fig.3. Brazilian expansion of photovoltaic solar DMMG (2013-2022) Source: EPE, 2024 (adapted by the authors)

With the increasing prominence of renewable sources in the Brazilian electricity matrix and their growing share in supply expansion, a significant portion of generation growth no longer relies primarily on large hydroelectric projects with energy negotiated in the centralized auctions of the Regulated Contracting Environment (RCE). Instead, a multitude of geographically dispersed projects, predominantly engaged in energy negotiations within the Free Contracting Environment (FCE), spearheads most of the expansion (Abraceel, 2022). This transformative shift results in "greater difficulty in managing information related to prospecting the generation supply, reducing the predictability of amounts and their location" (EPE, 2022).

Furthermore, FCE solutions, especially those related to wind and photovoltaic solar generation, often involve faster implementation projects and shorter timelines for connection to the NIS (ANEEL, 2023a), thus spawning less synchronization between generator deadlines and processes related to network infrastructure (which typically have longer time frames). Together, these new factors create significant challenges to the coordination of generation and transmission, thereby impacting the planning and expansion of the transmission system.

Amidst these challenges, Law No. 14,120 of 2021 eliminated the discounts from TUST and TUSD for renewable sources while instituting a 12-month transition period[5]. The looming end of discounts prompted a rush for generation licenses, primarily among photovoltaic solar projects and, to a lesser extent, wind generation projects. Fig. 4 illustrates this scenario by showing the evolution in the issuance of Dispatches of Licenses' Receipt Records (DRO)[6] from 2015 to 2023

As a result, the number of generators vying for access to the NIS not only exceeded the system's capacity but also outstripped the anticipated rise in demand for centralized generation over extended time horizons[7], thus rendering an expansion of the transmission system to accommodate this surge in supply unjustifiable. As a result, a scenario of intense competition has arisen for the NIS's remaining transmission capacity.

In light of this scenario, the current queue-based criterion (chronological order) for accessing the transmission system is inadequate. To address the sector's new reality and achieve enhanced results in terms of allocative efficiency, access dynamics, and coordination between generation and transmission, the adoption of a competitive mechanism for allocating the scarce transmission capacity is essential (Schittekatte and Batlle, 2023). In this context, the presidency of the Brazilian republic issued the Decree No. 10,893 of 2021 to authorize such a mechanism.

[5] Law No. 14,120 maintained transmission and distribution tariff discounts for generators who applied for a license within 12 months of the law's publication and commenced operation of all their generating units within 48 months of the license date. Subsequently, Provisional Measure No. 1,212 of 2024 authorized requests for a 36-month extension of the deadlines initially set for entry into operation.
[6] The DRO is a document provided by ANEEL to agents who submit a request for authorization to operate a generation plant.
[7] From January 2021 to October 2021, Technical Statements issued for the North and Northeast regions, as well as for the states of Minas Gerais and Goiás, indicated an interest in adding approximately 165 GW solely in new wind and photovoltaic solar generation (ONS, 2021b). To put this value in perspective: (i) Brazil's installed generation capacity, excluding DMMG, is approximately 205 GW (ANEEL, 2024c); (ii) The reference scenario projected for the year 2031 in the Ten-Year Energy Expansion Plan (PDE) suggests the country's installed capacity at the end of this period to be 275 GW, with around 43 GW of this growth achieved through centralized generation expansion (EPE, 2022).

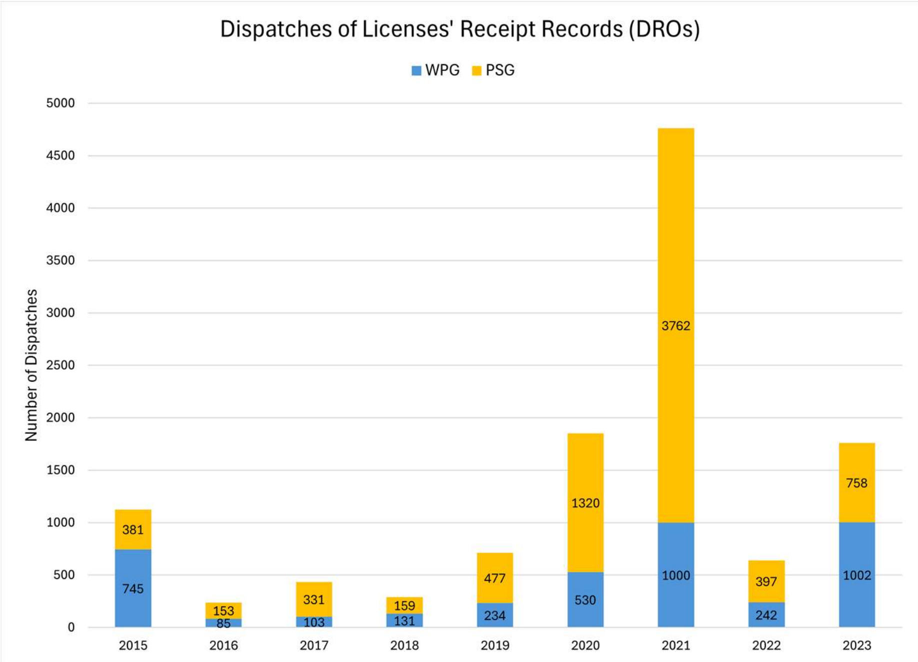

Fig. 4. DROs issued since 2015 (WPG and PSG). Source: ANEEL, 2024b (adapted by the authors)

3. On the rationale for a competitive mechanism

While the "*First Come First Served*" (FCFS) method and its variations are traditionally employed in the electricity sector, both in Brazil and in most countries, using a chronological order criterion for allocating transmission capacity in a scenario of rapid expansion of generation supply (and/or a high number of access requests) has clear drawbacks, with two standing out:

i. Longer Timelines

All access requests must be individually analyzed. Consequently, queue-based methods lead to longer timelines, "congestions", and a substantial increase in the effort required to conduct the necessary analyses.

ii. Allocative Inefficiency

Projects with higher technical and economic viability, and consequently, a higher value assigned to the remaining capacity in each location, may not connect to the system if they occupy less favorable positions in the queue.

Another consequence of FCFS mechanisms, also related to allocative inefficiency but extending beyond concerns with generators that will come into operation, is the potential assignment of capacity to agents less committed to the effective utilization of the transmission system (who may ultimately not even implement their projects). Fig. 5 shows that this is a problem already observed in the Brazilian system.[8]

Finally, it's also imperative to underscore the inherent lower level of transparency of the FCFS method, along with its increased susceptibility to discretion, capture, and legal disputes[9], elements that may lead to outcomes diverging from social optimum.

Therefore, considering the problems with a criterion based on chronological order, which are also present in other possible alternative methods (e.g. administrative processes or *beauty contests*, attribute-weighted queues, etc.), competitive mechanisms, particularly auctions, stands as a much better allocative device. This alternative not only results in more efficient allocations but does so using a simple, straightforward, and transparent procedure. Moreover, it unveils and leverages crucial information that would otherwise remain inaccessible to the government and could generate revenues that benefit the system's users (such as by directing the collected funds towards tariff reductions).

[8] Regarding this situation, it is important to highlight that the proposal under consideration for "exceptional treatment in the management of generation licenses and CUSTs" (ANEEL, 2023b), which establishes a "Forgiveness Day" for the "amnesty and regularization" of generators, not only fails to address the original issue but also risks exacerbating it by creating a moral hazard problem, as it could lead to the expectation that such a solution might be used again in the future.

[9] In the Brazilian context, there is already evidence of generating agents submitting administrative and judicial requests to ANEEL for "special treatment" in the queue (see, for example, process 48500.001699/2023-15 in ANEEL, 2023c).

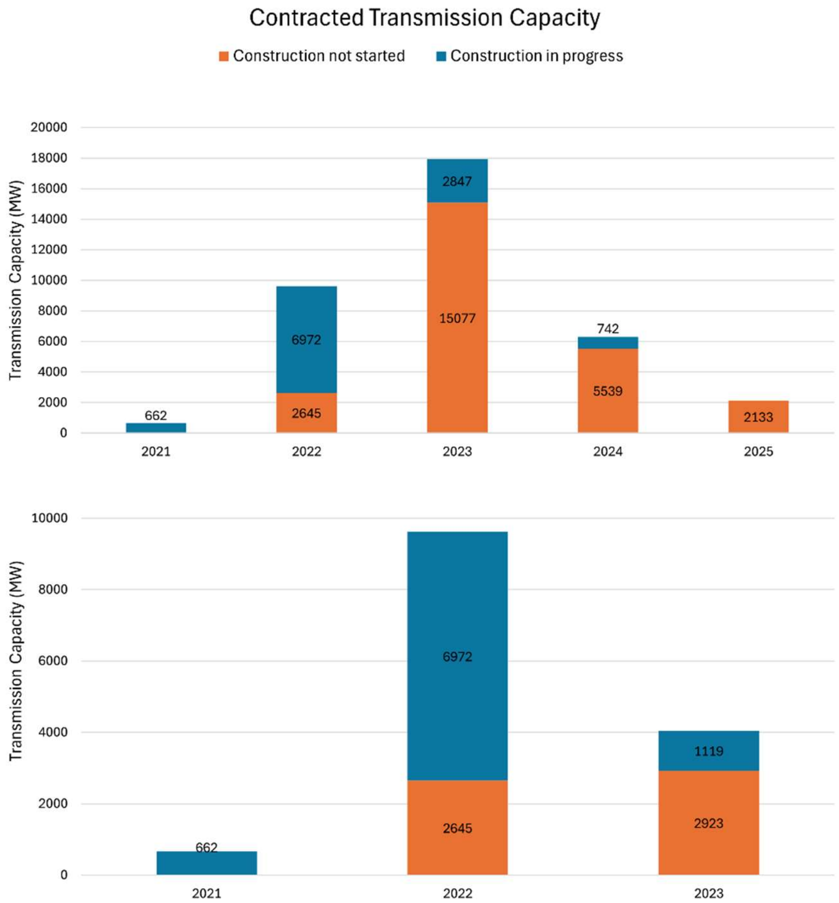

Fig. 5. Transmission capacity contracted in March 2023 by power plants not yet in commercial operation, categorized by the year of CUST (Transmission System User Agreements) execution commencement. The total is shown above, and the capacity only for power plants with CUST under execution is shown below. Source: ANEEL, 2023b (adapted by the authors)

However, despite its benefits, the adoption of auctions for allocating remaining transmission capacity still encounters substantial resistance from specific sector agents. The two primary objections are linked to: (i) the presumed impacts on energy prices; and (ii) the resistance to charging for grid access (MME, 2022b; Filho and Guarnier, 2023).

The first objection is that generators would pass the costs incurred in these auctions to the end consumer through higher energy prices. However, this argument fails to distinguish between fixed and marginal costs. Regardless of the amounts invested in the auction, winning generators will set energy prices to maximize their profits.[10] Obviously, the final price may be influenced by the competitive environment or regulatory framework, but in such cases, the problem does not originate from the auctions. Moreover, the systematic use of auctions, due to their efficient outcomes, might yield effects that, over the medium and long term, could lead to reductions in final energy prices.[11]

Concerning the second objection, with the limited supply of transport capacity in the NIS and the growing demand from generators, transmission margins have become a scarce resource that inevitably carries a value. Whether through direct action, like the TMA, or indirectly, access to the transmission system will have a price even if granted to generators without any charge (one should simply notice that, in the current scenario, generation ventures with granted access will have a portion of their value associated precisely to their guarantee of connection to the NIS). Given that the transmission system is a public resource funded by all its users, granting free access to a few fortunate generators who could benefit from this privilege does not seem to be the most reasonable solution.

[10] A useful approach to examining this objection is to extend the argument to the real estate market and reflect on its implications. As highlighted by Binmore and Klemperer (2002): "*The price of new housing is no lower when the developer had the good fortune to obtain the land below its current market value (e.g. because it was obtained free through inheritance or was bought before planning permission was available) than when the developer has paid the full market value. In either case, the price is determined by the housing market at the time the new housing is sold*".

[11] Although we do not expect an impact on energy prices, there will be an impact on generator returns. Thus, we already anticipated that the involved generators and their associations would use arguments of this nature to influence the discussion. However, it should be noted that the impact on generator returns essentially represents a transfer of part of the firms' earnings to the government. By appropriately directing the collected funds (for example, towards tariff reduction), the government is essentially reclaiming a portion of a socially owned resource for the benefit of society. Moreover, in the Brazilian context, this option would also help reduce distortions caused by sector subsidies, redirecting funds from subsidized agents to the benefit of those who ultimately bear the subsidy costs, namely, the end consumers.

4. Designing a transmission margin auction for the Brazilian Electricity Sector: Principles

Auctions are essentially allocation mechanisms used for the assignment and pricing of scarce goods, particularly in the absence of fully established markets. However, they are not a "*one size fits all*" solution. The appropriate design tailored to the desired objectives and specific economic environment is crucial for achieving positive outcomes (Klemperer, 2002a). Specification failures can lead to inefficient allocations, revenue losses, and manipulation of the mechanism, undermining some of its key benefits (McAfee and McMillan, 1996; Binmore and Klemperer, 2002; Klemperer, 2002b; McAfee et al., 2010).

In view of the above, the TMA proposal meticulously draws upon the sector governance and regulatory framework, as well as the current scenario for transmission system access and the primary objectives envisioned for the competitive mechanism: efficiency, transparency, and improvement of access dynamics. The proposal also paid careful attention to the fact that the TMA introduces an innovative solution for all involved agents. In this way, failure to achieve a straightforward and easily comprehensible design could lead to misunderstandings, suboptimal decision-making, and ultimately result in inefficient allocations.

4.1 Main Objectives

The MME established allocative efficiency as the paramount objective for the competitive procedure. The goal was also to devise a solution that would, within the context constraints, maximize grid utilization, improve current access dynamics, and foster competition. Notably, revenue generation was not a primary focus. In this regard, the sole directive stipulated that any generated revenue should be allocated to reduce tariffs for public transmission services.

With regard specifically to the improvement of the current access dynamics, it should be noted that the adoption of the TMA already addresses a major part of this objective, as in this case, only the winners need to have their access requests analyzed (whereas in the current queue procedure, all requests must be examined).[12]

4.2 Selection Criteria

Different selection criteria (i.e., types of bids) were available for potential adoption in the TMA, with the main options including upfront payment (in R$/kW)[13], anticipation of charges (upfront payment in R$/kW with subsequent deduction from the transmission usage charge)[14], guarantee insurance (in R$/kW), and a premium on the TUST (percentage or R$/kW).

The increased risk of default or renegotiation with payments contingent on project operations (Binmore and Klemperer, 2002; Bugarin and Ribeiro, 2021), potentially exacerbated by the country's legal and institutional framework, led us to favor options involving payments in advance (such as the first two options). However, the complete evaluation of these alternatives took into account legal and political dimensions, with a level of detail that exceeds the intended scope of this article. Therefore, we limit our discussion to the fact that, based on the analyses conducted, the initial choice was to adopt bids based on upfront payment. However, due to resistance from some agents who cited potential legal disputes and the risk of procedural nullification (MME, 2022b), and considering that revenue generation was not among the primary objectives set for the TMA, the MME decided to change the initial choice to bids based on the anticipation of charges.

4.3 Auction Format

4.3.1 Pricing Rules

Because the TMA introduces a new solution for all involved agents, with no historical precedent of access payments (exacerbating the lack of information about values assigned to the transmission margin), we considered it essential from the outset to adopt a pricing rule that reduces the informational complexity of bidding. As a result, our work oriented the solution towards designs that exhibit characteristics of second-price auctions.[15]

In second-price auctions, within a scenario of private values[16] and without budget constraints, *bidding truthfully*—according to the real value attributed to the good—is a weakly dominant strategy (optimal from the perspective of payoff maximization regardless of the bids of other participants)[17]. In other words, unlike first-price auctions, under these assumptions, second-price auctions do not require inferences about other bidders' valuation and behavior and, therefore, do not demand great sophistication from participants. Moreover, given the standard allocation rule in which the participant who makes the highest bid wins, in this case the behavior of making *truthful bids* results in efficient outcomes.

[12] For more details about the improvement in the current access process, such as the elimination of the current Access Information stage, refer to Guedes et al. (2024).
[13] R$ is the symbol for the Brazilian currency ("Real").
[14] In this alternative, the amount paid in the auction would subsequently be deducted from the winner's transmission usage charge according to rules to be defined by ANEEL. In other words, the auction bid would not correspond to a new expense to be paid by the generator, but rather to an anticipation of the charges it would already incur upon connecting to the NIS.
[15] In a second-price auction the highest bidder wins but pays a price equal to the second-highest bid.
[16] In a private value situation, each bidder knows the value of the object to themselves at the time of bidding, and this value remains unaffected by the knowledge of other bidders' values.
[17] In scenarios of private values with budget constraints, the dominant strategy in second-price auctions remains quite straightforward: bidders should place a bid equal to the lower value between their budget constraint and the value assigned to the good.

The optimal strategy for second-price auctions in a context of private values is not only simple but also quite robust. Since its results can be obtained through *ex-post* analysis, the equilibrium doesn't rely on any probability distributions and, therefore, does not depend on assumptions such independent and symmetric values. Consequently, the assumption of private values is the only one relevant from the Independent, Private and Symmetric Values (IPS)[18] basic reference model.[19] Even when the assumption of private values is relaxed, under certain conditions, such as auctions involving affiliated values and symmetric models, a bid based on a simple strategy, similar to the one previously described, remains optimal for second-price auctions in various equilibria (Krishna, 2010).

4.3.2 Open vs. Sealed-Bid

In order to promote the disclosure of participants' information (values) during the auction, enabling refinement on estimates and adjustment in strategies throughout the procedure, the decision was to adopt an open format. Specifically, given the chosen pricing rule (second-price), an open ascending format, or *English Auction*[20]. Once again, this decision stemmed primarily from the innovative nature of the solution and the lack of information regarding the value of access (due to its history of queue-based allocation and absence of charges). In such a context, information disclosure is expected to play an important role in achieving the efficiency objectives set for the TMA.

In a scenario marked by interdependent values—likely the most reasonable assumption for the TMA's context (see subsection 4.3.3)—an open ascending format also helps mitigate the risk of the *winner's curse.*[21] Moreover, although secondary to the TMA objectives, this format addresses an effect related to the *winner's curse*, where participants may bid too cautiously to avoid potential overpayments (the fear of the *winner's curse* can induce overly cautious bidding behavior, ultimately resulting in lower prices).

Due to the positive correlation between information dissemination and auction revenue (*Linkage Principle*), disclosing information may also reduce the *informational rents* earned by winning bidders, potentially leading to higher final prices (Milgrom, 1989).[22] Additionally, when dealing with asymmetric participants, open formats tend to be more efficient (McAfee et al., 2010) and, under certain conditions of asymmetric interdependent values where no other auction is efficient, open ascending formats are more likely to yield efficient outcomes (Maskin, 1992).

Finally, some secondary attributes of open formats might also be of particular interest to the TMA, especially for ensuring the continuity of its adoption despite initial resistance from some agents. These attributes mainly relate to the absence of regret (winning participants do not end up with bids much higher than the second-place bid), legitimacy (all participants are given the opportunity to beat the highest bid), and assurance to winners that there were other participants willing to pay values close to their bid (Cramton, 1998; McAfee et al., 2010).

However, open formats also have weaknesses, with risk of collusion being their primary issue (Cramton, 1998; Klemperer, 2002a). Participants' ability to directly observe the behavior of others facilitates collusion (Graham and Marshall, 1987; McAfee et al., 2010) and, therefore, makes open formats susceptible to a greater number of collusive equilibria (Milgrom, 1987). Besides that, the deterrence of entry and encouragement of predatory behaviors can also be identified as other problematic aspects of open formats (Klemperer, 2002a).

Regarding these matters, the key aspect to be observed for the TMA is the scenario of intense competition for the system's remaining capacity, with a high number of generators contesting for very limited margins (MME, 2022c; ONS, 2022c). With such a perspective on competition (and as long as a similar scenario persists), the main risks associated with open formats are largely mitigated (for the risk of collusion, one only needs to recognize the immense difficulty of coordination in these circumstances, while the number of potential competitors addresses the concerns about deterrence of entry and predatory behaviors).

Nevertheless, considering their ease of implementation and minimal impact on the desirable attributes of the mechanism, it is reasonable to adopt some measures commonly recommended to strengthen the robustness of open auctions (McAfee and McMillan, 1996; Cramton, 1998; Klemperer, 2002a; McAfee et al., 2010). These measures essentially involve keeping participants anonymous and pre-specifying price increments, thereby making it more challenging to use bids for signaling to other participants. Both measures have been incorporated into the final design proposed for the TMA.

[18] The IPS (Independent, Private and Symmetric Values) scenario, which corresponds to the basic reference model in auction theory, adopts independently and identically distributed private values as its key assumptions, as well as risk neutral agents.
[19] In contrast, the fundamental results of first-price auctions specifically depend on the probability distributions of other participants' values, thus emphasizing the significance of assumptions about independently and symmetrically distributed private values.
[20] In the single unit, independent private value framework, the *English Auction* is the open strategic equivalent of the sealed-bid second-price auction (Krishna, 2010).
[21] This phenomenon occurs when the winning bidder overestimates the value of the item and consequently pays more than its actual worth. However, it is important to note that the *winner's curse* effect only manifests when participants fail to accurately determine their strategy based on all available information and knowledge, including the awareness that being declared the winner in the auction can lower their estimate for the value of the item (Krishna, 2010).
[22] Although this result does not necessarily apply to contexts involving multiple units (Reny and Perry, 1999).

4.3.3 *Final Design*

The initial analyses guided us towards an open ascending auction, which embodies the desired features concerning pricing rules and information disclosure. However, a concern with this option emerged immediately due to the nature of the TMA, which typically involves multiple-unit auctions (the available transmission margins at each connection point are not unitary and usually can accommodate the connection of multiple generators). In such scenarios, open ascending auctions generally lack crucial characteristics that were decisive in our previous selection of the pricing rule, particularly those pertaining to *bidding truthfully*. [23]

Nevertheless, while the supply of transmission capacity per connection point is not unitary, each participant's demand exhibits a unitary characteristic. Given the current regulatory framework, participants are only entitled to contract a predetermined amount of transmission capacity that corresponds to their power generation. Therefore, each generator demands uniquely and exclusively a transmission margin equivalent to its generation capacity. In simpler terms, each participant has a single-unit demand that matches its power output.

Additionally, we employed a simplifying assumption of symmetric demands in our analyses. This assumption posits that all generators competing for a specific connection point possess identical generating capacities, thereby characterizing generators' demand for transmission margin as a standard case of single-unit demand.[24] While acknowledging that this assumption does not perfectly reflect reality, its results illuminate the most relevant aspects of the situation under analysis, while ensuring that the models remain reasonably treatable.[25]

Reference Scenario (Private Values)

In a scenario involving multiple units, single-unit demand, and private values, multiunit open ascending auctions inherit the strategic characteristics of second-price sealed-bid auction (Krishna, 2010).

In this context, unlike situations with multiple demands, a participant's bid for an additional unit—once it no longer exists—cannot influence the price for his initial unit. As a result, there is no longer an incentive for behaviors such as bid shading and demand reduction.[26] Therefore, under these assumptions, the multiunit open ascending auction presents the characteristics that were pivotal in the selection of the pricing rule and effectively achieves the desired objectives for the current application.[27]

However, the initial rationale for adopting an open format suggests that, within the context of the TMA, the assumption of private values might not be suitable. Given the innovative nature of the proposal, a more accurate assumption would involve interdependent values, particularly affiliated values.

Interdependent and Affiliated Values

In scenarios with single units, interdependent, and affiliated values under a symmetric model[28], open ascending auctions provide a highly robust equilibrium that is independent of the signal's distribution[29]. Moreover, participants' equilibrium strategies possess a particularly relevant feature: the absence of regret. At the end of the auction, regardless of the signal realization, participants do not regret the decision made based on the revealed information. Under the same conditions, such a characteristic is not present in any of the other traditional auction formats (Krishna, 2010).

In the aforementioned scenario, traditional auction formats also differ in expected revenue. The expected revenue of open ascending auctions is never lower than that of second-price sealed-bid auctions, which, in turn, provide revenue at least as large as that of first-price sealed-bid auctions or descending open auctions (Milgrom and Weber, 1982; Weber, 1983).

Finally, in terms of efficiency, none of the traditional formats yield efficient outcomes in the configuration under analysis.[30] All of them have ascending symmetric equilibria, but these equilibria are ascending in the signals of the participants, not in their values.

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[23] In a multiple unit scenario, open ascending auctions are not the open equivalent format of second-price sealed-bid auctions. Instead, in such scenarios, the open equivalent of the latter is the Ausubel auction.

[24] In all parts of the text where reference is made to "single-unit demand," it should be understood as "symmetric single-unit demand.".

[25] Ultimately, a scenario with asymmetric generation capacities would constitute a variation of the Knapsack Problem, leading to what is known as a Knapsack Auction (Khezr et al., 2024).

[26] Refer to Krishna (2010) for a discussion of these aspects and their impacts on multiple-object auctions.

[27] Under these assumptions, the multiunit open ascending auction is strategically equivalent to the Ausubel auction (this follows directly from a straightforward adaptation of the results presented in Milgrom (1985) and Krishna (2010)).

[28] In a symmetric model, the signals of all participants are drawn from the same interval. Additionally, the function that determines the value assigned to the object is the same for all participants and is symmetric with respect to the signals of the other competitors (the order of these signals can be swapped without affecting the resulting value). Refer to Krishna (2010) for further details.

[29] The signals are the participants' private information that, if revealed to other competitors, could change their values.

[30] If the "Single Crossing Condition" is satisfied for the function that determines the participants' valuation of the item, then all these auction formats have efficient equilibria. However, this conclusion does not hold in cases of participant asymmetry. In such cases, the "Single Crossing Condition" property guarantees the existence of an efficient equilibrium for open ascending auctions only in auctions restricted to two participants. A more general result, encompassing a larger number of participants, can be achieved only by fulfilling the "Average Crossing Condition" (Krishna, 2010).

While these results are relatively positive for open ascending auctions, they specifically apply to scenarios involving the sale of a single unit. Given that TMA potentially involves multiple units in the same auction, this prompts us to consider whether these results extend to the case under analysis.

A significant portion of the difficulties associated with multiunit auctions result from the multiplicity of items demanded by participants, rather than the multiplicity of items being sold by the auctioneer. Thus, a single-unit demand scenario, such as that in the TMA, often allows for the extension of various results obtained in simpler setups to these contexts with multiple units. Indeed, this is partly what occurs in a scenario of affiliated values, symmetric model, and single-unit demand. Under such assumptions, the previous ranking of expected revenues remains valid in the context of multiple units and, consequently, we still observe some positive results for open ascending auctions. Specifically, we have the following ordering for the expected revenues ($E[R]$) of open ascending auctions (OAA), uniform price sealed-bid auctions (UPSA), and discriminatory price sealed-bid auctions (DPSA) (Weber, 1983; Milgrom, 1985): $E[R_{OAA}] \geq E[R_{UPSA}] > E[R_{DPSA}]$.[31]

4.3.4 Design Conclusions

Considering the factors previously outlined, an open ascending auction emerges as an optimal choice for the TMA. It is an alternative that, through a simple design whose potential weaknesses are mitigated by the highly competitive implementation scenario, meets the key desired characteristics.

Additionally, it is an auction format that yields good results not only in a basic reference scenario (multiple units and unitary demand, with private, independent, and symmetric values), but also in scenarios that are more likely to resemble the reality of the TMA (multiple units and unitary demand, with interdependent and affiliated values in a symmetric model).

Hence, we opted for an open ascending auction in the TMA proposal, more specifically the modality known as the *ascending clock auction*, in which the price increments are determined by the auctioneer and carried out at predetermined time intervals.

5. Designing a transmission margin auction for the Brazilian Electricity Sector: Implementation

5.1 General Features

In line with the goals of enhancing allocative efficiency and optimizing grid utilization, our design premise dictates that all available capacity within the planning horizon of ONS's current Expansion and Reinforcement Plan (PAR/PEL) should always be offered. Thus, with the PAR/PEL's planning horizon spanning five years (ONS, 2021a), the available capacity for each of those years should be auctioned separately in the same TMA. Additionally, it would also be important to ensure that all participating generators have the opportunity to compete for any available connection point.

These two characteristics provide competitors with more alternatives for connection, both temporally and spatially, thereby enhancing the efficiency of the allocation process. Moreover, it allows generation sources with locational flexibility to identify other points in the transmission system with available transport capacity, enabling better use of both the existing and future transmission network, and potentially reducing tariffs for electrical energy transmission services.

Incorporating all margins of PAR/PEL’s planning horizon also eliminates any discretion in the auction’s product selection, reducing the risk of undesirable practices (e.g., selecting nodes that favor a particular participant), increasing the transparency, and minimizing potential legal disputes.

5.1.1 Margin Offer

Given the substantial workload involved in calculating remaining margins by the ONS, automatically offering all available margins across every busbar in the NIS would needlessly complicate the process.[32] To avoid unnecessary calculations for access points without interested agents, participants should be required to indicate their busbars of interest in advance.

Evidently, to ensure the effectiveness of this measure, it is necessary to limit the number of busbars each participant can indicate. In this way, participants must be restricted to indicating only three busbars each. Given the current demand scenario, this limit seems sufficient to meet the efficiency objectives of the auction (the high number of potential competitors and the concentration of projects in regions like the Northeast suggest that this number of indications is likely adequate to cover most, if not all, of the available points in these areas of greater interest). Additionally, it is worth noting that this restriction applies, to some extent, to the generators themselves, both technically and economically (due to factors such as their locations[33] and the limited availability of alternatives for connecting to the transmission system within a reasonable distance).

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[31] The presented results depend on the assumption of risk neutrality among participants. In a situation where participants are equally risk-averse, the discriminatory price sealed-bid auction would yield a higher expected revenue than the uniform price sealed-bid auction (Weber, 1983).

[32] For readers unfamiliar with terms and nomenclatures of electrical systems, in this case, it's sufficient to understand busbar as the connection point by which generators can access the transmission system.

[33] The locations of the projects themselves would also be restricted to a predetermined area based on their technical characteristics, previous studies, and land availability.

5.1.2 Sequential Auctions vs. Simultaneous Auctions

Considering the premises outlined in subsections 5.1 and 5.1.1, the mechanism devised would auction, within the same competitive procedure, all available margins across the multiple busbars indicated by participants for each year in the planning horizon. Two alternatives are possible: simultaneous auctions or sequential auctions.

The option of a simultaneous auction involves offering all available busbars for each year of the planning horizon simultaneously through individual open ascending auctions. Despite generators naturally having a limited range of choices among available busbars, this approach introduces additional complexity into the decision-making process of a completely new procedure, potentially resulting in efficiency losses due to misguided choices. Thus, its adoption would be justified only in the presence of significant benefits within the context of the TMA.

However, the greatest benefits of simultaneous auctions are related to the presence of complementarity and substitution among different units (McMillan, 1995; McAfee and McMillan, 1996; Cramton, 1998; Binmore and Klemperer, 2002; Milgrom, 2004). In a scenario with unitary demands, such as in the TMA, benefits related to complementarity among units can be disregarded.[34] As for the benefits related to substitution, these would be limited due to the technical and economical restrictions for a generator to connect in different points of the transmission system.[35] Moreover, given the non-revenue nature of the TMA, the *spill-over* effect of competition—one of the main benefits of simultaneous auctions in the presence of substitution (McAfee and McMillan, 1996; Binmore and Klemperer, 2002)—might also be overlooked in favor of a simpler solution that could enhance allocative efficiency.

In terms of sequential auctions, their primary issues revolve around the potential for predatory bidding in the early rounds and the risk of regret stemming from the failure to achieve planned complementarity (McAfee and McMillan, 1996). However, once again these concerns do not arise in the TMA scenario of single-unit demand.[36] Another challenge concerns the necessary inferences if units are substitutes, leading to the strategic issue of choosing between securing victory early or waiting for a later opportunity with potentially fewer competitors (Portugal and Bugarin, 2021). This problem would also be mitigated by technical and economic restrictions on connecting at different points in the system, as well as by the context of intense competition for transmission margins.

Therefore, considering the characteristics, context, and primary goals of the TMA, the decision was to use sequential auctions.

5.1.3 Sequential Auctions

For an analysis of sequential auctions within the context of the TMA, we make the following assumptions: (i) all busbars relevant to a specific project are treated as identical units; (ii) projects located in the same region share an interest in the same set of busbars. Additionally, we also assume that participants do not discount the payoffs of auctions held later and use independent and symmetric private values as a basic reference scenario (remembering that the TMA already entails a scenario of unitary demands).

Given these specifications, there exists an equilibrium for the sequential open ascending auction that yields efficient results and does not rely on the announcement of previous outcomes (Krishna, 2010).[37] However, under these assumptions, efficient outcomes are also achieved with other traditional formats of sequential and simultaneous auctions, and they are also equivalent in terms of revenue (Weber, 1983; Klemperer, 1999). Hence, in these circumstances, there is no difference between the results obtained from the sequential auctions and simultaneous auctions.

In situations characterized by affiliated values, even with unitary demands and identical units, the information revealed in previous periods becomes relevant to participants' strategies. As a result, the previously presented results are no longer valid (Weber, 1983). However, some general results can still be drawn. In a scenario with affiliated values, unitary demands, and identical units: (i) sequential first-price auctions generally yield higher revenues than simultaneous discriminatory price auctions; (ii) sequential open ascending auctions and sequential second-price auctions generally generate higher revenues than simultaneous uniform price auctions (Milgrom and Weber, 2000).

Based on these results from a sequential setup in scenarios with single-unit demand and identical units, as well as previously discussed factors—such as TMA's characteristics, implementation context, primary objectives, and the preference for a simple solution—the decision was to use Sequential Auctions. As a result, the initial design comprised a

[34] A possible exception could arise in situations involving projects that belong to the same company or controlling group, where implementing specific projects might yield greater synergies and economies of scale. However, since this exception is not expected to significantly impact the TMA (McAfee and McMillan, 1996), we have disregarded any of its potential effects.

[35] These limitation on benefits related to substitution due to technical and economical restrictions could also be exacerbated by the scenario of intense competition for the transmission capacity. Given the number of generators that would prefer a particular busbar as their primary option, any generator less interested in this specific busbar, due to its relatively higher connection cost, would likely be less competitive in its auction.

[36] Possible exceptions would once again pertain to scenarios like those discussed in Footnote 34, which are ignored here for the same reasons previously explained.

[37] These results remain valid even when some of the fundamental assumptions of the model are relaxed (Weber, 1983). For example, they hold true when the total number of participants is unknown to all competitors or when the assumption of private values is dropped (while still maintaining the hypothesis of independent values and assuming a type of symmetry derived from identical valuation functions for all participants).

competitive procedure that would progress sequentially through the years of PAR/PEL's planning horizon (in increasing order of years) and, within each year, also sequentially over the eligible busbars (in decreasing order of competitiveness[38]).

5.1.4 Implementation of Sequential Auctions

The proposal for a sequential auction that spans the years of the PAR/PEL's planning horizon and, within each year, progresses also sequentially over eligible busbars, while appealing in terms of mechanism, presents a practical concern: the procedure may become excessively lengthy depending on the volume of transmissions margins and number of busbars to be auctioned.[39]

Additionally, since the beginning of discussions on the TMA, all involved official entities have expressed significant reservations about lengthy procedures. In this way, to address this issue and reduce potential duration, we evaluated several variations of the original proposal, despite acknowledging that these changes could potentially lead to a reduction in efficiency and/or an increase in complexity.[40]

We then consolidated the proposal as follows: during a registration stage, each participant indicates their three busbars of interest for ONS's margin calculation and declaration of eligible busbars. Subsequently, before the start of auctions for each offered year, every participant must select a single preferred busbar to compete for the available margin in that specific year (limited to the set of eligible busbars). The option for an open ascending format was retained for busbar auctions. Table 1 provides a summary of the auction design.

Table 1. Auction Design Summary

	Design Feature	TMA Proposal	
Auction Format	Pricing Rule	Second Price	Open Ascending Auction
	Information Disclosure	Open	
Auction Implementation	Multi-Year Margin Offer	Sequential	
	Multiple Busbar Offer	Simultaneous*	

* Each participant can compete only on their chosen preferred busbar.
Source: Authors

5.2 Design Details

The following subsections provide a detailed description of the proposed competitive procedure, covering aspects crucial for the TMA implementation. At the end, Fig. 6 presents a summarized flowchart of the TMA, where PAD refers to the Preliminary Access Diagnosis, a document that should consolidate the technical analyses of the Margin Map and enables the issuance of a preliminary grant for signing the CUST or CUSD (Distribution System User Agreement).

5.2.1 Eligibility

Guided by principles of technological neutrality and equality among sources and contracting environments, and with the clear intention of avoiding additional distortions in access granting, any generation project without a valid CUST or CUSD—regardless of its energy source or whether it holds a generation license—must be eligible to participate in the TMA.

5.2.2 Different Products

To accommodate the available margins for every year within the current PAR/PEL's planning horizon, our design treated each year as a distinct product. These products (years) must be sequentially offered in ascending order, with a reasonable predetermined interval between them (this interval allows participants time to assimilate results from the previous product and, if necessary, adjust their strategies for the subsequent ones).

In each of these products (years), all eligible busbars will be simultaneously offered through *ascending clock auctions*.

5.2.3 Eligible Busbars

During the TMA registration phase[41], participants may indicate up to three candidate busbars for the calculation of possible transmission margins to be offered in the auction. Based on the participant's indications, ONS must calculate and

[38] The prior establishment of an order for busbar auctions was adopted to mitigate risks associated with arbitrary ordering, such as order manipulation and legal disputes. A descending order of competitiveness aims to promote greater competition throughout the bidding process.
[39] A quick analysis, using the "new energy" auction from 2022 (LEN A-5) as a reference (see ONS, 2022b), revealed a scenario in which over 130 sequential auctions would need to be conducted for a single year of the planning horizon within the competitive procedure.
[40] Refer to Silva (2023) for further details regarding the different proposals analyzed.
[41] For further details on the registration phase refer to MME (2022a).

disclose the available margins for each candidate busbar. Busbars with remaining transmission capacity and physical availability for connection will be eligible for the competitive procedure.

5.2.4 Stages of the Competitive Procedure

The auctions for busbars within a specific product (year) will start only after the completion of all auctions for the preceding product (including additional rounds for area and subarea constraints, as described in subsection 5.2.7).

Before the start of each product, there will be a preliminary stage in which every participant must select their preferred busbar for the upcoming product, irrespective of the three options indicated during the registration phase. Once selected, participants can only compete for the chosen preferred busbar in that specific product (year).

After all participants have chosen their preferred busbar for the current product (or opted not to compete in this product), simultaneous auctions will be conducted for each eligible busbar that has been selected as the preferred choice by a participant.

Following the proposed format, busbar auctions will be conducted in a single, continuous, ascending-value stage. Participants must indicate their willingness to stay in the auction at the current prices (in R$/kW) within a predefined time interval. Each busbar auction will continue until its demand is either less than or equal to its available remaining transmission capacity.

If a price increase results in no demand for transmission capacity at a particular busbar, the respective auction will revert to the previous price and be closed. Remaining participants will then be ranked in descending order of capacity. In the event of a tie, participants will also be ranked by the chronological order of bids (which in this case corresponds to the chronological order of indicating participation in the previous round).

5.2.5 Duration of the Competitive Procedure

Unlike the customary practices in the BES, which typically advocate for brief, uninterrupted auctions that start and conclude on the same day, the TMA design adopted a different approach. It considered that once the competitive procedure begins, no pre-established deadline should dictate its conclusion.

In addition to being a good (and commonly adopted) practice for auctions in general, with auctions concluding only when there is a convergence in final prices, this aspect becomes particularly relevant in this case, since the TMA introduces a completely new procedure, wherein participants, including the conducting institution, lack prior information about the actual value of the asset being auctioned.

5.2.6 Disclosed Information

Another departure from the usual practice in the BES concerns the information made available to participants during the auctions.

Aside from the standard information usually provided to participants, such as the Initial Price and Current Price, for the TMA we recommended disclosing the number of remaining participants and their total power capacity in the current round, while preserving bidder anonymity. This decision directly correlates with the adoption of an open auction format and the desired outcomes associated with its information disclosure effects.

Additionally, it is also important to disclose information about the presence of subarea and/or area constraints in the auction of each busbar, signaling to participants that, at the conclusion of the ongoing dispute, they may not emerge as final winners (as described in Subsection 5.2.7).

5.2.7 Area and Subarea Constraints

The interconnections within the NIS and its resulting power flows can impose constraints on busbar that are more restrictive than their initially assigned capacities (ONS, 2017). These constraints, known as area and subarea constraints, arise when additional generation at specific points in the system violates pre-established requirements and criteria (see, for example, ONS, 2022a). Properly addressing these additional restrictions is essential in the competitive procedure for accurately determine the winners.

Given that in an open ascending auction winners do not reveal their willingness to pay—the auction ends at the willingness to pay of the marginal loser—the more straightforward solution of ranking busbar winning bids in descending order within each subarea or area would not be suitable for the envisioned format of the TMA.[42] Such a methodology would likely result in an incorrect final ranking of winners and, consequently, in an inefficient allocation of remaining margins.

In the TMA, winners of busbars within a subarea facing constraints must participate in an additional auction, competing amongst themselves for the available margin in that specific subarea. Similarly, if there are additional area constraints, winners from each involved subarea must engage in another additional auction, now competing for the available margin within the respective area.

[42] This is the methodology currently employed in Brazilian energy auctions for managing such additional constraints.

5.2.8 *Initial Price*

Given the option for an open ascending auction, as well as the possibility of *pass-through* when the margin supply exceeds demand at a specific busbar (as described in Subsection 5.2.11), our design established a starting price of R$0.00 per kW for all busbar auctions.

Exceptions to this initial price would happen in the additional auctions triggered by subarea and/or area constraints. In such instances, we suggested adopting a criterion where the winners of busbars (or subareas) commit to the prices attained in their preceding auctions.[43] This measure prevents participants from securing victories in the additional auctions at values lower than the final prices determined in the auctions for their respective busbars (or subareas).

5.2.9 *Price Increment*

The decision on the appropriate price increment balances the need to prevent excessively long auctions with the requirement for sufficient granularity to allow fine adjustments, particularly toward the auction's conclusion. Consequently, for all auctions within the procedure, including those related to area and subarea constraints, the standard price increment should be set at R$1.00[44] per kW.

A rapid examination, using the power of participants from recent energy auctions as a reference, reveals that this value will not result in excessively small increments. At the same time, concerns about the increment being too high are mitigated by analyses showing that larger increments do not significantly impact the efficiency of outcomes (McAfee et al., 2010). In fact, they may be the most effective approach for expediting the auction process (McAfee et al., 2010).

To enable better calibration, our design considered the possibility of adjusting the price increment criterion during the auctions, subject to prior communication to all participants via the auction system and adherence to some pre-established criteria that must be outlined in the auction public notice. This flexibility allows for increasing the price increment at the outset of the auctions, facilitating their advancement when there's a larger number of active participants. Conversely, as the number of participants decreases towards the end, reducing the increment permits finer adjustments, enabling participants to manifest subtle differences in the value they assign to the remaining margin.

5.2.10 *Bid Acceptance Time*

In determining the time for bid acceptance, our objective was to strike a balance between avoiding excessively long auctions and ensuring participants have adequate time to assess the effects of the previous increment before making decisions for the current round.

The proposal recommended setting a bid acceptance time of 5 to 10 minutes for all auctions in the competitive procedure, including those related to area and subarea constraints. Extending the bid acceptance times beyond these recommendations would not pose significant issues; in fact, it could likely improve the procedure (the restrictions on bid acceptance time were primarily driven by concerns about the auction’s duration raised by the involved official entities).

Additionally, we also included a rule whereby the system automatically moves to the next round if all remaining participants accept the bid before the time limit expires.

Once again, to enable better calibration, the design considered the possibility of changing this acceptance time during the auctions (with prior communication to all participants via the auction system and according to some pre-established criteria that must be stated in the auction public notice).

5.2.11 *Pass-Through*

Following the preliminary stage, during which participants select their preferred busbars for the next product, a *pass-through* mechanism should be employed if any busbars have a lower margin demand than the remaining available transmission capacity. In such cases, these busbars will not be auctioned, and all participants who selected them as their preferred choice will secure access at the initial price (in this instance, R$0.00 per kW).

This solution aligns the proposed mechanism with the currently prevailing access rules in cases where the margin demand remains lower than the supply, not imposing any charges for access to the NIS in such situations. Furthermore, it is a solution consistent with the economic logic that underpins the rest of the proposal and simplifies the execution of the procedure by avoiding unnecessary busbars auctions.[45]

5.2.12 *Residual Margins*

Given the low probability that the power of winning projects at a specific busbar will exactly match its remaining available margin, it was also important to consider how to handle the residual margin that might remain at the end of some busbar auctions.

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[43] The detailed proposal for this criterion, including a suggested preliminary algorithm, can be found in Silva, 2023.

[44] On February 28, 2024, R$1 corresponds roughly to US$0.20.

[45] This *pass-through* mechanism also introduces significant flexibility to the procedure, making it suitable even for scenarios with lower competition for the margin. Consequently, this reduces the relevance of the recurrent discussion, particularly in the Brazilian context, about whether the current scenario reflects a conjunctural or structural problem.

In such situations, since the same TMA will include various products corresponding to the different years of the PAR/PEL planning horizon, the residual margin from a specific busbar will be allocated to its auction in the following product (year). Residual margins from the last product must be carried over to the next TMA.

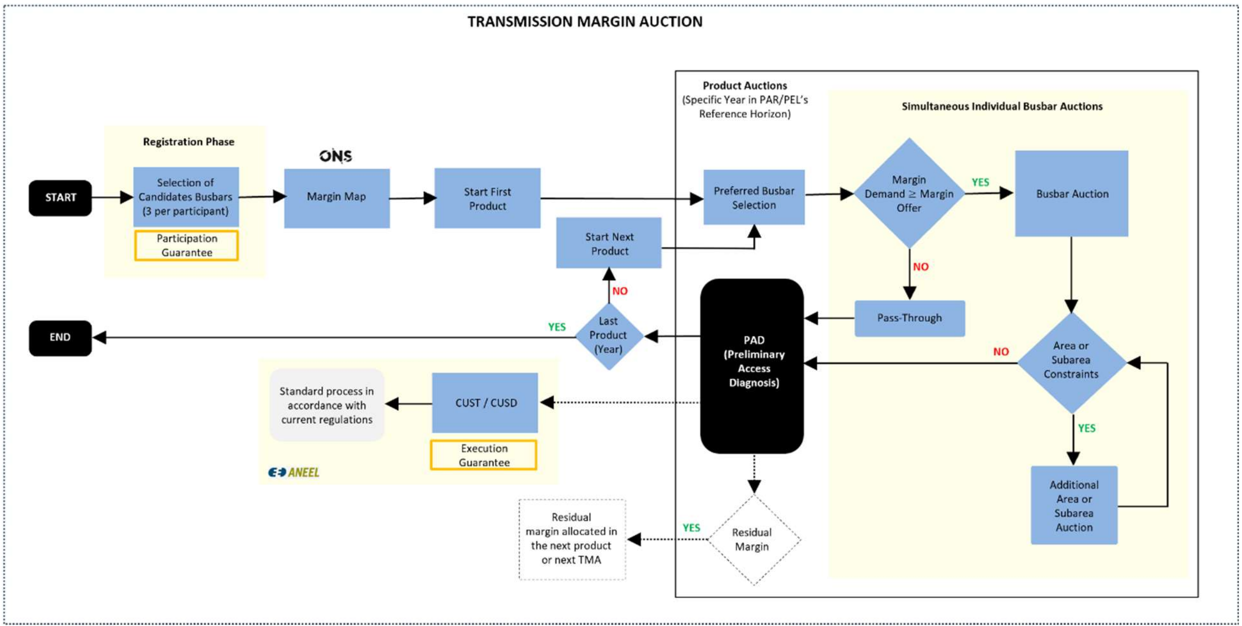

Fig. 6. Transmission Margin Auction Flowchart. Source: Authors

5.3 Enforcement

Alongside an appropriate design, the participation of the "right bidders", and ensuring that winners will honor their payments (and, when applicable, their other commitments) are crucial factors for the success of an auction (Milgrom, 2004).

If default costs are low, participants would actually be competing for prize options rather than the prize itself. Moreover, if smaller participants can sidestep commitments through bankruptcy, then the auction may favor these participants over larger competitors (who would face greater difficulties in defaulting). In such scenarios, aggressive behavior in the auction, evidenced by exceedingly high bids, could simply indicate the leniency of enforcement mechanisms established for the procedure (Klemperer, 2002a).

Therefore, addressing the level of enforcement was another crucial point for ensuring the effectiveness of the newly proposed solution for accessing the NIS.

This topic becomes even more relevant when considering the current scenario of generation expansion in Brazil, where several projects secure their access to the transmission system but do not commence operations within the scheduled timeline (see Fig. 5 presented previously). As the process of reclaiming access and its corresponding reserved margin tends to be lengthy, potentially involving legal actions, this problem may ultimately lead to unnecessary expansions of the transmission system to compensate for this capacity that is not actually used but remains reserved for a particular generator.

The main measures proposed in the TMA regarding this subject were: (i) specifying an additional guarantee deposit (or guarantee insurance) at the registration phase ("participation guarantee"); (ii) requiring a performance bond for the faithful fulfillment of the connection and use of the transmission system contract ("execution guarantee")[46]; and (iii) stipulating that bids placed by winners will not be refunded in case of non-compliance with the obligations subsequent to the auction.[47]

The proposal also established that winners' contracts could not be advanced or postponed, nor could they undergo changes regarding the connection point and technical characteristics related to the reserved transport capacity.

Moreover, in the event of non-compliance of previously determined conditions, the generator would have its contract terminated, and without prejudice to the application of regulatory penalties, the respective guarantees would be executed, and the reserved margin would be made available to the NIS again. In such situations, ventures affiliated with the same

[46] As determined by Decree No. 10,893 of 2021, this should be an additional guarantee beyond the one already required for signing the CUST.

[47] Refer to MME (2022a) for further details on these enforcement measures.

controlling group would not be eligible to compete again for the same margin during a pre-established period (to be determined by the Electric Energy National Agency).

6. Conclusions and Policy Implications

Motivated by recent changes in the environment for accessing the Brazilian transmission system, this paper presented a comprehensive proposal for a Transmission Margin Auction (TMA), with a design that not only is firmly grounded in the principles of auction theory, but also considers the specific characteristics of the BES and its broader regulatory framework.

The rapid expansion of renewable energy sources and the subsequent surge in generation licenses under Law No. 14,120 of 2021 have intensified competition for access to the NIS, rendering the current queue-based allocation mechanism inadequate. By adopting a competitive approach, the TMA aims to enhance allocative efficiency, improve access dynamics, and optimize grid utilization. Representing a significant departure from the traditional "*First Come First Served*" method, the TMA offers a more efficient and transparent mechanism for allocating the scarce transmission resource.

Although challenges remain, such as the need for robust monitoring and enforcement, as well as the integration of the TMA with existing BES processes (see, for example, Hochberg and Poudineh, 2021 and Tolmasquim et al. 2021), the proposed auction presents a promising path forward for addressing the growing complexities of the Brazilian electricity market. As the sector continues to evolve, ongoing evaluation and refinement of the auction mechanism will be essential to ensure its effectiveness and adaptability to changing circumstances.

The implementation of this new procedure, especially as a long-term solution for NIS access, also offers opportunities for continuous improvement. By refining auction parameters, addressing unforeseen circumstances, and learning from initial results, the TMA design can be further optimized. Moreover, this proposal could serve as an initial step toward more sophisticated designs as market participants gain knowledge and experience with the new method.

Finally, as the global energy landscape faces increasing challenges in grid access, the findings and proposed solutions of this study, although rooted in the Brazilian context, offer valuable insights for policymakers and industry stakeholders in other regions facing similar constraints. By examining the complexities of transmission capacity allocation in Brazil, this research contributes to the broader discourse on grid management and infrastructure development worldwide.

CRediT authorship contribution statement

Lucas Santos e Silva: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Mauricio Soares Bugarin**: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.

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