APEx
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APEx Objective

To facilitate the development and communication of ideas and practices in the operation of global competitive electricity markets. One of its primary intentions is to provide a platform for the sharing of information between its members.

In the Spotlight

HOW TO BEST PRICE DAY-AHEAD MARKETS?

WELFARE OPTIMALITY, ALGORITHM SCALABILITY, AND PRICE SIGNALS

Abstract

Since the early waves of electricity market liberalizations, pricing in day-ahead markets has raised challenging questions rooted in economics and optimization theory. In general, finding uniform paid-as-cleared market prices, i.e. clearing prices that uniformly apply to bids such that all price-compatible bids are accepted and price-incompatible bids are rejected, is mathematically impossible in day-ahead (or more generally closed-gate) electricity markets, due to the presence of indivisibility constraints.

We discuss here how that pricing challenge is addressed currently in the EU Single Day-Ahead Coupling (SDAC), in the US, and why Non-uniform Clearing prices may potentially be a key enabler leading to more welfare and better algorithm scalability. The question of obtaining meaningful price signals is also briefly discussed.

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Cecilia Maya

Chief Market Operations
Colombian Power Independent System and Market Operator

This year 2022 the number of challenges that the world is facing keeps compounding. After two years of the pandemic, with hard consequences for human life, in February, the Russia-Ukraine war added to the disruptions in the World Economy, its sustainability, and the Energy Markets, among many others.

In APEx, we should reflect on the many risks we are facing in Energy Markets, as we, the members of this Association, are Market Operators with a clear mandate for guaranteeing security, reliability, and efficiency of energy supply. For the analysis, we may start with the risk that we were all mapping and working hands-on before the pandemic erupted: climate change. This risk may cause severe draughts as those we face periodically in Colombia - and some other neighboring countries - due to the phenomenon called El Niño which makes our work really hard. Now, with climate change, El Niño comes in a more irregular timing, but it is not the only cause for diminished hydraulic reserves and high temperatures, as is the case these days in California and India. The result is a more stressed grid and very high prices in the electricity market.

Many energy markets were adapting to climate change by investing and building capacity in new clean technologies, like non-conventional renewables. The upside for this strategy is the low variable costs (actually zero costs) for generation, however, it requires large fixed investments. The commitment of a great number of countries which adopted COP21 and later versions is strong and has translated in growth of these new technologies around the world, contributing to their goals of reaching carbon neutrality around 2050. This is the good news. The risk of this strategy is to keep reliability when you have a large participation of these resources like wind or solar, due to their variability, especially when non renewable plants have been closed. Cases like UK that had to turn on coal plants again may illustrate this risk. The lesson learned here is that we Operators need to promote a diversified matrix policy and capacity markets to maintain reliability and efficiency in our markets.

SAVE THE DATE

To the challenges posed by climate change, we should add the supply chain collapse. Colombia may be a good example for this risk. After a very successful auction for non-conventional renewables in 2019, closing at prices never seen for long term contracts up to 15 years, the following auction that took place in 2021 closed at just fair prices due to less than expected participation of generation. The explanation seem to be in the fact that shortage in solar panels caused by restrictions in the supply chain prevented some project developers from committing energy in this auction. This disruption in the supply chain should be included in the short and medium term operation planning and a careful consideration should be given to the inclusion or reinforcement of capacity markets.

Above all this, the Russia-Ukraine war has complicated all the efforts to have a reliable Grid and an efficient power market. The war and the sanctions imposed on Russia caused an increase in fuel and natural gas prices and a reduction in supplies, with the consequence of rising prices. Demand for coal also increased as well as its price. The impact has been felt mainly in Europe but it has extended to the rest of the markets that use these fuels -probably all the energy markets. This situation compromises efficiency and, most importantly, reliability and has revive the old discussion of having markets or a strong control by the government. We at APEx believe in markets which design may be adjusted through adequate policy and regulation and the number of risks we are facing right now probably is calling for a prompt response from all the participants in the market, institutions, market members and, of course, market operators.

In conclusion, for us, APEx members, operating the Grid and the Wholesale Markets under a new architecture that has more participation of variable generation, adapting to climate change, and disruption in the supply chain caused by both the pandemic and the war, is becoming increasingly challenging. To be prepared, we should continue hiring the best talent, be proactive in providing timely signals and proposals for the policy makers and regulators, diversifying the energy matrix, promoting new technologies as storage and hydrogen, and keeping our eyes open to the changing circumstances and other risks (i.e. cybersecurity) that may impact the service we provide.

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Perfect uniform prices, in general, do not exist

Uniform pricing means that in the market outcome, every market participant of the same market segment (location and hour of the day) will pay or receive the same electricity price and no other transfers or payments are considered. Uniform prices correspond to the classic pay-as-clear design.

Competitive equilibrium is a market outcome where the market clears (balance of supply and demand), and where market prices are such that no one (buyers or suppliers) has an incentive to deviate from the accepted quantities satisfying the power balance. Equivalently, for these market prices, there is no paradoxical acceptance (in which case the market participant would rather prefer its order not to be matched), or paradoxical rejection (in which case the market participant would rather prefer its order to be accepted).

When only demand and offer curves are in scope, classic economics teaches us that the intersection of the supply and demand curves determines a competitive equilibrium and its market-clearing price.

In day-ahead electricity markets, additional more advanced bids than simple demand and offer curves are used to take into account technical-economic constraints such as minimum power output levels or start-up costs for generation assets. In such a case, it is in general not possible to find a "single price fits all" supporting a competitive equilibrium and ensuring that every market player is perfectly fine with the market outcome. A simple example is demonstrated in the full version of this article is available here.

The current approach for Indian and European wholesale markets

In the current design in the EU Single Day-ahead Coupling and in India, the welfare optimal allocation would most of the time be discarded, in case it is not possible to find uniform prices avoiding that some orders are paradoxically accepted. A concrete example can be found in the full version of this article here.

An advantage of this design is for example that there is no need to organize compensations (also called side-payments) to bids losing money because they are paradoxically accepted, as those solutions are forbidden.

Regarding fairness of the outcome, on one hand, every accepted order will be cleared at the same prices without relying on anonymous discriminatory side-payments, but on another hand, some (block) orders are paradoxically rejected, which can be perceived by some market participants as an unfair or at least undesirable market outcome. Paradoxical rejection of orders is however in general unavoidable in ("non-convex") day-ahead electricity markets

Such a design requires checking specific price conditions every time an order matching candidate solution is found, and to discard such a solution if paradoxical acceptance of some so-called block orders cannot be avoided. Technically speaking, this implies that the market-clearing algorithm needs to "iterate" between a volume problem (which a.o. determines the acceptance of bids), and a price problem (which verifies that prices are compatible with the accepted bids actually exist).

Non-uniform pricing

Non-uniform pricing essentially consists in dropping price conditions in the welfare optimization stage, and purely focusing on finding the welfare optimal order matching, i.e. the optimal allocation, optimizing the value of the accepted demand and of the supply costs (while taking into account all sorts of the market and network constraints, but without checking explicitly the market-clearing prices).

Because the problem is less constrained, solutions with more welfare are allowed. It also eases calculations of the market results, since there is no need to iterate anymore between the search for optimal bid acceptance and the calculation of clearing prices when a candidate solution is found.

On another hand, to ensure that all market participants are cleared at least at the price of their bids, compensations should be paid to so-called “out-of-the-money” orders that are losing money (i.e. those which are paradoxically accepted). This results in side-payments that differ among the impacted market participants.

The most extreme example of a non-uniform pricing scheme is pay-as-bid, as pay-as-bid settlement outcomes can be seen as resulting from some market-clearing prices, and (in general high) side-payments. However, in practice, pricing schemes such as Convex Hull pricing or Extended Locational Marginal Pricing, used by leading Independent System Operators in the US (MISO, PJM, ...) aim at being as close as possible to a uniform pricing scheme, and as far away from a pay-as-bid scheme.

Meaningful price signals

Several questions arise with non-uniform pricing, and pricing rules in day-ahead electricity markets are still subject to active research in academia and in the industry. For the pricing stage aimed at computing market prices and side-payments, several requirements or objectives could be imposed.

For example, Convex Hull Pricing aims at minimizing actual losses and lost opportunity costs of market participants and on the network side (congestion rent). With Convex Hull Pricing (or variants aimed at minimizing make-whole payments), some classic network price requirements enforced by strict Locational Marginal Pricing are usually not met, for example, the fact that prices must be equal in different locations if there is no congestion in the network do not necessarily hold under Convex Hull Pricing.

Another property not guaranteed with Convex Hull Pricing is fractionally accepted orders set the clearing prices. For those two reasons, Convex Hull Pricing may not be seen as a good candidate for implementation in EU or Indian markets.

On another hand, Convex Hull Pricing and variants generally focus on making market prices as significant as possible, by minimizing deviations from a competitive equilibrium and minimizing the discretionary payments complementing the settlements purely based on these market prices.

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Meaningful price signals

The non-uniform pricing is by design leading to higher welfare and lowers computational complexity compared to pure uniform pricing. On another hand, non-uniform pricing implies side-payments, which in turn mean an additional complexity in terms of settlements. How market participants would behave under various pricing schemes is also an interesting question.

Non-uniform pricing is currently studied in the R&D program of Euphemia under the supervision of the Single Day-ahead Coupling Market & System Design body, as a promising avenue to improve market and algorithmic efficiency [1]. Further research will be needed in the future to have a complete understanding of the advantages and disadvantages of the pricing paradigms in scope for (European) day-ahead electricity markets.

Access the full version of this white paper here.

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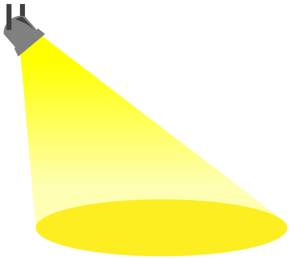
References: [1] CACM Annual Report 2020, All NEMO Committee in collaboration with ENTSO-E, available online here



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