Analysis of the Possible Impact of Complex Bids in the Italian Electricity Spot Market

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Abstract
The liberalization of the electricity market, already affirmed in many European and worldwide countries, has originated many technical debates over the definition of the market model that can be considered as optimal for electricity. The required simplicity and transparency of market rules often contrast with the intrinsic complexity of the electrical system, due to physical and security requirements. For these reasons, issues related to the mechanism for bid selection in the energy market are one of the most debated during the phase of market rules definition.
In this paper, we present an analysis of the possible quantitative impact of complex bids in the Italian electricity day-ahead market, in order to evaluate benefits and drawbacks.

Key Words: Clearing Procedure, Energy Market, Market Rules.

1. Introduction
In the liberalized electricity market, one of the most discussed issues is the mechanism for bid selection in the day-ahead energy market. The method used to define electricity price and accepted quantities must aim to simplicity and transparency, essential requirements to allow an adequate development and a constant monitoring of the market; on the other hand, it must consider the physical and security requirements of the electric system, translated into specific technical-economical constraints.
The definition of suitable market rules has been object of debates within the scientific community [1], [2], [3], [4].
An efficient bid auction system is essential to ensure a correct market behavior [5] and to reduce price volatility [6], [7]. On the other hand, a too complex bid system could have a strong impact on market transparency and controllability, encouraging strategic behaviors [8].

2. Structure and features of simple bids
The selection mechanism based on the so-called "simple bids", used at present for example in the Italian Market, enables the producers to submit sale proposals containing only the indication of offered amount and requested price. In this case, the target of obtaining a production profile consistent with the technical performances of his own power plants, and economically profitable as well, is left to the bidding skill of each single generating company.
Precise critics have been addressed to this methodology, because this mechanism does not take into account some technical aspects about generation units (max load gradient, technical minimum, etc.) or economical issues not directly expressed by the price-quantity curves (no-load costs, start-up costs, etc.).
On the basis of these consideration some electricity markets, like the Spanish one, are providing for the possibility of producers to submit so-called "complex bids", containing technical-economical specifications in addition to the indications provided by the simple price-quantity pairs.
This paper proposes a quantitative approach to compare the economical and technical effects of simple and complex bids. By means of a market simulation tool, the possible impact of complex bids in the Italian electricity market has been estimated.
bid curve, decreasing or increasing depending on the kind of bid.

The possibility to submit multiple bids enables the operators to prepare more structured purchase and sale bids, so to optimize their business strategies. For example, multiple bidding enables a share of the energy of a certain generation unit to be offered at zero price; having such energy the maximum probability of acceptance by the market, this technique guarantees, except in case of over-generation, the dispatch of a quantity higher than the technical minimum of the production unit.

The presence of multiple bids does not modify the market solution procedure, i.e. a bid of n steps could always be displaced by n simple bids having price and quantity values equal to those of the single considered step. In particular, the presence of multiple bids does not imply the application of iterative computational processes; the only computational increase is constituted by the number of variables of the problem, which becomes equal to the total number of steps present in the bids.

3. Structure and features of complex bids

With a “complex bid” the owner of a production plant can define specific technical-economic conditions that constraint the acceptance of his offer.

Complex bids are allowed for example in the Spanish market, which constitutes the main reference for the following description [10].

Such a market, which enables also multiple sale bids with a maximum of 25 steps for each reference period, provides for the possibility to specify additional acceptance conditions, as detailed in the following.

3.1. Condition of indivisibility

This condition means that the first block of the bid (the cheapest one) is indivisible. Thus the producer has the guarantee that, if the block is accepted by the Market Operator, it’s for the whole offered amount and not for a part of it.

This condition was introduced in the Spanish Market to enable the operators to declare the power limit relative to technical minimum of production units as indivisible, in order to ensure in case of acceptance a technically feasible dispatch.

3.2. Minimum income condition

The producers can include, as a necessary condition for the acceptance of the sale bid of a single unit, the so-called “minimum income condition”. This way, they can declare to the Market Operator that a bid is to be considered valid only if the owner of the production unit achieves, for that plant, a minimum daily income indicated via a fixed term and a term proportional to the assigned energy. Producers typically use this condition to cover their start-up costs or fixed costs.

3.3. Scheduled stop condition

This is the condition that sellers may include in the sale bids they submit for each production unit, so that, in the event that these bids are not matched due to the application of the minimum income condition, they can be treated as simple bids in the first block of the first three hours of the daily scheduling horizon. The bid that includes the scheduled stop condition shall be decreasing during the above-mentioned three hourly scheduling periods.

Thanks to this condition, a production unit excluded by the energy market can make a scheduled stop with a maximum length of three hours.

3.4. Load gradient condition

This condition enables producers to declare, for each generation unit, the maximum variation of average power that can be technically realized by their plant between two consecutive hours (increasing and decreasing ramp). Such a condition limits the energy that can be produced at a certain hour by the considered unit, depending on the energy accepted in the previous or following hour.

This condition is not applied to bids that are subject to the Scheduled stop condition.

4. Market clearing procedure

The mechanism used for market clearing is the algorithm that defines on an economical basis the merit order list of the bids submitted to the market, identifying the quantity accepted for each bid and the relative remuneration.

The possible algorithms are strictly dependent on the market rules:

- energy remuneration: national/zonal/nodal price;
- presence of complex bids.

In the following, the impact of complex bids on the market resolution algorithm is analyzed.

4.1. Simple bids

In the presence of solely simple bids, the Market Operator (MO) can use a clearing mechanism that can independently work for each relevant period. Anyway, the algorithm is different as long as the market rules provide...
for a national price of electricity (Spain) or a zonal pricing, like in the Italian system.

4.1.1. Market not subdivided into geographical zones. The Market Operator (MO) proceeds in three conceptually distinct phases: definition of the supply curve, definition of the demand curve and application of the crossing procedure.

In order to determine the aggregated supply (demand) curve, the MO identifies on an economical basis the merit order list of bids, starting from the one with the lowest (highest) price and progressively proceeding towards the higher (lower) priced bid. Multiple bids with n blocks are treated as n simple bids. If two bids have the same price, the market rules nevertheless define a priority order between them, based on different criteria other than price.

The procedure used to cross the demand and supply curves is composed by the following steps, performed independently for each relevant period:

a) determination of the intersection point of the demand and supply curves;

b) definition of the system marginal price, that is the price of the last sale bid, whose acceptance is necessary to satisfy the electricity demand;

c) definition of quantities assigned to each generation unit (quantities offered at a price lower or equal to the system marginal price);

d) definition of quantities assigned to each buyer (quantities requested at a price higher or equal to the system marginal price).

The market clearing procedure therefore determines the quantity sold and bought, as well as their price. For example, in Figure 1 the crossing procedure relative to an hour of the 11th July 2001 for the Spanish market is shown.

4.1.2. Market subdivided in geographical zones. The presence of geographical zones with potentially distinct energy prices makes the above-mentioned market clearing procedure, based on the simple crossing of the demand and supply curves, inapplicable. In fact, in this case the constraint of maximum power flow between the zones must be introduced into the market procedure.

Therefore the algorithm corresponds to the resolution of a constrained problem: the maximization of an objective function (the so-called Social Welfare), respecting equality constraints (energy balance) and inequality constraints (accepted quantities must be in a given range; inter-zonal flows must respect the physical transport limits).

As easily predictable, the resolution procedure becomes more complicated compared to the simple determination of the curves’ intersection point, but the absence of complex bids nevertheless allows dispatching the system with a maximum Social Welfare in a single iteration.

Figure 1. Market clearing procedure in the Spanish Market (Source: OMEL)

4.2. Complex bids

In the presence of complex bids, the Market Operator must include additional conditions in the “matching algorithm”. This substantially modifies the market resolution procedure, with a substantial computational increase. For example, the presence of a load gradient condition excludes the possibility of solving the market independently for each hourly period, because each hourly production is constrained to the previous one. Furthermore, the minimum income condition of each production unit is extended to the whole day period.

The complexity of the market resolution procedure in presence of complex bids makes it necessary to sub-divide the method into a series of, theoretically distinct, simpler sub-problems; the definition of a maximum computational time (or a maximum number of iterations) retained acceptable for the market resolution, is also necessary; above such a limit, the process is interrupted and the best solution obtained until that point is considered as optimal.

In the Spanish market this process is applied using the following steps.

4.2.1. Searching for an initial solution. The aim of this phase is to find a whichever daily market solution, which satisfies the conditions of indivisible bids, the restrictions due to the load gradient of production units, the conditions of scheduled shutdown and the minimum income conditions.

To achieve this goal, firstly the Market Operator applies the “simple matching method”, above described
for simple bids, with the further condition of obtaining a solution that complies with all the constraints imposed by the complex bids, except for the minimum income condition. This method is called “simple conditioned matching”. Then, in order to satisfy the minimum income condition, the Market Operator uses an iterative procedure which performs several “simple conditioned matching”, successively eliminating all the sale bids corresponding to a production unit that does not comply with the minimum income condition, until all the complex conditions are satisfied.

In the simple conditioned matching, as described in the previous, the load gradient condition limits the accepted quantity of a sale bid, when the power variation between two consecutive hourly periods exceeds the value stated in the bid.

The condition is checked both with a forward analysis (by verifying each period respect to the previous one) and a backward analysis (by verifying each hourly period respect to the following one).

The first check takes into account the rising gradients (production increase or start up) and the second the descending gradients (production reduction or stop), verifying that the eventual re-dispatch necessary to satisfy this last condition does not invalidate the results obtained from the first verification. The indivisibility of bids and the scheduled stops are respected as a sub-product of the load gradient verification.

The operative procedure of “simple conditioned matching” for the Spanish market is described in detail in [9].

For the fulfillment of the Minimum income condition, starting from the results of the “simple conditioned matching”, the Market Operator determines whether there are production units for which the eventual Minimum income condition is not satisfied.

In this case, the Market Operator calculates, for each of these units, the average price per kWh requested to satisfy the Minimum income condition, as well as the average price per kWh they would collect as the result of the simple conditioned matching.

The sale bid corresponding to the production unit which has the largest difference between the two calculated prices is eliminated, except for the blocks for which the Scheduled stop condition has been declared.

Once the sale bid corresponding to the above-mentioned production unit has been eliminated, the Market Operator repeats, for all the sale bids that were not eliminated, the “simple conditioned matching process”.

The Market Operator performs this gradual elimination process, until a solution is reached in which all accepted sale bids respect the Minimum income condition.

This iteration process issues the so-called “First Valid Solution”.

4.2.2. Improvement of the First Valid Solution. Once a first valid solution has been found, respecting all the constraints expressed by the accepted complex bids, the Market Operator begins the improvement phase of such a solution. This procedure is based on the identification of at least one production unit that, even though it has not been accepted in the First Valid Solution, has a positive difference between the income corresponding to the marginal market price and the minimum income requested by the unaccepted unit.

5. Study case

From the previous considerations, the increase in complexity, imposed by the presence of complex bids even in absence of zonal pricing, is evident.

In Italy, the introduction of a mechanism based on complex bids would be in addition to the solution, already articulated, of an electric market sub-divided into geographical areas, making the market clearing procedure even more complicated.

The adoption of such a mechanism for the Italian Energy Market must therefore be adequately justified, for example estimating the energy quantity that, in case of
solely simple bids, would not respect the constraints related to reasonable complex bids.

Using this logic, an electricity market simulator instrument, which operates on a yearly horizon, has been used to analyze a possible market dispatch relative to an year when the simple matching mechanism were employed.

Afterward, the energy quantity that would need to be re-dispatched in order to respect the technical or minimum income constraints imposed by assumed complex bids were estimated.

The simulation software generates the hourly energy bids of 137 thermal units, using a pre-defined bidding strategy based on a classical hydro-thermoelectric unit commitment.

On the basis of the hourly demand and on the sale bids, the simulator defines the hourly energy prices and the market dispatch.

5.1. Verification of technical minimum of production units

Such constraint can be efficaciously included in the simple bids, recurring to multiple bids that have a first energy block equal to the technical minimum of the unit, offered at an extremely low price (at worst, zero). With this expedient, the constraint is always respected even without the use of complex bids, except for the hours where the sum of technical constraints exceeds the load; in the performed study case, over-generation occurred only in one hour every two hundred.

5.2. Verification of gradient constraints

The gradient constraint is very difficult to be simulated. Each unit has in fact different gradient constraints, which are not easy to calculate, related to several technical factors. In the performed simulations, an average gradient of 1 MW/min has been assumed. The verification of this constraint has been performed checking that the variation of the energy assigned in two consecutive hours to the same production unit was lower than 60 MWh. In the considered case study, the energy to be re-dispatched to respect this constraint resulted to be approximately 1% of the annual load; on average, in the single production unit the gradient constraint results to be violated in less than 3% of the hours.

5.3. Verification of minimum income

The constraint of minimum income represents potentially the most restrictive condition among those provided by the complex bids mechanism. The impact of such a constraint is potentially larger than other constraints, because its violation causes the elimination of the considered unit from the matching process.

The use of such a condition is strictly related to the bidding strategies of generating companies. In the study case, this constraint has been assumed violated when the daily earnings (considered as the difference between incomes for energy selling on the day-ahead market and production variable costs) of the considered unit result to be negative. In other words, we assumed that the producers indicate in the complex bid the request of a positive return during the considered day.

Figure 3 shows the amount of units that did not respect the constraint of minimum income.

Figure 4 summarizes the energetic volumes affected by the re-dispatch imposed by the respect of the constraints expressed in the complex bids.

5. Conclusions

The market clearing procedure, which defines the energy that each operator must produce or consume and its price, represents one of the crucial points of the operating rules of an electricity market.
The possibility to add to the simple bids (quantity-price pairs) further technical-economical indications can deeply affect the resolution mechanism of the market.

In this study, the rules being in use in the Spanish and the Italian electricity market have been numerically compared. The Italian procedure, where only the price-quantity pairs are specified in the bids, has been compared with the methodology used in Spain, with the possibility of indicating in the bids further acceptance constraints, like technical minimum, load gradient, minimum daily income and scheduled stop.

The procedure adopted in the Spanish market does not provide for zonal pricing of electricity, so the matching process is immediate and rather simple in computational terms. A market with complex bids, associated to zonal pricing, would make the matching procedure far more laborious.

On the basis of these considerations, in the proposed study case the possible impact of possible complex bids in the Italian system has been estimated.

The conclusions obtained have highlighted a relatively modest impact, in quantitative terms, related to the gradient constraint. Furthermore, in order to respect such constraint the Italian market already puts a specific tool at producers' disposal, the so-called “balanced bids” of Adjustment Market.

With respect to the constraint of technical minimum of production units, it is to be noted that even with the simple mechanism such a condition can be efficiently included in the sale proposal, with the use of multiple bids.

The question related to the constraint of minimum daily income is more complex. Its impact on the Italian market, in the considered case study, exceeds that of the other constraints three times, involving about 5% of the annual energy. This constraint also constitutes the main cause of complexity increase in the market solution mechanism, requiring an iterative process to find the final solution. Basically, the introduction of this condition is aimed to minimize the producer risk of not being able to recover the plant costs, or to guarantee a quick pay back of the investment.

This logic assumes the use of the minimum income constraint for the realization of defensive strategies and not for aggressive strategies or strongly speculative behaviors.

In a liberalized market, the use of the minimum income constraint for this aim is not obvious: in fact such a constraint, if associated to the already laborious procedure of zonal pricing, could be used for speculative behaviors in presence of local market power positions.

In the Italian case, the performed analysis has shown that the market resolution mechanism based on complex bids, very complicated and difficult to be monitored by the competent authorities, seems to be not justified by the sporadic activation of the constraints expressed in the complex bids, nor by the reduced energy amount that such a mechanism would affect.

7. References


