Increasing the Flexibility of Continuous Intraday Markets in Europe

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Abstract. The FLEXITRANSTORE project inter alia aimed at improving the flexibility of the organized, wholesale electricity markets of Bulgaria and Cyprus fitted into the European electricity market framework. The paper introduces the market settings of these countries and defines the intraday time horizon as a focus for the research. The authors take into account the needs of the different market participants in order to increase the flexibility of the electricity market. After a review and evaluation of the currently available spot market products and orders, the authors propose the introduction of new orders and products on the intraday market so that the trading capabilities of storage and DSM-based technologies are facilitated. The suggestions would help the integration of variable renewable generation as the participation of new flexibility providers such as storage owners and aggregators are facilitated. The most significant proposals of the authors are the volume constrained and the cumulative volume constrained order types that are realized by proposing a new set of execution constraints for existing basket orders. The paper also highlights the advantage of the novel orders compared to the recent product developments of power exchanges.

Keywords: Electricity market · Flexibility · Intraday market

1 Introduction

In line with the EU decarbonisation targets, the share of renewable generation is steadily increasing and the high emission conventional generation is being phased out. The integration of intermittent renewable generation demands more flexibility in the electricity system to balance its scheduling inaccuracy and real-time variability. The assets providing the required flexibility are currently mostly thermal power plants. Unfortunately from this perspective, most of the flexible gas-fired generation is usually priced out of the markets while coal fired power plants are being phased out.

The FLEXITRANSTORE project selected the power markets in Bulgaria and Cyprus to demonstrate and analyse the effectiveness of proposals aiming the smooth integration of South-Eastern Europe to the pan-European electricity market. Apart from the difficulties mentioned above, the authors identified other problems, too, specific to the Bulgarian electricity market. Partly due to the market immaturity, liquidity is

low. The day-ahead market (DAM) started in 2016 while the continuous intraday market (IDM) only in April 2018. The market operator, IBEX, operates a Centralized Market for Bilateral Contracts, besides DAM and IDM [1]. The market platform is provided by Nord Pool. The share of the organized market in Bulgaria is approximately 55%. There is a significant potential for market power as a single company owns around 75% of the built-in generation capacity and more than 80% of the electricity production. Therefore competition is limited. New market participants owning flexible resources would increase competition on the market and support the integration of more renewable energy resources (RES).

Cyprus faces difficulties regarding market competition being an islanded system without any connection to mainland Europe. (The Eurasia interconnector is however planned between Cyprus, Israel and Crete according to [2], but it is only expected to be in operation by December 2023). Moreover, electricity trading is not marketed yet, DAM is not foreseen to be opened before mid-2020 and IDM is expected to start even later. The islanded system also hampers the spread of renewable generation. More flexibility sources available in Cyprus could alleviate these issues.

The paper analyses how new flexibility sources could be incentivized to engage in the electricity markets. First of all, the selection of the time horizon is presented then a connection between market flexibility and liquidity is discussed. Secondly, ideas are gathered for increasing market liquidity. In the following part, the needs of the newly entering market participants demanded by flexibility constraints are explained. The main part of the paper examines the short-term market horizon and the available orders and products to deduce the proposed orders and products, among other things the volume constrained and the cumulative volume constrained orders. Finally, the significance and the further steps of this research are presented after drawing a conclusion.

2 Increasing Market Flexibility

This section contains the deduction of market flexibility improvement starting from the selection of the time horizon, showing the relationship between flexibility and liquidity, ways of improving liquidity and finally satisfying the flexibility needs and capabilities of market participants.

2.1 Focusing on the Intraday Market

The authors decided to put one market time-horizon into the focus of the research. The IDM has been chosen because of the following reasons. Flexibility means fast adjustment capability at short notice. Renewable generation forecasts become more accurate close to delivery period thus possibility for trading should be available to adjust the schedules caused by revised forecasts. A liquid IDM market is suitable for this purpose in contrast to bilateral trading due to time constraints. Proper balancing markets incentivize BRPs to cover their imbalances (and so to avoid high balancing costs), and any open positions before the TSO operated real-time balancing process. The deadline for offer submission can reach 5 min before delivery as in Belgium and in

the Netherlands [3]. Day-ahead markets are usually more advanced and liquid than IDMs, and the ability of being flexible is worth more, closer to delivery.

Balancing markets already have several flexibility products, not only standard frequency containment reserves and restoration reserves but also some specific, non-standard ones. For example in the UK specific frequency control ancillary services are introduced that either allow storage and aggregators to participate (in Firm Frequency Response and Enhanced Frequency Response) or are fitted for demand-side management (DSM) based participants (Frequency Control by Demand Management and Demand turn-up, [4]).

Energy storage equipment, especially batteries are in the spotlight of the author's research. The most promising service of batteries clearly is frequency regulation. The current potential for profitable spinning/ramping (RR) reserve service provision is much smaller according to a US study [5]. Batteries are mostly owned by independent power producers or investor-owned utilities. Only high capacity batteries are used for peak shaving and arbitrage in an outstanding proportion.

An extra argument against relying only on balancing markets for providing flexibility is the longer contract and thus the requirement of constant availability periods (for a whole day or even week) and longer delivery length (usually hours). These specifics are especially unsuitable for storage and DSM assets competing with stored primary fuel based conventional generation. The IDM is close to real time, therefore the bidders do not need to undertake long availability commitments far ahead of the delivery.

The need for flexibility can come from RES generation or from balance responsible parties (BRPs). Our suggestions for more refined market orders are also suitable for the intraday schedule adjustment of traders and RES generators.

Flexibility need will rise to solve grid congestion management issues both on transmission and distribution level. However, this might rather be at a separate new local flexibility market, especially when solving distribution level problems. Some projects are already dealing with the location-related market design such as NODES [6] and ENERY [7]. The scope of the current proposal does not include this spatial dimension, thus neither does any data specify the place of energy injection or off-take in the proposed orders, nor is separate market platform required for the enhanced flexibility trading. Besides, the presented approach of the authors is in line with the current wholesale market designs and market platforms.

2.2 The Connection of Market Flexibility and Liquidity

As mentioned above, market flexibility could be enhanced by attracting new, flexible (storage or DSM-based) participants to the market. Apart from this the market could react to unexpected needs for flexibility if there were corresponding offers every time. These all lead to increasing the number of participants, the offered and traded volume as well as market activity. If a market is liquid, it satisfies more the flexibility needs and price signals are better. Furthermore, a flexible market also gives possibility for conventional flexible power plants to adjust their output in response to the more accurate generation forecast of intermittent renewable generation and load forecast.

Furthermore, this market-centric approach would result in flexibility incentivizing price signals for the considered intraday timeframe.

2.3 Increasing Market Liquidity and Thus Flexibility

Market liquidity and thus flexibility can be increased by market couplings as it attains easier and the most efficient (implicit) access for the available cross-border capacity, increases the number of market participants and orders while diminishes the risk. The XBID (Cross-Border Intraday) project aims this multi-lateral implicit IDM market coupling. The first wave went live in Western-Europe on 12 June, 2018. The Bulgarian market is in the second-wave expected in June 2019 [8].

However, there are transaction types that would result in more trades and thus more social welfare but are currently not supported in coupled markets, only available in single markets. This is the case with cross-product matching used e.g. at the IDM of Hungary (HUPX) but this feature is not supported by the XBID project. This restriction is probably because of algorithmic difficulties and unrepeatability [9]. Cross-product matching allows the matching of different products namely the quarter hourly and hourly products.

Other actions to increase electricity market liquidity can be the introduction of new products (the introduction of block orders is planned in Bulgaria), the reduction of the minimum built-in capacity for compulsory organized market participation (reduced already to 4 MW in Bulgaria) or the procurement of energy previously tendered off the market platform (e.g. system loss). Concerning the latter, Bulgaria is planning to procure the transmission system loss at the power exchange, but the sale of renewable generation under feed-in tariff system done on exchanges could also increase the traded volume. The most prominent marketing place is usually the DAM, but the IDM could also profit from adjusting the day-ahead schedules according to the intraday close-to-delivery weather forecast such as at the HUPX. Opening the futures market in Bulgaria is also under discussion.

Lower limit for minimum offer quantity usually facilitates the participation of new, smaller players but in the case of the IDM trading is based on 0.1 MW lots. The higher resolution of the market orders can also advance liquidity. In most intraday electricity markets, trading is only allowed in hourly products except for the German IDM which can also handle quarter hourly and half hourly products. This enhanced temporal granularity is especially important as balancing is generally settled (and planned to be settled as in [10]) on a quarter hourly basis.

It should also be considered what type of IDM trading is more efficient: the continuous or the auction-based one [11]. Day-ahead markets are typically auction based in Europe while IDMs are mostly continuous. Intraday auctions allowed by market rules are already applied by some countries [12]. In Germany, there is an auction after the main day-ahead auction of 12:00 on D-1 (the day before delivery) at 15:00 exclusively for quarter hourly products. There are separate intraday auctions for the hourly products at D-1 22:00 for the 1–24 h product and at 10:00 for the 12–24 h products [3]. UK also runs a separate auction after the main day-ahead on D-1 at 14:30 solely for half-hourly orders [13]. Some authors state that auctions are more effective than continuous trading. This could be confirmed as most of the trading activity is close to the gate

closure. Moreover, at continuous IDMs, an order is matched with the first corresponding order despite that a better matching order would follow later leading to more social welfare.

3 Flexibility Product Development

Based on the above discussions, the authors identify that there is significant opportunity in the development of new flexibility products for the current IDM i.e. products tailored for storage and DSM-based technologies. Before presenting the suggestions, a review is given on some of the European IDMs and special day-ahead products.

3.1 The Review of Current Intraday Markets

The following tables summarize the tradable contracts, order types (Tables 1 and 2), and lead time (Table 3) of some of the European IDMs. The lead time is the gate closure or in other words the end of order submission before delivery ([3, 13–15]).

Table 1. Tradable contracts on intraday markets

Market area	Products			
	Hourly	30 min	15 min	Block
Germany	✓	✓	✓ + D-1 15:00 auction	s, u
Austria	✓	–	✓	s, u
Belgium & Netherlands	✓	–	–	s, u
France	✓	✓	–	s, u
Switzerland	✓	–	✓	s, u
Great Britain	✓	✓ + D-1 14:30, 17:30, D 8:00 auction	–	spec*
Nordic & Baltic	✓	–	–	s, u
Hungary	✓	–	✓	s, u
Bulgaria	✓	–	–	s, u

The letters ‘s’ and ‘u’ refer to standardized (base, peak) and user-defined blocks, respectively. Half hourly and quarter hourly (Q) products can help to better balance the portfolios closer to the balancing settlement period. There are also 2 h (2H) and 4 h (4H) long products in Great Britain, as well as special pre-defined blocks by the variation of H, 2H and 4H consecutive products, day base, day peak, day extended peak, day overnight and block 3+4. Extra auctions after the coupled day-ahead auction at 12:00 are also marked in Table 1. These can be interpreted as pre-intraday auctions giving more sequential possibilities for trading.

Table 2. Order types on intraday markets

Market area	Order types		Execution constraints			
	Limit	Market sweep	IoC	FoK	AoN	IBO
Germany	✓	✓	✓	✓	✓	✓
Austria	✓	✓	✓	✓	✓	✓
Belgium & Netherlands	✓	–	✓	✓	–	✓
France	✓	✓	✓	✓	–	✓
Switzerland	✓	✓	✓	✓	✓	✓
Great Britain	✓	–	✓	✓	–	✓
Nordic & Baltic	✓	–	✓	✓	–	✓
Hungary	✓	–	✓	✓	✓	✓
Bulgaria	✓	–	✓	✓	✓	✓

Regarding the abbreviation of order types, IoC means Immediate-or-Cancel, FoK means Fill-or-Kill, AoN stands for All-or-nothing and IBO for iceberg execution constraints. The term ‘market sweep order’ is used by EPEX for special user-defined blocks with IoC execution constraints [14]. The None (NON) constraint is used in the UK and at HUPX for hourly blocks that allows partial execution, not necessarily executed immediately and can be executed against multiple other orders [15, 16]. As shown in Tables 1 and 2, block orders and the well-known execution constraints are already widely spread including Bulgaria. Nevertheless, current order types and constraints are not adequate for bidding the capability of electric storage or DSM-based bidding. The execution constraints are rather specialized for continuous trading than certain market participants. They limit the validity (IoC and FoK is only valid for immediate execution), divisibility (IoC permits partial acceptance while FoK not) and the visibility of orders (some part of the order are hidden and only one clip is shown).

Lead times closer to delivery could also contribute to the flexible reaction of the market thus both the shorter duration products and the shorter lead times should be encouraged also in the selected countries of this project.

Table 3. Lead time of intraday markets

Market area	Lead time
Germany, Austria, Belgium, Netherlands	5 min
Great Britain, France, Switzerland	30 min
Nordic & Baltic, Bulgaria	60 min
Hungary	90 min

3.2 Flexibility Products on the Day-Ahead Market

Although these are not intraday products, but market platform providers introduced new types of day-ahead orders recently that are worth mentioning. Nord Pool's DSM-related clients can choose the 'flexi order' in the Nordic, Baltic and UK DAMs where Nord Pool is the market operator. The offer maker can give an interval within a day within which the algorithm can choose a shorter specified period for delivery. The algorithm chooses the delivery periods providing the highest welfare [17].

Since 12 December 2018, the loop block has been introduced on the Austrian, Belgian, British, Dutch, French, German and Swiss Day-Ahead markets by EPEX together with the curtailable blocks [18]. The loop block is fitted for storage equipment because a sale and a purchase block can be bonded together as the discharging and charging phase of a battery. The two blocks must be executed or rejected simultaneously. The limitations of this approach are that the offer maker needs to decide the sequence and the possible periods of sale and purchase beforehand limiting the maximum number of charging and discharging periods per day.

Other order types on the day-ahead markets comprise of single hourly and block orders. Blocks can be of linked, curtailable, profile or exclusive types. The two latter are often mentioned as smart blocks on EPEX. Out of these, linked blocks might be used for storage bids and exclusive blocks for DSM bids. For example an off-peak period purchase can be executed on condition of (i) a previous peak sale and (ii) the buy-sale combination being in-the-money but only with precisely defined periods. The exclusive block can find the highest welfare block out of a group to optimize DSM but the block must be predetermined by the bidder [19]. A summary of DAM products is given in Table 4 on the day-ahead tradable contracts per market platform.

Table 4. Tradable contracts on day-ahead markets

Tradable contracts		DAM market platform	
		Nord Pool	EPEX
Single hourly order		✓	✓
Blocks	Regular	✓	✓
	Linked	✓	✓
	Curtailable	✓	✓
	Profile	✓	–
	Exclusive	✓	✓
	Flexi	✓	–
	Big	–	✓
Loop		–	✓

3.3 NEW Flexibility Product Suggestions for the Intraday Market

Quarter-Hourly Product and Cross-Product Matching

According to Sect. 3.1, the quarter-hourly product is advised to be introduced on the Bulgarian IDM. It can increase the trades of all participants including RES, storage and conventional power plants. Brijs et al. in [20] also emphasize the importance of closing the positions market-based on the imbalance settlement temporal resolution. It would be beneficial for less flexible participants to be less exposed to balancing prices. Moreover, this could reduce the reserve need of the transmission system and give better price signals for flexibility.

The authors also propose the use of cross-product matching for quarterly limit orders that allows the pairing of an hourly product with corresponding quarter-hourly products.

Exclusive Block Orders

The exclusive block order on the IDM would be similar to the order type known from the DAM, except that not only one but a maximum number of orders could be matched if the limit price criterion is fulfilled. Consequently, the intraday exclusive order would contain a set of bids with volume and limit price parameters plus a third parameter would stand for the maximum number of accepted bids.

Volume Constrained Order for DSM

One of the most refined order types suggested by the authors is a basket order with volume constraint tailored for aggregators bidding DSM. A basket order is a set of orders for different contracts submitted simultaneously to the IDM [21]. Although [22] only proposes the support of linked orders (set of orders with fill-or-kill restriction, all of them shall be executed together) for the common IDM, the basket orders (set of orders without any restrictions) are already implemented in the M7 Trading System widely used in Europe (EPEX, HUPX). On the other hand, according to the requirements for continuous trading matching algorithms in [23], “the algorithm shall be able to support non-standard products to the extent this is technically feasible and approved by the competent regulatory authorities”.

The Volume Constrained (VC) order is a conditional order similar to the exclusive block except that not the number of acceptable bids but the total accepted volume is constrained. A VC order contains a set of bids (volume and limit price pairs) for different products plus a parameter that maximizes the daily allocable volume. An example is shown in Fig. 1. Bids can have different volume and price parameters. The cause of non-paired offers marked with light grey can be either the higher offer price (e.g. possibly in QH25) or the volume limit (as in QH32). A modification of this VC order can be when a minimum income constraint (MIC) would be used instead of the limit prices per each bid.

Fig. 1. Example of a Volume Constrained (VC) order.

Given a 10 MWh volume flexible load with a power of 2 MW. The latter determines the volume of the limit purchase bids in the basket. Suppose that 4 MWh energy has been sold previously. Therefore the maximum volume restriction must be 6 MWh. If the Basket Order has been already committed into the order book, the Maximum Volume parameter cannot be modified.

Cumulative Volume Constrained Order for Storage

The other innovative order type suggested by the authors is a basket order with cumulative volume constraint fitted for storage bidding. It considers the state of charge (initial stored energy volume) as a parameter to avoid overcharging or undercharging. Another parameter of the cumulative volume constrained order (CVC) is the maximum cumulative volume that models the maximum power of a battery. The initial volume must be lower than or equal to the maximum volume. Figure 2 presents an example of the CVC order. According to the paired orders, the battery is fully charged in QH24 to 3 MWh, then discharged during QH26-27 limited by the CVC constraint and charged again in QH33 up to 2 MWh. The parameters of the CVC order comply with the recommendations in 20 including charging power, discharging power and limit price.

Suppose a battery with 20 MWh capacity, 0.5 MW charging and 0.4 MW discharging power. The storage capacity gives the maximum cumulative volume restriction while the charging power should be used as the volume of each limit purchase bid in the basket and the discharging power as the volume of the limit sale orders in the basket. The initial volume parameter needs to reflect the charging level of the battery at the beginning of the day. For example a 40% charging level corresponds to $20 \text{ MWh} \cdot 0.4 = 8 \text{ MWh}$ initial volume parameter. If the Basket Order has been already committed into the order book, the Maximum Volume and Initial Volume parameter cannot be modified.

The application of MIC could work also in case of the CVC order and a further development could be the addition of a gradient constraint.

Fig. 2. Example of a Cumulative Volume Constrained (CVC) order.

4 Conclusions

It has been shown that some special products had already been introduced tailored to the needs of new market participants, facilitating their bidding and incentivizing their market participation. But these specific products are set up solely on the day-ahead and balancing markets. The suggestions presented in the paper attempt to fill this market time horizon gap regarding the IDM. The authors recommend establishing quarter-hourly products on the IDM where they are not in use yet (e.g. in Bulgaria) and their extension with cross-product matching. Further recommendations include the introduction of the volume constrained orders and cumulative volume constrained orders tailored for aggregated DSM and storage bidding, respectively. These new order types would also be useful at any other European continuous IDMs. The added value is significant as the authors did not find any other flexibility product proposals in the literature for IDMs.

The next phase of the research is the functional extension of the current continuous IDM algorithm by the above mentioned orders. The initial prototyping results are promising. The final goal of the project is the demonstration of the products on a parallel-run marketplace in Bulgaria and Cyprus.

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