Aggregation and Flexibility for Grids' Operation: the EU Path Toward the Opening of the Ancillary Services Market to Distributed Energy Resources

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Abstract

The present paper proposes an analysis of EU policies related to the enabling of the Distributed Energy Resources (DERs) participation into the Ancillary Service Market (ASM). Indeed, the rising of renewables and DERs penetration in the power system recently called for the enlargement of the pool of actors that can actively participate in the grid balancing. Therefore, Europe, through directives and guidelines, is gradually fostering the involvement of DERs into the ASM. This paper firstly provides an overview of the regulations actually in place in the EU Member States concerning the participation of DERs into the energy markets. Then, a detailed analysis of the Italian framework is proposed. In the last years, Italy has undertaken a process aimed to increase the observability of DERs, through the installation of suitable monitoring and communication devices, and to enable the provision of ancillary services by dispersed units. The main features and the preliminary results of this process are analyzed and commented, highlighting the benefits and opportunities related to it.

Keywords: electricity markets, aggregation, ancillary services, distributed resources, energy policies

I. INTRODUCTION

In the last years, the ambitious environmental policies defined by the Paris Agreement [1] and promulgated by the European Community through the "Climate and Energy Package" [2] and "2050 Long Term Strategy" [3] have imposed ambitious environmental targets in Europe, such as 32% share of gross final energy consumption from Renewable Energy Sources (RESs) by 2030 and the net-zero greenhouse gasses by 2050. These environmental targets are clearly modifying many sectors, among which the energy one. Indeed, the sustainability targets set by these agreements have promoted the increasing share of Distributed Energy Resources (DERs) connected to medium and low voltage distribution grids and the exploitation of Non- Programmable Renewable Energy Sources (NP-RESs), introducing higher requests of flexibility from the power system to manage the intermittent and scarcely predictable nature of these new energy sources. Additionally, conventional power plants, historically in charge to provide Ancillary Service (ASs) to the power system, are undergoing a gradual phase-out, due to the above-mentioned need for greater sustainability and a reduction in their competitiveness. This process has firstly caused a progressive decrease of the electric system inertia. As a consequence, in many countries worldwide, more challenging performance requirements have been introduced for the AS provision. Moreover, more recently, some national authorities have foreseen the opening of the relevant Ancillary Service Market (ASM) to new actors, as for example DER and NP-RES units, in order to enlarge the number of actors enabled to provide services to the grid [4][5].

Even if the involvement of DER and RESs in ASMs in perspective will have clear benefits for the grid's operation, the participation of these small units in the market as disaggregated entities is infeasible, both for technical (i.e. market resolution issues, low controllability, etc.) and practical reasons (in Italy, for example, there are almost 800,000 power plants connected to MV/LV grids) [6]. A promising way to address these issues, enabling the provision of ASs from DERs, is to aggregate and manage as a single entity several flexibility resources [7].

In the EU, this concept was first introduced by the European Parliament's directive 2012/27/UE [8], which defined the Aggregator as the subject that, controlling several energy resources, is enabled to offer the resulting flexibility in the electricity markets. Therefore, according to this definition, the Aggregator can be considered as an intermediary between the System Operator, which manages the electricity market as a central counterpart to collect ASs, and the owners of DERs units. To this purpose, the Aggregator should group, on a voluntary basis, the resources connected on the distribution network and, by implementing adequate controls tools, it has to manage the units in its portfolio making them act as a single

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controllable power plant (concept also known in the literature as Virtual Power Plant [9]). Usually, the Aggregator's portfolio (i.e. the resources through which it can offer flexibility to the system) can be extremely diversified, including: i) distributed production units, typically from RESs and characterized by a small power capacity; ii) energy storage systems, such as stationary Electrochemical Storage System (ESS) and Electric Vehicles (EVs); iii) flexible consumption units, capable to change their absorbed power.

In this framework, the European Community is promoting the opening of the electricity markets to aggregates of DERs, through directives envisaging the activation of demonstration projects and the setting up of a framework of rules enabling in the future new opportunities for network operators. In this process, Italy is playing a pivotal role, since the national Energy Authority (ARERA), together with Terna (the Italian Transmission System Operator), and other stakeholders of electricity sector, has recently started a procedure to reform the existing dispatching discipline. As a first result, a pilot project that unlocks, for the first time in Italy, the participation in the ASM of aggregated DERs managed by an Aggregator has recently started.

The remainder of the paper is structured as follows: in Section II it is proposed a detailed literature review of works proposing an optimized management of aggregates of DERs. Section III analyzes the regulations actually in place in some EU countries regarding the participation of DERs in the electricity markets. Section IV focuses on the path adopted in Italy for a better DER integration. Finally, some conclusions are drawn.

II. AGGREGATION METHODOLOGIES IN THE SCIENTIFIC LITERATURE

In the present energy scenario, characterized by high penetration of distributed and renewable generation and by increasing electrification of consumptions [10], it is universally recognized that the figure of the Aggregator could bring many advantages for the power system. In particular:

- the target fixed by the EU to achieve the climate neutrality by 2050, with an expected percentage of energy production from RES of 54%, requires the exploitation of all the flexibility resources, including DERs, to guarantee an efficient and reliable operation of the electric grid;
- a greater number of units enabled to participate in the ASM is expected to boost the competition on the market and, consequently, the economic efficiency of the latter is also supposed to enhance;
- thanks to the technological diversification and the redundancy of units in the Aggregator's portfolio, the ASs provided by a coordinated aggregate of DERs can be characterized by a degree of programmability and reliability higher than the same units operating with a disaggregated approach;
- the involvement of domestic and industrial users in the portfolio can promote the spreading of demand response techniques among passive users, which has been recognized as one of the fundamental steps to achieve the emission targets [8].

However, the management of a heterogeneous aggregate of units, highly dispersed on the network and characterized by hardly predictable power profiles, is particularly challenging for an Aggregator. Therefore, researchers have dedicated many works on the development of suitable tools aiming to allow the participation of DERs in the electricity market.

An example of these works can be found in [11], where an approach is described to optimize the participation into the Day Ahead Market (DAM) and in the ASM of an aggregate composed of wind turbines and a natural gas microturbine. Starting from the power forecasted for NP-RESs and the corresponding level of uncertainty, the quantity and price offered on the DAM by the Aggregator are first optimized. In order to properly take into account the uncertainty of the NP-RESs production and the DAM prices, the authors propose a multi-stage stochastic algorithm. Subsequently, the AS provision is analyzed. The Aggregator, taking advantage of the forecast update of the wind turbine power production and considering the gas turbine regulating margins and technical limits (i.e., ramp rates, maximum power, etc.), offers the remaining power capacity as flexibility on the market. More recently, the constant reduction in the prices of ESS and the significant growth in the electrification of final uses have fostered the exploitation of innovative flexibility resources, such as residential storage systems and domestic loads [12][13]. However, as analyzed in [14], the stringent privacy issues that emerge when residential loads are managed by an Aggregator and the need of avoiding detrimental impacts on the user caused by participation in the market, are slowing down the exploitation of these resources. To face these concerns, the scientific community has designed some decentralized approaches to coordinate and manage the residential loads and ESSs, limiting the amount of information needed to share [15]. In the decentralized approach, the Aggregator does not directly manage the resources in its portfolio, but it informs each user about the price at which it is willing to pay their flexibility. Then, each unit, considering the price signal and anticipating the user's needs, decides whether to perform or not the service requested. Adopting this approach, data exchanged between the Aggregator and the users only refer to price signals, with clear benefits on privacy issues; moreover, the user's freedom to use his own devices as/when he wants is also respected.

An example of decentralized approach can be found in [16], where an aggregate of NP-RESs, residential ESSs, and loads is considered. In particular, the Aggregator during the real-time directly manages the dispersed production and the ESSs, and exploits the loads' flexibility by sending adequate price signals in order to optimize the energy exchanges with the grid. To consider the uncertainties of power production and flexibility delivered by loads, a stochastic optimization algorithm is implemented. Finally, the results obtained by the optimization process are evaluated by means of Value-at-Risk (VaR) and Conditional Value-at-Risk (CVaR) methodologies.

As analyzed in the following, EU countries are increasingly opening their electricity markets to DERs managed by Aggregators. However, due to the intrinsic uncertainties of these markets (e.g. prices and quantity cleared), the development of bidding strategies is particularly complex. In this regard, in [17] a comprehensive methodology is proposed to optimize the markets participation of an aggregate of ESS and dispersed NP-RES. During the market sessions, the Aggregator is considered as a price-maker (i.e. its offers are assumed to modify the clearing process results), therefore the authors modeled the bidding strategy of all market actors. Moreover, to consider the errors committed in the forecasting of the power production by NP-RESs, the authors implemented a robust optimization algorithm aiming to define the quantities and prices offered by the Aggregator in both DAM and ASM. To simulate the ASM participation, the power grid structure is modeled to ensure acceptable levels of reserve capacity and the real-time balancing. Finally, the real-time energy exchanges between users in the aggregate and the power grid are managed by using two distinct approaches: ESSs are directly controlled by the Aggregator by a centralized approach, while the power absorbed by flexible loads is regulated indirectly through the price signals sent to users. This (decentralized) approach allows guaranteeing the respect of the privacy issues that could arise in some circumstances.

As emerged from the literature review, different approaches can be adopted to model the behavior of the Aggregator's portfolio.

However, despite the methods proposed can be different, it is usually possible to identify some common steps:

i. Forecasting phase, in which the Aggregator predicts the energy exchanges for the following days (up to 1-2 days ahead). Usually, the forecasted quantities are the power produced by NP-RES, the availability of storage systems (also including the presence of EVs under charge) and the power absorbed by consumption units. The forecasted profile, and the related uncertainty, will be used to optimize the bidding strategy on the market.

ii. Electricity market participation, during this phase, the Aggregator, according to the predicted power profiles and the availability of the units in its portfolio, optimizes the quantity and the price offered on the market. In most of the countries worldwide, each unit or aggregate of units must participate first in the DAM, in which each actor sells/buys the power produced/absorbed for the next day, and then in the ASM, where margins of flexibility with respect to the bidding schedules agreed on the DAM are offered. These margins are then exploited by the Transmission System Operator (TSO) to balance the grid during the real-time operation and to solve other operational issues (e.g. congestions).

iii. Real-time operation, in which the Aggregator adjusts the energy exchanges between the units in its portfolio, according to the results of the market and considering the actual energy production/consumption, the ESSs' state of charge and the units' availability. In this phase, the Aggregator is also requested to exchange data with the relevant plants, to monitor them, and to deliver control signals according to TSO's requests.

Starting from the encouraging results obtained by researchers, and considering the tecno-economic advantages that a better involvement of distributed resources would bring to the energy scenario, national regulating authorities are progressively enabling the participation of DERs into the electricity markets. To have a clearer picture of the situation in place in the EU, in the following Section an overview of the regulatory frameworks and initiatives devoted to achieving a more effective DERs integration is provided.

III. AGGREGATION IN EUROPE

To achieve the environmental targets described in Section I, the EU is seeking to reform the electricity market regulations of Member Countries. In particular, about 20 years ago, Europe started a gradual harmonization process of national electrical grid codes, with the purpose to evolve toward a unique and fully integrated European ASM [18]. Indeed, as stated by Regulation

2016/631 [19], the completion of a fully functioning and interconnected European energy market is crucial to ensure a suitable security of energy supply also in case of high RES integration. Moreover, the Regulation promotes a closer cooperation between national authorities to favor investments and to support the spreading in the energy sector of new actors (as the Aggregator) and technologies.

Although this harmonization process started several years ago, given the complexity of the matter and the need to align national regulatory and technical frameworks very far each other, it is still in an early stage, defining standardized flexibility products exchangeable in national and European ASMs.

Actually, the EU guideline on electricity transmission system operation 2017/1485 [20] identified a set of products to manage congestions in the transmission lines, to regulate system frequency and control voltage profiles. This work will focus on the products devoted to the frequency regulation and power balance, because they are strictly related to system operation security. Moreover, given that the provision of these "global" services is marginally influenced by the position of the resources within the network, they can be theoretically offered by a greater number of actors, including the distributed resources.

In particular, the EU's guidelines define the following services related to the provision of frequency regulation and balancing:

- Frequency Containment Reserve (FCR), aimed to contain the system frequency deviation after the occurrence of an imbalance. The FCR has an activation time up to 30 s and it is usually provided automatically by enabled units.
- Frequency Restoration Reserve (FRR), activated automatically (aFRR) or manually (mFRR), and which shall be supplied in a continuous manner. This product has an activation time typically between 30 s and 15 minutes and it is used to restore the system frequency.
- The Replacement Reserves (RR), an active power reserve that is used to restore the required level of FRR. The activation time for this product is usually 15 minutes.

In Figure 1 the standardized products for frequency and reserves restoration in place in EU are shown. More recently, a new ancillary service has been established: the Enhanced Frequency Control (EFC) [21]. This product has been introduced to cope with the progressive reduction of the power system inertia. Indeed, it is designed to rapidly limit the variation of the system frequency deviation and therefore it is characterized by a very small activation time, i.e. 1 s.

Despite the ongoing harmonization process, the regulations about the participation of aggregated DERs in the ASM are however still different in EU Member States, slowing down the spread of the Aggregator figure in the electricity sector. Therefore, in the following, a brief review of the regulatory frameworks in place in EU countries is provided, analyzing the abovementioned products negotiable by Aggregators in the national ASMs, the corresponding bid size and the possible regulatory barriers in place.

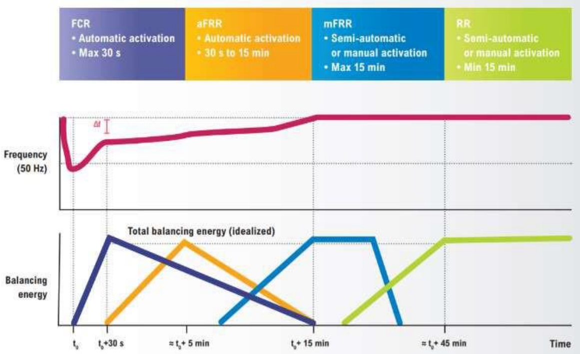

Figure 1. Products for frequency restoration in Europe [22].

A. Germany

Over the past years, the German electricity scenario has undergone a major change due to the large deployment of DERs, especially based on renewables [23]. The main driver for the spreading exploitation of RESs in Germany is the Renewable Energy Act, first adopted in 2000 and subsequently revisited several times. This Act introduced different aspects promoting the use of RESs, such as the obligation for the DSOs to allow the connection of new RESs to the distribution grid and a remuneration scheme for these resources, with fixed price, usually guaranteed for 20 years [24]. In addition to that, the ongoing decline in prices for rooftop photovoltaic plants has increased the use of NP-RESs, reaching 90% of renewable capacity connected to the distribution grid [25].

This transformation has introduced a range of technical challenges, since in the past distribution grids were not designed to accommodate high penetration of DERs. To overcome these technical issues, German national authorities have introduced the possibility for the DSO to curtail NP-RES production in critical situations [26]. However, it is clear that this curtailment highlights inefficiencies in the system, causing, for example, a significant increase of relevant costs (it is estimated that during

2016 this procedure costed 375 M€) [27]. Therefore, to enhance the network's hosting capacity for DERs and to improve their coordination, the figure of the Aggregator has been introduced in

Germany, initially with the purpose of better coordinating the resources to limit congestions and so the NP-RSE curtailment. Subsequently, starting from 2018, the Aggregator has been enabled to provide ASs to the power system. To date, all the above-mentioned services (FCR, aFRR and mFRR) are open to DERs, as long as they fulfill the technical requirements prescribed by the national grid code. The minimum bid size to participate in the market is 1 MW for FCR and 5 MW for aFRR and mFRR.

B. France The French energy framework has been characterized, during the last years, by the creation of different Energy communities through the decrees "Self-consumption Ordinance" and the "Self-consumption Decree" [28][29]. Following the French regulation, an Energy community is an entity in which geographically close consumers and produces, connected to the low voltage distribution grid, are brought together to obtain a single self-consumption unit. Actually, the nominal capacity of each Energy community is fixed to 3 MW and the maximum geographical distance between community's members is limited to 20 km [30].

These decrees led to a great deployment of small-scale photovoltaic power plants, almost 500,000 at the end of 2019, some of which (15% of the total) devoted to the self-consumption communities. More recently, the high penetration of DERs has also pushed national agencies to enable the qualification to the ASM of DERs suitably aggregated. Therefore, today, aggregates of distributed resources are allowed to provide all the three services previously described. The minimum bid size is equal to 1 MW for the FCR and aFRR services, and equal to 10 MW for the mFRR one. The participation of DERs in the FCR balancing market is still limited, since 70 MW of DERs are enabled. Instead, for the mFRR product, a total capacity of 500 MW from distributed resources is enabled [24].

C. United Kingdom Even if, after Brexit, United Kingdom is no more an EU Member State, it has been included in this analysis because its current regulation has been also influenced by the abovementioned EU directives. UK was one of the first European countries that allowed the participation of DERs in electricity markets to support the stability of the grid [24].

Indeed, as result of the poor transmission capacity with Continental Europe, the electrical balancing of UK has always been characterized by severe criticalities. These issues required the introduction of balancing products on the ASM particularly diversified and technology specific. However, this complex technical framework represented a potential barrier to the integration of DERs in balancing markets.

Currently, only the primary control service (FCR) and the downward Replacement Reserve have a minimum bid size compatible with the typical aggregation size (i.e. 1 MW) [31]. Concerning the EFC and the mFRR, the former is characterized by a minimum bid size too elevate to allow the participation of DERs' aggregates (i.e. 25 MW). While, the latter is procured through a different mechanism, based on a pay-as-bid tender with a minimum bid size of 3 MW [24].

D. Finland

Finland is one of the most virtuous EU countries in terms of accessibility to electricity markets by DERs. These resources are enabled to procure all the three products defined by the European guidelines [20]. Moreover, thanks to the low minimum bidding size, equal to 0.1 MW for the FCR in normal condition and 5 MW for aFRR and mFRR services, the aggregated resources participate actively in the ASM. Indeed, during 2018, the DERs have provided approximately one third of the energy required in the mFRR market [24].

E. Italy

Currently, in Italy, only conventional power plants with a power capacity higher than 10 MVA can access to the ASM, providing ASs to the grid. However, during the last years, the Italian Regulatory Authority for Energy, Networks and Environment (ARERA) has moved to enable also the participation of DERs. In this regard, in 2017, Resolution 300/2017/R/eel [32] started a pilot project allowing the provision of RR service from dispersed generation, properly aggregated and coordinated [33]. A further extension to the aFRR service (secondary frequency reserve) is also foreseen [34]. Actually, the minimum bid size is set at 1 MW; however, a reduction of this threshold to 0.2 MW is under discussion [35].

Despite the harmonization process ongoing in Europe, there are still many differences in terms of participation of DERs into the ASM between the EU countries. However, in spite of national peculiarities, the survey underlined a common path of Member States toward the opening of their ASMs. In this framework, Italy is playing a pivotal role to progressively enable the participation of the distributed resources into the ASM. In the next section, the path undertaken in Italy in this regard and the preliminary results of the Italian pilot project are depicted.

Table 1. Minimum bidding size required to the participation of aggregate of units in ASM.

Country	Minimum bidding size [MW]		
	FCR	aFRR	mFRR or RR
Germany	1	5	5
France	1	1	10
United Kingdom	1	/	3
Finland	0.1	5	5
Italy	/	(Under discussion)	1

IV. THE ITALIAN PATH TOWARD THE OPENING OF THE ASM TO DERS

Similarly to the evolution of many EU countries, also Italy has been characterized by a large deployment of DERs driven by environmental targets and economic incentives. For example, during the decade 2008-2018, the yearly energy production from DERs increased by 3 times, reaching 20% of the national annual consumption. This rapid evolution has required a process of standardization of the technical requirements to enable the connection of power plants to the grid. This process started in 2008 with the introduction of the technical standard CEI 0-16 of the Italian Electrotechnical Committee, defining the technical prerequisites to apply for the connection of loads and generators to the medium voltage distribution grid [36]. With a similar approach, the standard CEI 0-21 defined the prescriptions to follow for the connection of power plants to the low voltage grid. These rules were updated in 2012 and 2014, introducing further requirements for DER power plants, such as the obligation to control the reactive power to adjust the voltage profile over the grid and to limit the active power injected in critical circumstances (e.g. overfrequency transients). However, the exploitation of distributed resources to provide grid services cannot be limited to critical conditions. Indeed, as expressed by the EU Regulation 2019/943 [37], there is the need to completely integrate all the resources, connected at any voltage level, to achieve a safe and reliable system operation. Therefore, to this purpose, ARERA has recently initiated two paths to improve this integration:

i) increasing the observability of DERs by the system operator through the installation of suitable monitoring and communication devices (also enabling the sending of control signals to dispersed units, when needed);

ii) opening the national ASM to aggregate of DERs.

i) Increase of DERs osservability

One of the main problems introduced by large penetration of DERs is related to the limited data available on their real-time production and predictability of their energy exchanges. To overcome these issues, ARERA, following the directions of EU guideline 2017/1485 [38], has opened to the possibility of collecting measurements on DER power plants to be delivered to the TSO. This process, started by the Resolution 628/2018/R/eel [39], provided the installation of an innovative device specified by the last release of technical standard CEI 0-16, which is aimed to monitor and, in perspective, to enable the remote control of dispersed units: the Centralized Plant Controller (following the Italian nomenclature "Controllore Centrale di Impianto": CCI). The CCI is an integrated device capable to supervise the performances, in terms of active and reactive power exchanges, of a single power plant or aggregate of DERs. It is equipped with a modem capable to provide a bidirectional communication between the local generator, the system operators (i.e. TSO, DSO) and the Aggregator. Hence, the implementation of this device allows achieving not only a higher observability of DERs, but also promotes a greater spreading of the Aggregator concept, since it facilitates and standardizes the exchange of data and signals between the Aggregator and the units in its portfolio. According to the Italian regulation (still under definition), probably the CCI will be mandatorily installed on all the new generators or group of generators with a total power greater than 1 MW and aggregates of units that are enabled, through pilot projects, to provide ASs to the power grid. It is also foreseen a further extension to plants and ESSs already installed and clusters of units having a nominal power between 11.08 kW and 1 MW [39].

As already anticipated, Italy is also playing an important role in experimenting the supply of ASs from DERs. In this regard, in the next subsection, the preliminary results of the Italian pilot project enabling the provision of ASs from aggregates of dispersed resources are presented.

ii) Opening of the ASM to DERs

Recently, the Italian Regulatory Authority (ARERA) started a pilot project to test the provision of ASs from aggregates of distributed resources. This pilot project started in 2017 and defined, for the first time in Italy, the concept of Virtually Aggregated Unit (in Italian "Unità Virtuale Abilitata": UVA) [32]. Based on the latest resolution, published in 2018, an UVA is defined as an aggregate of many small-scale generation plants, consumption units and energy storage systems (e.g. also including electric vehicles). These resources are grouped and coordinated by an Aggregator, which, by using suitable control tools, can participate to the ASM offering the units' flexibility.

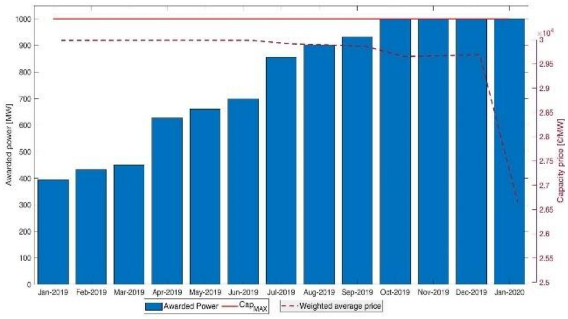

Figure 2. Capacity allocation and average price of the capacity auctions

To favor a larger involvement of stakeholders, ARERA has introduced a dual remuneration scheme for Aggregators. In particular, it was introduced a remuneration based on long term capacity contracts, in addition to the standard mechanism based on the energy supplied during the regulation. In these contracts, the TSO acquires a certain amount of capacity from the Aggregators (i.e. 1 GW in total for 2020) through annual and intra-annual auctions, with a strike price of 30,000 €/MWh. The Aggregators receive the capacity remuneration monthly upon the commitment to submit offers in the ASM during the peak hours (i.e. from 2 p.m. to 8 p.m. of the weekdays). The introduction of a capacity remuneration has produced two main advantages: i) it has favored the Aggregators' involvement, covering part of the investment costs required to equip the coordinated DERs; ii) it has also facilitated the creation, during the peak hours, of the high margin of reserve required by the TSO [40].

Secondly, to further facilitate the aggregation of DERs, the aggregation perimeter, i.e., the geometrical area within which the Aggregator can group DERs, has been opportunely defined. Following the actual regulations, this perimeter can group a few provinces. However, it is expected that in the next future this aspect will be revised, because to avoid congestions in the transmission lines due to energy exchanges between the units in the aggregate, the aggregation perimeters should consider the transmission network topology and not the geographical area. The results of 2020 auctions for the capacity contracts showed a large involvement of the stakeholders in the pilot project. Indeed, all the capacity issued available by the Italian TSO (1 GW) has been assigned to the

Aggregators. Analyzing the auctions from an economic perspective, it is possible to highlight a constant decrease of the weighted average price paid by the TSO for the capacity remuneration. Indeed, the mean weighted price accepted in the annual auction decreased by 13% between 2019 and 2020 (i.e. from 29,980 €/MWh to 26,500 €/MWh). Therefore, as presented in Figure 2, the growing involvement of Aggregators in the project (the blue bars in the plot indicate the capacity awarded) led to a more competitive market, pushing for a reduction of the average capacity remuneration price (the magenta dotted lines).

During the project, 231 aggregates, with an overall capacity of 1,348.9 MW, have participated. Most of them, almost 75% of the total, are currently located in the North of Italy. Concerning the technical composition, a positive aspect that should be underlined is related to the large participation of consumption units: almost 80% of the Aggregators have at least one flexible load in their portfolio. However, the participation of aggregates of dispersed RES is still limited. This is caused by the fact that, on the one hand, many of these resources in Italy benefits of incentive schemes, which push users to maximize their energy production.

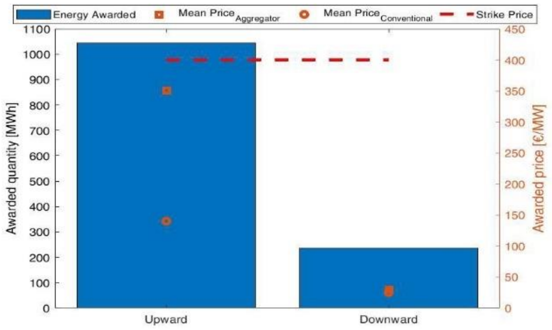

Figure 3. Quantity and mean price accepted from the Aggregators' bids

On the other hand, usually the regulation performed by RES is carried out by curtailing their power. Therefore, the participation to the ASM of these resources is not convenient without the adoption of proper expedients (e.g. ESS) able to avoid the loss of production.

Another critical aspect emerged in the Italian pilot project is related to the small number of units currently involved in the Aggregator's portfolio. Indeed only 8 aggregates operate with a portfolio with at least 10 units, and in 25% of the cases, the portfolio is composed by a single unit. This result can be justified considering the greater ease to control and manage, in this first phase, a small aggregate of plants. However, even though the management of a larger and diversified portfolio could be more complex, it is expected to bring in the future greater technical and economic advantages: a wide and heterogeneous portfolio, as described in Section II, implies a higher possibility to provide services to the market, but also allows to increase the reliability of the AS provision, reducing for example possible penalties for the non-fulfilment of the requested service.

Despite the advantages related to the procurement of capacity margins, so far, UVAs have been only partially exploited for the provision of ASs. In particular, during the period 2019-2020, only 1,045.23 MWh of upward regulation (i.e. request to increase the power produced) has been acquired from Aggregators. In relative terms, the awarded bids represent only 0.02% of the total quantity offered. This limited exploitation of the flexibility made available can be justified considering the prices at which the upward service has been offered: the average price of the Aggregators' bids was about 351 €/MWh, which is close to the strike price (i.e. 400 €/MWh), and it is 2.5 times the average price offered by conventional power units (see Figure 3). Clearly, since the offers selection process in the ASM aims at minimizing the overall system costs, the offers of the Aggregators have less probability of being selected. Considering the bids submitted for the RR downward service, only 234.83 MWh submitted by the Aggregators have been accepted (i.e. 0.5% of the total bids). However, in this case the average price submitted was 30 €/MWh, value in line with the average value offered by traditional power units, which is 25 €/MWh.

In spite of the fact the UVA pilot project is still at a preliminary stage, where the actors involved are still shaping their dynamics of participation into the market and there is a scarce competition among offers, the Italian TSO has frequently declared the importance of this project to prove the feasibility of the proposed approach and to support the creation of the reserve margins requested by the TSO.

V. CONCLUSIONS

In this paper, a comprehensive analysis of the EU path toward the opening of the ASM to DERs has been proposed. The survey has shown that, despite differences are still present, EU countries are moving toward a higher integration of DERs in their ASMs. In this rapidly changing scenario, Italy is playing a key role. To face the issues introduced by the massive penetration of RES, the Italian Regulatory Authority (ARERA) has moved to allow a better integration of DERs into the power system and electricity market. The preliminary results of the UVA pilot project, which opened the Italian ASM to aggregates of distributed resources, have shown the potential of DERs to contribute to the ASs provision. The opportunities related to the involvement of DERs in the market are expected to further increase in the next future, with the adoption of the communication and monitoring devices prescribed by Italian technical standard CEI 0-16, aimed to allow a better observability of dispersed resources and to enable their remote control and coordination by Aggregators

VI. ACKNOWLEDGMENTS

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