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EEM15 - 12th International Conference on the European Energy Market. 20-22 May 2015.

Aggregation of Demand Side flexibility in a Smart Grid: A review for European Market Design

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***Abstract* - The increased share of renewable generation and the integration of Distributed Generation (DG) require more electricity system flexibility. One way to increase this flexibility is to use the potentials of demand response (DR). In order to activate the full range of customers in DR, a new market intermediary actor is needed to aggregate the resources in an adequate technical and economical format. These actors, so called "*aggregators*", can act as flexibility providers to support security of supply considering network, generation and consumers constraints. However, despite their technical and economical utility, aggregators are not self-emerging in many European countries. Consequently, this paper aims at identifying the main barriers accounting for this lack of aggregators in Europe. Eventually this paper provides a policy review for European market designs that support aggregation.**

***Index Terms*— Aggregator, demand response, demand management, regulation**

I INTRODUCTION

Demand side participation is of significant interest in the European transition toward a carbon free electricity sector. Till now, mostly industrial customers are providers of demand response (DR) in electricity markets. Smaller users like residential and commercial customers are in many places left inactive for DR provision. To enable those users to offer their flexibility resources and receive adequate economic compensation, load aggregation is required. Within electricity systems that aim to stimulate bottom-up contribution of the end-user an aggregator is therefore inevitable. In a scenario with high levels of installed renewable distributed generation feeding-in volatile electricity inflows, system reliability could be achieved with the contributions of DR on both distribution and transmission networks. End-users can be incentivized to provide DR through dynamic electricity prices, which are given on long or short-term notice

Current research on load aggregation frequently focuses on specified management of Electric Vehicles (EVs) [1]–[5] and furthermore optimal bidding methods of such load flexibility in electricity markets [6]. However, besides for EVs, load aggregation is required for many other small flexible units to become active flexibility offers on the market. Besides this, current literature leaves out the actual role and positioning of an aggregator within the economic, technical and institutional context of the electricity system.

Therefore, in this paper the authors are concerned with providing a more analytical definition of a load aggregator as a market intermediary (MI). Based on that, the authors will define the actual roles and tasks of an aggregator in the electricity sector and will draw some preliminary policy recommendations for European market design to set up a more favorable environment for load aggregation. In Europe, few markets are open for demand response and aggregation: France, Ireland, Great Britain, Belgium, Switzerland and Finland. In most other European countries regulatory barriers exist, and in even some of them demand response is illegal [7].

Specifically, this paper focuses on the aggregator as supplier of flexibility in markets, not the aggregator as electricity service supplier to the end-user, which generally is the role of the retailer. The difference lies in the fact that the retailer sells electricity to the end user, and thus provides a service to the electricity consumer, while the aggregator is an enabler of electricity consumers to provide flexibility to the system within the existing (or upcoming) trading platforms for flexibility (e.g. real-time and balancing markets). In reality, the aggregator could simultaneous be a supplier and aggregator, to prevent conflicts arising due to independent aggregators and balance responsibility of traditional suppliers [8]. However in this paper we remain focused on the primary role and function of an aggregator.

This paper starts with highlighting the needs for aggregation. Then, a definition of load aggregators as intermediary firms is provided in section III. Section IV is dedicated to the analysis of the possible flexibility sources, and requirements for the electrical grids. Section V follows up with case studies of aggregators. In Section VI and VII the results and conclusions will be presented.

II THE NEED FOR AGGREGATION TO ENABLE FLEXIBILITY FROM SMALL CUSTOMERS

In Europe, mostly large electricity users have been suppliers of demand response in electricity (balancing) markets. Large electricity users that remain excluded from those markets are those that cannot fulfil the requirements of the markets (for instance in terms of availability or reliability). To offer their flexibility on the markets, they need be aggregated. Smaller electricity users like households or commercial facilities also need to be aggregated by Market Intermediaries (MI) because they provide per unit too little capacity and/or energy to be tradable in electricity markets.

This MI function of aggregation could be practically conducted by any technologically capable entity, for example a new aggregating entity, traditional retailers, IT companies, financial actors, energy suppliers or energy service companies (ESCO) [1].

III The Functions of an Aggregator

A. *The aggregator as a market intermediary*

The aggregator is a firm that can functionally be compared with intermediary firms that exist in many other sectors, for example gas shippers in the energy industry [9]. Generally, intermediary firms act as third parties between buyers and suppliers. Regarding the electricity sector, DR aggregators may not be necessary for all kinds of DR providers. Large industrial are able to provide their flexibility services directly to the TSO.

B. *Intermediary functions in the electricity sector*

The main roles of the intermediary firms are described by Spulberg (1999) and Codognet (2004); they are based on four main functions [10], [11]. The first one is *information management*. In the electricity sector, an aggregator should have insights into the loads of flexibility providers. For instance, it should be able to foresee the energy demand of its customers, the tradable values of flexibility, the size and the reliability of those services. Furthermore it should know the prices for different types of flexibility in the market and possible price evolutions. Information management is a requirement for profitable decision-making of the aggregator.

The second function is *bundling of services*. The aggregator receives value on markets for flexibility due to the fact that it aggregates many different individual flexibility services into tradable values. This is done based on technical characteristics of the flexibility services (for example availability, capacity, slow versus fast-ramping services and duration). The flexibility is then activated when certain types of flexibility are needed in the market using IT communication and control to secure reliability and registration.

The third function is *matching and market clearing*. An intermediary firm bids the bundled services on an electricity market. These markets could be based on capacity trading, like in balancing and ancillary markets. Or rather energy based trading like in day-ahead markets or with long-term contracts. Furthermore, future flexibility markets could include network management services for the TSO and DSO.

The fourth and last function is *transaction guarantee*. In the electricity sector, aggregators will be required to provide TSOs with reliable flexibility offers. The aggregator manages the risk of delivery of DR and should therefore ex-post control on the "real provided DR". Based on the ex-post analysis the provider of demand response should be remunerated (or penalized, depending on the contract conditions). See Figure 1 for a presentation of the four-presented activities.

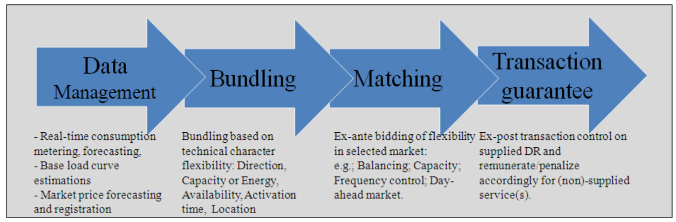

Figure 1: Aggregation functions in the electricity sector, adapted from [11]

IV Providing Flexibility Value in Electricity Markets

By performing the four MI functions, aggregators are necessary firms that could help to activate decentralized resources and provide flexibility to the TSO. Figure 2 shows the role of the aggregator in the flexibility trading process.

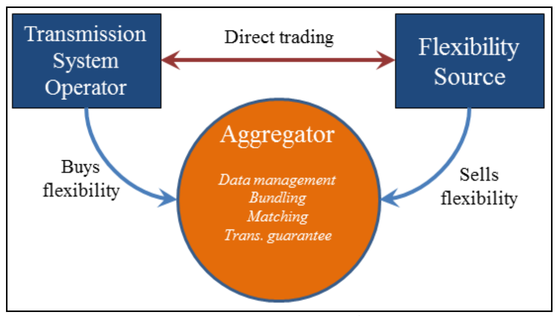

Figure 2: The aggregator central location in the flexibility trading process

A. *Flexibility resources from a technical perspective*

In electricity systems, *flexibility can be defined as a power adjustment sustained for a given duration in order to balance supply and demand at a given moment in time*. Thus, a flexibility service is a multidimensional good characterized by the three attributes (see Figure 3): its *direction* (a) (up or down); its *electrical composition* in capacity or power (b) and its *availability* defined by starting time (c) and duration (d).

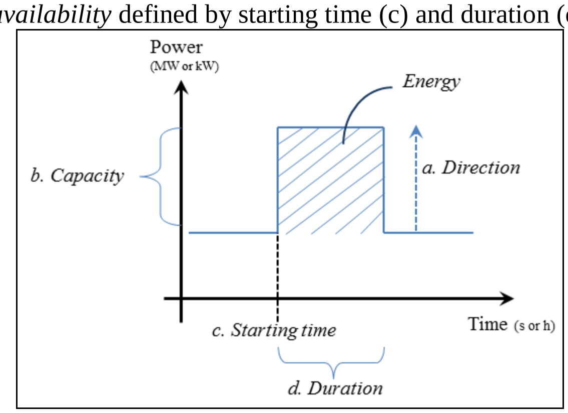

Figure 3: Characterization of flexibility products

Electricity flexibility could be provided by many different types of resources, e.g. Electric Vehicles, combined heat and power (CHP) units, water heaters and storage units. In order to be able to provide flexibility offers on a given market, it is important to characterize these different types of technologies according to the three attributes that have been defined.

For instance, some of the resources may just have a single direction potential contribution (for instance typical households loads, such as water heaters, electric heaters etc.), while others have bidirectional capabilities (i.e. they can act both as producers and consumer).

In the same line, a clear distinction should be made between the capacity and energy type resources. The former have a rather high capacity/energy ratio. They can provide the aggregator with a high capacity value, but are not able to maintain this capacity level for a long time. The latter, have a low capacity/energy ratio and are more appropriate to maintain a capacity level for a longer period of time.

Moreover, the time availability of sources is a constraint that identifies those units. Some resources may only be available during specific periods of time – for instance EVs are most likely to be available from 6PM to 6AM. Similarly, different resources may offer various activation times, that is some resources may be able to adjust their power much quicker than others. Furthermore the location of the sources is of importance depending on the nature of the required demand response. For example, geolocation based demand response could be of interest for local congestion management or distributed generation (DG) optimization. See Figure 4 for an overview of our typology of flexibility resources.

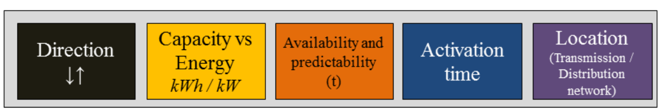

Figure 4: Technical characteristics of flexibility resources

B. Transmission System Operators and electricity markets

In order to fulfill the task of balancing electrical supply and demand, TSO's buy services flexibility. TSOs are interested in particular flexibility offers depending on current system status. Therefore, they organize several electricity markets targeting the various desired flexibility needs. In a perfect market design, each market addresses a particular flexibility need, and has accordingly the suited requirements.

First, for each flexibility need, an ex-ante notification time is set. This time can range from one hour in the fastest markets to one day for the day-ahead and longer, energy-oriented markets. Furthermore, the duration at which resources are requested to be available vary: from one hour to several months. Lastly, the frequency of the call for the flexibility offer can have various specifications. Some flexibility resources may be solicited once a month, others on a continuous basis. Furthermore, the location of the resources might be an important factor for location dependent demand response.

Besides these needs of flexibility on nationwide electricity markets, also additional local flexibility could be required. Most electricity market designs have been defined before the development of current innovations like distributed generation (DG) and EVs, and therefore those neglect the needs for more decentralized demand flexibility.

It is expected that in the future the DSO and TSO might request more demand response operated in a decentralized way. For these types of needs, new local markets would be needed to develop for the use of flexibility within a local distribution grid or 'export' to the rest of system.

In the following section we will provide case studies underlining the contributions that MI could provide to electricity markets.

V CASE STUDIES OF EXISTING AGGREGATORS: WORKING SOLUTIONS AND PROJECTS

In most other European countries (except France, Belgium, Switzerland, Great Britain, Finland and Ireland) regulatory barriers remain an issue and hinder market growth of demand response [7]. The next sections outline some cases regarding existing aggregators around the world that plaid for more experimentations across Europe.

A. Energy Pool (France)

In France, Energy Pool is an aggregator that started operations in 2008 [12]. Its clients are mainly large industries and electricity consumers (e.g., metal industries, data centers and hospitals), which are geographically spread across the country (i.e. not geo-location bound). The DR flexibility consists of around 1500 MW flexible capacity in the form of load reduction. Energy Pool takes charge of optimal decision-making for the industrial user; it identifies flexibility potential, integrates the DR in normal business processes of its clients and offers the load adjustments in different markets. These markets are the balancing mechanism, security reserves, capacity markets and energy market transactions. Clients of Energy Pool receive specific payments for their participation in load management programs, which are both in energy and capacity based trading [12].

B. Voltalis (France)

Differently from Energy Pool, Voltalis[1] is an aggregator mainly for residential users. Customers contracted with Voltalis receive a free box installed in their home, named Bluepod, which reduces their electric heating device operation in short time intervals when Voltalis receives a signal from the TSO. The dispatch signal is mostly related to endangered electricity supply sufficiency in Brittany. Customers who have the box installed are automatically enrolled, but can opt-out at any time by pushing a button on the device and use their electric heater as usually. Voltalis as an aggregator is able to trade the aggregated flexibility in different markets like balancing markets and demand

[1] Find more information on Voltalis via: www.voltalis.fr

response mechanisms of the TSO. The customers do not receive any financial benefit when their heating device reduces their load, but observe a reduction of their normal electricity bill due to those interruptions in electricity consumption for heating.

C. *Direct Energy (France)*

Until now Direct Energy has been an electricity retailer serving more than 1 million customers with electricity supply in France[2]. However, currently, next to their retailer service, Direct Energy started a pilot as an aggregator of electricity demand response from their electricity customers[3]. It aims to participate in load-shedding programs, with 500 of its customers participating in the NEBEF mechanism, the demand response load-shedding program of RTE, the French TSO [13]. Those 500 customers represent around 1500 devices, mainly water heaters and convector heaters.

D. *Flextricity (United Kingdom)*

Flextricity[4] is an industrial demand response aggregator, which started operation in 2004 in the United Kingdom. Flextricity provides both generation and load aggregation, meaning that it can incentivize clients for upward and downward load adjustments and eventually trades this flexibility in markets. Flextricity's clients are large industrial and commercial customers (over 500kW) and owners of small hydro and stand-by generators.

Usually there is no cost at all for the customer to participate in Flexitricity's aggregation programs as the company itself installs the communication, metering and control equipment. The flexibility is supplied to short-term operating reserve (STOR), which is a service for the provision of additional active power from generation and/or demand reduction if power fails or demand is higher than expected. Furthermore DR is used for triad management, which is carefully targeted generation and demand reduction periods to optimize revenues in contingency situations. Lastly this DR is provided in frontline (open for both generation and load adjustments) in short notice (below 10 seconds, for 750 kW or more).

E. *Delaware EV pilot in the United States*

In the University of Delaware (US) the Vehicle to Grid (V2G) project presents an interesting aggregator potential business [14], [15]. The EV aggregator in Delaware acts as an intermediary firm between PJM (local TSO), and flexibility service providing EVs. This project has a fleet of electric vehicles (EVs) whereof the aggregator collects information regarding EV availability by calculating the current state of charge and planned trips. Furthermore the regulator receives the regulation dispatch signal from PJM.

The aggregator sells capacity to the grid operator, PJM in this case. So far, it only participates in frequency regulation. In PJM, the aggregator bids in the hourly auction market for frequency regulation and is for the available power capacity each hour ($/MWh). When participating in this frequency regulation, EVs receive a dispatch signal from the local TSO (PJM) and are remunerated accordingly. If the regulation service offered by the Delaware EV aggregator has not met the performance thresholds over a specified time period in terms of correlation (delay) and precision, PJM is able to disqualify the aggregator [16].

VI RESULTS/DISCUSSION

This paper presented a definition of the aggregator, its activities and documented existing business cases. Till now, it is seen that most of the aggregators are focused on certain type of users (industry or smaller customer) and specific types of flexibility sources. Demand response provision is found mostly in traditional markets for balancing services and direct methods with TSO load shedding programs. The next paragraphs list main market barriers existing in Europe for further development of aggregators.

A. *The lack of smart-metering*

Currently, large industrial users are main customers of aggregators. Many of those users already have devices installed (smart-meters) that give insight in their real-time consumption. In Europe solely Sweden and Italy have 100% smart meter roll-out, therefore leaving many other customers measured with traditional meters that are not communicating in real-time with the retailer or potential aggregator [17]. For flexibility to be tradable and profitable, it is required that it is a reliable and therefore metering and control is needed to check performance of actually provided demand response per user [18]. This issue of smart-metering and contracting of the customer is related to the *data-management* and *transaction guarantee* function of the aggregator.

B. *The unadapted actual market design for aggregation and DR*

Current electricity market rules are based on the traditional assumption that generation follows demand. However, developing a smart grid vision of electricity markets requires that markets are open for the trade of demand flexibility services. Therefore strong requirements on minimum bidding volume and bid duration could restrict DR participation possibilities. Due to the fact that large upfront investments are needed for contracting, metering and control of DR, barriers of market entry for aggregators should be reduced. Furthermore market rules should involve a definition of performance criteria for DR, for example related to the performance in terms of DR correlation, delay and precision that is also applied by PJM.

Due to the fact that DR affects traditional load curves, a change in such consumption might lead to increased cost to suppliers that procured electricity ex-ante. Therefore some financial compensation models have been suggested to allow

[2] More information on Direct Energie via www.directenergie.com

[3] See press release http://www.ecoco2.com/blog/10450-direct-energie-premier-fournisseur-agree-pour-leffacement-diffus

[4] More information on Flextricity via www.flextricity.com

third party aggregators to trade flexibility of end-users that have been ex-ante contracted by suppliers for their traditional consumption curves [8].

Besides providing value in traditional electricity markets, aggregators can also provide potential value for evolving markets, for example in local balancing for distribution grids. These types of markets are not yet existent in Europe. Recommended is that policy makers set the right environment and cooperation possibilities with DSO's and TSO's regarding this geolocation based demand response. Of course, it is possible that demand response in those settings could be mandatory or on tariff basis, but this entirely depends on decisions regarding market design. This issue of market design is related to the *bundling* and *matching* function of the aggregator.

VII Conclusions

This paper provided an overview of the different functions of an aggregator together with case examples. In Europe, there are still only few aggregators found. In many places electricity market rules do not foster the entry of aggregators. These rules involve minimum bidding values, bid duration and strong penalties for non-supplied services. Furthermore the lack of harmonized market rules between countries in order to support cross border aggregation hampers market entry, providing no coherent European approach to aggregation. Moreover, for flexibility to be tradable and profitable, it is required to check performance of real provided demand response ex-post. Therefore barrier relates to the fact that few customers own smart-meters. Consequently, no sufficient management and control can be conducted to signal and register demand response. In this setting, aggregation should be seen as one of the options to trigger demand response, next to dynamic tariffs and direct load control.

Policy should therefore take a holistic approach on suited market design for demand response. Therefore, besides trading flexibility in traditional electricity markets (e.g., day-ahead, intraday and balancing markets) aggregators can also provide potential flexibility for evolving markets, like local balancing in distribution grids. These markets are not yet existent in Europe but they could be potential markets for aggregation focusing on locational problems like local network and supply constraints.

Acknowledgements

Cherrelle Eid has been awarded an Erasmus Mundus PhD Fellowship and would like to express her gratitude towards all partner institutions within the program as well as the European Commission for their support. Paul Codani and Yurong Chen benefit from the support of the Chair "PSA Peugeot Citroen Automobile: Hybrid technologies and Economy of Electromobility", so-called Armand Peugeot Chair led by CentraleSupélec, and ESSEC Business School sponsored by PEUGEOT CITROEN Automobile. Furthermore the authors would like to thank Elta Koliou and Anne-Sophie Chamoy from Energy Pool for their feedback on this paper.

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