The conclusions of the ADVANCED project on the impact of active demand on the electrical system and its actors

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ABSTRACT

Distribution System Operators (DSO) are required to operate and plan their networks so as to support a potential peak demand increase and the connection of additional loads and Distributed Generation (DG) units in the future. Huge investments may be required to reinforce the network capacity in order to ensure a reliable electricity supply even during periods of critical loading or congestions caused by maximum feed-in, which generally occur only a few hours a year.

Active Demand (AD) encompasses a wide range of strategies and mechanisms aimed at allowing consumers to become active participants in electric power systems, by adjusting their electricity use in reaction to economic signals from the market, and to provide services to different electricity system agents, by making their electricity consumption either controllable or reactive to specific requests. The added value of AD for the electric system is a higher efficiency in the use of electricity that can be realized across the value chain of electricity supply at different levels.

In particular, DSOs could take advantage of the load flexibility provided by AD by offering specific products for system services in order to operate networks more efficiently. As a consequence, the simultaneity of peak loads at critical times could be reduced, or activated demand could help in avoiding congestions that are caused by feed-in thus moderating the need for new investments in both cases.

Due to a relatively scarce experience on AD, there is still great uncertainty about the magnitude of the impact that can be expected of AD in distribution grids. The quantification of these benefits is crucial for regulators and DSOs in order to evaluate the cost effectiveness of possible investments in these smart technologies and the design of network tariffs and network operation procedures that incorporate AD.

This paper provides the results of the ADVANCED project in terms of quantitative analysis of the potential economic impact of AD on distribution grids and identification of the services that can be provided to ensure system performance and stability.

ADVANCED is a research project co-funded by the European Community's Seventh Framework Programme under grant agreement n° 308923, that aims to shed light on ways to overcome the barriers hindering the mass deployment of AD in Europe. The studies developed in the project are based on real consumption data collected from European AD pilot experiences in combination with the VaasaETT database.

The analysis within ADVANCED included three steps: First a scenario based report was compiled that based on a methodology developed by the consortium calculated the flexibilities that AD might offer on a general level. Afterwards a special DSO perspective was taken in order to find a fit between DSO's (expansion) needs and the possibilities of AD. Finally large-scale distribution planning tool was used to estimate the reinforcement needs to meet the local demand growth, a higher penetration of DG and the alterations in the shape of peak load patterns that are expected in a particular distribution network in a ten-year horizon.

As a result, this analysis provides a quantitative scenario-based estimate of the impact of different forms of AD and other boundary conditions on the potential of AD to bring benefits to distribution networks as well as a deep view on how AD can support distribution grids in critical situations. Moreover it provides useful insights into the added value of AD for DSOs and the convenience of promoting and investing on certain types of AD services at distribution network local level.

INTRODUCTION

The objective of the ADVANCED (Active Demand Value and Consumer Experience Discovery) project is to develop actionable frameworks enabling residential, commercial and industrial consumers to participate in AD initiatives, thus contributing to its mass deployment in Europe. The ADVANCED project comprises four pilot projects, currently underway or already finished, that test AD solutions among real residential consumers in different locations of four European countries: two

ADDRESS pilots in Spain and France, the E-DeMa pilot in Germany and the Enel Info+ pilot in Italy. Furthermore, the ADVANCED project relies on a set of in-depth qualitative interviews and a vast amount of data collected in the VaasaETT database.

The main goal of this paper is to assess the inherent impacts of AD on electricity systems (how create value using AD), and to evaluate the economic benefits of AD on the DSO's perimeter from a societal perspective, as well as their allocation between DSOs, consumers and AD providers. This quantification is done under different scenarios of regulatory frameworks and economic boundary conditions that were defined and discussed within the project and reported in this paper. Furthermore, the regulatory barriers for the implementation of AD in the different contexts of the European scene are identified and some recommendations are provided in this sense in order to facilitate the future development of AD in electric power systems.

Scenario-based results on the flexibilities AD might offer

One of the scopes of the ADVANCED project was the identification of the Active Demand (AD) potential for demand response and energy efficiency in France, Germany, Italy and Spain. For the purpose of this work, demand response potentials are defined as the general ability to steer power demand out of peak times. Energy efficiency on the other hand is understood as an incentivized reduction in the (yearly) electricity consumption. The potentials in both dimensions of AD are quantified for a baseline, optimistic and technical potential scenario for France, Germany, Italy and Spain. The baseline scenario projects the current development by making assumptions e.g. on the overall electricity consumption or on the roll-out of Smart Metering (SM). The optimistic scenario takes more ambitious assumptions outlining an ideal degree of energy savings and tapping of load shifting potentials. Due to the contribution of Entelios to the consortium's work, the AD potential for the C&I sector is evaluated for Germany as well. The analysis for the residential sector is based on AD programs (feedback and dynamic pricing programs).

The aim of the work that has been carried out for these purposes are:

- Develop a methodology to assess AD potential for demand response and energy efficiency in France, Germany, Italy and Spain in all described scenarios
- Identify boundary conditions in scenarios in each country to ensure maximum benefit of AD at the lowest possible cost. Aggregate AD potential regarding demand response and energy efficiency for each country for the residential and commercial sectors.
- Identify some first indications on AD potentials for the C&I sector.
- Calculation of KPIs such as economics savings and CO_2 reduction achieved by SM and feedback programs in the residential sector.

The following results from this first step of the work are worth reporting:

Energy efficiency in the four countries:

- The baseline scenario leads to an AD potential of energy efficiency of between 216 GWh for Italy (0,27%) and 3.898 GWh for Germany (3,07%)
- The optimistic scenario leads to an AD potential of energy efficiency of between 1.879 GWh for Spain (2,28%) and 9.220 GWh for Germany (7,26 %)

Inasmuch as the results indicate that energy efficiency that stems from feedback to consumers is indeed one of the most important untapped energy resources today. Concerning the ADVANCED KPI "economic savings" it could also be shown that raising the energy efficiency potential would also create significant advantages for consumers in monetary terms. Albeit one should not forget that the analysis undertaken in this deliverable did only cover the potentials and not the cost involved.

Demand response in the focus countries:

- The outcome of the AD potential in the baseline scenario in the sector of households for demand response is very low (between 0,12% for Germany and 0,20% for Spain). These relative numbers relate only to a power demand of 120 MW for Germany up to 200 MW for Spain (this does not take into account the current flexibility in Germany of 26,1% of residential peak load1).
- Focusing on the outcome of the AD potential in the optimistic scenario leads to 280 MW for France (0,65%) up to 1.320 MW for Italy (8,25%), (this does not take into account the current day-night flexibility in France of 7,91%2).
- Higher potentials are most probably to be found in the C&I sector as ADVANCED's analysis for the German market clearly shows; here even in the baseline scenario some 3.200 MW could become flexible in the future.

As figure 1 shows potentials in terms of demand response might be small per country or sector but the effect of abolishing existing regulatory barriers (i.e. moving from baseline to optimistic assumptions) is still very significant. For instance the potential increases by a factor of 7 in German households.

1 mostly electrical heating systems that are charged overnight and are controlled by ripple control based systems today.

2 Boilers connection system and mostly electrical heating customers have a peak-off-peak tariff today in France.

		demand-response	
country	sector	baseline scenario	optimistic scenario
		GW	GW
France	residential	0,14	0,28
Italy	residential	0,08	1,32
Spain	residential	0,2	0,75
Germany	overall	3,22	9,92
of which	*industry*	*2,7*	*7,2*
	commercial	*0,4*	*1,8*
	residential	*0,12*	*0,92*
Sum		*3,64*	*12,27*

figure 1: Synopsis of additional AD potentials for all countries and sectors surveyed; Source: ADVANCED

The future market of flexibilities requires different products to content the demand of flexibilities for the DSOs. It also requires that current day-night flexibility programs in France and Germany are retained and upgraded, to allow for fully dynamic control by consumers or their service providers while at the same time respecting network bottlenecks where and if they exist. Without these upgrades, consumer will be barred from using their own flexibility to full advantage, consuming more during low priced hours and less during hours with high prices - thereby supporting the integration of wind and solar generation.

Basically different types of flexibilities are available which comply with different demands like e.g. local or temporal availability. Which kind of flexibility option will be successful is determined by the market. Currently flexibility is rewarded indirectly in most cases, i.e. it is part of the supplier's calculation as the suppliers offer their customers flexibility of usage for the most part. Thus such flexibility does not provide an outright value. There is albeit one exception to this conjecture: suppliers might use flexibility from customers to try and avoid causing imbalances with their balance groups. For the future the increasing feed-in of renewables will foster the demand of flexibility like AD.

TSOs also purchase consumer flexibility to provide low cost balancing resources. Today these contracts are generally with large industrial consumers, with or without the support of an aggregator. In future it can be expected that commercial and residential consumers will begin to participate in the balancing markets, as is already taking place in Finland and the UK for example. [1]

Active Demand System Services

In the ADVANCED project main issues related to the use of AD by network operators have been found:

- the need to integrate AD in a "merit order" of other relevant solutions,
- to clarify the frontier between technical minimum requirements and market-based products,
- to take into account the geographical dimension of network operators' expectations,
- to optimize coordination between TSOs and DSOs
- and to insert the use of AD in different timeframes and business use cases.

When looking for flexibilities or AD solutions to answer their needs, DSOs will have three main concerns: location of the proposed solution, reliability of the solution (expressed in terms of probability of reliability, including firmness and reactivity), and available capacity (power in MW as opposed to energy in MWh) or reactive power.

The expectations of network operators have been analyzed four major categories of (future) system services have been identified:

- frequency control,
- optimization of distribution network planning and construction,
- optimization of system operation,
- management of emergency situations, network or system restoration and islanding.

For each system service, the potential fit of AD to the individual technical needs of that systems service has been analyzed, associated flexibility requirements described and the views of the ADVANCED DSOs on the proposed concepts presented.

Potential applications include peak load reduction, provision of power flow control and voltage regulation. How AD can support distribution grids in critical situations like grid congestion was also investigated. Whether AD can be applied to resolve emergency situations in grids which typically require a quick real time response was also discussed.

The views of the DSOs might differ depending on each national context: main drivers for network investments (renewable energy sources development or peak load increase), regulatory context (for example, existence of aggregators or not, or level of smart meters roll-out).

DSOs generally express the fact that AD could help them defer or down-size investments in the future or help them control power flows and optimize operations but question the potential of AD for voltage control and stress the risks of intentional islanding (though micro-grids in degraded mode operation might be studied in pilots).

They are also very consistent on major issues. DSOs stress out the fact that the impact of AD on system losses can be positive or negative and that the reduction of system losses will only be a side-effect of using AD, and not a main objective.

Feasibility and implementation costs of using AD for DSOs (including the integration of AD in new or evolving business use cases) were pointed out to complement the analysis of benefits developed in and show major operational issues for DSOs, mainly to develop IT systems adapted to their new challenges.

A proper regulation is needed to allow DSOs to use AD for system services. The regulation of DSOs' revenues is an important element for facilitating the penetration of AD: if DSOs are not able to materialize the benefits from

purchasing AD, they will not be interested in doing so.
Finally, cooperation between TSOs, DSOs and AD operators (mainly aggregators or suppliers) will be key to assess and prevent undesirable side effects of AD on distribution networks and for the evaluation of AD benefits for DSOs.
When the application of AD is solely market driven and does not take into account the state of the grid, AD may affect grid stability and thus increase the need for distribution network investments. On the contrary, effective interactions between all players and cooperative approaches will help maximize the value of AD. [2]

AD Impact assessment on electricity system

The potential economic benefits that AD could have at local level and if DSOs were able to use it (exclusively) have been quantified for a set of country-specific case studies and scenarios. These benefits have been measured as the avoided distribution network reinforcements that a more efficient use of existing and new grid capacity due to AD could defer or avoid. The regulatory barriers that hamper the achievement of these quantified benefits have also been analysed and some recommendations are provided.
The results of the economic analysis show that under certain circumstances, AD could effectively help distribution network operators to reduce investment costs without endangering reliability, allowing for a more efficient network planning strategies. These avoided investments have been observed especially at LV networks and MV/LV transformers and not only in the MV network. Notwithstanding, one of the main conclusions of this work is that this potential is very dependent on local characteristics of the networks and too low to provide a strong signal to many consumers, but not all. Various local and country-specific circumstances have been observed to influence the desirability and the effectiveness of integrating certain forms of AD into network planning strategies for DSOs and regulators. In particular, the following aspects have proven to be of great relevance:

- **Network expansion drivers**. AD has a great potential to defer network investments whenever they are driven by significant load increases but only small or hardly any effect if new DG penetration is the driver, and in this case only special realizations of demand response, like Dynamic Pricing, have a limited potential to help to reduce reinforcement needs to integrate e.g. massive amounts of new Solar PV.
- **Network typology**. In general, urban networks capacity utilization is higher so reinforcements due to load increases are deemed more necessary. Therefore, AD has a strong potential to defer investments in that kind of scenario. However, this is clearly conditioned by the expansion drivers.
- **Current level of network constraint**. AD is expected to have a more positive impact on investments in highly constrained networks. For example, in densely populated areas where small load increases would easily cause overloads in network assets. This aspect is related to the network typology and the network expansion criteria because grids that have been designed to have ample capacity to absorb load increases and new network users or that supply geographically scattered small loads are in general less constrained.
- **Location of responsive consumers**, especially for low participation rates in AD. In general, it is more beneficial from the perspective of network investments that the location of consumers participating in AD is concentrated and under control by the network planner. A dispersed location is favourable if required reinforcements are uniformly distributed across the network.

It has been discussed that part of the achievable net benefits at distribution network level could be transferred to final customer and part could be kept by DSOs, according to the design of the remuneration mechanisms and the distribution network tariffs in the specific country reality. Retailers and other intermediaries could share part of these savings with customers. This means that even when the potential economic benefits of AD may be significant from the perspective of society as a whole, and therefore from the regulator standpoint, they may be dispersed across the value chain and among involved stakeholders. This may reduce the incentives for participation but not the need for the efficiency improvement that AD could bring to electricity systems and society.[3]

Main regulatory barriers

The main **regulatory barriers** to develop AD are related to the difficulties to equally access and operate in the electricity markets. Some of these impediments are only physical or technological, but others are regulatory. Other barriers are related to difficulties already encountered when putting in practice any form of AD.
From the revision of the main regulatory aspects that should be reviewed in order to unlock the potential of AD, the most critical concerns that have arisen are:

- **DSO regulation** could be revised in order to incentivize DSO to make long-term efficient investments and reward innovation more than focus on short-term optimization.
- Regulation should ensure that end users receive cost-reflective **tariffs** to make the most efficient decisions as a whole (considering as well simplicity concerns).
- DSO could be entitled the choice to count on certain forms of AD to alleviate **congestions**, which remain to be defined and delimited but a

direct commercial relationship with customers may not be advisable because DSO have an advantageous position in relation to access to metering data.

- A **competitive market** without entry barriers should be ensured for retailers, aggregators and other commercial agents to provide smart AD services.
- **Standardization** in relation to Smart Metering functionalities and smart appliances is an open issue of discussion but under certain circumstances, it could be advisable not only at MS level but even at EU level.
- **Consumer protection** should be guaranteed beyond the security of the data to the rights of consumers to be informed and be provided the tools to understand the new smart tariffs and complex contracts to which they can be exposed.

It is hence possible to improve the current regulatory practices for the application of Active Demand in the European context and consequently contribute to the achievement of the EU targets of energy efficiency improvement and consumer engagement and protection. [3]

Conclusion

Within the ADVANCED research project, co-funded by the European Community's Seventh Framework Programme under grant agreement n° 308923, the impact of active demand on the electrical system and its actors have been quantified.

The flexibilities that AD might offer with demand response and energy efficiency in France, Germany, Italy and Spain have been calculated for a baseline, optimistic and technical potential scenario. The results about energy efficiency in the four countries show it is one of the most important untapped energy resources today. In fact the baseline scenario leads to an AD potential ranging between 216 GWh for Italy (0,27%) and 3.898 GWh for Germany (3,07%), while the optimistic scenario leads to an AD potential of energy efficiency ranging between 1.879 GWh for Spain (2,28%) and 9.220 GWh for Germany (7,26 %). It could also be shown that raising the energy efficiency potential would also create significant advantages for consumers in monetary terms. Potentials in terms of demand response might be small per country or sector but the effect of abolishing existing regulatory barriers (i.e. moving from baseline to optimistic assumptions) is still very significant. In the baseline scenario potential ranges between 0,12% for Germany and 0,20% for Spain. These relative numbers relate only to a power demand of 120 MW for Germany up to 200 MW for Spain (this does not take into account the current flexibility in Germany of 26,1% of residential peak load). In the optimistic scenario leads to 280 MW for France (0,65%) up to 1.320 MW for Italy (8,25%), (this does not take into account the current day-night flexibility in France of 7,91%). Higher potentials are most probably to be found in the C&I sector, where for German market even in the baseline scenario 3.200 MW have been estimated. The future market of flexibilities requires different products to content the demand of flexibilities for the DSOs. Basically different types of flexibilities are available which comply with different demands like e.g. local or temporal availability. Which kind of flexibility option will be successful is determined by the market.

A special DSO perspective was taken in order to find a fit between DSO's (expansion) needs and the possibilities of AD. The outcomes of this analysis are four major categories of (future) system services: frequency control, optimization of distribution network planning and construction, optimization of system operation, management of emergency situations, network or system restoration and islanding. The views of the DSOs might differ depending on each national context: main drivers for network investments (renewable energy sources development or peak load increase), regulatory context (for example, existence of aggregators or not, or level of smart meters roll-out). DSOs generally express the fact that AD could help them defer or down-size investments in the future or help them control power flows and optimize operations.

The benefits in terms of investments for the distribution network reinforcements that a more efficient use of existing and new grid capacity due to AD could defer or avoid have been evaluated. The analysis showed that these benefits are strongly dependent on network expansion drivers, network typology, current level of network constraint, and location of responsive consumers. The main regulatory aspects that should be reviewed in order to unlock the potential of AD have been identified: DSO's remuneration, tariff design, market rules and business models, standardisation and consumer protection.

REFERENCES

[1] R. Bachiller, S. Brambilla, O. Franz, P. Frias, M. Laskowski, M. Miquel, T. Schmid, 2014 "Quantification of flexibilities based on AD for the impact assessment", ADVANCED project

[2] M. Miquel, M. Viana, S. Di Carlo, P. Frias, T. Schmid, R. Bachiller, O. Franz, 2014 "AD applied for system services primarily in LV-MV grids", ADVANCED project

[3] M. Valles, P. Frias, R. Bachiller, M. Miquel, O. Franz, T. Schmid, S. Di Carlo, J. Rodrigues, 2014 "Quantification of economic AD benefits for stakeholders in different regulatory frameworks" ", ADVANCED project