DISPATCH 2: Energy Flexibility from Large Prosumers in the Urban Area

A legal and technical case study on the Amsterdam ArenA stadium

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I. INTRODUCTION

The anticipated integration of large amounts of stochastic renewable energy sources (RES) and energy intensive distributed energy resources (DER) increases the uncertainty in power consumption and production. Especially in dense urban areas, stochastic behaviour of DER changes energy demand and consumption patterns over time due to the changes of heavy appliances, such as heat pumps, charging electric vehicles and other electric transportation systems. Meanwhile, another important source of uncertainty in future power systems comes from the intermittency of RES. RES are much harder to predict and schedule than on-demand sources. These uncertainties make it increasingly difficult to: 1) operate the electricity network within secure operation limits, and 2) balance the demand and supply over time. To cope with these issues, current distribution networks evolve from passive to more active distribution systems, using advanced monitoring and control applications. However, notwithstanding the promising capabilities of these control applications and functionalities, additional flexibility from system users is expected to be required in order to address these challenges.

Several research projects address possible approaches to invoke flexibility from large prosumers and end users through aggregators. While these projects are different depending on the goals of using customers' flexibility, considered time horizons, as well as other physical constraints, this work will focus on how the availability from large system users in urban areas can be made available for both distribution network operation and system balancing. The presented framework aims to open up flexibility to energy markets, reserve markets and local flexibility markets facilitating distribution network operation, illustrated by a practical case study of the dense urban area surrounding the Amsterdam ArenA stadium.

II. POWER SYSTEM CHALLENGES

A. Distribution system operation

The introduction of large amounts of RES and DER will undoubtedly lead to increasing network problems for distribution system operators (DSO), such as power congestions or large voltage variations. It is expected that the required peak capacity will increase over the years. Conventionally, increasing the peak capacity requires installing additional cables and/or expansion of components in substations. Installing new cabling infrastructure requires opening the underground, which is often not a preferred choice in dense urban areas. Also, the already limited space available in substations is likely to be insufficient to host additional equipment. Besides congestion problems, voltage problems due to heavy loads and distributed generation with fast transients will require voltage controllers, such as on-load tap-changers, to act more frequently, causing additional life-time degradation. Finally, distribution losses will increase under heavier loading, causing additional operational costs. As a solution, local demand and supply matching or peak shaving is expected to provide a better solution, preventing an increase of operation and investment costs for the network operator. An additional benefit for large customers might be savings on their connection costs, as the peak capacity often determines part of the connection costs.

B. System balancing

These days, liberalized electricity markets are in place on a system level scale with day-ahead, intra-day, and balancing trading mechanisms, to ensure energy balance in the system as a whole, at different time scales. Balance responsible parties (BRPs) should have a balanced position for every programme time unit (PTU) [1], whereas transmission system operators (TSO) are responsible to resolve any remaining imbalances and charge the responsible BRP with the corresponding costs. With massive amount of intermittent power sources, it becomes increasingly difficult for BRPs to meet their programmes. Additionally, TSOs face increasing difficulties in ensuring a system balance at all times. Therefore, besides central electricity markets, a need for a new market design, establishing market participation of system users in lower system levels, emerges.

III. FRAMEWORK FOR PROVIDING FLEXIBILITY

In order to establish a framework, in which flexibility can be traded, it is important to define the relevant roles, current actors, and market structures used for trading flexibility. A second necessary step is to identify the relevant legal structures applicable to flexibility trade and, consequently, how actors

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can trade flexibility within the possibilities and limitations specified.

A. Roles in energy flexibility trading

In flexibility trading, multiple roles can be identified and carried out by various actors. Firstly, in generating flexibility by system users, their aim is either to lower the costs of their own energy, or to increase their trade profits. As all system users have balance responsibility, their energy portfolio has to be balanced [1]. Secondly, DSOs, TSOs, BRPs, energy traders (ETs), and energy service providers (ESPs), might be interested in exploiting flexibility for network operation or balancing purposes as introduced in section II. All actors play a role to lower the costs of system operation, hence, lower the total system costs, by minimising investment costs, maintenance costs, network losses and imbalance costs. ETs buy and (re)sell flexibility to make a profit out of either selling flexibility as a commodity or service, or by using flexibility to increase the profit margin of their energy trades (e.g. by buffering electricity from PTU to PTU in the wholesale electricity market). ESPs offer services related to electricity consumption, production, and trade. For example, an ESP can act as a BRP on behalf of system users, or it can offer services that increase or generate efficiency and flexibility on system users' premises. In addition, ESPs can act as aggregators of flexibility. It is the ESP's aim to offer services to clients that make the clients' processes more efficient. By doing so, the ESP is able to create value for its services and increase its profits.

B. Overall framework

System users (or ETs on their behalf) or ETs can either sell flexibility using spot markets, or bilateral agreements. As flexibility can be used for different purposes, multiple platforms within the current market structure can be used for trading flexibility. In addition, flexibility can be traded in different forms. For example, flexibility can be sold as energy on the wholesale electricity markets, or as a service, on for example the ancillary services market or in bilateral agreements with third parties [5]. Most relevant to this paper are the ancillary services market, used by the TSO, wholesale electricity markets, used for energy trade, and bilateral connection and service agreements between DSOs and system users.

C. Relevant legislation

The relevant legislation can be divided into three different categories: 1) EU Regulations and Directives; 2) National Acts; 3) National network and tariff Codes. Also on EU level Network Codes (NCs) are adopted. However, as these codes are adopted as (Commission) Regulations, the EU NCs are considered as (general) Regulations [4]. Whilst EU law provides the general framework for system operation and electricity trade for all EU Member States, most detailed legislation can be found in national legislation, and more specifically, national codes.

IV. CASE STUDY: AMSTERDAM ARENA

The case studies in this section demonstrate the appropriateness and the feasibility of the framework applied to the network in the urban area of the Amsterdam ArenA to gain benefits for all parties involved [6].

A. Case study 1: DSOs' Benefits

This case study aims to identify a potential solution for repeated transient and voltage instability of the distribution network surrounding the ArenA due to frequent changes in primary energy demands. As a railway station sites right next to the ArenA, accelerating trains causes frequent, short-term voltage drops in the distribution network. Leaving the station, a train requires a high amount of energy within a 30 seconds window to accelerate. Due to the limited network capacity, this substantial demand significantly decreases the voltage at the station bus bar, which is shared with the ArenA. By automatically initiating a voltage control mechanism at the subsystem/transformer, which takes around 20 seconds to complete, the voltage level is compensated until the situation is restored back to normal. As this happens several times within just a few minutes, these fluctuations lead to the voltage instability and cause life time degradation of the involved components. In this case study, the issues are addressed using the described framework with the application of a storage system and an active control algorithm.

B. Case study 2: System Users' Benefits

This case presents a cost-effective solution for peak load shaving using battery storage. It demonstrates the cost reduction in the ArenA's operation with the support of a local supply and demand matching system. Firstly, by balancing out and shifting the ArenA's local loads during the day, the ArenA requires less connection capacity and is able to benefit from lower connection tariffs. Secondly, energy stored in the battery system could also reduce the ArenA's peak power demand. Reducing peak power demand would lower the ArenA's transport tariff (kW_{max} and $kW_{contracted}$) [7], and as a result, could reduce the energy costs for various stadium events.

V. CONCLUSIONS

To address future challenges of power system operation in dense urban areas, flexibility from large system users can surely play an important role. In order to operate an effective and successful flexibility market, adequate technical and legal frameworks are crucial. The full paper will show this in the case of the ArenA.

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