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A LOCAL ELECTRICITY MARKET DESIGN FOR THE COORDINATION OF DISTRIBUTED ENERGY RESOURCES IN A NEIGHBORHOOD

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Abstract. The increasing presence of distributed energy resources (DERs) at the residential distribution grid level creates concerns regarding its successful integration without an appropriate market structure. The current market structure has been designed by not taking DERs into account. Nevertheless, the coexistence of generation and consumption at the premises of a neighborhood enables the creation of a local electricity market, a step towards the economical and technical integration of DERs. Numerous local electricity market designs have been proposed for different configurations of market participants, type of products, trading horizons, market rules, relations between the participants, degree of DERs penetration, and information and communication technologies (ICT) used. This paper focuses on these market designs, attempts to recognize the appropriate market design choices and proposes a local electricity market design in a neighborhood with the presence of inelastic loads, photovoltaic (PV) generators and small-scale energy storage.

Keywords: distributed energy storage, electricity market modeling and design, local electricity market, integration of distributed energy resources, residential distribution grid.

INTRODUCTION

Distributed energy resources (DERs) include distributed generators (DGs), distributed energy storage (DES), and demand response (DR) [1]. These resources are useful for diversifying the generation mix, increasing energy autonomy of consumers, providing energy for remote areas, reducing CO_2 emissions, and provide ancillary services. Nevertheless, their integration in the existing power system raises technical concerns regarding their participation into the existing electricity market structure [2]. While DERs of intermittent nature, such as PV or wind turbines already constitute a significant part of the generation mix, the European wholesale electricity markets have not been designed taking their characteristics (production variability, low-predictability, zero marginal cost of generation and strong site specificity) into account [3], thus making their market integration harder. Furthermore, the introduction of bidirectional power flows due to DGs in a grid designed for mono-directional flows implies the need for technical changes to adapt to the emerging grid configuration.

A solution proposed for the market and technical integration of DERs is the establishment of local electricity markets in order to apply market-based control (MBC) [4]-[8]. These markets, via appropriate price-signals, enable the coordination of the DERs for avoiding violation of grid stability limits or power quality issues, as well as for providing ancillary services. Moreover, taking advantage of the locality of generation and consumption, these local markets can reduce the electricity price for the end-user and the transmission losses by realizing energy trading between end-users in close proximity. The design of a local electricity market depends on the configuration of the local power system, the objectives of the stakeholders involved and the characteristics of the market participants. For example, the local power system can be grid-connected or isolated, the designers can aim for maximum social welfare or minimum equilibrium market price and the participants can be passive energy consumers, producers, or prosumers (consumer and producer). In this paper, the appropriate design choices for a local electricity market with inelastic demand, PV generators and small-scale energy storage is examined. The demand is assumed to be inelastic to represent household occupants not willing to affect their comfort by changing consumption patterns according to price-signals. The use of PV generators and their combination with energy storage is a natural choice for a household, since PV generators are noiseless, emission-free, require little maintenance and can be mounted on unused space such as rooftops. The flexibility offered by small-scale energy storage is used as a response to the diminishing and soon to be extinct feed-in tariffs, as well as the need to mitigate the intermittent nature of PVs.

MARKET-BASED CONTROL AND LOCAL ELECTRICITY MARKETS

In [9], the authors divide the market participants into macroplayers (Producers, Suppliers, System Operators, Network Operators) and microplayers (consumers, prosumers, aggregators). The former provide the technical constraints of the system and produce the appropriate price-signals for the latter, who adapt their generation or consumption accordingly. Thus, they define MBC as the design and implementation of the price-signals by the macroplayers in order to optimize global system performance through the coordination of the resources of the microplayers towards predefined network and market system goals. The price-signals are control signals which provide set-points for the generators, storages or loads of the local network. These price-signals can be converted to actual prices to enable direct electricity trading between the local market participants. In this way, the technical constraints of the local network are satisfied, while the end-users gain access to a free market for their traded products. Depending on market designing criterion, MBC can been implemented in hierarchical structures [10]-[12], [16], or fully distributed [13], [14]. While central accounting and logging node(s) are a necessity in every structure, the distinction between hierarchical and fully distributed structures in this case is based on the possibility of communication between the end-users, which is possible in fully distributed structures. The hierarchical control structures are characterized by supervisory nodes at higher levels of the structure, reducing the risk of unresolved conflicts between the nodes at lower levels of the structure and requiring less communication signals. The fully distributed control structures are more flexible, require less monitoring and enable the coordination of the system at the lower level with every node possessing only local knowledge. A schematic of market-based control is shown in Fig.1. The Distribution System Operator (DSO) monitors the performance of the distribution neighborhood and determines the network constraints that influence the price-signals in the local electricity market. The prosumers in the distribution network submit their bids to the local market (organized by an aggregator) and expect the price-signals to determine the set-points of their devices.

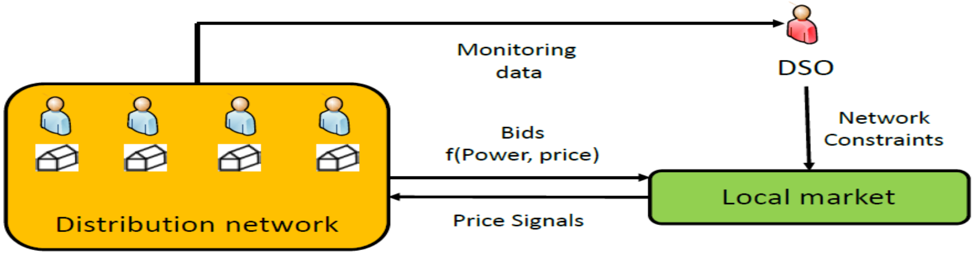

Figure 1: Market-based Control Schematic.

EXPECTED RESULTS

The expected result of the insights gained from the bibliographical research is a market model designed to coordinate the DERs of a neighborhood with the presence of inelastic loads, PV generators and micro-storage at the household level. The objectives, the rules, the trading horizons and the forecasting horizons of the market have to be defined. This work is a step towards the design and implementation of a multi-agent framework for the coordination of DERs, especially PV generators and energy storage, at the residential distribution grid level.

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