THE INNOVATIVE ROLE OF LOCAL SYSTEM OPERATOR AS A FACILITATOR OF GRID AND COMMUNITY SERVICES IN THE LOCAL ELECTRICITY MARKET

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ABSTRACT

Local electricity markets offer attractive solutions to long pending grid challenges associated with grid balancing, power quality and supply security, particularly with increased introduction of distributed renewable energy resources. This paper addresses questions regarding the roles, responsibilities and rights associated with local market participation, as well as issues that relate to the activities which can be carried out in the market. We describe the local system operator (LSO) as the most central role that is in charge of the operation of the local electricity market and we add to the state-of-the-art by paying particular attention to the possibilities that digitization offers within the local market context. More specifically, the capabilities of utilizing big data, machine learning and artificial intelligence to provide new or amplified business opportunities for the local market participants are central for the market design configuration that this paper focuses upon. Furthermore, we expect high stakeholder interest in the digitization-enabled innovative services around smart mobility and complementary offers of high diversity.

INTRODUCTION

Decarbonization of the European electricity system has been set in motion with the rapid proliferation of distributed and renewable energy production sources. By 2050, it is expected to have millions of prosumers, electric vehicles and storage units willing to provide energy and flexibility that will be capitalized on by distribution grids. Additionally, the EU has committed to cut CO_2 emissions by at least 40% and increase share of renewable energy to 27% of the total energy consumption by 2030. To achieve this target and overcome challenges associated with renewable sources (intermittent production, integration with grid, self-consumption versus storage, etc.), the European Commission recently published the Clean Energy Package with a proposal to revise and regulate internal electricity markets. Article 16 of the proposal defines local energy communities and considers them to be an efficient way to manage energy at the community level. This has resulted in a global surge in interest for local electricity markets that can provide a wide range of grid and community services for both the network operators and neighbourhoods. Enabled by advances in ICT and digitalization of the grid, there is immense scope for multiple stakeholders assuming varied roles in the local electricity markets.

The proposed market concept is developed within the E-REGIO project, funded through the ERA-Net Smart Grids Plus initiative, with support from the European Union's Horizon 2020 research and innovation program. While previous research on local markets has predominantly focused on utilizing renewable and local energy and the associated flexibility-related attainment of economic benefits for community members, E-REGIO adds to the state-of-the-art by paying particular attention to the possibilities that digitization offers within the local market context. More specifically, the capabilities of utilizing big data, machine learning and artificial intelligence to provide new or amplified business opportunities for the local market participants are central for the E-REGIO market design configuration. In particular, we expect high stakeholder interest in the digitization-enabled innovative services around smart mobility and complementary offers of high diversity.

The proposed market design serves the market activities in a local power system, i.e. the system on MV and LV distribution level. The local system is mainly supplied by energy through national transmission grid, while small-scale distributed generation (DG) is connected at distribution grid level. We consider the local electricity market as a complement of the wholesale market and the traditional top-down trading framework. It is designed according to following principles: fulfils market participants' requirements; caters for the provision of diverse complementary services; enables small customers to actively participate in the energy market; encourages the utilization of local renewable energy; facilitates the control and utilization of demand-side flexibility; improves price equity and energy consciousness; promotes investments in renewable energy; applies market rules that are simple for small customers to understand and implement.

THE ROLE OF LOCAL SYSTEM OPERATOR

The E-REGIO local market (E-REGIO LM) design is grounded on robust local community interests based on the following four fortifying elements:

Figure 1 -Local community interests as foundation for robust E-REGIO local market design

Participants in the E-REGIO local market are the LSO and the two types of LSO customers - end-users (small customers) and MV/HV level customers. The LSO carries out a joint optimization of flexibility loads (as an aggregator), energy planning (as a retailer and intermediary), energy storage scheduling (as an energy storage manager) and EV scheduling (as an EV operator) to provide grid and community services. Based on customer preferences, the objective of the LSO's optimization could be to prioritize either community or grid services or both. Additionally, the LSO can also provide technical and value-added services through the complementary services platform (Figure 2).

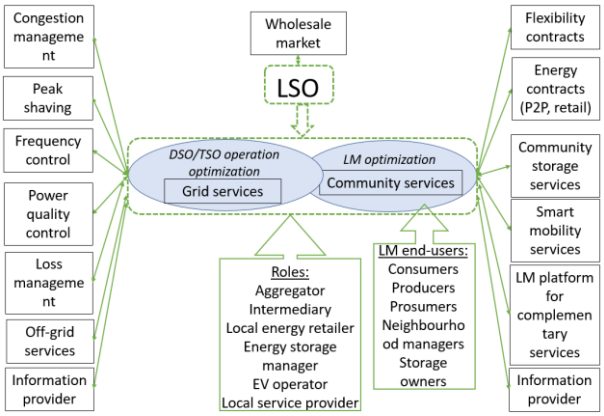

Figure 2 - – E-REGIO local market design (LSOs roles/services and local market participants)

A more detailed description of the key roles of the LSO as manager of the local energy market is provided below:

Aggregator

The LSO aggregates the flexibility loads of the local end-users through flexibility contracts. The flexibility can then be sold to the various HV/MV-customers, or other customers that need balancing/back-up power

Market maker

The LSO incentivizes community members to purchase and sale locally generated power. Facilitates the local trade. This role could be particularly important under the conditions of constrained /congested areas and during specific periods with high demand/supply fluctuations. In such occasions the possibility that the LSO optimizes local trade with the help of community storage could be highly beneficial.

Intermediary

The LSO acts facilitates the trade between the external electricity markets and the local market - selling/buying flexibility via agreement/contract to provide various balancing services/grid services on a multi-sided platform (to transmission/distribution system operators (TSO/DSO) and balancing responsible parties (BRPs)).

Energy storage manager

The LSO optimizes the use of storage systems based on a predefined set of priorities and moods of ownership and operation (integration and combination of price arbitrage and local balancing usage). The set of priorities should be fixed for each particular business model alternative (e.g., the business use cases described later on). Yet, it should be acknowledged that in case the set of priorities is not fixed, but dynamic, its configuration will become subject to an internal trading scheme (e.g., an internal flexibility market utilizing on storage capacities).

Local energy and flexibility retailer

As a local retailer, the LSO creates the local energy & flexibility contracts and ensures that they are clear, concise and transparent. Three types of contracts are mainly offered by the local energy and flexibility retailer.

Energy retail contracts: 1) conventional retail contract issued by any retailer (fixed, spot, etc.); 2) local peer-to-peer (P2P) contract issued by LSO; 3) Joint solution with conventional and P2P contracts combined.

Flexibility retail contracts: 1) conventional flexibility contracts related to the previously described aggregator role; 2) local P2P contract; 3) combined contract.

Combined energy and flexibility contract: a combination of the above proposed types.

The values built for the customers lie in addressing their various preferences. Depending on the purpose(s) of using the contracts, the LSO creates the following values to the participants of the community services:

Trade energy (electricity) through LSO

Consumers, prosumers and producers can buy or sell electricity through LSO with the energy retail contracts. With the conventional retail contract, customers will buy or sell electricity at a predefined price (flat or spot-related) from a typical retailer. Meanwhile, the local P2P contract complements the conventional retail contract by introducing more favorable energy prices for local producers and prosumers to sell the renewable generation to the local market. Under the supervision of LSO, the traded electricity volumes, time periods, and prices are issued in the contracts.

As a result, the following values are brought to the customers:

- Change the unprofitable conditions for prosumers and local producers and mitigate cross subsidy
- Raise the sustainable energy awareness among the consumers
- Local community contributions and empowerment
- Access to real-time information about local production & consumption

Conventional retailers could also benefit from P2P contracts by obtaining new revenue streams and engaging new customers via innovative services.

Trade flexibility through LSO

Due to the increasing number of inhabitants who are equipped with flexible devices such as electric vehicle (EV), battery, decentralized power generation unit, etc., the LSO offers flexibility retail contracts to get access to the flexibility data and manage the smart energy assets for enabling the customers to trade flexibility.

The following values are brought to the customers:

- Schedule flexibility to utilize the devices in a more economic and efficient way
- Facilitate trading and aggregation of flexibility by providing, e.g., time varied electricity tariff, real-time information about price or renewable generation, scheduling program, consumption profile forecast, etc.
- Share the revenues from supplying flexibility resources to the external energy markets via the LSO aggregator

EV operator

The LSO as an EV operator offers a wide range of smart mobility services. It can also be part of the energy and flexibility trading solutions as long as the energy storage or EVs are included in the customers' portfolio. In this way, the EV operator provides a service platform which enables the end-users to have access to an EV pool, and take the EVs for driving in a shared scheme without worrying about the charging status. The EV fleet owner(s) can rent out the EV assets for driving, peak shaving in the facility loads (or backup energy resources for building blocks), and also delivering flexibility services to external power market (vehicle-to-grid). To provide the services, the EV operator should be able to coordinate the charging schedules, EV driving requests, and internal & external flexibility service requests (e.g. peak shaving, frequency control and portfolio balancing, etc.). The following values are brought to the customers of the EV operator:

- Economical charging solutions
- Maximum the usage of e-mobility batteries – vehicle-to-building (V2B) services and peak tariff savings
- Revenue from V2G: renting out EV flexibility and making revenues out of it
- The state of charge (SOC) is assured to be sufficient for the driving plans through implementing a 24h-dynamic scheduling system
- Raise "green" community awareness

Local service provider

The LSO can also provide technical and value-added services through the complementary services platform. Some examples could be clearing information, maintenance, advertising, cross-subsidies, etc. Part of the services would be typically outsourced to external actors (complementors to the platform).

A relevant example could be integrating the local market (LM) with the existing "charging networks", operated by various complementors, across the cities and countries. This kind of ecosystem should be embraced, so as to provide a more holistic and flexible solution. So, under some circumstances, customers can take advantage from the third party network, and easily get access to their existing systems via the connections built or facilitated by the LSO.

The benefits associated with catering for complementary services can be twofold, associated with the reinforcing process of business growth that they provoke. The more diverse specter of highly customized and innovative services that the LSO provides (or enables the provision of), the more citizens will be attracted to become its customers. On the other hand, the larger the customer base that an LSO has, the more complementors will be willing to add to the LM platform for complementary services, thus again create a greater ecosystem.

BUSINESS USE CASES

In this chapter, two business use cases based on two of the LSO roles will be discussed respectively. Following the methodology presented in Figure 2, each business case shows a specific commercial opportunity in the current market, from both technical and value-added service perspective (e.g., related to the complementary service market domain). The two main business cases are: i) P2P energy & flexibility contract, ii) smart electric mobility service. Figure 3 is formulated to visualize the approach to business use case implementation within the E-REGIO project - trough pilots and practical tests.

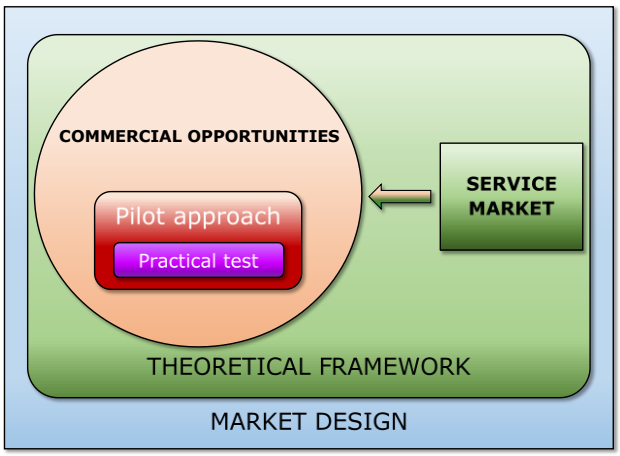

Figure 3 - Approach to business use case implementation within the E-REGIO project

P2P energy & flexibility contract

The idea of the P2P contract is to improve the economic conditions and environmental/community consciousness of prosumers/local producers and enhance the more efficient and economically beneficial usage of flexibility from the distributed energy resources. In this relation, the LSO delivers energy & flexibility services to the

customers via inserting value-added options to the existing retailing contract frames.

Collection of premium in the P2P energy contract
In general, consumers pay an electricity price with following components: electricity fee, grid fee, retailing fee, energy tax, certificate, and VAT. The proposed contract introduces a premium scheme for encouraging local renewable production and consumption. In order to generate incentives for collecting the premiums, the energy tax paid by the consumers could be reduced through regulatory support. To do so, the tax reduction initiatives need to be approved by the authorities. A LM customer can subscribe to the new service option of "P2P contract" in the retailing contract issued by the LSO (as an energy and flexibility retailer), or by an "alliance" of the LSO and conventional retailers. In this way, the consumers pay reduced taxes for their electricity consumption from local market, at the same time, the prosumers receive a certain amount of premium. Moreover, consumers/prosumers ca be authorized with "free use of energy" for specific purposes, like free use of community EV charging stations while there is renewable supply from the prosumers to the local market. In addition, they will be allocated with sustainability coins and can later use them as credits/tokens for getting energy consumption discounts or for exchanging other services

Conditions contained in the P2P flexibility contract
In the P2P flexibility option, the flexibility providers can register their distributed power assets digitally on the "P2P contracts". The terms in the contracts include the ID, available time, volume, and price of the flexibility in their assets (e.g., EVs, heat pumps, boilers, etc.). On the other hand, the flexibility buyers will state their procurement conditions in the "P2P contracts".

Execution of the P2P energy & flexibility contract
Since the aforementioned services are significantly based on measuring, collecting, monitoring and analyzing data and information flows, a SMART Ledger for the consumers and prosumers is created to manage the real-time energy and flexibility data, and also to conduct forecasting when it is needed. Upon this fundamental ICT system, the contracts are issued and executed automatically to fulfill the supply and demand. At the same time, the financial settlements are also documented in the SMART Ledger, showing customers the transaction records regarding the P2P energy & flexibility contracts.

Smart electric mobility service

The business case of this service is built on a multi-sided platform. This platform is designed to interact with different types of customers, so as to meet various requirements. On the top layer of the platform, the core functionalities are clarified. The primary function is to allow the end-users (e.g., employees working in the building and resident tenants) to book the EVs for driving. Secondly, the platform optimizes the charging cost of the EV fleet. Last but not least important, the service system enables "vehicle to building" (V2B) and "vehicle to grid" (V2G). As a result, the residential housing owner (EV pool owner in this case) can benefit from the dynamic charging/discharging for peak-shaving of facility loads. At the same time, the external energy market actors (TSO, DSO, BRP, etc.) can obtain frequency regulation, congestion management and portfolio balancing via the V2G functionality.

Future research related to the E-REGIO LM, will examine the linkage between the mobility service platform and the platform for complementary services. At first, the flexibility volume is increasing via deploying EVs in the system. Besides that, the EVs can be controlled through dynamic charging strategies, which means that they are able to use the real-time available renewable generations, and also the less expensive energy stored in the local battery units. In this way, the distributed energy resources can be connected in an optimized way. The integrated system can be operated and supervised by the LSO - e.g., as part of its aggregator role.

CONCLUSIONS

In this paper, we present a broad techno-economic design framework for local electricity markets managed by a local system operator (LSO). On the technical front, the LSO provides a range of network and grid services such as congestion management, aggregated demand side management, reactive power management, etc. On the community front, LSO provide services such as local energy/flexibility retail, smart electric mobility, energy storage management and a host of other soft complementary services. In order to provide these services, the LSO assumes multiple roles such as market maker, aggregator, EV mobility manager, etc. On the economic front, these roles present the LSO with ample business opportunities that provide economic/value benefits for all stakeholders. The proposed techno-economic local market design will be implemented and validated through pilots in the E-REGIO project.

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