EMBEDDING OF ENERGY COMMUNITIES IN THE UNIFIED *LINK*-BASED HOLISTIC ARCHITECTURE

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ABSTRACT

Certain categories of citizen energy initiatives are increasingly recognised as "local/citizen energy communities". This implies an enabling regulatory framework, fair treatment and a well-defined catalogue of rights and obligations to deploy certain functions in the energy system at local level.

The establishment of energy communities should be valuable and profitable both for society and energy market players by providing the ability to drive local environmental, economic or social benefits for its members or the local area where they operate.

There are a variety of approaches available that will determine the direction in which the power system will evolve and adapt to meet the future requirements. Some of these approaches have been tested in real life, operational environments and demonstrated to be technically viable solutions for providing a more cost effective way of integrating renewable generation while maintaining the required levels of security of supply and power quality. In this short paper, focus is placed on the approach Energy Communities, which is leveraging on the fast diffusion of Distributed Energy Resources in most worldwide grids

In order to foster the emergence of Energy Communities, while facilitating their integration into the electrical energy system through the minimization of data exchange requirements and allowing them to provide ancillary services to the system, a holistic architecture is proposed in this paper (LINK-based holistic architecture).

INTRODUCTION

Electricity systems are facing challenges of unprecedented proportions. In coming decade a very substantial proportion of the electricity generation would become largely decarbonized, while beyond 2030, it is expected that significant segments of the heat and transport sectors will be electrified. Furthermore, in response to growing concerns associated with the security of energy supplies there is a growing interest in enhancing supply reliance based on local energy resources and smart decentralised control.

In this context coordination of distributed energy resources (DER) that provide flexibility services could facilitate cost effective and secure system evolution. DER integration at several voltage levels creates replicative managing schemes to meet the demand and the technical constraints of the network, and enables the development of energy communities. It also leads to the need to redefine the holistic architecture of the system, to clarify the relation between different entities and voltage levels, and to reassess the data exchange between different segments of the sector.

Worldwide, there are many “energy community” related concepts like “Local Energy Communities, LEC” in EU [1], “Advanced Energy Communities” in USA [2], “Smart Community” in Japan [3], “Community Energy” in Australia [4], etc. Basically, all these concepts differ only in their formulation, they actually have a common basis and a common goal. The scope of all of them comprises prosumers and Distributed Energy Resources, DERs, but without having defined the voltage level (medium or low voltage level or both). In each of them it is underlined the participation to the energy market without discriminating nor impairing the market and competition. Additionally, in each of them the focus is set on the benefits of the whole community rather than individuals. The development and the implementation of energy communities face many challenges and obstacles of various kinds, such as technical, regulatory, legal, economic and stakeholder-related issues [5].

Many technical challenges for the Energy Community (EC) realization exist in Microgrids that are still subject to research by both academia and industry [5] [6] [7]. The size of Microgrids is still undefined, which makes their practical implementation almost impossible. The interactions between the transmission and distribution grids can hardly be considered, so the Microgrid operation connected to the host power system does not seem to be realistic. The scope of the host power system is undefined which in many cases creates confusion.

The power system is a unique, huge electromagnetic machine that encompasses the entire power system and customer facilities. A holistic view of this huge machine combined with the electricity market is necessary to enable the new developments.

The *LINK*-based holistic architecture encompasses the entire power system, customer facilities and the market [8] [9] [10]. In this context, *LINK*-based holistic architecture will also put Energy Communities and end consumers in the center of decision-making processes regarding future system operation and development, while simultaneously delivering significantly more competitive electricity markets.

It uses the secondary control (on active and reactive power) as an instrument to reach a resilient operation of the whole grid. Autonomous operation is the main operation mode of the *LINK*-Solution. In this case each individual Link or Link-bundle operates independently by respecting the contractual arrangements with other relevant boundary Links or Link-bundles. Autarkic is an optional operating mode, which may be applied in any Link-bundle, which consists of at least one Grid-Link and one Producer-Link or Storage-Link, as long as it is self-sufficient and self-sustaining without any dependency on electricity imports.

This paper presents the concept and criteria for application of embedding Energy Communities in the unified *LINK*-based holistic architecture. It is based on the common aspects of the different energy communities' concepts circulating worldwide. Firstly, the overall EC concept and the facilities's ownership is discussed. Secondly, the embedding of EC with facilities ownership into the holistic architecture is presented, followed by the embedding of those without the ownership. Finally, conclusions and recommendations are outlined.

ENERGY COMMUNITY AND FACILITIES OWNERSHIP

By definition, ECs are no-profit cooperatives or organisations that include prosumers and DERs. They should enable the participation on the energy market without discriminating neither impairing the market and competition. They should bring benefits to the community participants and should represent their interests. Concerning the ownership on the electrical facilities, two cases are distinguished: EC with and without ownership on facilities as follows:

1. ECs are organized in cooperatives with ownership on the electrical facilities. Figure 1 shows an overview of an EC with ownership of electrical facilities. In this case, the EC acts as a vertically integrated company that owns and operate the distribution infrastructure, as well as DERs.

2. ECs are organised in associations or partnerships without ownership of electrical facilities. Figure 2 shows an overview of an EC without ownership of electrical facilities In this case ECs do not own or operate any electric facility. DSOs and DERs owners operate their facilities on the basis of schedules approved by the corresponding EC.

The unified *LINK*-based holistic architecture supports the embedment of ECs in both cases as shown in the following section.

EC WITH FACILITIES OWNERSHIP

Figure 3 shows the embedment of an EC with ownership on electrical facilities into the unified *LINK*-based holistic architecture. High, medium and low voltage, customer plant Grid-Links are presented through HV, MV, LV and CP_Grid-Links respectively [8]. Storage and Producer-Links are connected to all Grid-Links through technical interfaces, T. The electricity market surrounds the whole power system and the customers, enabling them all to participate in a non- discriminatory way in the market through market interfaces, M. All grid operators, both TSO and DSO, indicated by dash lined market interfaces in the figure, coordinates the market to guarantee a reliable and secure functioning of the power system [9].

The EC-cooperative, marked in green, surrounds all electrical facilities of its participants. EC owns and operates the LV_Grid-Link, and the producers and storages connected to it. Prosumer who participate in the EC are marked by a dashed area. They own their electrical equipment and act as black boxes opposite the EC, stating only the difference between their own production and their consumption. Thus, the data privacy of each customer is guaranteed. A local electricity market can be set, where the participants are all EC-cooperative members. There, they can trade the electricity with each other. The EC energy surplus or deficit can be traded throughout the market, with each EC acting as a retailer. Each market actor - i.e. simple consumers, prosumers, DER operators' service providers, who is not an EC-cooperative member –, can trade its electricity directly or through an aggregator to the whole

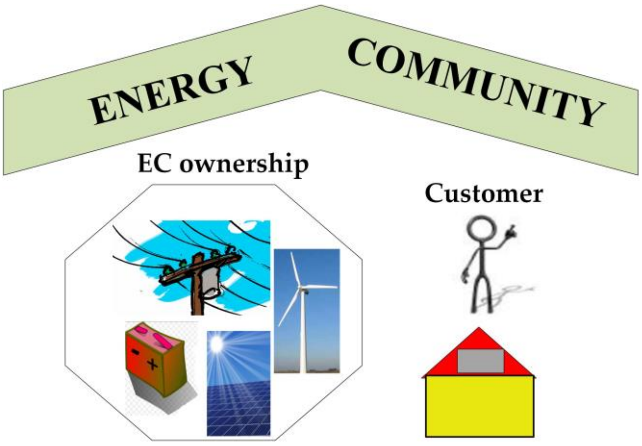

Figure 1. EC with ownership on electrical facilities

StO–Storage Operator; **EPO**–Electricity Producer Operator

Figure 2. EC without ownership on electrical facilities

market. Thus, all market actors, members and no EC members participates in the market in a non-discriminatory way. EC operates the LV_Grid-Link and coordinates the local electricity market by guaranteeing a reliable, economical and secure electricity supply. EC is responsible for the local long term supplying and storage planning and the corresponding coordination with the relevant DSO and with the neighbours (EC or Grid-Links) to guarantee the reliable power supply in its own area. The whole EC area acts as a black box opposite the neighbour Grid-Links with which it has connections. EC should exchange the required information [8] and coordinate the operation (also in terms of ancillary services provision) with neighbour Grid-Links.

EC WITHOUT FACILITIES OWNERSHIP

Figure 4 shows the embedment of an EC without ownership on electrical facilities in the unified *LINK*-based holistic architecture. All market actors, including customers joining energy communities are participating in the market in a non-discriminatory way. Each market actor - i.e. simple consumers, prosumers, DER operators, service providers - may choose to participate in the market directly, or through an aggregator or else through the EC. All grid operators, both TSO and DSO, indicated by dash lined market interfaces in the figure, coordinate the market to guarantee a reliable and secure functioning of the power system. In this case, too, a local electricity market can be set up where all participants are EC partnership members.

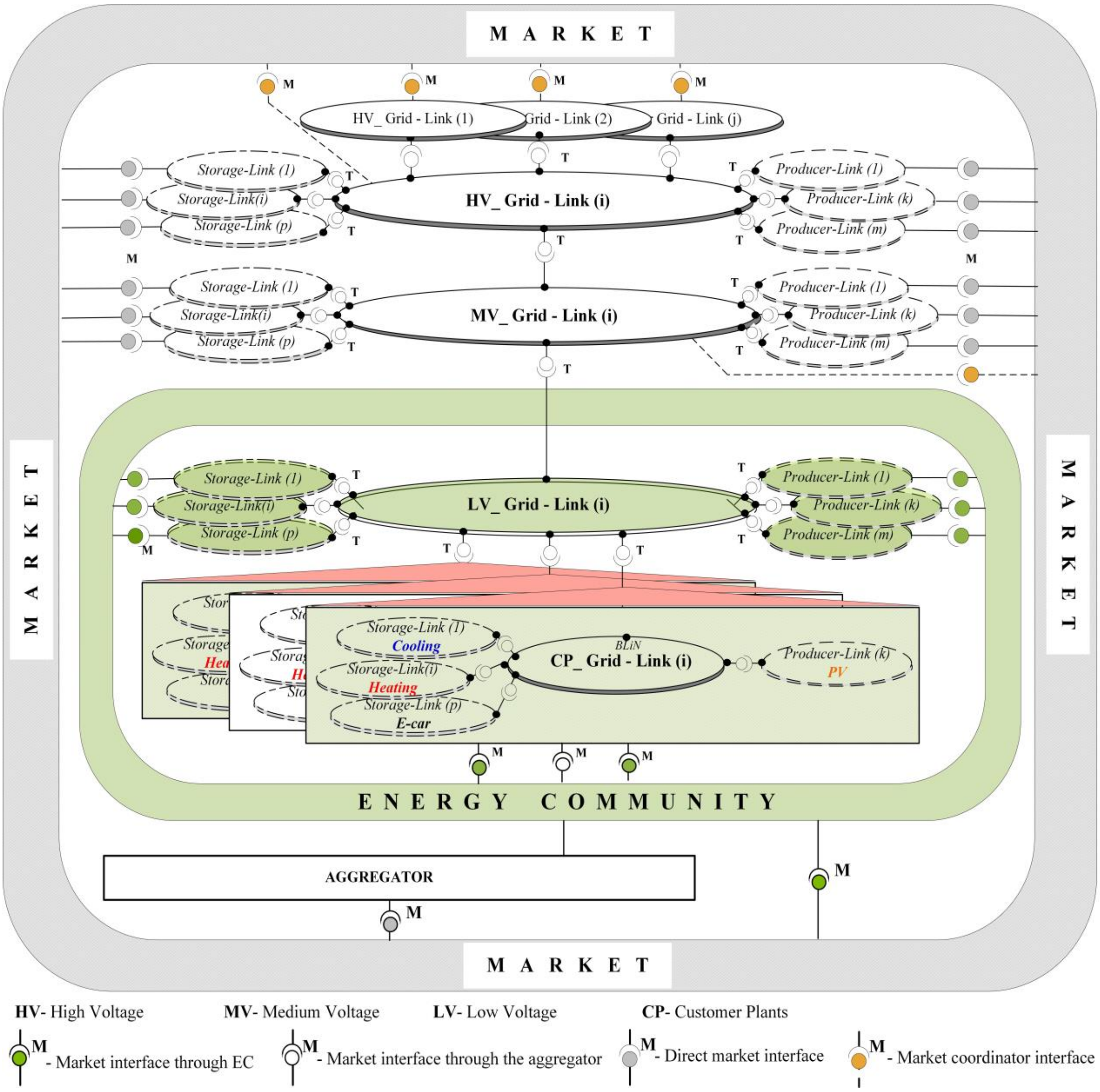

Figure 3. EC with ownership on electrical facilities embedded on the unified *LINK*-based architecture

There, they can exchange the electricity with each other. The real time schedules will be generated by EC-local market and coordinated by the operators of the neighbour Grid-Links. In the case shown in Figure 4, the LV_Grid-Link operator (DSO) will check the technical feasibility of the schedules and approve or reject them. EC is responsible for the local long term supplying and storage planning and the corresponding coordination with the neighbours Grid-Links to guarantee the power supply in its own area. Based on the *LINK*-Solution, which use the secondary control (on active and reactive power), DSOs have the technical possibility to comply with the schedules proposed by ECs [8] [9] and to coordinate the operation with the relevant TSOs (also in terms of ancillary services provision) using minimum data exchange.

CONCLUSIONS

As a conclusion, the *LINK*-based holistic architecture accommodates Energy Communities and facilitates a resilient operation of the whole power system. The main impact of EC is on distribution systems, both in planning and operation, while the impact on transmission systems is indirect. Indeed, the Very High Voltage grid shall continue to play a role of overall system supervision, especially in large and interconnected power systems like the European one. However the EC, if spread above a certain amount of penetration level, may modify the amount and directions of power flows and the daily/seasonal load patterns. Moreover, the EC may affect (in positive manner, if properly managed) the way ancillary services are provided to TSOs and traded/valorised through market mechanisms.

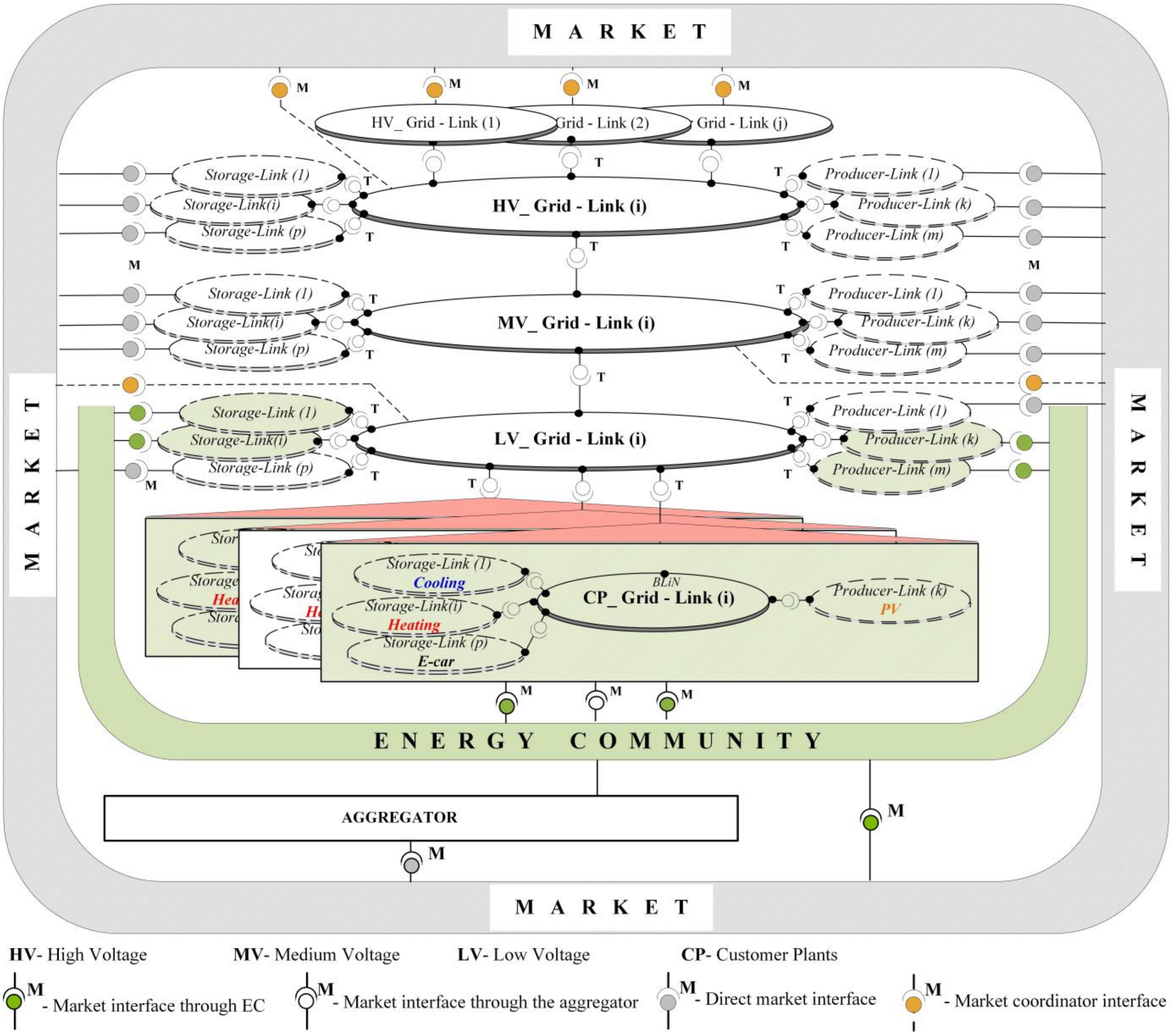

Figure 4. EC without ownership on electrical facilities embedded on the unified *LINK*-based architecture

They can also provide flexibility services to the DSO, facilitating energy transition strategies associated with increasing renewable energy hosting capacity and facilitating the deployment of electrical vehicles while minimizing the network expansion investment requirements.

While some approaches have been tested in real network environments and it has been demonstrated that they are technically viable, further economic evaluation would be needed to determine the merits of each approach. The feasibility and practicality, as well as the implementation and transition, from today's architecture to the new system, would also have to be considered. It also remains to be determined whether the best approach is a standardized approach or the implementation of different approaches that provide the most optimal solutions based on local conditions.

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APPENDICES

EU → ***Local Energy Community*** means an association, a cooperative, a partnership, a non-profit organisation, SME or other legal entity which is based on voluntary and open participation and is effectively controlled by local shareholders or members, the predominant aim of which is to provide local environment, economic or social community benefits for its members or the local areas where it operates rather than where it generates profits, and which is involved in activities such as distributed generation, storage, supply, provision of energy efficiency services, aggregation, electro-mobility and distribution system operation, including across borders [1].

USA → ***Advanced Energy Communities*** are customer-focused demonstrations that integrate multiple customer resources such as Energy Efficiency, Demand Response, Customer storage, PV(or other local generation); electrification and electric vehicles in an electrically contiguous area are to achieve larger utility and societal goals such as decarbonisation, grid hardening and grid support while enabling the utility customers with advanced technologies that provide comfort, convenience, and cost benefits to the customer. [2]

Japan → A ***Smart Community*** is a community where various next-generation technologies and advanced social systems are effectively integrated and utilized, including the efficient use of energy, utilization of heat and unused energy sources, improvement of local transportation systems and transformation of the everyday life of citizens [3].

Australia → ***Community Energy*** is generally defined by ARENA as being any renewable energy project initiated and/or developed by the community in order to deliver broad benefits to the local community. A community energy project may also be delivered in partnership with a private developer or independent power producer [4].