DEPLOYING E-MOBILITY IN THE INTERACT ENERGY COMMUNITY TO PROMOTE ADDITIONAL AND VALUABLE FLEXIBILITY RESOURCES FOR SECURE AND EFFICIENT GRID OPERATION

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ABSTRACT

The volatility of renewable energy sources and the increasing share of decentralised ones imply significant systemic requirements on the flexibility of Smart Grids. E-mobility can support their greater integration by offering flexibility in shaping the electricity demand curve, thereby reducing system costs and CO_2 emissions. This paper deploys e-mobility in the LINK-Energy Community to promote additional and valuable flexibility resources for secure and efficient grid operation. Results show that energy communities are the most vital instrument to motivate customers to provide flexibility through e-mobility actively. They may efficiently coordinate their territory's electricity generation and charging schedules and promote carpooling between the EC members. Developing the harmonised fractal market structure with the power grid based on the holistic solution LINK creates all the conditions for the deployment of successful business models. The use case and the respective business model for the congestion alleviation - emergency driven demand response involving e-mobility are described in detail. This study shows that energy communities developed under the holistic perspective of LINK offer flexibility to the grid, even in the case of electromobility.

INTRODUCTION

Power system operators, Transmission and Distribution System Operators (TSOs, DSOs) face significant challenges arising from integrating Renewable Energy Sources (RES) at the transmission, distribution and customer plant levels and the electromobility. Meeting these challenges requires flexibility on the generation and demand side.

Numerous research studies have been underway for more than a decade to enable "active demand." The identified barriers are often technical, organisational, legal, and social [1-3]. Almost all relevant research projects such as the Beywatch [1], Address [2], Fenix [3], etc. stress the need to introduce a new actor. He is referred to as a supervisor, an aggregator, an agent or a local market operator to interface between the utility, local market and customers.

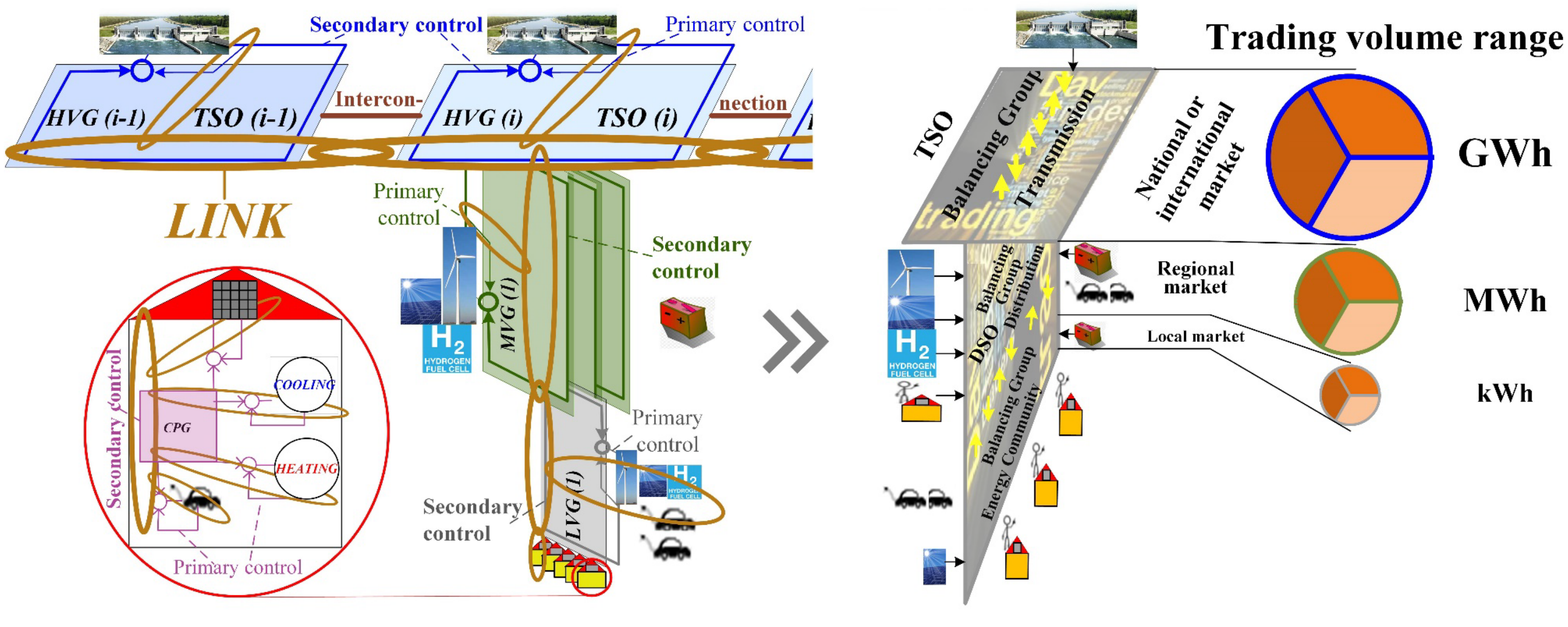
The INTERACT project considers Energy Communities (EC) a suitable actor enabling the active demand and providing the required flexibility for power system operation. They offer significant opportunities for local electricity production, consumption and Electrical Vehicle (EV) integration, taking full advantage of infrastructures by sharing resources and thus contributing to environmental protection [4]. However, the coordination of EC activities with the power grid operation and the market is essential for their emergence and a reliable and sustainable power supply and flourishing energy trading.

The INTERACT- or *LINK*-EC is developed based on *LINK*-Solution [5], built on smart grids' fractality[6].

This paper further develops the *LINK* market structure based on fractal principles. It follows an analysis of the electromobility for flexibility considering the integration to the grid, the customer attitude, the municipalities views and EC role. Finally, the use case and the respective business model for the congestion alleviation - emergency driven Demand Response (DR) involving e-mobility are described and concluded.

MARKET'S FRACTAL STRUCTURE

Like many other studies [7], *LINK* Solution postulates the creation of a local market to facilitate the local trade enabling the effective implementation of ECs. Fig. 1 shows an overview of the fractal structure of the power industry in *LINK*-Solution, which automates various processes and information exchange related to market and system operation [8]. The "Energy supply chain net," Fig. 1a, is the holistic technical model of Smart Grids, being the fundament of the *LINK* fractal structure. It has a T-arrangement, where the very high and High Voltage Grids (HVG) are set on the horizontal axis, while the Medium and Low Voltage Grids (MVG and LVG) and Customer Plants (CP) are placed on the vertical axis. The *LINK*-market design, Fig. 1b, has the same T-arrangement as the Smart Grids enabling their harmonisation. It increases the space granularity [9] of the electricity market, establishing different market categories such as the national/international markets in the transmission area, regional markets in the distribution area, and the local markets in customer plants alias EC-area.



(a) (b) (c)

Figure 1: Overview of the fractal structure of the power industry in *LINK*-Solution: (a) Energy supply chain net holistic model; (b) *LINK*-market structure; (c) Fractal range of the trading volume.

The local market consists of customers (prosumers and consumers) and Distributed Energy Resources trading energy and services in the vicinity of power production based on environmental, socio-economic and technical criteria (e.g., CO_2 reduction, welfare maximisation, power system reliability, etc.). Transmission System Operators (TSO) and Distribution System Operators (DSO) take over the role of whole market players for the transmission and distribution wholesale markets, respectively. The *LINK*-EC takes over the role of the local market player.
Fig. 1c shows the power market set up conform the fractal principle: Similar market patterns and shapes repeated in ever-smaller sizes. The trading volume defines the market size. It refers to the total energy traded during a specific period. The Average Trading Volume (ATV) calculates by dividing the total energy trading volume (E_{Tr}) over a period by the length of the period (h). The result is the average trading volume per unit of time, typically per day.

$$ATV = \frac{E_{Tr}(Period)\cdot 24}{Period} \quad \text{[GWh], [MWh], [kWh]} \qquad (1)$$

The ATV for the national market ranges to GWh, for the regional one goes to MWh, while for the local one, it ranges to kWh. All market categories have the same segment structure, as depicted in Fig. 2. TSOs, DSOs, and *LINK*-ECs manage the corresponding markets in all segments such as energy (day ahead), flexibility (intraday) and other services[7]. Market participants have a similar nature in all three market categories. Based on *LINK*-Architecture, production and storage facilities are available in all Smart Grid fractal levels. Their operators participate in all three market categories. Producers supply energy and ask in the day-ahead market, ask and bid in the intraday market, and bid for other services. Storage supply or consume energy, and their operators ask and bid in all market segments. Markets have two peculiar additional participants: the prosumers and consumers. Prosumers behave in the market similarly to storage operators because they can supply or consume energy, i.e. they ask and bid in all market segments (prosumers are treated as black boxes in the *LINK-S*olution). While consumers only consume energy and bid in the day-ahead and intraday market and ask for other services.

Each market category is defined as a pricing area, as the largest geographical area within each market participant trades without capacity allocation. I.e., a Link-Grid area where congestions at the boundaries are controllable through the *LINK*-Control strategy. These areas are defined by the regulator and the TSO, DSO and *LINK*-EC.

E-MOBILITY FOR FLEXIBILITY

The electric vehicle battery forms the transport and energy sectors interface by providing a new flexibility resource for grid operators. Their proper integration opens significant opportunities for the decarbonisation of the transport vector.

Technologies for EV integration into grid operation

Two technologies integrate EVs into the grid operation: the V2G and smart charging.
V2G is a technology that enables energy to be pushed back to the power grid from an electric car's battery.

V2G →Supply/Consume →It acts as a storage

Batteries are charged and discharged based on various signals - such as power generation or consumption nearby or in the grid - in addition to the natural charge/discharge cycles from the transport process. This technology stresses battery obsolescence by increasing the number of charge/discharge cycles.
Smart charging enables the control of the charging of the EV battery to allow the charging power to be increased and decreased as from the grid needed.

SmartCharging → Consume →It acts as a consumer

More than 80% of people who intend to be future EV owners plan to charge them in housing proximity [10], which will tend to charge the EVs in the early evening, just on the grid's peak times. Smart charging is an opportunity for utilities to actively use EVs to shift the demand and optimise grid performance.

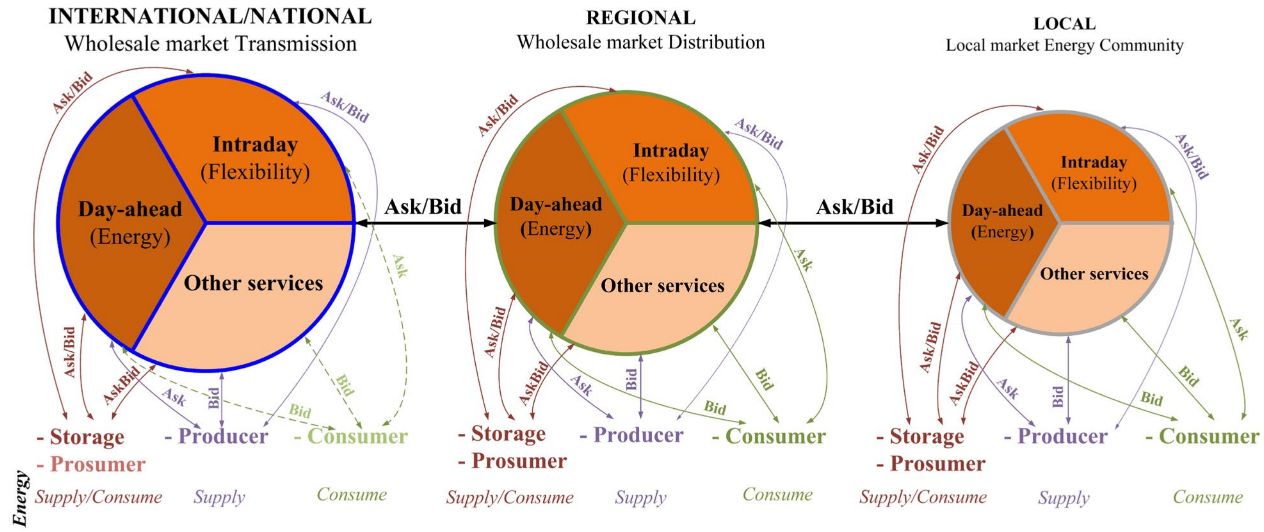


Figure 2: Overview of the electricity market structure derived from the fractal *LINK*-structure.

Customer attitude

Customers are very hesitant about incorporating car batteries into grid issues. The major barriers were users' range anxiety, anticipated inconvenience, battery performance degradation, uncertainty about standards, and low availability of related infrastructure. [11][12]. In contrast, smart charging technologies have a broader acceptance since the EV batteries are not additionally stressed, and the reduction of the range should not happen. Nevertheless, their credibility among the charging station owners varies.

Municipalities views on charging stations

Municipalities provide for the particular and unique welfare and benefit of their residents. They are very active in creating the necessary charging infrastructure in this context. They face a transition process when a small experimental approach becomes an essential part of the infrastructure. This transition is associated with various technical and legal challenges.

Municipalities are guided by the appropriate average number of recharging points in directive 2014/94/EU, which states that there should be one charging point per ten EVs. It means that the number of available charging stations should increase significantly with the recent EV increase. Municipalities can strongly affect the implementation of charging stations in the planning phase of a new area set up rules in the detailed planning. For existing areas, the municipalities should mostly work via information campaigns and municipality-owned housing company's. They can strongly affect the implementation of charging stations in the planning phase of a new area by setting up rules in the detailed planning. They should mostly work via information campaigns and municipality-owned housing companies for already built-up areas.

Smart charging gains importance when coordinated with distributed energy resources in the nearby area. EC, which municipalities promote, can take on this task [13].

LINK-EC role

The advantage of an energy community organising the electromobility solution is greater trust within the EC members or shareholders than between an individual and a utility or other company. Two major possibilities for EV integration are connecting each member car separately or setting up a carpool within the EC. In the *LINK*-EC, revenue sharing is transparent. Each member will only need to share data within the EC instead of sharing with a larger actor on the energy market. EC may take over the Charging Point Operator (CPO) role.

USE AND BUSINESS CASE: CONTINGENCY ALLEVIATION

Flexibility is the ability to change or be changed easily according to the situation. DR is the most appropriate method to provide the network with valuable demand-side flexibility. The use and business case emergency driven DR are described in the following

Use case

Figure 3 shows the use case of the DR process supporting the congestion alleviation process. In a high-voltage transmission line, a forthcoming overload is assumed. TSO starts the congestion alleviation process and notifies the DSO after defining the relevant TSO-DSO connection points. The request to change the setpoints goes to EC. The

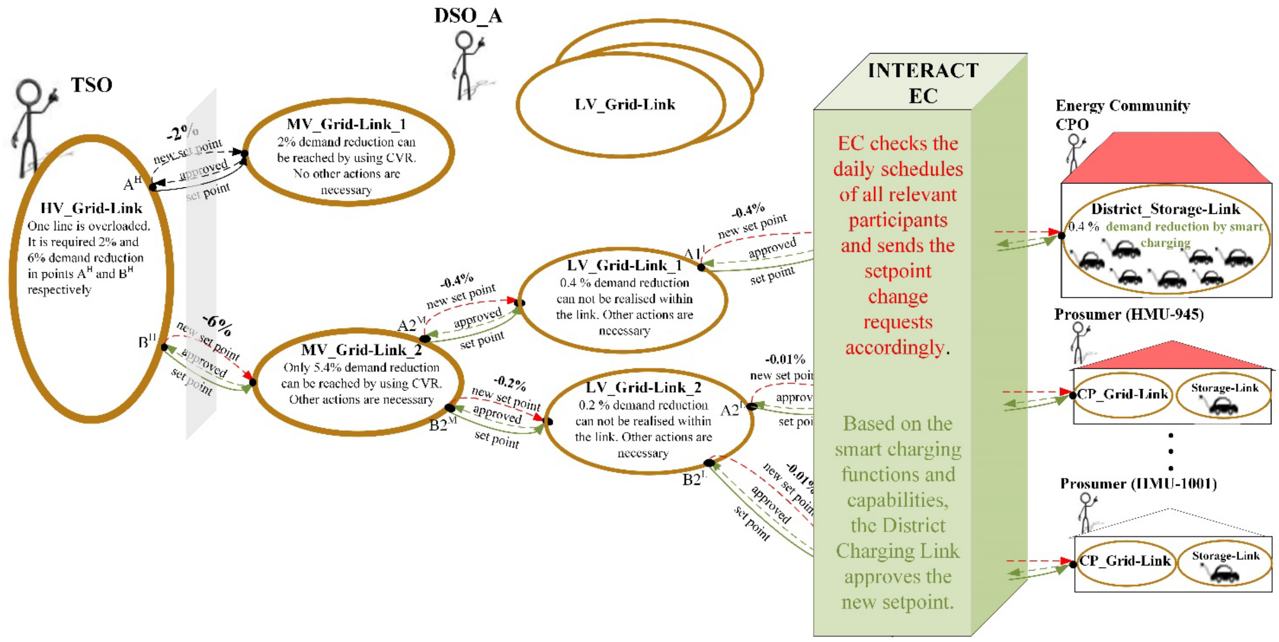


Figure 3: Overview of the use case: Congestion alleviation – Emergency driven DR involving e-mobility.

latter can reduce demand at the charging point by using the smart charger [14] to charge the charging patterns of e-cars, shifting energy consumption to a different time.

Business case

Various business models have been identified related to the integration of EV into the market [12]. Most of them may apply to the *LINK*-EC, mentioning those related to monetising flexibility and storage using EV batteries.
There are various possibilities of monetisation of flexibility. For EC to capture all of them, it is needed to become an equal player in the local market (see Figure 1).

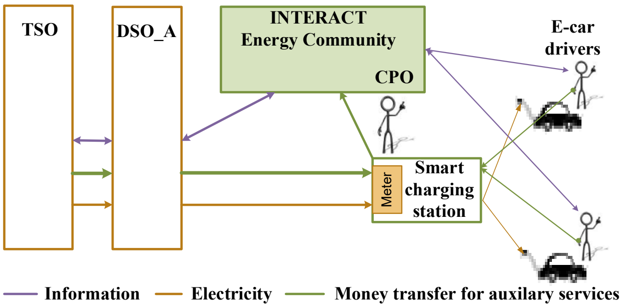


Figure 4: Business model of the use case: Congestion alleviation - Emergency driven DR involving e-mobility.

Figure 4 shows the business model underpinning the above use case. Four actors are involved: TSO initiates the process and requests an auxiliary service from the DSO, the DSO that forwards the request to the EC. The latter identifies the e-car drivers that can deliver the requested service. The funds' transfer is from the TSO requiring the ancillary service to the DSO, EC and the e-car drivers. The business model involves the development of a transparent pricing methodology with a level of granularity for the implementation of local marginal pricing or zonal markets.

CONCLUSIONS

The study shows that the fractal development of the market structure harmonised with the grid enables customers to provide energy and flexibility and make ECs lucrative. The advantage of an energy community organising the electromobility solution is the greater trust within the EC members or shareholders than between an individual and a utility or other company.

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REFERENCES

[1] M. Perdikeas, et al., 2010, "*The BeyWatch Conceptual Model for Demand-Side Management*," In: N. Hatziargyriou, et al. (eds), *Energy-Efficient Computing and Networking*, vol 54. Springer, Berlin, Heidelberg.

[2] C. Evens, et al., 2010, "*Aggregate Consumer's Flexibility in Consumption and Generation to Create Active Demand*," NORDAC, Aalborg, Denmark.

[3] J. Corera, 2006, "*Virtual power plant concept in electrical networks*," 2nd International Conference on Integration of Renewable and Distributed Energy Resources, December 4-8, Napa, Canada.

[4] P.Stawiarski, et al., 2021, "*Social Attitudes Towards the Benefits of and Barriers to the Development of Electromobility*," in J. Nesterak and B. Ziębicki (eds) *Business development in digital economy and covid-19 crisis*, Institute of Economics Polish Academy of Science, Warsaw, Poland.

[5] ETIP SNET white paper "*Holistic architectures for future power systems*, " 2019.

[6] A. Ilo, 2019, "*Design of the Smart Grid Architecture According to Fractal Principles and the Basics of Corresponding Market Structure*," Energies, vol 12, p 4153.

[7] N. Rossetto (ed.), 2017, "*Design the electricity market(s) of the future*," Proceedings from the Eurelectric-Florence school of regulation conference, Florence, Italy.

[8] A. Ilo, D.L. Schultis, 2022, "*A holistic solution for smart grids based on LINK– Paradigm*, " Springer Nature, Swiss, 366p.

[9] IRENA, 2019, "*Increasing space granularity in electricity markets*," International Renewable Energy Agency, Abu Dhabi. Available online: Last access 10.01.2022.

[10] Accenture, 2019, "Electric vehicle adoption to overtake conventional vehicles by 2040 and unlock a US$ 2trillion opportunity for utilities," Available online: Last access 03.02.2022.

[11] K. Heuveln, et al., 2021, "Factors influencing consumer acceptance of vehicle-to-grid by electric vehicle drivers in the Netherlands, Travel Behaviour and Society, Vol. 24, 2021," p 34-45. Available online: Last accessed 03.02.2022.

[12] Amsterdam Roundtables Foundation, McKinsey &

Company Electric, 2014, "Vehicles in Europe: Gearing Up for a New Phase?" Available online: Last access 04.2.2022.

[13] Project INTERACT Integration of Innovative Technologies of Positive Energy Districts into a Holistic Architecture.

[14] H. Mårtensson, 2019, "Electric Cars for Balancing Variable Power on Gotland, " Lund, Sweden.