Planning and operating future energy communities

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Abstract

Energy communities have recently been introduced as new legal actors in the European Union's energy system. This paper introduces first concepts to energy communities' planning and operation based on the CLUE research project. It introduces the legal framework and identifies open issues for the legal transpositions into national law, as well as arising questions concerning planning and operation.

1 Introduction

Energy communities (ECs), as introduced in the European Union's (EU) 'Clean Energy for all Europeans Package', aim for a local improvement of energy efficiency, and an increasing integration of renewable energy sources. This shall be achieved by jointly producing, temporarily storing, sharing, consuming, and selling locally generated energy. Households and individuals are thus able to take an active part in the energy transition and thus support the reduction of greenhouse gas emissions. However, ECs' concrete structures (e.g., their organization, memberships, or scope of activities) might be completely different; for instance, depending on their location in an urban or a rural area.

The CLUE project aims to develop EC operational models and technical solutions by maximizing the up-scaling and replication of lessons learned from demonstration projects in different member states and by sharing knowledge and best practices in order to further develop and improve related technologies and system solutions.

This paper will focus on how to ensure an efficient operation taking the underlying electrical grid infrastructure and the role of a distribution system operator (DSO) into account (Section 2). Afterwards, the recent introduction of EC as legal actors in the EU energy system is described and open legal issues for the member states are discussed (Section 3). Furthermore, various possible use cases developed within the CLUE project and the implementation of an EC in previous work will be described (Section 4).

2 Energy community operation from the DSO perspective

An EC is a small distribution system area with, compared to its size, a high penetration of distributed generation, battery storage, e-mobility, community storage systems as well as the application of disruptive technological trends like Blockchain or local energy market approaches. If the intended operator of the EC is a DSO or a DSO needs to secure its operation, the first assumption might be to upgrade the existing operation framework. Thus, the DSO needs to find ways to easily integrate the new type of connected customer into the existing systems.

2.1 State of the art

As an example, the current state of power distribution grid control and automation system components in typical urban distribution grids in Austria will be described, followed by the current state of development and the actual situation in international research projects.

The degree of automation of today's power distribution grids highly depends on the network level and is quite heterogeneous [1]. They are usually highly automated for high-voltage grids down to the substation level, whereby it is operated and monitored by supervisory control and data acquisition (SCADA) systems. DSOs begin to automate medium-voltage networks in secondary substations as well as to increase systems reliability and recovery time in case of failures. Low-voltage grids are usually not automated and still primarily passively operated. There, hardly any active control components or measurements are available.

The operation of an EC is thus challenging due to the expected high penetration of photovoltaic systems, batteries, and electric vehicles. In order to fulfil future needs, power distribution grids must be transformed into active grids; medium-voltage as well as low-voltage grid components are equipped with remote-control functions and monitoring possibilities enabled by integrated remote terminal units (RTU). Those devices are usually connected to SCADA systems and offer similar remote control and monitoring functions to energy utilities. However, the communication and control of RTUs is mainly carried out in a proprietary way by using communication protocols and field bus approaches provided by large vendors. Smart grid applications require open, interoperable, and scalable systems to support solutions of low engineering efforts.

2.2 EC operation approach

In classical grid operations in medium and high-voltage tiers, DSOs monitor grids using a topological view requiring an undivided attention of the personnel 24/7 and, more critically, a detailed modelling of the entire grid. In this system paradigm, the operator usually observes several fault indicators and deals with notifications and alarms. For appropriate reactions to faults, it is up to the operator to interpret this data. The higher the degree of modelling of the grid, the easier this task becomes.

To support the operation of ECs, in imminent demand with the increase in complexity and automation, this approach is considered infeasible due to the massive number of different assets. As it is unclear who operates the ECs' technical equipment [2], CLUE considers scenarios with different responsible subjects. Therefore, a decision support system shall be provided following two main principles:

- An event-based operation approach [3] using an assistive operation system that informs the operator of a detected failure at the exact location and its cause. This hinges on a roughly exact topological and geographical modelling of the grid, as well as some intelligence, either on the field device side or in post-processing.
- It is not expected that the person taking over parts of the technical operation and troubleshooting locally, e.g., a local electrician, is similarly specialized as an operator in the DSO's control centre. Therefore, a reduced digital grid twin based on system modelling to understand functional correlations shall be offered to provide user-specific views. For the sake of inclusiveness, prosumers in ECs could be provided with a view with a minimal level of complexity.

Regarding national initiatives, the responsible ministries and regulatory authorities are currently considering potential economic benefits for ECs (e.g., tariff and tax reductions), based on which business cases are being worked out [4,5]. However, according to the legal framework (cf. Section 3), the main benefits of ECs shall be charitable rather than financial. Thus, the expected economic benefits may not be that significant to trigger an extensive rollout. To support the energy transition, additional factors must be considered. One example, as another focus topic within CLUE, is resilience, i.e., the ability to maintain an acceptable level of service at all times and to recover from adversity. In this context, providing resilience is a challenging task due to the complex technical framework in combination with different stakeholder interests. However, in many applications one cannot strictly distinguish between normal operation and a failure state; rather, the level of service the system is able to provide in presence of failures is of importance.

3 European Union law on energy communities

The "Clean Energy for All Europeans Package" introduces several new actors into the legal framework:

- on the single-family-house level: the renewables self-consumer and the active consumer,
- on the apartment-building level: the jointly acting renewables self-consumers,
- and on the energy community level: the renewable energy community (REC) and the citizen energy community (CEC).

They are contained in the Renewable Energy Directive (RED) and the Electricity Market Directive (EMD); national transpositions of them are due by 2020/2021. For the scope of this paper, the RECs and CECs are of main relevance. There are overlaps between those two types, but neither one of those forms a subset of the other regarding their area of operation [4,6]:

- The application area of CECs is restricted to electricity (not necessarily renewables only), while a REC may be involved in any type of renewable energy (e.g., heating, cooling).
- The geographical area of a RECs operation is restricted to a (to be nationally defined) proximity, which is not necessary in CECs.

The main identified open issues for the national transpositions are:

- the definition of proximity regarding the REC's operational limits, to be either defined using a technical or a geographical delimitation,
- the option for a CEC to act as a DSO, non-obligatory for national implementation,
- and the optionally permitted operation of a CEC over member-state borders.

Several proximity-restricted RECs could form a CEC, as they are not restricted in this regard. Any REC or CEC is required to be incorporated as a legal entity of its own. Additionally, those joining RECs must operate on local renewable electricity solely. Only the recitals of the EMD state that decision-making powers are limited to certain types of members for which 'the energy sector does not constitute a primary area of economic activity'. That, however, is exactly the area of the REC. Consequently, the members of the original RECs could be the deciding members, though it is not clear yet whether it is possible to join more than one energy community at the same time.

The - still re-appearing - terminus technicus ‘local energy community’ (LEC) was legally replaced during the legislative process by the CEC. Although CEC lack the proximity aspect, it is arguable to use LEC as an umbrella term for both energy community types, as the sole term ‘energy community’ is also used for an international organization (formerly: Energy Community of South East Europe) in close proximity to the EU and its energy system.

4 Energy community implementations

4.1 EC example using Blockchain

One possible implementation of an EC is by using Blockchain technology [2], including smart contracts, for example to enable peer-to-peer energy trading among its participants [5]. As high-frequency energy consumption data of households - required for the operation of the community - could reveal personal habits of its members [7] and considering privacy-related issues inherent to Blockchain technology, a special focus was laid on a privacy-friendly implementation [2]. This approach has been deployed in a small Austrian municipality, where it is currently validated with customers. Relating to the many different structures of ECs mentioned earlier in this paper, results of various projects utilizing Blockchain technology for EC implementations have determined different subjects carrying privacy-related obligations (i.e., the ‘controller’ in terms of privacy law) [2]. It is responsible to fulfil the data subject’s (i.e., the consumer’s) rights (e.g., the rights to rectification and erasure), and ensure those rights even though Blockchain technology does not allow later changes of data saved in the chain.

4.2 EC implementation and connection in CLUE

This example shows that a set of very diverse challenges must be considered within EC operation in future. Within CLUE, a more generic approach to investigating a large bandwidth of requirements and possible solution paths is chosen. The starting point is the integration of several renewable energy sources and flexibilities into the ECs and optimization of their usage. Therefore, an EC tool kit will be developed to support the development of an EC, both technologically and from the process side. Therefore, CLUE provides the framework to create and investigate technology and process interaction based on different proof-of-concepts in different states of realisation. Taking the readiness of the individual EC candidates into account, CLUE aims to provide a system environment in which stakeholders, involved with their different perspectives, can validate the assumptions made. The following parts of the EC tool kit are under investigation and the validated results will form the basis for the economically viable solutions that must be developed following CLUE in productive solutions:

- Planning tool: Planning of the EC to integrate renewable energy sources, storage, customers, electric mobility, and power-to-heat applications.
- Monitoring and information tools: Capabilities for a real-time overview of the EC, for example, the energy flow within the community considering the necessary “depth of information”, depending on whether the access is made by a technician for service work or an EC participant.
- Operation tool: Event-based operation environment with fully-automated services for analyses and alarming for the community operation.

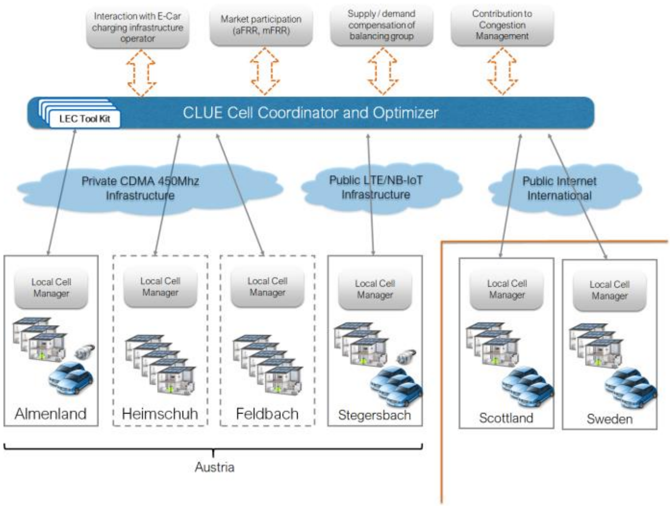

Fig. 1: CLUE system overview and demonstrators

Fig. 1 gives an overview about the CLUE architecture with focus on the Austrian demonstration sites (cells) Almenland and Stegersbach. Furthermore, Heimschuh - the testbed for the above-mentioned Blockchain-based peer-to-peer community [2,5] - and Feldbach are shown. Experiences and results from the cells will be considered in all activities. They are connected to the CLUE cell coordinator and optimizer that contains the EC tool kit. Different types of connections and ICT infrastructure (private vs. public) can be used for connecting the cells with the innovative tools. Future connections (e.g., to an existing ancillary service market, charging point operator, etc.) are prepared and indicated by dotted arrows. The focus of the Austrian demonstrator is on the connection of cells and their interaction to enable additional value streams utilising the implemented technological base.

A series of prototypes will be developed, and their quality evaluated both along the lines of usability (by observation of actual users) as well as characteristics pertaining to relevant scenarios. The most common scenarios are evaluated in interviews with EC participants and domain experts, catalogued and reconstructed in simulation. A scenario planning and simulation tool will be deployed where the reactive operations prototypes can be looped into a virtualized environment. Testing the prototypes against actual scenarios affords a consistent approach towards a decision which technologies, algorithms, usability patterns and architectural ideas can be followed towards a final demonstration and recommendation.

5 Conclusions and outlook

Energy communities have recently been introduced in the EU to empower consumers, as well as to facilitate and encourage local generation and consumption. As these are new types of actors in the energy system and national transpositions of the EU directives are still underway, many operational and organizational questions remain open. The CLUE project will employ observational and projected techniques, such as direct field observation and ideation workshops with operators, to generate ideas for novel operational methods following an assisted, reactive operations approach, which provides better scalability and cost-efficiency in increasingly complex automation scenarios.

Aside from legal, regulatory and ownership issues, pervasive automation and the availability of observational data in ECs provide a novel and unique scenario for operation, maintenance and usage of critical infrastructure. Mirroring the paradigm of intelligence distribution as pertaining to local sensor and actuator installations (instead of a top-down hierarchy), responsibilities within the EC can also be shared. Participants might take a passive role and limit their actions to monitoring their own assets' data, take responsibility for a small cluster or the entire EC. This calls for completely new interaction and user experience paradigms, as compared to existing top-heavy approaches. Interactions must be transparent, secure, and personalized to ensure accountability and safety. Considerations towards applying shared responsibility principles towards critical infrastructure will open a wide field or research.

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