INTERACT

Integration of Innovative Technologies of Positive Energy Districts into a Holistic Architecture

D 4.2 Use Cases for the integration of the existing innovative technologies with the *LINK*-solution

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V0	Initial draft of ToC	TU Wien	March 2022
V1	Use cases describtion	TU Wien	June 2022
V2	Emission driven Demand Response use case	TORNET	June 2022
V3	Executive Summary & Final review	SON, LEEF, TU Wien	July 2022

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Executive Summary

This deliverable “Use Cases for the integration of the existing innovative technologies with the *LINK*-solution” shows from a technical perspective the operational processes of the INTERACT Energy Community. In this context, use cases are methodologies and processes used to design technical systems with the target to help identify, interpret, and organize a system's requirements and functions and understand how they are used.

Based on this deliverable, we are describing the business cases of the INTERACT Energy Community within Work Package 5. Also, we will show the market interfaces in the last deliverable of Work Package 4 based on the processes shown in the following.

After a short introduction into the document in Chapter 1, we show in Chapter 2 the normal operations of the Energy Community: day-ahead schedules and deviation management, peer-to-peer trading and integration of smart charging. In Chapter 3 we focus on flexibilities, and describe the use cases of congestion alleviation with its impacts on different consumption types, as well as price-driven demand response and emission-driven demand response. In Chapter 4 we describe the emergency recovery process and show, how the INTERACT Energy Community can support the grid after a blackout. And in Chapter 5 we describe the different processes of long-term planning with investment planning initiated on different organizational levels. The deliverable summarizes its conclusions in Chapter 6.

The information gathered and developed within this document is important for the description of various business cases of the INTERACT EC as well as the economic evaluation of them. It is also a vital contribution to the final Deliverable 6.1 - “Roadmap for the implementation of the designed INTERACT energy community in general and for the specific local perspectives” as it shows the functionalities of the INTERACT Energy Community from a technical perspective, targeted for the power engineering industry and its related sectors.

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List of Abbreviations and Acronyms

BLiN	Boundary Link Node
CPO	Charging Point Operator
CPMU	Customer Plant Management Unit
CVR	Conservation Voltage Reduction
DER	Distributed Energy Resources
DR	Demand Response
DSO	Distribution System Operator
EC	Energy Community
EV	Electric Vehicle
HV	High Voltage
LV	Low Voltage
MV	Medium Voltage
MVSO	Medium Voltage System Operator
PV	Photovoltaic Power Plant
TSO	Transmission System Operator
WP	Work Package

Table of Content

1 Introduction

Use cases are methodologies and processes used to design technical systems. Use cases help identify, interpret, and organize a system's requirements and functions and understand how they are used. Use cases often help outline who's using the software or website, the user's goal and what the user wants to do, what ordered steps the user takes to complete a specific task, and how the system reacts to the user's action.

For new technical systems, as the INTERACT Energy Community represents one, use cases are especially valuable to describe and show the intended structure in a systematic way, minimizing misunderstandings and supporting the grasp of its functionalities. Based on these technical use cases, the description of business cases will be drawn, and the interactions with the different actors and the market can be described in a more detailed and systematic way.

1.1 Purpose of the document

This document aims to create use cases that show how the INTERACT Energy Community works and how the energy community members may act. The use cases are sorted in four categories: normal and abnormal operation, flexibilities, and long-term planning. For each use case, the document gives a process chart in a standardized layout, and the description of the process flow. It defines the actors involved, the goal of the use case, and a potential expected reaction on the process.

1.2 Relation to other project activities

Use cases created in this document are derived from the technical and organizational descriptions of the INTERACT Energy Community within WP3 and WP4. They go hand in hand with current power system changes (increase of DERs and increase of EVs). The described use cases will be one foundation for developing business cases and their economic evaluation within WP5 and will contribute to developing the roadmap in the WP6 of the project.

1.3 Structure of the document

The deliverable structure is in accordance with the categories of identified use cases: Chapter 2 shows the normal operation, Chapter 3 the management of flexibilities, Chapter 4 the abnormal operation, and Chapter 5 is dealing with long-term planning aspects. The document concludes with the summary in Chapter 6.

2 Normal operation

One of the normal operation use cases of the Energy Community is bidding on the electricity surplus. Each of the actors concerned should notify the resources or the load.

2.1 Notification and approval of day-ahead schedules

One of the most popular processes in power systems is the notification of the day ahead schedules on electricity production and consumption (production-load balance process). Each actor concerned should notify the market facilitator of the available resources or the load for the next day.

Actors: EC members, EC in the role of the local market facilitators and DSO in the grid operator role.

All EC members acting as prosumer or consumer are equipped with a Customer Plant Management Unit (CPMU) that automatically generates the day-ahead schedules and send them to the local market facilitator (EC).

Goal: Notify the resources

Process: All EC members, be it prosumers (CPMU), producers or storage operators, send the day ahead schedules for active and reactive power, if relevant, to the energy community in

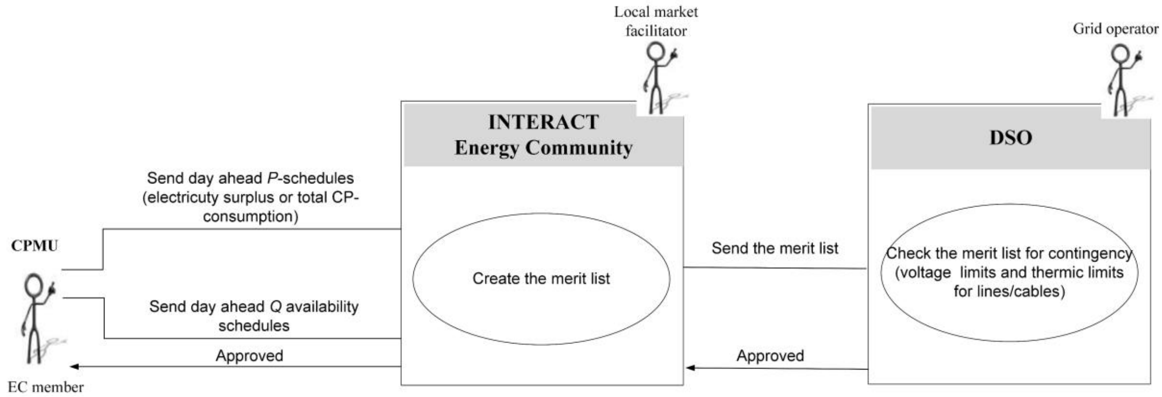

Figure 1 – Notification and approval process of day ahead schedules

the role of the local market facilitator, Figure 1. The latter creates the merit list based on the electricity price and sends it to the DSO for verification and approval. After checking the grid for contingency, i.e. voltage violations and thermal limits of lines and cables, the DSO approves the merit list. The local market facilitator gives this information further to the energy community members. This process may require a few iterations if the DSO detects contingencies.

Reaction: Day-ahead schedules approved.

2.2 Deviation from the day-ahead schedules

Despite good forecasts and advanced algorithms, it is possible that due to unforeseen events, electricity surplus or consumption during the day may deviate from the announced and approved day-ahead schedule.

Actors: EC members, EC in the role of the local market facilitators and DSO in the grid operator role.

All EC members acting as prosumers or consumers are equipped with a CPMU.

Goal: Change request for electricity consumption or injection

Process: The affected EC member, be it prosumers (CPMU), producers, storage or charging point operators, send a change request to the energy community in the role of the local

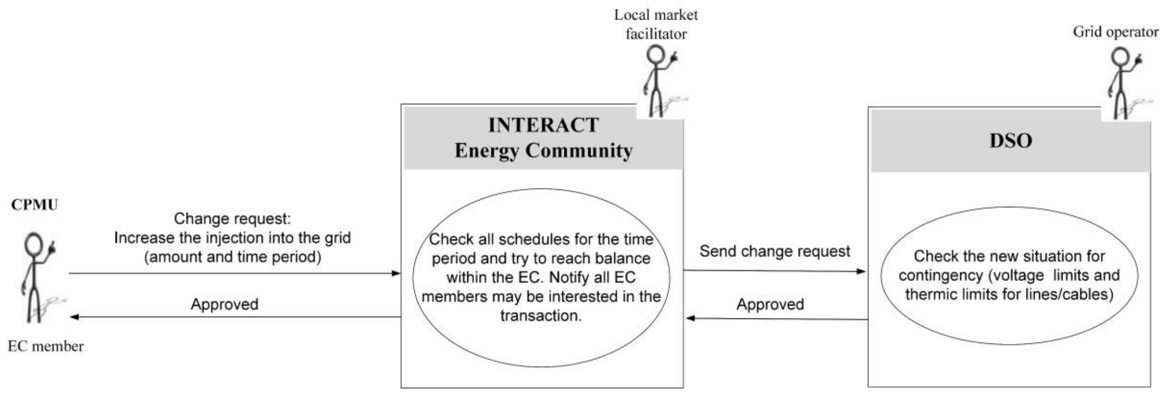

Figure 2 – Notification and approval of the change request

market facilitator, Figure 2. The latter checks all schedules for the relevant time period and tries to reach balance within the EC. He notifies all EC members who may be interested in the transaction. Afterwards, he sends a change request, including all affected members, to the DSO for verification and approval. After checking the new grid situation for contingency, i.e. voltage violations and thermal limits of lines and cables, the DSO approves the change request. The local market facilitator gives this information further to the energy community members. This process may require a few iterations if the DSO detects contingencies.

Reaction: Change request approved.

2.3 Peer to Peer electricity trading

Peer-to-peer energy trading refers to the selling and buying power between two or more grid-connected parties. Peer-to-peer electricity trading allows consumers to select who they buy electricity from and to who they sell it. This use case describes the checking of the technical feasibility of this kind of transaction.

Actors: EC members, EC in the role of the local market facilitators and DSO in the grid operator role.

All EC members acting as prosumers or consumers are equipped with a CPMU.

Goal: Peer-to-peer trading

Process: After reaching an agreement with each other, both EC Member A and EC Member B,

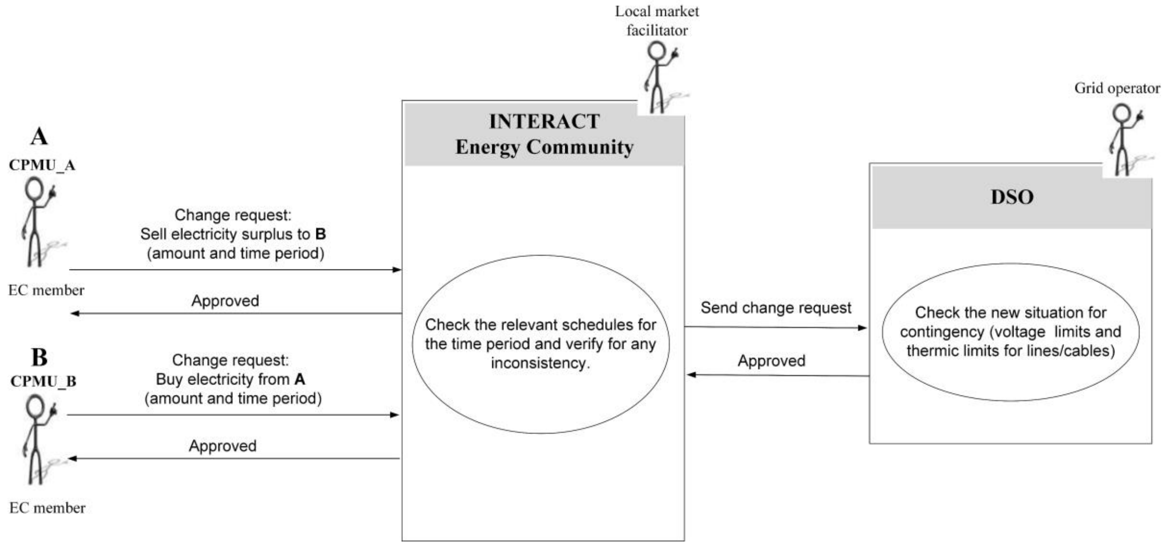

Figure 3 – Notification and approval process for peer to peer trading

be they prosumers (CPMUs) send their requests to the energy community in the role of the local market facilitator, Figure 3. The latter, check the relevant schedules for the period given and verify for any inconsistency. He sends then the requests to the DSO for verification and approval. After checking the grid for contingency, i.e. voltage violations and thermal limits of lines and cables, the DSO approves the request. The local market facilitator gives this information further to the energy community members. This process may require a few iterations if the DSO detects contingencies.

Reaction: Peer-to-peer electricity trading approved.

2.4 Smart charging-driven change request

The smart charger calculates the best time to start charging instead of starting it immediately after the vehicle is plugged in. The starting point is set to achieve the most favourable tariff. As an EC member, the CPO can benefit from the fair tariffs within the local energy market.

Actors: EC members including CPO, EC in the role of the local market facilitators and DSO in the grid operator role.

Goal: Consider the actual smart charging solution

Process: To reach the best solution, CPO sends a change request to the energy community in the role of the local market facilitator, Figure 4. The latter checks the relevant schedules for

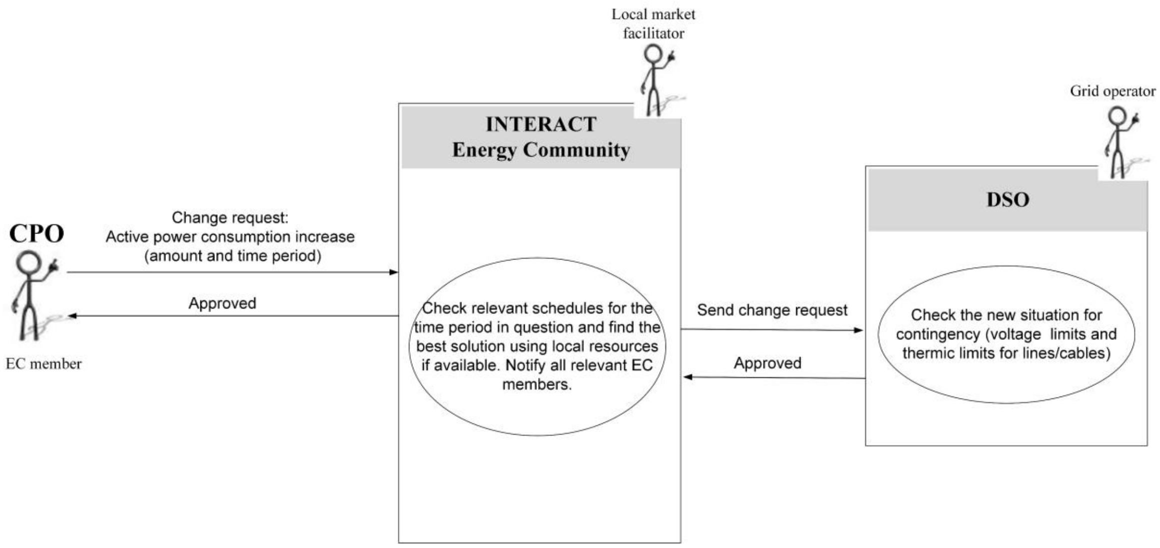

Figure 4 – Notification and approval process of a CPO change request

the time period in question and finds the best solution using available local resources. He notifies all appropriate EC members and sends the change request, including all relevant EC members, to the DSO for verification and approval. After checking the grid for contingency, i.e. voltage violations and thermal limits of lines and cables, The DSO approves the change request. The local market facilitator gives this information further to the energy community members. This process may require a few iterations if the DSO detects contingencies.

Reaction: CPO change request approved.

3 Flexibilities

Flexibility concerns the power system's ability to manage changes, which can impact preserving a secure and reliable power system operation. Flexibility has a central and local dimension [1]. The central dimension includes the flexibilities of big power plants (producers such as hydropower plants, etc. and storage such as pumped hydropower plants) and big customers. In contrast, the local dimension implies the distributed resources such as prosumers, commercial and small businesses, etc.

Flexibility and resiliency are core design principles of *LINK*-Solution. Flexibility means overcoming every challenge appearing during the operation of Smart Grids by maintaining the quality of parameters of the supply. It ensures a resilient infrastructure, providing its services even during exceptional events.

INTERACT energy communities promote the distributed energy resources, thus making the local dimension of flexibility relevant as the central dimension. The new generation of prosumers has become active and is ready to provide power system services powered by the energy communities.

Demand Response, be price-, emission- or emergency driven, is one of the most comprehensive operation processes of Smart Grids, including the entire power system, customer plants and electricity markets. This process extends the flexibility of power systems on all distributed resources. It is dedicated to short-term load reduction or increase in response to a signal from the power grid operator or a price signal from the electricity market or emission data. There are very slow uptake of Demand Response, particularly in the residential, commercial and small business sectors. The proposed structures are complicated and require significant data exchange, which causes an increase in the complexity of system operation etc. *LINK* holistic solution promotes this comprehensive process [2],[3].

3.1 Congestion alleviation – Emergency-driven demand response

The current structure and operation of the electricity market result in a costly re-dispatch process for congestion management. The new market's fractal structure introduced by INTERACT project [4] harmonises with the grid enabling customers to provide energy and flexibility and making ECs lucrative. The grid operators always initiate the congestion alleviation process, be it TSO or DSO. In this process, one thing that matters to TSOs is whether active power flows decrease or increase at the intersection points with DSOs, without being interested in how they occur. Whereas the DSOs are required to keep voltages throughout the grid within limits at all times; also during the demand response process.

3.1.1 Implication of prosumers and commercial and small businesses

This use case describes the extensive Demand Response, particularly involving the residential, commercial and small business sectors. For the large-scale deployment of the latter, a holistic approach is essential to ensure the reliable and safe operation of Smart Grids.

Actors: TSO, affected DSOs, EC and EC members.

Goal: Implication of prosumers and commercial and small businesses in the congestion alleviation process.

Process: Figure 5 shows the demand response process used to support the congestion alleviation process. Suppose an increase in the overload is expected in a high-voltage transmission line up to 8% in the following hours. TSO starts the congestion alleviation process: Using the relevant applications, he defines the BLiNs A^H and B^H on his grid, where the load decrease should be 2% and 6%, respectively. Both Grid-Links connected on the BLiNs are MV_Grid-Links. They are operated from the same operator DSO_A. Afterwards, TSO initiates a demand decrease request and proposes two new setpoints accompanied by the setting and duration. After receiving the request for the new setpoints, DSO_A starts the demand response process and investigates all possibilities to realise the demand decrease using their internal resources, e.g., the CVR. The 2% power reduction in the BLiN A^H realises by performing the CVR on MV_Grid-Link. No other actions are needed. The new setpoint is notified to the TSO.

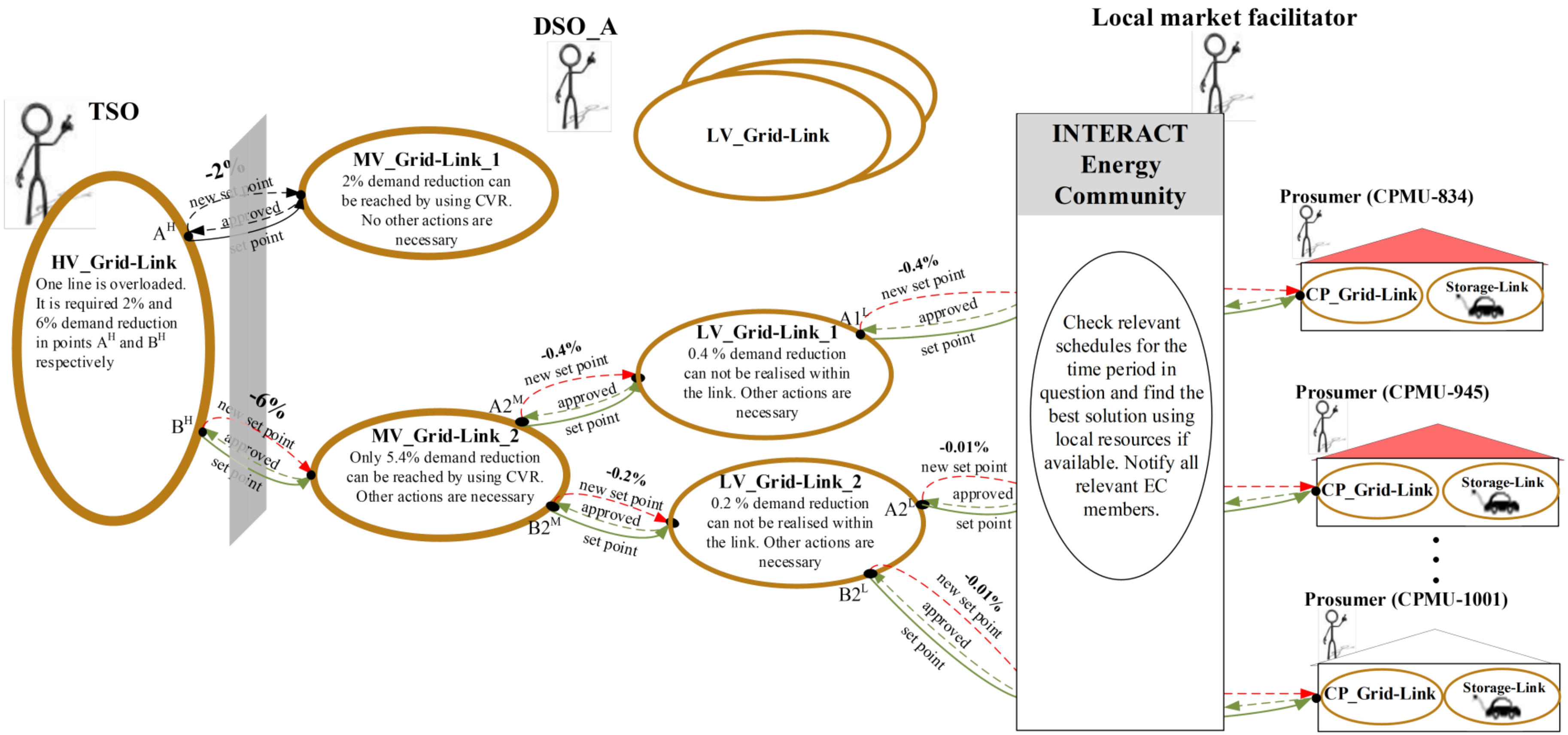

Figure 5 – Implication of prosumers in congestion alleviation process: Emergency driven Demand Response

The reduction desired on the BLiN B^H is more extensive than at A^H, about 6%. Only one part of it, e.g. 5.4%, can be reached by performing CVR in MV_Grid-Link_2. Other actions are necessary for the rest, about 0.6% demand reduction. DSO_A investigates his Link-Grid and the day-1 schedules and identifies the BLiNs $A2^M$ and $B2^M$ as the most suitable ones, where the flow should be reduced by 0.4% and 0.2%, respectively. LV_Grid-Link_1 and LV_Grid-Link_2 are connected respectively to the BLiNs $A2^M$ and $B2^M$. Both links are operated from the same DSO. Afterwards, DSO_A initiates a demand decrease request and proposes two new setpoints accompanied by the setting and duration. After receiving the request for new setpoints, DSO_A involves the EC. The latter investigates all possibilities based on the available contracts for participation in emergency load control and the daily schedules and sends a request for consumption reduction to the concerned participants. CPMUs of the affected prosumers check the relevant schedules for the time period in question, find the best solution using available local resources, and approve the new set points. The information goes back to the TSO, who acknowledges the new setpoints. This process may require a few iterations if the DSO detects contingencies.

Reaction: The new setpoints to alleviate congestion approved.

3.1.2 Implication of e-mobility

The smart charger calculates the best time to start charging instead of starting it immediately after the vehicle is plugged in. The starting point is set to achieve the most favourable tariff. As an EC member, the CPO can benefit from the fair tariffs within the local energy market.

Actors: TSO, DSO, EC, EC as CPO, EC members.

Goal: Consider the actual smart charging solution

Process: Figure 6 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 latter can reduce demand at the charging point by using the smart charger [5] to charge the charging patterns of e-cars, shifting energy consumption to a different time—the information spreads through the chain as described in §3.1.1.

Reaction: The new setpoints for Smart Charging to alleviate congestion approved.

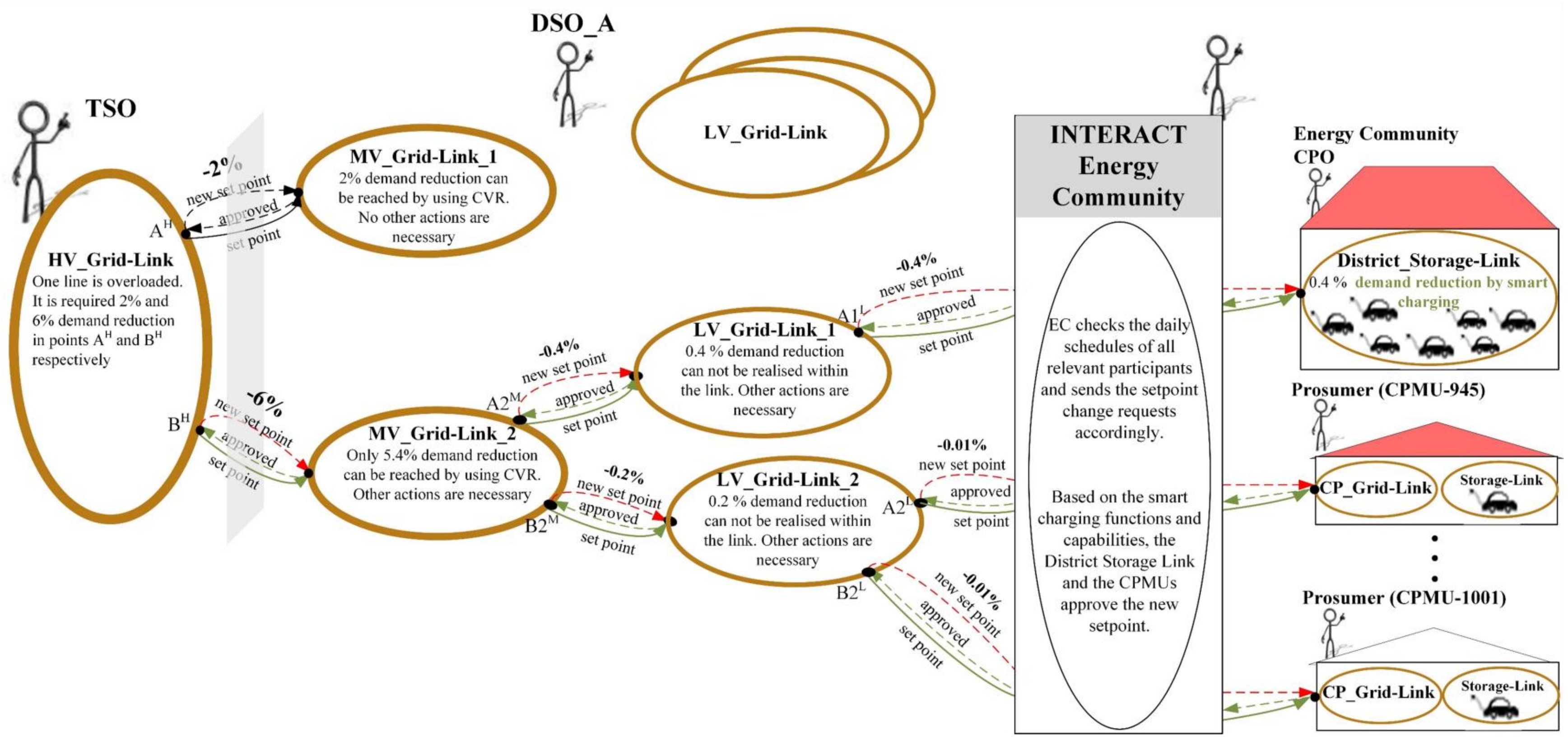

Figure 6 – Overview of the use case: congestion alleviation – Emergency driven demand response involving e-mobility

3.2 Price-driven Demand Response

The massive increase in volatile energy resources may provoke an electricity production that exceeds the current load in particular cases. As a result, the price of electricity decreases, which sets in motion a mechanism to increase the load: The fractal structure of the INTERACT-market allows a price-driven Demand Response process to emerge. All grid operators, affected TSOs and DSOs, should be notified to react and set measures for this process.

The Demand Response process could also be activated due to high prices, resulting in load reduction or shifting.

Actors: TSO, DSO and EC as market facilitators, TSO, DSO, EC, EC members.

Goal: Increase the load to balance the power surplus on the grid.

Process: Because of extensive wind in a day with a low system load, wind parks will produce more electricity than needed. The electricity price in the national/international, regional and local markets will decrease. EC notify all EC members, through CPMUs, for the electricity price decrease. Figure 7 shows the information flow during price-driven demand response process. It enables residential, commercial, and small business sectors to perceive transparent energy prices and contribute to the reliable and efficient operation of Smart Grids. After checking the possibilities of demand increase in CP, CPMU-123 declares a consumption increase by 0.4% to the BLiN $A1^L$ of LV_Grid-Link_1. CPMUs 945 and 998 act similarly. DSO-B checks power flow limits (voltage and thermal limits) under the new conditions at its Grid-Links. If the power exchange in the BLiN $A2^M$ or $B2^M$ on the MV_Grid-Link_2 is affected, DSO-B should also check the limits and pass the request to the Medium Voltage System Link-Grid Operator-A (MVSO-A). He requests the TSO for a flow increase of 0.6% in the BLiN B^H. TSO collects all incoming requests and performs the necessary calculations, i.e. power flow, n-1 security, etc. If no limits are violated, TSO approves the new setpoints and notifies the DSO-B. The last one accepts the new set points in BLiNs $A2^M$ and $B2^M$ and notifies the EC. The latter notifies the respective CPMUs to execute the demand increase.

Reaction: The load increase to balance the power surplus on the grid approved.

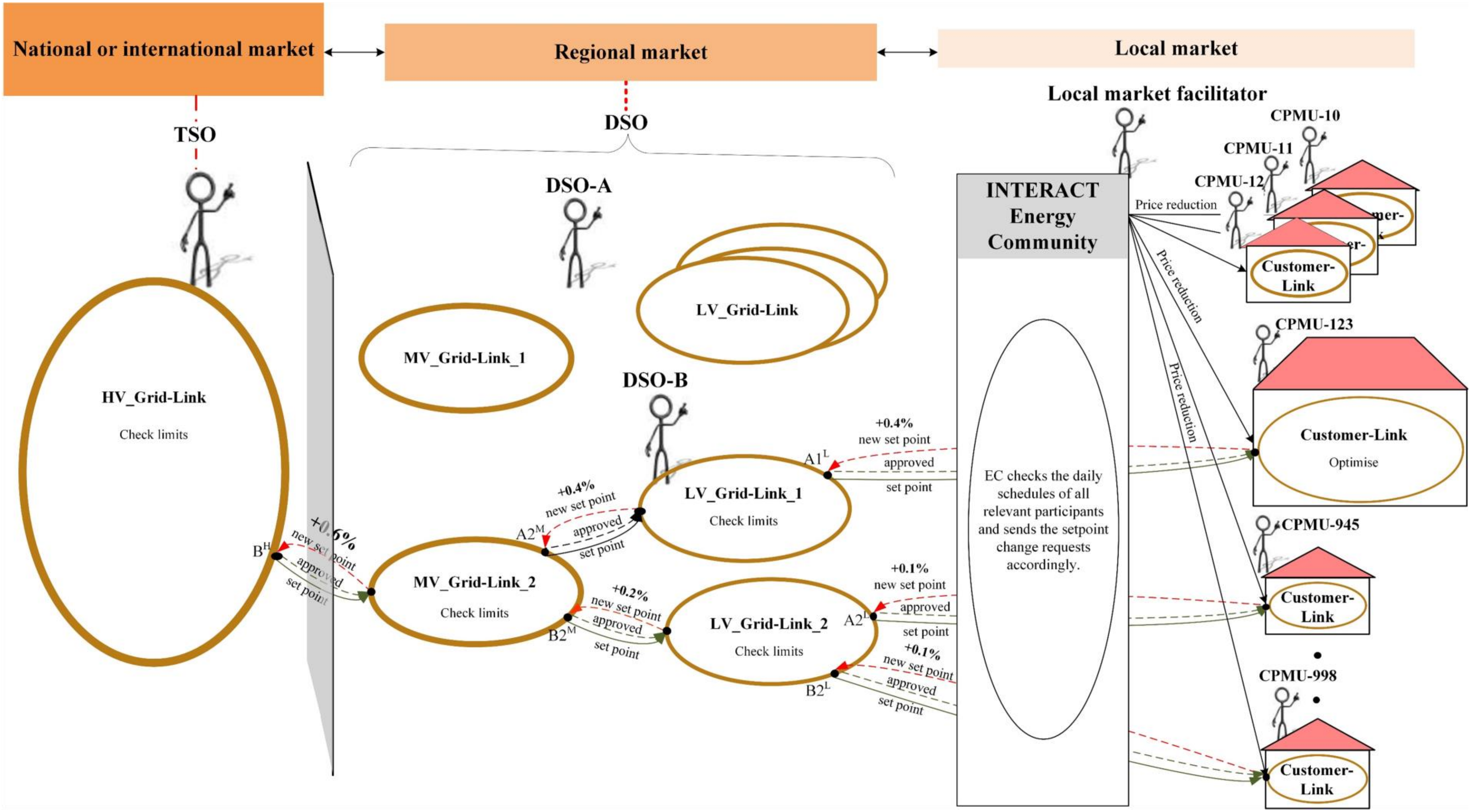

Figure 7 – Price driven demand response

3.3 Emission-driven Demand Response

All use of electricity comes with some kind of environmental impact. The main environmental issue related to energy consumption is the emission of greenhouse gases. The emission-related to electricity use can be considered in several different ways. When reporting emissions, an average over a year is usually applied either based on your contract with producers (market-based approach) or based on the production in the electricity system you are a part of (location-based). This is, however, mainly a tool for retrospective reporting. When assessing the effect of a change in electricity consumption in the near future, the marginal electricity perspective is usually applied. This approach aims to define which emissions would be associated with an increase or decrease in consumption at a certain hour. The marginal carbon intensity of these data is available as a 24-hour prognosis which makes it possible to plan the energy use not to occur during hours with high marginal carbon intensity in the same way as is possible to control based on a price signal.

Actors: EC, EC members, Data scientists/emission models
Goals: to reduce emission by shifting energy consumption to hours with less carbon intense electricity production.
Processes: Due to high demand and low production from renewables the marginal carbon intensity between 1600 and 1800 the coming day is foreseen to be extrelemy high. The prognosis is sent to the EC. The EC realizes that the high carbon intensity correspond with a high demand based on the proposed daily schedules from the CPMUs. Suggestions are sent to the CPMUs to shift the load in time or to increase the use of locally stored energy for the 2 hour period. This is accepted or rejected either automatically by the CPMU or manually by the user.
Reaction: Reduction of events with high consumption correlating with high marginal carbon intensity.

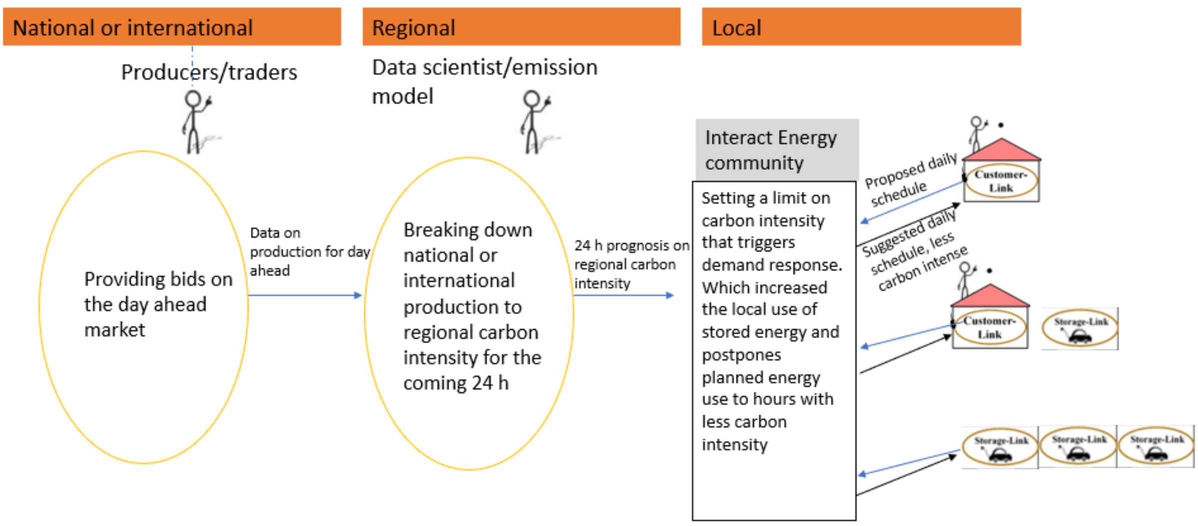

Figure 8 – Process of emission driven demand response

4 Abnormal operation: Service restoration after a blackout

A total blackout is the loss of power supply to all end-users in a TSO area. This is the most serious form of an outage that can occur in power grids. Power outages can last from a few minutes to a few weeks, depending on their category and the power grid's type and configuration. The economic and social damage is always more significant the longer the recovery time. Therefore, various countermeasures are taken to reduce recovery time, especially in critical facilities.

Power failures are critical at sites where the environment and public safety are at risk. Critical institutions such as hospitals, waste and water treatment plants, etc., typically have emergency power sources such as standby generators, which automatically start up when power is lost. Other ones, such as telecommunication facilities, may have backup batteries used during extended power outages.

The comprehensive integration of distributed resources offers a tremendous opportunity to reduce recovery time after a partial or complete power outage. This use case describes the service restoration process after a blackout involving distributed resources. Figure 9.

Actors: EC members, EC and the DSO.

Goal: Fast restoration involving the distributed resources.

Process: All prosumers (CPMUs) detect power supply interruption and notify it and the free capacities (power amount and time period) to the EC, Figure 9. The latter gathers all notifications about the power interruption. He coordinates the reported free capacities, including common facilities, to provide power to as many customers as possible in the region. EC then sends the recovery schedules to the relevant DSO and requests a topology update to enable the recovery process. The DSO checks the situation, updates the topology and approves the recovery process. EC advises EC members to change the CPMU operating mode to Autarky-Restore (see §3.2.4 at D3.2 Gap analysis including the list and description of existing technologies and infrastructure as well as necessary replacements/upgrades/additions to the infrastructure and measuring devices) and updates the recovery schedules.

Reaction: Fast restoration process.

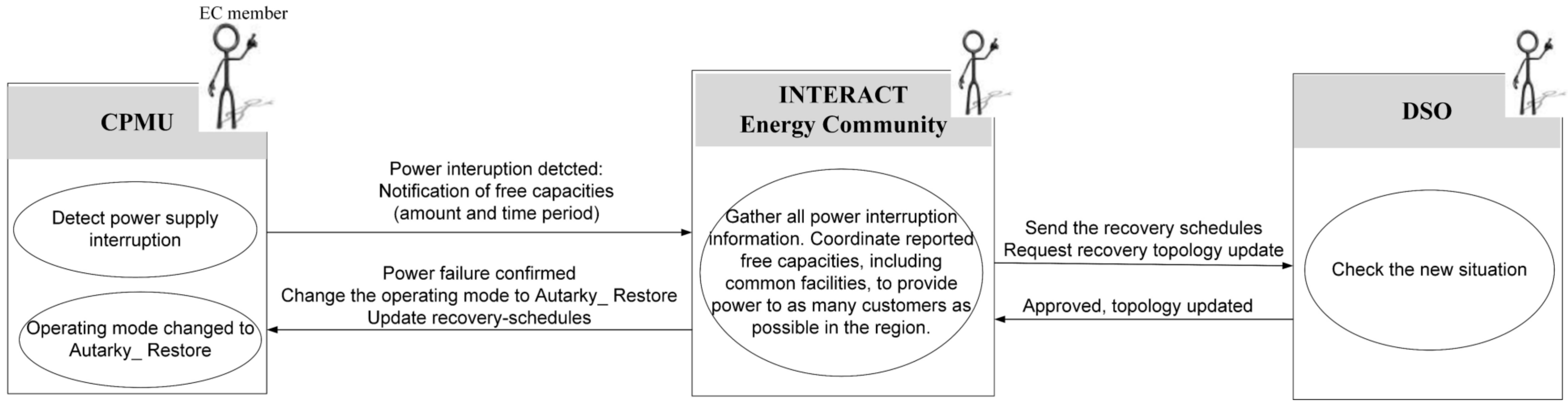

Figure 9 – Service restoration after a blackout

5 Long term planning

Long-term planning shows how asset investments can be successful over an extended period. Keeping those assets running for this extended period commits Energy Communities to decisions being made before their full impact can be understood. The best strategies will identify paths that maintain flexibility and options for alternative paths. Crucially, course corrections are possible, and the opportunity exists to take advantage of technological breakthroughs. This behaviour is one of the main ways to lock in many innovative, emerging technologies that can significantly reduce emissions (e.g., rooftop PV panels). Energy communities, or their members, need to feel more comfortable moving away from familiar approaches and taking a risk on newer, cleaner technologies and processes.

5.1 Voltage support through vars: investments in reactive devices

In general, any properly designed CPMU will be capable of delivering reactive power on demand. But, studies have shown that concentrated reactive power consumption at the end of a violated feeder has the most significant effect compared with the distributed one (Q(U) control installed at each prosumer or distributed supplier)[6]. Installing reactive power devices at the end of feeders will therefore allow EC to provide ancillary services to the DSO, who is legally obliged to keep the voltage within the limit at all times. With the increasing share of the distributed generation, i.e. rooftop PV facilities, in radial structures sooner or later, countermeasures will be necessary to keep the voltage within limits.

Actors: EC members, EC and DSO.

Goal: Installing reactive power devices or oversize inverters

Process: An EC member would like to invest in a reactive device and provide var ancillary services. He sends an investment request to EC. The latter checks the current situation and sends to DSO a permission request for the reactive device connection and asks for the appropriate size of the device, Figure 10. The DSO checks the connection point of the reactive device and determines the size. The DSO approves the technical parameters of the investment. This process may require a few iterations.

Reaction: DSO approves investments in the reactive power device.

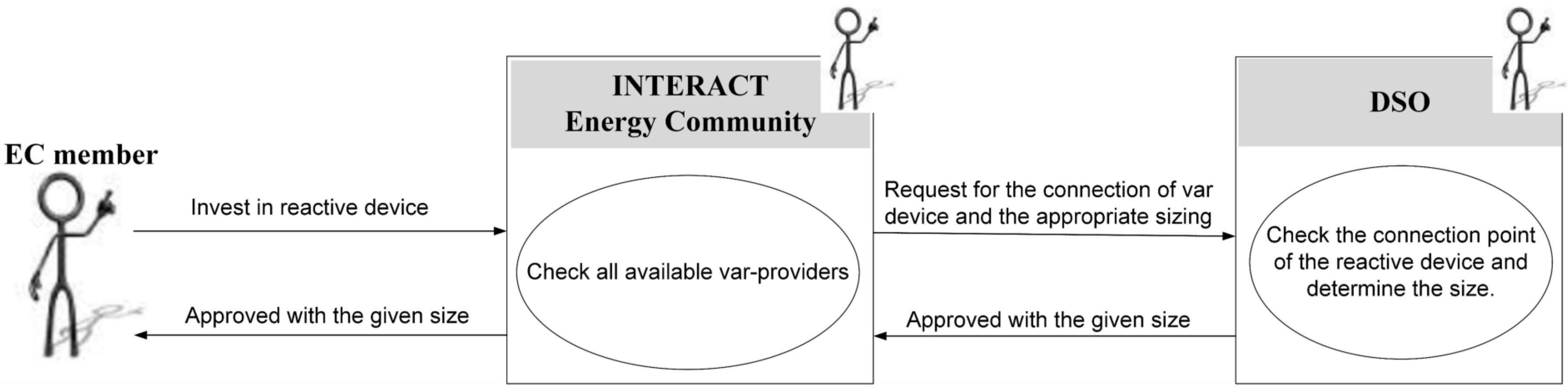

Figure 10 – Long term planning use case: Connect a new PV facility on the EC member's premises

5.2 EC member's initiative to invest in new appliances

One of the reasons for establishing Energy Communities is the investment promotion of distributed renewable energy resources. This use case dedicates to fulfilling this goal. EC members would like to invest in new appliances on their premises, e.g., a new PV or a battery.

Actors: EC members, EC and DSO.

Goal: Integrate a new PV facility.

Process: One EC member expresses interest in investing in a new PV facility on its premises, Figure 11. The EC reviews the current situation and consults the member on the benefits and

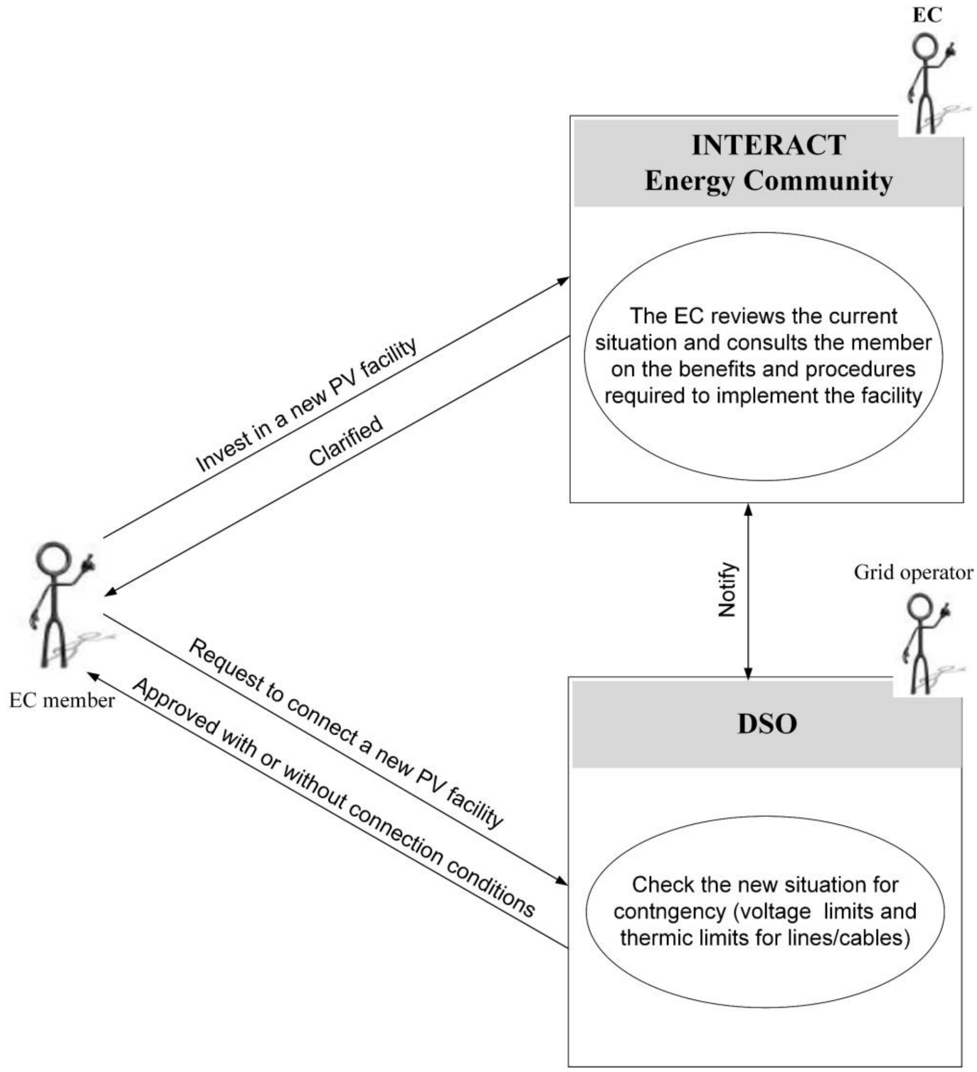

Figure 11 – Long term planning use case: Connect a new PV facility on the EC member's premises

procedures required to implement the facility. Afterwards, the EC member requests the relevant DSO to connect the new PV facility. After checking the grid for contingency, i.e. voltage violations and thermal limits of lines and cables, the DSO approves the connection request with or without connection conditions. This process may require a few iterations if the DSO detects contingencies.

Reaction: The connection of the new PV facility approved.

5.3 EC's initiative to invest in new appliances

EC would like to invest in common new appliances, e.g., a new PV facility, battery or charging station.

Actors: EC members, EC and DSO.

Goal: Invest in new common appliances

Process: EC plans the installation of a common PV facility, Figure 12. He notifies all EC members of this intention and opens the discussion. After the democratic decision, EC

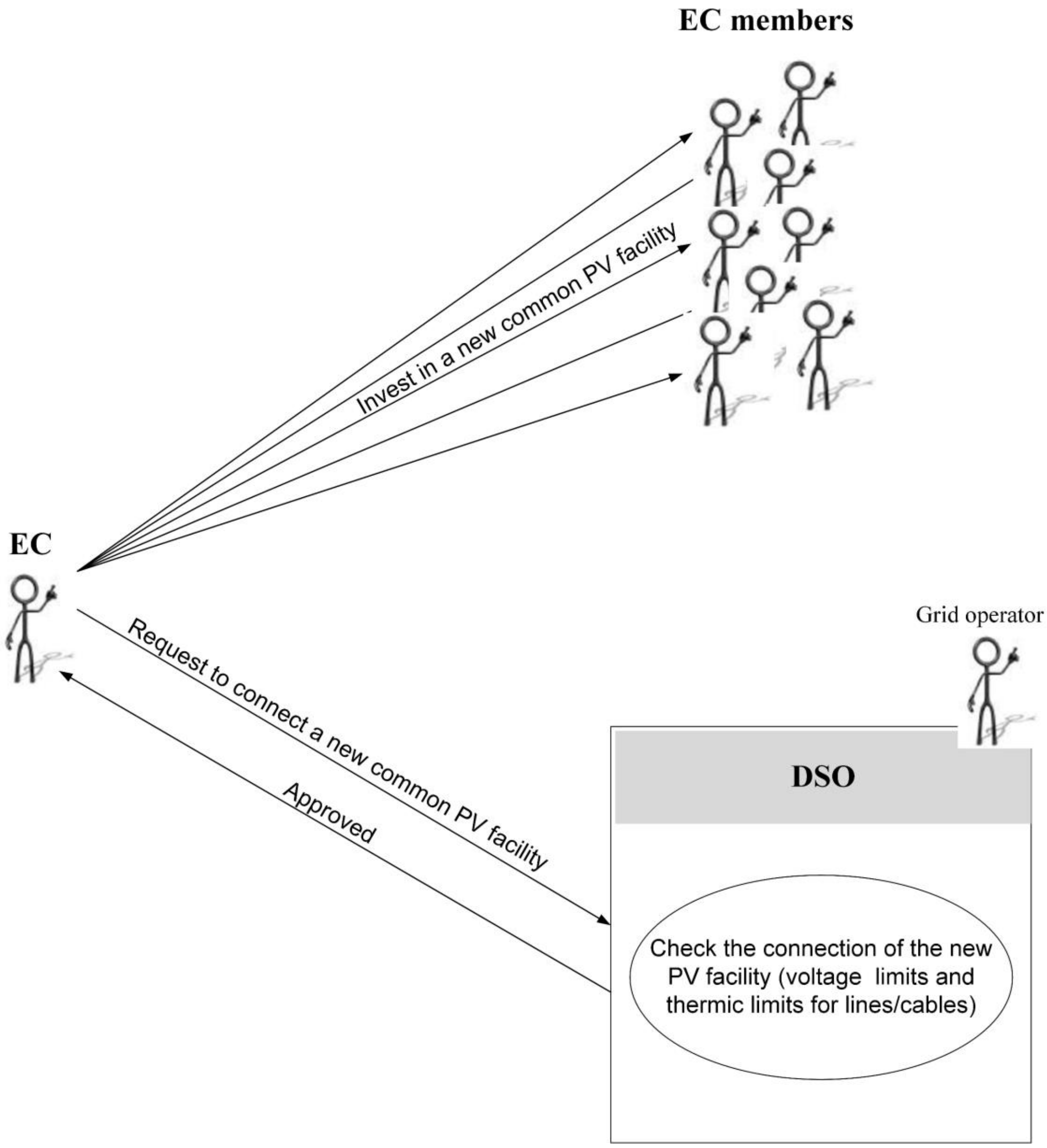

Figure 12 – Long term planning use case: Connect a new common PV facility

requests DSO for PV facility connection to the grid. After checking the grid for contingency, i.e. voltage violations and thermal limits of lines and cables, the DSO approves the connection request. This process may require a few iterations if the DSO detects contingencies.

Reaction: New common appliance approved.

5.4 New developments in the region

Municipalities are constantly developing, and new investors may want to invest in various businesses in the region and be ambitious to build up, e.g. rooftop PV facilities. This use case describes the process of considering new developments in the region.

Actors: Investor, EC members, EC, and DSO.

Goal: New EC member

Process: An investor is interested in opening a new business in the region and is ambitious to build a rooftop PV facility. He notifies the municipality of its intention. The municipality checks the new business, and clarifies and approves the plan. It also informs the EC about the region's

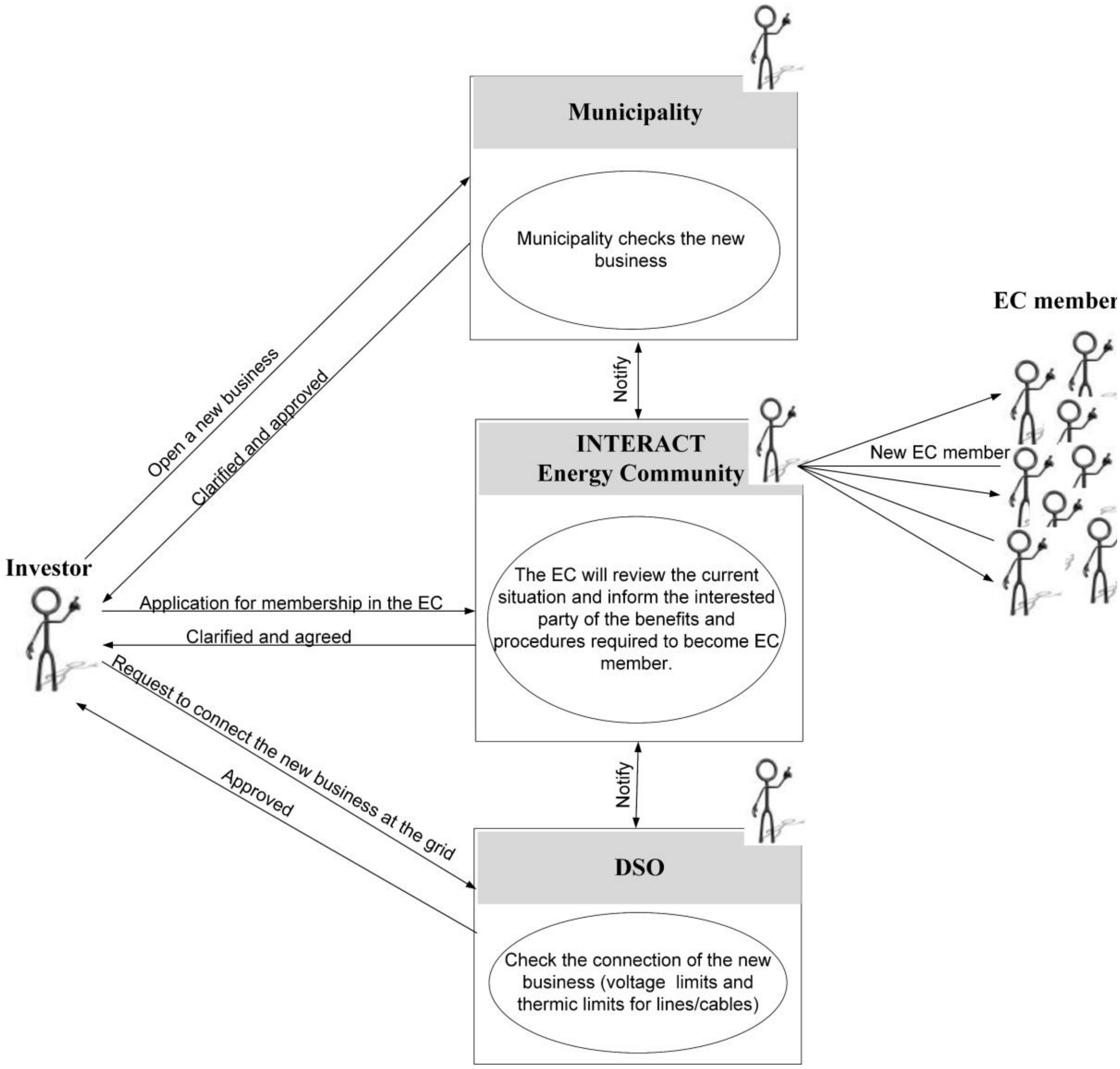

Figure 13 – Long term planning use case: New developments in the region

new developments and the investor's interest in joining the EC. The investor applies for membership in the EC. After briefing and discussing the new membership with all members, EC clarifies to the interested party the benefits and procedures of becoming an EC member. The investor requests the DSO to connect his business, including the PV facility, to the grid.

After checking the grid for contingency, i.e. voltage violations and thermal limits of lines and cables, the DSO approves the connection request. This process may require a few iterations if the DSO detects contingencies.

Reaction: New business, including the rooftop PV facility, approved.

6 Conclusions

The INTERACT energy community, embedded in the holistic *LINK*-architecture, promotes many use cases that enable harmonized interaction with the power grid.

Capturing different use cases promotes business cases that make the energy community viable. The emergency-, price- and emission driven Demand Response use cases seamlessly integrate distributed resources such as prosumers, commercial and small businesses into the flexibility for resilience process. Peer-to-peer use case empower the electricity trading between the energy community members. The extensive integration of distributed resources in the frame of the INTERACT energy communities offers a tremendous opportunity to reduce recovery time from a partial or total blackout.

Thanks to the standardized architecture, all described use cases are generic and can be implemented in all INTERACT partner countries as well as all over Europe.

The described use cases are in no way all possible use cases, but from a current technological perspective the most relevant. Further use cases, e.g. between different EC members, or between different ECs, can be described and integrated as they might be requested and/or developed by the different system actors.

7 References

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