Platone

PLATFORM FOR OPERATION OF DISTRIBUTION NETWORKS

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PLATform for Operation of distribution NEtworks

D5.2 v1.0

Detailed Use Case Descriptions

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Abstract

The deliverable D5.2 “Detailed Use Case Description” details the Use Cases to be applied in the German demonstrator of the Platone Project. Avacon is targeting to apply and test new energy supply strategies for the integration of low voltage connected energy communities. Avacon aims to enable a local network to act as an energy community, to implement, apply and evaluate the following Use Cases:

- Islanding
- Flexibility Provision
- Bulk energy supply
- Bulk energy export

The deliverable describes the motivation, scope and objectives of each Use Case. It further gives a detailed overview over the use cases to be tested and demonstrated, including motivation, KPI, expected results and impact on future operations.

Keyword list

Islanding, Local Energy Community, Distributed Resources, Use Case, KPI

Executive Summary

Distribution System Operators (DSOs) face challenges regarding the integration of Renewable Energy Sources (RES) into the existing grid. Especially in low voltage (LV) networks, the amount of installed generation capacity is increasing. Over the coming years, the increase is expected to continue, creating even more stress on low and medium voltage feeders and transformers. Additionally, the electricity demand in distribution grids from residential and small commercial customers is expected to increase beyond today's peak load levels. One way to deal with these challenges is to extend and reinforce existing network infrastructures, which requires high investments and consequently will increase grid charges for the customer. With the Use Cases (UC) presented in Platone, Avacon's aim is to investigate innovative strategies in grid operation and the utilization of flexibility to keep the inevitable increase in costs to a minimum, taking into account the evolving role and behavior of customer and prosumers.

In the future private households connected to the LV grid may elect to participate in Local Energy Communities (LEC) or Citizen Energy Communities (CEC). The intention of European legislators to promote the concept of energy communities is evident in the clean energy package, for example in Art. 22 of the renewable energy directive which states: "Member States shall provide an enabling framework to promote and facilitate the development of renewable energy communities" [1]. The German demonstrator of Platone and the associated UC accept this intended development as a fact and explore efficient ways of integrating energy communities into the distribution grid, thereby promoting the realization and growth of these communities.

To account for today's non-existence of energy communities, Platone will create a test local energy community with which the UC will be demonstrated and evaluated.

In the context of the German field test trial of Platone, Avacon will upgrade a rural LV grid with all assets required to operate a local energy community. The core of the demo will be a newly developed energy management system (EMS) which takes charge of monitoring and controlling the power flows within the community and between the community and the MV-feeder. There are four UCs:

- UC 1 – Islanding is focusing on the demonstrator's ability to operate as an energy community.
- UC 2 - Flexibility Provision explores the ability of energy communities to adhere to a fixed setpoint of power exchange with the distribution grid at the DSO's request or in response to market signals.
- UC 3 and 4 - Bulk energy supply/export are grounded in the realization that energy communities will remain very likely to require some degree of interaction with the distribution grid, either to export surplus energy during times of high local generation or to import energy to cover a deficit likely to arise during the winter semester. These UCs will investigate the degree to which the import and export can be organized in bulk packages, by assigning fixed windows of grid access to energy communities.

Within the frame of the field test demo the DSO will be the main actor to set the UCs. The Avacon Local Flex Controller (ALF-C) will be the central Energy Management System (EMS) to be developed jointly by Avacon and RWTH to monitor the LEC's generation, demand and available flexibility and send setpoints to local storages and flexible loads to fulfill requests set by the user. The ALF-C will be integrated in the Platone framework and connected to systems located in the field, such as sensors in customer households and the secondary substation providing measurement data. CEC participating in the project may provide additional flexibility from flexible loads and household energy storage systems. A large-scale battery energy storage will be implemented in the field to provide additional storage capacity and controllable load in order to ensure a successful application of the use cases.

Key Performance Indicators (KPI) will measure the data and results collected during the field test phase. The results evaluate the potential of the UCs and their possible impact on future operation. For now, it is expected that the future application of the UCs will contribute to more efficient and reliable distribution networks.

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1 Introduction

The project "PLATform for Operation of distribution Networks – Platone - aims to develop an architecture for testing and implementing a data acquisitions system based on a two-layer approach (an access layer and a service layer) that will allow greater stakeholder involvement and will enable an efficient and smart network management. The tools used for this purpose will be based on platforms able to receive data from different sources, such as weather forecasting systems or distributed smart devices spread all over the urban area. These platforms, by talking to each other and exchanging data, will allow collecting and elaborating information useful for DSOs, Transmission System Operators (TSOs), customers and Aggregators. In particular, the DSO will invest in a standard, open, non-discriminating, economic dispute settlement blockchain-based infrastructure, to give to both the customers and to the aggregator the possibility to more easily become flexibility market players. This solution will see the DSO evolve into a new form: a market enabler for end users and a smarter observer of the distribution network. By defining this innovative two-layer architecture, Platone removes technical barriers to the achievement of a carbon-free society by 2050 [2], creating the ecosystem for new market mechanisms for a rapid roll out among DSOs and for a large involvement of customers in the active management of grids and in the flexibility markets. The Platone platform will be tested in three European trials in Greece, Germany and Italy and within the Distributed Energy Management Initiative (DEMI) in Canada. The Platone consortium aims to go for a commercial exploitation of the results after the project is finished. Within the H2020 programme "A single, smart European electricity grid" Platone addresses the topic "Flexibility and retail market options for the distribution grid".

The increasing number of distributed energy resources is accompanied by changing behavior of energy consumption and generation, creating a framework where energy communities can introduce an additional source of flexibility contributing to mechanisms that increase efficiency and safety of distributions grids. These communities will consists of a large portfolio of flexible storages, generators and loads monitored and controlled by an Energy Management System. An interface to receive and react on external requests will enable these communities to be connected to markets and integrated into mechanisms for grid balancing. In Platone, Avacon targets to investigate a solution for communities that introduces a principle of subsidiarity to households whereby the households are responsible for their assets and for balancing their generation and demand. Applying this principle reduces stress on the distribution network and thereby mitigates the DSO's challenge to run the distribution network. This will represent a second level of distribution management, which treats entire energy communities as a single source of generation, demand and flexibility. In doing so, Platone reduces the complexity of the control framework and the number of communication channels in pursuit of an efficient and future-proof approach to distribution management.

1.1 Task 5.3

This document outlines the outcome of the task 5.3. It documents and analyses the Use Cases and Key Performance Indicators (KPI) to be applied in the German demonstrator. Based on the general UC description in task 5.3 of the Grant Agreement Avacon explored potential ways for implementation in the German demonstration project of Platone and developed them further, in order to enable an energy community to be operated in an virtual island mode, provide power on demand and be provided with energy in bulks as well as export energy in bulks at predefined periods of time.

1.2 Objectives of the Work Reported in this Deliverable

The objective of this deliverable is to present and compare the UCs which are going to be implemented in the German demonstration project of Platone. With the demo site located in Abbenhausen, Twistringen Germany, Avacon sets out to implement an EMS integrated in the Platone framework that enables to monitor and balance a local network and implement new strategies of energy supply. Within the frame of the field test trial, four different UCs will be implemented enabling energy communities to:

- Maximize the consumption of local generation, minimize the demand from the feeding grid and maximize the duration of an islanding period

- Adhere to a fixed power value at the point of connection defined by a third party (e.g. DSO request or in response to a market signal)
- Satisfy the energy deficit left by insufficient local generation within previously defined timeslots (“Bulk supply”)
- Export the energy surplus generated by excess local generation within previously defined timeslots (“Bulk-export”)

The deliverable will identify the operation specifications, which will serve as input for the development of the algorithm, the Avacon Local Flex – Controller and field test design.

1.3 Outline of the Deliverable

Section 2 highlights the motivation by describing the current situations and challenges of operations of the distribution grid, motivation for the integration of future energy communities in the DSO grid and market operation. Section 3 gives technical details of each of the four UCs, describes actors, components, exchanged data, way of communication, functionalities in templates following the IEC-62559-2 format for the description of each UC. Key Performance Indicators to be applied for the measurement of success of the UCs are described in section 5. The expected results and impacts on future operation are drawn in section 5. Section 6 provides conclusions of this deliverable.

1.4 How to Read this Document

An initial concept of the solution design and technical specification of architecture of the German field test trial was provided in D5.1 [3]. This deliverable presents the Use Cases and KPIs for the German Demo. D1.1 [4], which is also released in parallel, compiles and compares the Use Cases in the three different Platone demos. D4.1 [5], which is released in parallel, includes similar information for the Greek Demo. Further details regarding the Italian Demo like its use cases and specific KPIs will be found in the D3.3 [6], due for release in month 18 of the project. D2.1 [7], which is released in parallel, describes the Platone architecture and its use across demos.

2 Motivation

This section gives an overview over the challenges of distribution grid operation and outlines the motivation for the founding of energy communities. Combining these two things leads us to the question of why the integration of such communities into the DSO's grid operation strategies is necessary and which UCs promise to support these integration efforts.

2.1 Challenges in Distribution Grid Operation

The German demonstrator of the Platone project is motivated by the challenge to increase the hosting capacity of distribution networks in an environment in which the energy sector has experienced tremendous changes in the recent years and will continue to do so in the future. The changes are noticeable along the entire energy supply chain, from generation, marketing, transmission, distribution to consumption. Not only are technologies evolving but also the behavior of customers in the wider sense, particularly in terms of generation and consumption, are undergoing fundamental changes.

Increase of distributed generation

As renewable energy becomes more and more competitive and industrialized countries strive to reduce their carbon emissions by replacing large-scale power stations with smaller decentralized units, the pressure on local power grids to adapt to this new reality grows. Germany is among those countries, where the change from nuclear and fossil-fueled power stations towards decentralized renewable generators is already happening. This change from a few large controllable generators to numerous small ones that are fluctuating based on the current weather has posed a significant challenge for all parties involved.

DSOs in Germany today have to deal with a significant increase in feed-in power from distributed generation (DG). The DGs are allocated based on communal planning, private initiatives and the accessible open space. The capacity of the electrical network at any given location has no direct impact on the allocation of new generators and subsequently the rise of these new generators can create local and regional hotspots of fluctuating generation which cannot be handled by the existing grid at all times.

Nowadays, due to the cumulative feedback of peak generation of photovoltaics (PV) in low voltage (LV) and medium voltage (MV) networks in some cases technical limits of lines and transformers are exceeded. DSOs operating in rural and suburban areas like Avacon are highly affected by these challenges. To maintain secure operation of the affected networks, the physical infrastructure needs to be upgraded, which leads to an increase in investments for the replacement of lines and the uprating of existing transformers. The cumulative feedback of peak generation of PV can also cause voltage limit violations along the feeder. This PV-induced voltage rise frequently pushes the local voltage close to its limits, requiring the DSO to add more feeders and reinforce existing networks. In some areas, these effects can be countered to some degree with the deployment of voltage regulating distribution transformers and proactive reactive power management. But still, the cumulative feedback of PV in rural networks remains a major challenge for DSOs.

Increase of end-customer demand

With the further development of new heating and cooling technologies and the constant increase in efficiency, electric heaters are becoming increasingly lucrative for many private customer households. The number of heat pumps in the service area of Avacon has been on the rise for decades. Generally, such heaters are used in households for heating. In addition, night storage heaters installed in the 1970's and 1980's are still in use in many households. These heaters are typically equipped with a solid-state heat storage, able to store and provide heat for up to 12 to 24 hours after being charged. During the cold season electrical heating accounts for a large share of network load. This load can partially be leveraged as a source of flexibility, effectively coupling heating and power.

Battery Storage Systems

Germany has seen a tremendous growth in domestic battery systems, almost exclusively in combination with a rooftop PV installation. By late 2018, the number of domestic battery installations exceeded 100,000 units. The majority of these systems range from 5 to 10 kWh in useable storage capacity and have a charging / discharging power between 2 and 6 kW.

The growth in the number of storages is encouraged by the government and regulator to use battery systems in combination with a PV generator as means to increase self-consumption and reduce feedback to the public network. The rationale was that by increasing self-consumption and reducing grid interaction, the overall costs of integrating DERs into low voltage networks could be kept in check.

Consequence

The solutions to tackle these challenges available to the DSOs are manifold. For example, the DSO can opt to reinforce and expand the existing grid. This uprating or addition of assets however can be very costly and bind a large amount of capital, it takes time and recently the public acceptance of new overhead-lines has diminished.

If the continued expansion and reinforcement of the physical grid is not the best solution, then an alternative way could be to make loads and generators more flexible and to control them in such a way that the system remains in balance. By ramping loads and generation up or down based on grid constraints or in response to a market signal, a significant portion of the estimated grid expansion could potentially be saved. Today's generators and loads along with recently developed technologies such as power storage devices or electric vehicles present a large pool of hitherto untapped potential of power-flexibility. A large amount of dormant flexibility can be found in low voltage levels, which are expected to be accessible in the future with the foundation of energy communities.

Energy communities can introduce a principle of subsidiarity to these issues and mitigate the aforementioned challenges by reducing the additional stress on the distribution network. The UCs in Platone would then represent a second level of distribution management, which treats entire energy communities as a single source of generation, demand and flexibility. In doing so, Platone reduces the complexity of the control framework and the number of communication channels in pursuit of an efficient and future-proof approach to distribution management.

2.2 Energy Communities

Driven by new legal framework conditions and technical developments, the generation and consumption structure in electrical distribution networks has changed fundamentally in the past decade. In 2019, the EU completed a comprehensive update of its energy policy framework to facilitate the transition away from fossil fuels towards cleaner energy and to deliver on the EU's Paris Agreement commitments for reducing greenhouse gas emissions. The agreement on this new energy rulebook, which was published in 2015, is named "Clean energy for all Europeans package" and marked a significant step towards the implementation of the energy union strategy.

Among a wide range of new and amended rules and regulations spread across several legislative tools, the rulebook extends the rights of private households in the energy sector to not only generate and consume energy, but also to market the flexibility provided by controllable generators and loads and make energy available to each other [8]. The framework, in addition to other incentive mechanisms, should encourage private households to organize and join local energy communities to share self-generated energy within the local network and target the maximization of the consumption of locally generated energy and minimize the amount of energy demand provided by the public distribution.

Among the actors of an energy community, we will find active customer households with small-scale generators, loads and battery energy storages connected to the low-voltage network. Generated energy surpluses could be stored in local storages and used when local demand exceeds the local generation. In networks with a high share of photovoltaic systems and consequently a high amount of energy generation, the optimization of self-consumption will enable the local community to temporarily be self-sufficient and potentially even disconnect from the public grid for short durations.

But even future energy communities with a large portfolio of DER consisting of small-scale generators, flexible consumers and battery storage systems are unlikely to be permanently energetically islanded. Future communities will probably retain a connection to the local distribution grid. The DSO will keep the responsibility to supply the community with energy and ensure that the demand of the community will be satisfied at any time and to accommodate energy export targeted at markets outside the community. As such, the DSOs role will transition from pure end-customer grid operator to a facilitator of highly complex energy markets.

Communities may not only target the optimization of self-consumption. Economic incentives may motivate communities or individual households to participate in emerging markets for provision of energy of flexible loads or more likely contract aggregators to handle the marketing of their production and flexibility. Legal requirements may lead to obligations for the community to support the connecting DSO by providing flexibility on request, e.g. via integration into congestion management mechanisms. Regardless of the purpose of the use of flexibility, the community requires an EMS providing monitoring and balancing functionalities in order to enable different UCs. Local sensors in conjunction with a capable communication infrastructure will enable the EMS to monitor local generation and consumption as well as to track available flexibility and storage capacities. The local portfolio of DERs will include any type of generator, load, storage or even assets enabling sector coupling. The responsibility for operating the EMS and local storages will likely fall to a new role of energy community operator (ECO), an independent party, or will lie with the DSO or an aggregator. The EMS will have to provide an interface to external users, such as the DSO, the TSO and other market participants such as aggregators, to enable triggering for the provision of power or energy provision.

Based on these future visions, Avacon's targets are not limited to the physical connection of EC to the distribution grid. In the frame of Platone Avacon seeks to develop and apply new strategies for grid operation that integrates communities actively into an innovative mechanism of energy supply. A pool of flexible assets provided by an EC consisting of batteries and flexible loads will be integrated into an energy management mechanism that enables load management and the application of an innovative mechanism of energy supply and export in bulk. This mechanism potentially contributes to the increase of a safe, reliable and efficient operation of distribution network and to promote the integration of renewable energy sources.

In the context of the Platone field test trial, the German demonstrator will apply four UCs that demonstrate the generation and consumption behavior of an energy community in a local low-voltage network in different scenarios and test mechanisms for the application of new strategies of energy provision. The UCs will be applied to a LV network in Avacon's service area consisting of an EMS, a large-scale battery energy storage system (BESS) and private customers' household energy storages.

2.3 Use Case 1 - Islanding

UC 1 forms the basis for testing UC 2 to 4 and enables a local network to behave like an energy community by is maximizing self-consumption of locally generated energy up to a virtual island mode at which the community is temporarily independent from the energy provision from the medium voltage network. UC 1 demonstrates the energy generation and consumption behavior of future local low-voltage networks, in which private households have formed a community in order to maximize the self-consumption of locally generated energy.

2.3.1 Overview and Objectives

Name	Islanding
Scope	The scope of the UC is the implementation of an EMS that operates a specific low voltage network in virtual island mode, i.e. minimization of the power exchange with the connected medium voltage feeder by utilizing available flexibility (local energy storage systems and controllable loads). The UC focuses on a local energy community.
Networks	LV
Objective	• Maximize consumption of local generation/Minimize demand satisfied by public grid • Islanding of local grid by making use of flexible loads and storages • Maximizing duration of islanding operation UC 1 is a prerequisite for UC 2, 3 and 4
Short description	The UC “Islanding” of an energy community aims to balance generation and demand of a local energy community in such a way that the load flow across the connecting MV/LV transformer is reduced to a minimum. The balancing is enabled by an EMS (ALF-C). The ALF-C monitors the power flow across the transformer and controls a BESS connected directly to the LV-terminal of the substation. Generated energy surplus will be stored in the BESS and released at times of a generation deficit. Private households equipped with batteries and controllable electric heaters can be dispatched to increase the degree of self-sufficiency further.

2.3.2 Detailed Description

The field test trial and application of UC1 will take place in a rural LV network consisting of family houses, agricultural buildings and a large amount of installed generation capacities provided by roof top photovoltaic systems. A local EMS (ALF-C) will monitor local generation, demand and storage capacities and control available flexibilities in such a way that the consumption of the locally generated energy will be maximized, and the energy demanded from the MV grid will be minimized. The application of UC 1 will be triggered by an operator from Avacon via a user interface (UI).

When local generation exceeds local demand, surplus energy will automatically be stored in local storages. When local consumption exceeds local generation, stored electrical energy in local batteries will be discharged. The optimization of self-consumption targets minimizing the load exchange with the MV grid along the MV/LV grid connection point up to a level at which the community is virtually islanded. In cases in which generation and demand cannot be balanced due to a lack of available storage capacity or flexibility, the residual load will be supplied by imported power from the MV grid.

A sensor located at the grid connection will measure the power exchange of all 3 phases between the medium voltage and the low voltage grid. The measured values indicate the real time flow of power along the feeder. Measurement data by sensors is provided to the EMS. Based on the provided information the EMS will increase or decrease the load demand of individual storages or flexible loads in order to balance the grid. Additionally, customer households provide flexible load and storage capacities for control. Flexible assets in the field are equipped with sensors and controllers to increase or decrease demand and to command charging or discharging of the local large Battery Energy Storage System and private customer household storages. Vendors of flexible assets provide a cloud data management platform from which measurement data is accessible for EMS via a backend. The interface also provides data to estimate the state of charge of batteries, flexible loads and potential available storage capacity. Historical measurement data and weather data provided by external service providers enable the EMS to predict energy generation and consumption to maximize self-sufficiency.

Controllers in the field are able to switch on or off flexible loads and trigger charging or discharging of batteries in order to increase total consumption or generation of the community. Flexible loads may be provided by storage heaters and heat pumps. Storage capacities will be provided by a local BESS and battery storages from households. In order to avoid customers sacrificing comfort due to a decrease of room heating, control of loads will be limited.

The communication between sensors, controllers and EMS will be web based on LTE or DSL and open protocols. The EMS and sensors will be fully integrated into the communication infrastructure of the Platone framework. The Blockchain Access Platform (BAP) will provide encryption functionalities whereas the Platone DSO Technical Platform (DSOTP) will act as a middleware enabling connection to sensors in the field and providing services to the EMS.

2.4 Use Case 2 – Flexibility Provision

In the coming years, the number of generation units, flexible loads and storages in distribution grids is expected to increase further and the challenges for the integration of these DERs into existing grids will rise. Additionally, the role of customers continues to change from passive users to active players in the energy system, being able to provide flexibility through flexible loads, generators or storages. The DSO will therefore have growing needs for the provision of real-time flexibility for a cost-effective, seamless, secure power supply, to address local congestions and voltage stability issues, while supporting the TSO in their system level responsibility. Use Case 2 shall demonstrate that energy communities can contribute to all the above by providing flexibility. Use Case 2 demonstrates how the flexibility required to enable a local balancing mechanism (UC 1) could temporarily be allocated to other uses, for example the provision of flexibility to a third party, e.g. the connecting grid operator. Use Case 2 uses the available flexibility in a given local energy community to maintain an externally defined non-zero setpoint for the power exchange at the point of connection.

2.4.1 Overview and Objectives

Name	Flexibility provision
Scope	Communities with a high penetration of photovoltaic systems and correspondingly high installed generation capacity can be expected to generate an energy surplus during times of peak generation and low local demand, and vice versa to run into an energy deficit during seasons of low generation. Surplus energy can be stored and shifted to times of low generation in order to satisfy temporary demand and hence increase the degree of self-sufficiency. UC 2 demonstrates how the flexibility required to enable a local balancing mechanism could temporarily be allocated to other uses, for example the provision of flexibility to a third party, e.g. the connecting grid operator. UC 2 uses the available flexibility in a given local energy community to maintain an externally defined non-zero setpoint at the point of connection.
Networks	LV
Objective	Maintain a fixed non-zero power exchange between the energy community and the distribution network for a limited duration.

Narrative	Local energy communities are likely to emerge in Europe in the near future but will most likely retain an interconnection to the distribution grid. These communities will require a large share of flexibility to enable their primary UC of islanding. Situations could arise that require the community to provide flexibility to third parties – driven by technical circumstances or following economic considerations (market incentives). UC 2 demonstrates the ability and practical feasibility of a local community to maintain constant non-zero power exchange with the distribution network for a previously defined duration.

2.4.2 Use Case 2 - Detailed Description

In the selected field test region, the EMS (ALF-C) monitors local generation, demand and storage capacities and control available flexibilities. An operator of Avacon triggers the EMS to apply UC 2 and sets a target value ($P'_{Breaker}$) for the power exchange at the grid connection. The EMS processes weather forecasts and measurement values from the grid connection point and flexible assets such as BESS, household energy storages and flexible loads located in the community. Based on the data and historic measurement values, the EMS forecasts the local generation and demand to determine the best strategy to reach ($P'_{Breaker}$) by utilizing the available flexibility to keep the power flow constant for a pre-defined duration.

During the application of UC 2, generated energy surplus will automatically be stored in local storages. When local consumption is exceeding local generation, stored electrical energy in local batteries will be discharged. In cases that generation and demand cannot be balanced to reach ($P'_{Breaker}$) due to a lack of available storage capacity or flexibility, the UC will be terminated.

A sensor located at the grid connection will measure the power exchange of all 3 phases with the MV grid $P_{Breaker}$ and provide data to the EMS. Based on the information the EMS determines deviations between $P_{Breaker}$ and $P'_{Breaker}$ and dispatches setpoints to increase or decrease the load in the grid in order to reach $P'_{Breaker}$. Additionally, sensors located in private customer households will provide measurements of energy consumption and State of Charge (SOC) or State of Energy (SOE) of storages and provide data to the EMS. Historical measurement data and weather forecasts provided by external service providers enable the EMS to predict energy generation and consumption to maximize the duration of maintaining $P'_{Breaker}$.

2.5 Use Case 3 – Bulk Energy Supply

One of the biggest challenges in the operation of distribution networks with high shares of DER is the stochastic nature of a network demand that is modulated by local production. While networks consisting of consumers and loads with standard load profiles can be planned and operated rather reliably, high shares of DER introduce an element of uncertainty that makes it difficult to plan and design networks efficiently. Uncertainty in the planning process must lead to over-dimensioning of assets to account for the risk of unexpected load configurations. Another challenge arises with the expected increase of peak loads in local low voltage grids arising from the increasing number of heat pumps, charging points for electric vehicles or other sector coupling technologies. New strategies for the increase of hosting capacity of existing grids are needed in order to enable the integration of these technologies in future.

One way to reduce uncertainty, increase hosting capacity of existing grid efficiency and reliability in network planning and operations, is to leverage flexibility and smart control algorithms to uncouple the low-voltage network from its MV-feeder by employing a package-based approach for energy supply. The residual demand of a network after local production can be forecasted and delivered to the network in bulk in advance. The energy can be stored in local batteries from which customers can withdraw energy as they please without affecting the MV-feeder.

2.5.1 Use Case 3 - Overview, Scope and Subjective

Name	Bulk energy supply
Scope	Energy communities with a high proportion of self-generation and flexible consumers and storage can maximize the self-consumption of locally generated energy. These communities are unlikely to meet their own needs with locally generated energy throughout the year and will potentially run into energy-deficit in times of low local generation. Energy deficits could be compensated by the supplying distribution network. To reduce the stress on the mid-voltage feeder and reduce overall network cost, energy deficits occurring could be forecasted and delivered in discrete packages ahead of time at fixed time slots and be stored in local storages until demand arises.
Networks	LV, MV
Objective	• Enabling temporary islanding even in times of energy deficit of the local community • Forecasting of residual energy demand of an energy community • Forecasting of residual energy generation of an energy community • Execution of power exchange schedule for the energy community for the grid connection point LV/MV (time and power of load exchange) • Determination of a setpoint schedule for individual local asset to meet energy community setpoint schedule • Execution of defined power exchange between energy community and the distribution network
Narrative	In the absence of sufficient generation and storage, the community is unlikely to be self-sufficient at all times. When energy deficits occur, they must be provided by the distribution network. Instead of a real time energy supply through the connected distribution network, energy deficits could be forecasted and supplied as an energy package with a defined time, duration and power value for the load exchange at the LV/ MV-grid connection point. The energy package shall be stored in local storages within the community and be available for use, when the demand is rising. Outside of the defined periods of energy provision, no power exchange on all the grid connection points shall take place, according to UC 1. This use case enables the DSO to reduce overall network costs, for example by gaining the ability to stagger the demand of multiple communities along a single feeder, thus reducing the factor of coincidence of peak load and peak load level accordingly.

2.5.2 Use Case 3 – Detailed Description

An operator of Avacon triggers the EMS to apply Use Case 3 and sets a schedule of target value $P'_{Breaker}$ for the period (t+1) for the power exchange at the grid connection point. The schedule can be defined for a duration for the next 1 to 24 hours.

The schedule contains time slots for the import of energy in which $P'_{Breaker} \neq 0$ and time slots in which no power shall be exchanged along the grid connection point ($P'_{Breaker} = 0$), following the principle of UC 1. During the application of UC 3, the total amount of imported energy shall meet the total amount of energy deficits that the community will have. The energy deficits will therefore have to be forecasted by the operator. During the energy package delivery, the energy package shall be stored in local battery storages. To maintain the given setpoint $P'_{Breaker}$ deficits shall be covered by energy provided by batteries located in the local network whereas generated surplus shall be buffered in available batteries.

After the user input has been confirmed, the EMS begins with the application of UC 3. The EMS receives weather forecasts provided by an external service provider and measurement values provided by sensors located at the LV/MV grid connection point, flexible assets such as BESS, household energy storages and flexible loads as well as household grid connection points. Based on the received data and historic measurement values the EMS forecasts the local generation and demands and determines the best strategy to reach and maintain the setpoint schedule by utilizing the available flexibility for the pre-defined duration.

A sensor located at the grid connection will measure the power exchange of all 3 phases with the MV grid $P_{Breaker}$ and provide data to the EMS. Based on the information the EMS determines deviations between $P_{Breaker}$ and $P'_{Breaker}$ and dispatches setpoints to increase or decrease the load in the grid in order to reach $P'_{Breaker}$. Additionally, sensors located in private customer households will provide measurements of energy consumption and SOC/SOE of storages and provide the data to the EMS. Historical measurement data and weather forecasts provided by external service providers enable the EMS to predict energy generation and consumption to maximize the duration of time of maintaining $P'_{Breaker}$.

In case generation and demand cannot be balanced to reach ($P'_{Breaker}$) due to a lack of available storage capacity or flexibility, the UC will be terminated.

2.6 Use Case 4 – Bulk Energy Export

Future distribution grids will display an increasing share of generation from RES. LV networks in Avacon's' service region already show a large amount of RES that temporary lead to load situations in which the generation exceeds the local demand. Generated surplus is exported from the LV into the MV network causing additional stress on MV lines and transformers. RES in Avacon's LV networks mainly consist of photovoltaic systems owned by private customers installed as rooftop systems. It is to be expected that the number privately owned PV systems will continuously rise in the coming years, leading to an increase of the amount of generated energy.

Therefore, future energy communities, which have a large pool of storage capacities, might not always be able to fully consume their own generated energy. Generated surplus will have to be exported into the feeding MV network. Rather than an export in real time, the application of a package-based approach following principles described in UC 3, energy can be exported out of local communities at suitable times for the feeding distribution grid, in which the physical stress is low.

UC 4 is targeting to demonstrate how generated energy surplus of a local energy community with a high amount of RES will be exported time shifted out of a local LV grid into the MV grid. For this purpose, generated energy surplus will be stored in local storages and exported out of the grid at defined time slots.

2.6.1 Use Case 4 - Overview, Scope and Objective

Name	Bulk energy export
Scope	Energy communities with a high proportion of self-generation and few flexible consumers can make use of local storages to maximize the self-consumption of locally generated energy. These communities are unlikely to fully consume locally generated energy throughout the year and will potentially run into surplus generation in times of low demand. Surplus energy could be exported to the supplying distribution network. To reduce the stress on the mid-voltage feeder and reduce overall network cost, surplus generation could be forecasted, stored in local storages and exported delayed in discrete packages at fixed time slots.
Networks	LV, MV

Objective	• Enabling temporary islanding even in times of energy deficit of the local community • Forecasting of residual energy demand of an energy community • Forecasting of residual energy generation of an energy community • Execution of power exchange schedule for the energy community for the grid connection point LV/MV (time and power of load exchange) • Determination of a setpoint schedule for individual local asset to meet energy community setpoint schedule • Execution of defined power exchange between energy community and the distribution network
Narrative	In the absence of sufficient generation and storage, the community is unlikely to be self-sufficient at all times. When surplus generation occurs, it must be exported into the distribution network. Instead of a real time energy export to the connected distribution network, surplus energy could be forecasted and exported time shifted as an energy package within a defined time, duration and power value for the load exchange at the LV/ MV-grid connection point. The generated energy surplus first shall be stored in local storages located within the community and be exported as an energy package time shifted, when the load in the upper grid decreases. Outside of the defined periods of energy export, no power exchange shall take place, according to UC1. This use case enables the DSO to reduce overall network costs, for example by gaining the ability to stagger the export of multiple communities along a single feeder, thus reducing the factor of coincidence of peak load and peak load level accordingly.

2.6.2 Use Case 4 – Detailed Description

UC 4 makes use of the same principles, steps and components described as in UC 3. The difference is that the energy packages are made up of surplus energy, which is exported out of the low-voltage network ex-post.

An operator of Avacon triggers the EMS to apply UC 4 and sets a schedule of target value $P'_{Breaker}$ for the period (t+1) for the power exchange at the grid connection point. The schedule can be defined for the next 1 to 24 hours.

The schedule contains time slots for the export of energy in which $P'_{Breaker} \neq 0$ and time slots in which no power shall be exchanged along the grid connection point ($P'_{Breaker} = 0$), following the principle of UC 1. During the application of UC 4, the total amount of exported energy shall meet the total amount of the residual energy surplus that the community will generate. The generated surplus will therefore have to be forecasted by the user. In times $P'_{Breaker} = 0$ the generated surplus will have to be stored in local battery energy storages systems. In times $P'_{Breaker} \neq 0$, local batteries will be triggered to discharge in order to export generated surplus from LV into MV grid. To maintain the given setpoint $P'_{Breaker}$ deficits shall be covered by energy provided by batteries located in the local network whereas generated surplus shall be buffered in available batteries.

After the user input has been confirmed, the EMS begins with the application of UC 4. The EMS receives weather forecasts provided by an external service provider and measurement values provided by sensors located at the LV/MV grid connection point, flexible assets such as BESS, household energy storages and flexible loads as well as household grid connection points. Based on the received data and historic measurement values, the EMS forecasts the local generation and demands and determines the best strategy to reach and maintain the setpoint schedule by utilizing the available flexibility for the pre-defined duration.

A sensor located at the grid connection will measure the power exchange of all 3 phases with the MV grid $P_{Breaker}$ and provide data to the EMS. Based on the information, the EMS determines deviations between $P_{Breaker}$ and $P'_{Breaker}$ and dispatches setpoints to increase or decrease the load in the grid in order to reach $P'_{Breaker}$. Additionally, sensors located in private customer households will provide measurements of energy consumption and SOC/SOE of storages and provide data to the EMS. Historical measurement data and weather forecasts provided by external service providers enable the EMS to predict energy generation and consumption to maximize the duration of time of maintaining $P'_{Breaker}$.

In cases that the generation and demand cannot be balanced to reach ($P'_{Breaker}$) due to a lack of available storage capacity or flexibility, the UC will be terminated.

3 Technical Details

The technical details of use cases are described by making use of IEC-62559-2 standard templates for the description of UC. Section 3.1 gives a graphical overview of the actors in the UC. Section 3.2 gives an overview of the sequences. A detailed description of actors can be found section 0 and description of different scenarios in section 3.5. The step-by-step description is provided in section 3.5 and the communication channels are described in section 3.6. A description of exchanged information is provided in section 3.7 and a description of functionalities in section 4.

3.1 Use Case Actor Diagram

The use case diagram in Figure 1 gives an overview of the actors participating in UC 1 to 4. The detailed description of roles and functionalities are described in the following section. The figure indicates the assignment of actors and components into zones and domains of the component layer of the Smart Grid Architecture Model (SGAM) and displays the communication link and direction between each other. A detailed description of the SGAM analysis for the German Demo is provided in D1.1 [4].

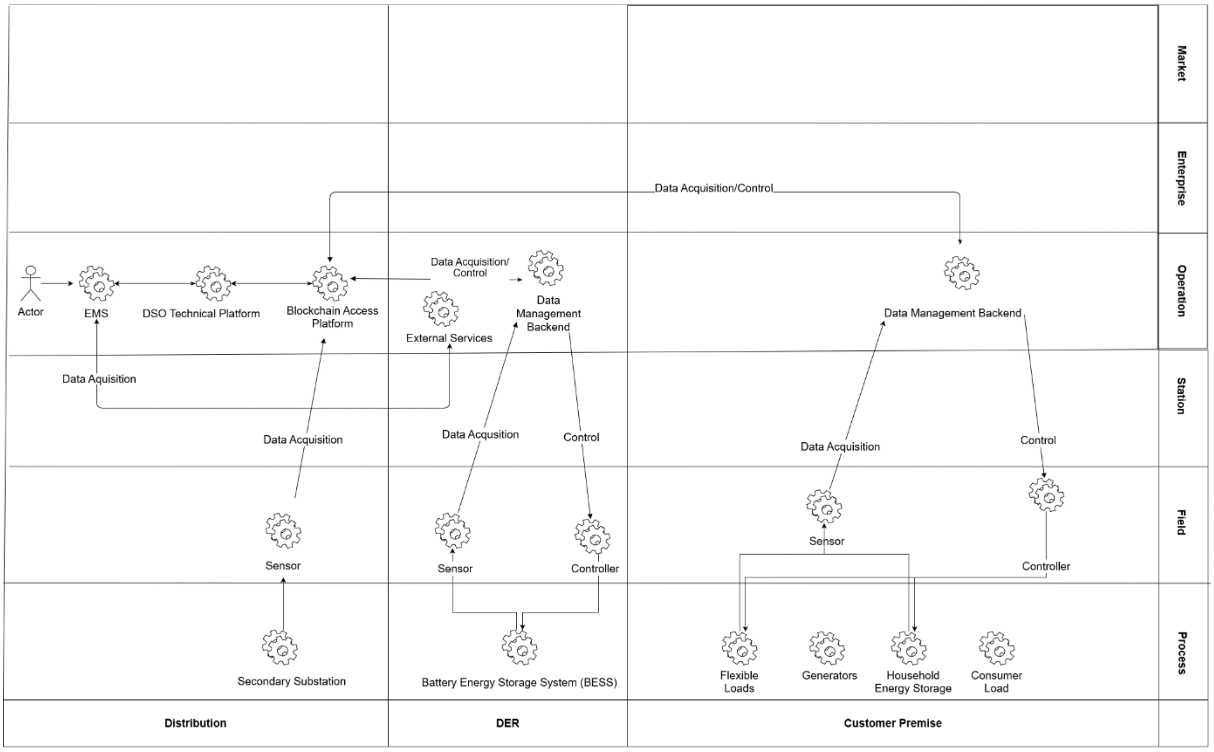

Figure 1: Use Case Diagram of Use Cases 1 to 4

3.2 Use Case Sequence Diagram

Figure 2 shows a system sequence diagram giving an overview of interactions of actors, systems and components arranged in time sequence. Since the UC 1,2,3 and 4 only differentiate on a functional level and involve the same actors, components and systems and sequence, the sequence diagram can be applied to all four UCs..

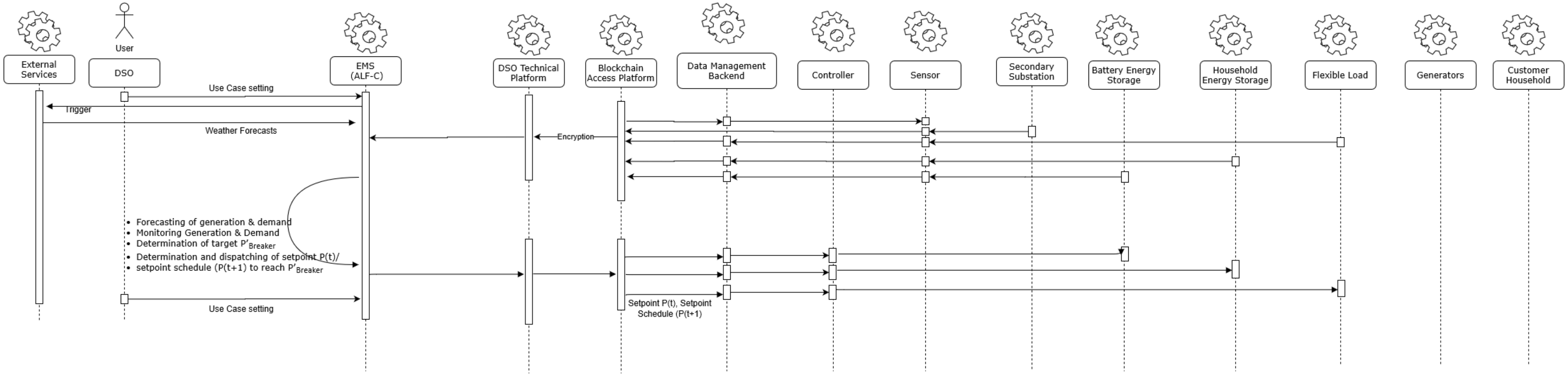

Figure 2: Sequence diagram of UC 1 to 4

3.3 Actors

The German demonstrator of the Platone project will test the technical development in a real scale demonstrator. In a bounded LV grid section, a large-scale BESS together with real household customers will be integrated into the local EMS for the UC application. A complete end-to-end integration of residential customers participating in the project shall be established to make dormant flexibility in private households accessible for measurement and controllability. To maximize the effects of the UC 1 to 4, a large-scale BESS will provide additional power and storage capacity. Additional sensors will be implemented in the secondary substation in order to measure residual load exchanges along the MV/LV feeder. Table 1 gives an overview of different actors of the UC 1 to 4.

Table 1: Actors of Use Case 1 to 4

Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this Use Case***
Consumer Load	System	Private customer household with a standard load profile energy consumption of a single household or energy consumer with a standard load profile of an agricultural building.	No direct measurement of energy consumption, demand not controllable (passive user).

Generators	System	Roof top photovoltaic system generating energy directly correlated with solar radiation at location.	Limited controllability (can be curtailed in extreme cases). Located on customers premise and can be operated in combination with a battery storage system, for optimization of own consumption.
Controller	Device	Summarizes all devices that are able to receive setpoints or setpoint schedules and translate them into actionable control commands for the flexible load or storage in order to increase or decrease consumption.	
Sensors	Device	Devices that measure voltage, current and angle of phase or SOE or SOC in case of storages and are able to communicate to external systems or devices.	PMU or other measurement devices
Battery Energy Storage System (BESS)	System	Large-scale battery energy storages, implemented as additional source of flexibility in field, operated by DSO.	300 kW/600 kWh, fully integrated in EMS and full time available for UC.
Household Energy Storage	System	System to be provided by private customer households participating in the project. Assets will be flexible in demanding, storing and feeding energy to the local grid/energy community.	Integrated in EMS and full time available for UC.
Flexible Loads	System	Electrical heater or heat pump used by households for generation of domestic heat.	Could be provided by customer households.
Weather Forecast Service Provider	External System	External service provider delivering weather forecasts for the next 24h of wind, solar radiation, cloudiness and temperature.	
BESS Data Management Backend	External System	Data Management Backend provided by BESS manufacturer for storing data and providing measurement data and forwarding setpoint to BESS.	
Sensor & Controller Data Management Backend	External System	Data Management Backend provided by vendor of assets (can be individual for different assets) storing data, providing measurement data of asset and/or interface for transmission of setpoints to asset.	Assets with different vendors, which require connection to different vendor cloud platform and backends.

DSO Technical Platform	System	Central Platform providing services, e.g. customer data storage, state estimation and services for graphical evaluations. The data bus provides middleware functions, access to measurement data acquisition and setpoint transmission to sensors and controller in the field.	Provided by WP 2 (RWTH Aachen)
Blockchain Access Platform	System	Platform for encryption and verification of data flows along the way of communication from EMS (ALF-C) to sensors and Assets in the field.	Provided by WP 2 (ENG)
EMS (ALF-C)	Component	Local Energy Management System developed by Avacon named Avacon Local Flex Controller (ALF-C) • Monitors local generation and demand • Monitors available flexibility and storages • Forecasts generation, demand and available flexibility via historic data and weather forecasts • Receives “Islanding” -Trigger from EMS Use Case Module and determines and dispatches setpoints for individual assets • Calculates the setpoint or setpoint schedule for the EMS Control	In a production environment, the operator could be the DSO, a retailer, storage system operators or any other energy service provider.
Distribution System Operator (Avacon)	Person	Local grid operator (Avacon) setting use case and setting setpoint for load exchange along the grid connection point ($P'_{Breaker}$)	Only in field-test trial. In future done by DSO, TSO, marketer or energy service providers

3.4 Scenarios

Three scenarios can occur during the application of UC 1 to 4. In the first scenario, an unforeseen increase of local generation leads to a generation of energy surplus. The surplus generation leads to an imbalance in the grid. Consequently, the generated energy surplus will be exported out of the grid and $P'_{Breaker}$ cannot be maintained. To reach the setpoint at the grid connection point $P'_{Breaker}$ the local balance must be restored by increasing the local consumption or triggering BESS and household energy storage systems to charge and increase total consumption.

In the second scenario, an unforeseen increase of local generation leads to an energy deficit. The exceeding demand leads to an imbalance in the grid, which needs to be balanced by triggering local flexible loads to reduce consumption or triggering local battery storages to discharge.

Scenario 3 describes a faulty situation at which the UC will be cancelled.

Table 2: Use Case Scenarios

<table>
<tr><th>No.</th><th>Scenario Name</th><th>Primary Actor</th><th>Triggering Event</th><th>Pre-Condition</th></tr>
<tr><td>1</td><td>Local generation exceeds local demand</td><td>• Generators
• EMS (EMS)
• Consumer Load
• Energy Storage
• Flexible Load
• BESS
• DSO</td><td>Measured load flow (export) at grid connection point</td><td>Sensors and controllers are connected with EMS
Enough flexible loads and storages capacity are available for balancing</td></tr>
<tr><td colspan="5">Scenario Description</td></tr>
<tr><td colspan="5">During times of intense solar radiation and low demand, the local community will generate an energy surplus. To maintain $P'_{Breaker}$ at the defined level according of UC 1, 2, 3 or 4, the generated surplus will be shifted to times of energy deficits, by time shifting the consumption of flexible loads and storing the remaining surplus in available storages.

In case that the local generation exceeds the local energy demand the residual generated energy surplus leads to an load flow from the low voltage grid to the medium voltage grid. A sensor located at the MV/LV grid connection point measures the load flow $P_{Breaker}$ on all three phases. The measured values (U, I, Phase Angle) of all three phases are provided to the EMS. The EMS balances the local grid by triggering local storages to charge or flexible loads to increase consumption until $P_{Breaker}$ equals $P'_{Breaker}$.</td></tr>
<tr><td colspan="5">Post-Condition</td></tr>
<tr><td colspan="5">$P_{Breaker} = P'_{Breaker}$</td></tr>
</table>

No.	Scenario Name	Primary Actor	Triggering Event	Pre-Condition	Post-Condition
2	Local demands exceed local generation	• Generators • EMS (EMS) • Consumer Load • Energy Storage • Flexible Load • BESS • DSO	Measured Load Exchange at grid connection	Sensors and controllers are connected with EMS Enough flexible loads and storages capacity are available for balancing	Charging power of local flexible loads and storages will be decreased in order to balance generation and demand.
Scenario Description					
During times of low solar radiation and high demand, the community suffers an energy deficit. To maintain $P'_{Breaker}$ at a constant level, demand is shifted to predicted times of generation of energy surplus, by delaying the consumption of flexible loads or triggering the discharge of local storages (BESS & Household Energy Storage). A sensor located at the MV/LV grid connection point measures the load exchange on all three phases. The measured values (U, I, Phase Angle) of all three phases are provided to the EMS. Based on given values, EMS balances local generation and consumption. Weather forecasts provided by external service providers and historical measurement data help the EMS to forecast generation and consumption and maximize the duration of Islanding.					
Post-Condition					
$P_{Breaker} = P'_{Breaker}$					

No.	Scenario Name	Primary Actor	Triggering Event	Pre-Condition	Post-Condition
3	Faulty Situation	EMS	• Faulty values • System Alerts	BMS of BESS and sensors are connected to EMS	Termination of UC
Scenario Description					
In case the EMS receives from Battery Management System (BMS) of BESS system alerts or faulty values from BESS or sensors, the EMS will stop the application of the UC.					

3.5 Step by Step Analysis

The following Table 3 gives a detailed description of steps carried out in each UC. Regardless of which UC is carried out, the individual steps are identical in each UC.

Table 3: Steps-by-Step-Analysis of Use Cases

Step No.	Event.	Name of Process/ Activity	Description of Process/ Activity
1	DSO initiates UC	Trigger of Use Case	Operator from Avacon sets EMS (EMS) UC mode of operation. Depending on which UC will be set additional data will have to be provided.
2	EMS receives weather forecast data	Weather Data – Acquisition	EMS receives real time weather data and weather forecasts (6h ahead) pushed by external service provider.
3	EMS receives forecasting values	Forecasting of generation and demand	EMS forecasts local generation and demand.
4	EMS receives measurement data from sensor at grid connection point	Sensor Data – Acquisition	The local sensor located at secondary substation measure the residual power $P_{Breaker}$ and pushes data to EMS. The communication will take place from the sensor via the sensor data management backend to the Blockchain Access Platform (BAP). The BAP acts as middleware for data encryption. From there the data will be forwarded to the DSO Technical Platform acting as second level middleware from where the signal is sent to the EMS. Data will be pushed by the sensor to the EMS every 10 to 60 seconds.
5	EMS receives measurement data from sensor located in the field	Sensor Data – Acquisition	Local sensors located in the field at BESS and private customer households push measurement data to the EMS. The communication will take place from the sensor via the sensor data management backend to the Blockchain Access Platform (BAP). The BAP acts as middleware for data encryption. From there the information will be forwarded to the DSO Technical Platform acting as second level middleware from where the signal is sent to the EMS.
6	All data collected	Evaluation and determination of control strategy and setpoints	Based on provided measurement and asset key data the EMS calculates the available flexibility of each asset (P_{Flex}). Based on generation, load and SOC forecasts the EMS calculates the optimum strategy for the activation of local flexible loads and storages in order to maximize the duration of maintain $P'_{Breaker}$. The EMS determines for each asset a setpoint in order to balance the local network while maintaining $P'_{Breaker}$, The determination of

			setpoints is repeated every 15 minutes to 10 seconds for BESS and every 60 minutes to 15 minutes for flexible loads and storages located at customer premises.
7	Individual setpoints determined	Transmitting setpoints to controllers	EMS send determined setpoints to BESS, households battery storages and flexible load in order to increase total consumption or decrease total consumption to reach $P'_{Breaker}$ at grid connection point.
8	Setpoint send to local storages and flexible load	Verification of setpoint execution Comparison of target and measured values	The EMS receives measurement data from local grid connection point and compares measured values $P_{Breaker}$ with the target value $P'_{Breaker}$. In case of deviation, the setpoints are redefined by walking through step numbers 3 to 7. The process is continuously cycled until the end of UC.
9	End of Use Case	End of Use Case	The UC ends, when the DSO triggers another use case, or not enough flex is available to reach $P'_{Breaker}$.

3.6 Communication Channels and Information

User input, locally measured metering data provided by sensors, external weather data and determined setpoints will be exchanged between the different actors and components of the IT-architecture. Table 4 gives an overview of the communication link between actors and components. Table 5 provides details of information exchanged in each step of the step-by-step analysis described in section 3.5.

Table 4: Communication Channels of Use Cases

Step No.	Service	Information Producer (Actor)	Information Receiver (Actor)	Information Exchanged
01	REPORT	DSO	EMS	I-01
02	GET	External System	EMS	I-02
03	CREATE	EMS	EMS	
04	GET	EMS	Sensor	I-03
05	GET	EMS	Sensor	I-03
06	CREATE	EMS	EMS	
07	EXECUTE	EMS	Controllers	I-04
08	CREATE	Sensor	EMS	
09	REPORT/CREATE	DSO or ALF-C	EMS	I-01

Table 5: Information exchanged in Use Cases

Information exchanged ID	Name of Information	Description of Information Exchanged
I-01	Setting from DSO via UI	• DSO triggers the UC via an UI to the EMS (ALF-C) to apply islanding. The trigger signal is: 0 = stop current UC 1 = application of UC 1 2 = application of UC 2 3 = application of UC 3 4 = application of UC 4 **In Case of UC 1** – $P'_{Breaker}$ will automatically be defined as $P'_{Breaker} = 0$. **In Case of UC 2** – The user will additionally define $P'_{Breaker}$ via UI. **In Case of UC 3** – The user will additionally define a schedule $P'_{Breaker}(t+1)$ for energy import via UI. **In Case of UC 4** – The user will additionally define a schedule $P'_{Breaker}(t+1)$ for energy export via UI.

I-02	Weather forecasts provision	The weather forecast provider pushes real time measurement data and weather forecast of: • Solar radiation (t + 24h) • Cloudiness (t + 24 h) • Temperature (t + 24 h) • Humidity (t + 24 h) • Windspeed (t + 24 h)
I-03	Sensor measurement data provision	The sensor sends measurement values containing: • Voltage (U), current (I) and angle of phase (Phi) values of all 3 phases, measured in secondary substation. Values indicate the residual power demand/generation as sum of demand or feed of BESS, household energy storage, flexible loads, generators and customer households and agricultural buildings.
I-04	Sending of setpoint (t) or setpoint schedule (t+1)	• Setpoint to increase or decrease demand/generation as static value [P] of flexible load, passive household consumption, total or residual generation of households with PV and State of Charge (SOC) or State of Energy of (SOE) of household battery energy storages and BESS.

3.7 Use Case Functionalities

To enable the ALF-C to act as an EMS and enable to provide flexibility and maintain a fixed setpoint as well as apply the package-based energy delivery and export mechanism, the ALF-C makes use of the set of functionalities. Most functionalities will run on ALF-C. At a later stage of implementation and further development of the Platone framework, some functionalities may be provided by BAP and DSOTP.

Table 6: Functionalities for Use Case Application

Function	Description	Application in UC-GE-0	Input	Output	Provided by
F-01	Monitoring	1,2,3,4	I-03		ALF-C
F-02	Data Storage	1,2,3,4	I-03	historic data	ALF-C, BAP
F-03	Analysis of Historic Data	1,2,3,4	historic data	load profiles	ALF-C, DSOTP
F-04	State Estimation	1,2,3,4	I-02, I-03		ALF-C, DSOTP
F-05	Forecasting Generation	1,2,3,4	I-03, I-02 asset data; load profiles	Generation forecast	ALF-C, DSOTP
F-06	Forecasting Demand	1,2,3,4	I-03, I-02 asset data; load profiles	Load forecast	ALF-C, DSOTP

F-07	Local Balancing	1,2,3,4	I-01, I-03, Generation forecast, Load forecast	Setpoint	ALF-C, DSOTP
F-08	Setpoint Dispatching	1,2,3,4	Setpoint	I-06	ALF-C

4 Key Performance Indicators

In order to measure the success of the UCs in the German demonstrator a set of Key Performance Indicators (KPI) has been defined. The KPIs will be applied to measurement data collected during the application of UCs 1,2,3 and 4 in the field test phase. A set of different KPIs have been identified for each UC aiming to measure, evaluate and compare the success of the implementation. The KPIs will be applied to measurements of different scenarios to take differences that are related to the season, weekday-related, weather-related or holiday-related into account.

The following list of KPIs give a detailed overview of the KPIs to be applied in the German demonstrator and describe the strategic objective, project objective, description and mathematical formulation for calculation and expected results. More details of the KPIs, including the methodology for KPI calculation, how the data is collected and how the KPI baseline is set are described in D1.2 [9].

4.1 KPI 1 - Reduction of Energy Exchange along the MV feeder

KPI Name	Reduction of Reduction of Energy Demand Exchange along the MV feeder
KPI ID	KPI_DE_01
Project's Objective	To improve customers' engagement and facilitate their fair participation to market. To unlock flexibility to address local congestion and voltage stability issues.
DEMO where KPI applies	☐IT ☐GR ☒DE
Owner	Avacon
KPI Description	UC 1 is targeting to maximize consumption of locally generated energy and minimize consumption of energy provided by the feeding MV grid. This KPI evaluates the ability of the developed solution to reduce and avoid the energy consumption from the feeding grid by measuring the deviation of energy consumption in times of UC 1 application and times UC 1 is not applied.
KPI Formula	RED - Reduction of energy demand $$RED = \frac{\sum_{t=1}^{T} \lvert Energy\ Exchange\ no\ Islanding \rvert_{i;t} - \sum_{t=1}^{T} \lvert Energy\ Exchange\ Islanding \rvert_{i;t}}{\sum_{t=1}^{T} \lvert Energy\ Exchange\ Islanding \rvert_{i;t}} * 100$$ **Description**: The KPI will be determined for different season of the year winter spring, summer, autumn and for different periods of investigation of 2, 6, 12, 24 and 96 hours. $\lvert Energy\ Exchange\ no\ Islanding \rvert$ – Is the absolute value of energy (kWh) that has been exchanges along the MV/LV grid connection point during the time period of investigation T while UC1 is **not** applied. The value of energy exchange is positive or negative direction will be added as absolute values. Where:

	$\sum_{t=1}^{T} \lvert Energy\ Exchange\ no\ Islanding \rvert_{i;t} = \sum_{t=1}^{T} U * I * (t_{t-1} - t_t)$ U – Voltage [V] measured at grid connection point I – Current [A] measured at grid connection point $(t_{t-1} - t_t) -$ Duration of time between two subsequent timestamps of measurement. $\lvert Energy\ Exchange\ Islanding \rvert -$ is the absolute value of energy (kWh) that has been exchanged along the MV/LV grid connection point during the time period of investigation T while UC1 is applied. The value of energy exchange is positive or negative direction will be added as absolute values. $T -$ Is the period of investigation for which measurements will take place considered for evaluation (2h, 6h, 12h, 24h, 48h, 96h). Constraint: For a comparison, the same environmental conditions must exist.
Unit of measurement	[%]
Target / Thresholds	The KPI target of RED = 60 % The reduction of energy demand from the MV grid is expected to be 70%. The target value is only valid for a period of time at which sufficient flexibility is available (flexible load and free and available storage capacity). Assuming an average energy consumption of household during the measurement and an average PV generation (no cloud cover), it is to be expected that the value of 60% can be maintained for up to 48 hours in winter months. In the summer months, however, it is expected that the target value can be maintained for a maximum of 3 hours in periods of full solar irradiation due to the limited storage capacity of approx. 650 kWh and the high installed PV generation capacity of 300 kW. It is expected that, due to latencies delays in the measure-switch-measure cycle, a real-time synchronization of generation and consumption will not be achieved and thus minor power exchanges will take place via the grid connection point during

	UC application. It is expected that this will lead to energy exchanges that in total equal 40% of the energy that will be exchanged, while UC1 is not applied.
Measurement Process	The KPI will be evaluated for different season of the year (winter, spring, summer, autumn) and different durations of investigations T (T - 2h, 6h, 12h, 24h, 48h, 96h). In order to calculate the KPI 2 measurements a different time but comparable environment (weather conditions) have to be applied. One the measurement of baseline $\|Energy\ Exchange\ no\ Islanding\|$ will take place before each investigation (T - 2h, 6h, 12h, 24h, 48h, 96h) after a measurement to determine $\|Energy\ Exchange\ Islanding\|$ for the duration T while UC 1 will be applied. 1.) <u>Determination of baseline</u> $E_{NO\text{-}UC}$_01: The measurement values for determination of $\|E\|_{Exchange,\ no\ Islanding}(dt)$ will be collected from the sensor located at the grid connection point in the secondary substation measuring the load exchange between MV and LV network of the field test grid. The values U, I, timestamp will be provided every 1 Seconds up to 15 Minutes and used for the determination of E = U * I * t. Positive and negative values will be added as absolute values |E|. 2.) <u>Determination of</u> E_{UC}_01: A second measurement has to be applied for the determination of the amount of energy that is exchanged along the grid connection for the time period of investigation T while UC 1 is applied, $\|Energy\ Exchange\ Islanding\|$. The environmental condition, such as temperature, solar radiation, cloudiness should be similar in order to create comparable scenario. Therefore, measurements will be done at the same time, at the same point of measurement but at a different day with comparable weather conditions. After the data of measurements have been collected, the KPI has to be calculated according to the KPI_DE_01 formula. Additional detail will be provided in D1.2.
Reporting Period	M24 with the D5.4 – Use Case 1 Technical Report

4.2 KPI 2 - Reduction of power recuperation peaks

KPI Name	Reduction of power recuperation peaks
KPI ID	KPI_DE_02
Project's Objective	• To improve customers' engagement and facilitate their fair participation to market. • To unlock flexibility to address local congestion and voltage stability issues.
DEMO where KPI applies	☐IT ☐GR ☒DE
Owner	Avacon
KPI Description	Use Case 1 targets the reduction of power peaks along the MV/LV grid connection point. A coordinated control of a local BESS, household energy storages and flexible loads enables the avoidance of power peak at grid connection point. This KPI evaluates the ability to reduce power peaks of an EC caused by fluctuating generation or demand within a defined period of time dt.
KPI Formula	$$Peak\ Reduction = \frac{\|P\|_{Max,\ no\ Islanding}(T) - \|P\|_{Max,\ with\ Islanding}(T)}{\|P\|_{Max,\ no\ Islanding}(dt)} * 100$$ **Description**: $\|P\|_{Max,\ no\ Islanding}(T) -$ is the absolute maximum value of active power (kW) measured at the MV/LV feeder within the period of investigation *T* while UC1 is <u>not</u> applied. $\|P\|_{Max,\ with\ Islanding}(T)$ is the absolute maximum value of power exchange (kW) along the MV/LV feeder within the period of investigation *T*, while UC1 is applied. $T -$ is the period of investigation for which measurements will take place to be considered for evaluation (2h, 6h, 12h,

	24h, 48h, 96h).
Unit of measurement	[%]
Target / Thresholds	The KPI target = 40 % The maximum peak load measured at the grid connection point is expected to be 60 % lower than the peak load measured without the UC 1 application. The BESS, from a theoretical point of view, provides enough load capacity for the compensation of generation or load peak along the grid connection point. But, due to expected latencies in the communication and data process of the infrastructure of the EMS and the resulting delays in the measure-switch-measure cycle, a real-time synchronization will not be possible. High fluctuating power feed from PV generators still my result in high load fluctuation. Therefore, a KPI value of 0 to 20 %, meaning a reduction of power peaks between 80 % to 100 % is expected to be not reachable.
Measurement Process	The KPI will be evaluated for different season of the year (winter, spring, summer, autumn) and different durations of T (T - 2h, 6h, 12h, 24h, 48h, 96h). In order to calculate the KPI 2 measurements a different time but comparable environment (weather conditions) have to be applied. One the measurement of baseline $\lvert P\rvert_{Max,\ no\ Islanding}(T)$ for the time period of investigation T and one measurement of the duration dt while UC 1 is applied for determination of $\lvert P\rvert_{Max,\ with\ Islanding}(T)$. 1.) <u>The measurement to determine the baseline $P_{Max\ NoUC}$</u> The baseline $\lvert P\rvert_{Max,\ no\ Islanding}(T)$ for this KPI is defined as the maximum value of active power that has been measured by a sensor located at the connection point in the secondary substation in the period *dt.* The sensor provides voltage (U) and current (I) measurement data and a time stamp. For each set of data the active power will be calculated by applying the formula P = U * I. The maximum value in the period dt will be used for the KPI calculation. 2.) <u>Measurement of $P_{MAX\ UC}$ while UC 1 is applied</u> A second measurement has to be carried out at the same point of measurement during the application of UC 1 to determine the maximum value of power $\lvert P\rvert_{Max,\ with\ Islanding}(T)$ measured at the grid connection point in the same for the time period of investigation T. The environmental condition, such as temperature, solar radiation, cloudiness

	should be similar in order to create comparable scenario. Therefore, measurements will be done at the same time, at the same point of measurement but at a different day with comparable weather conditions. After the data of measurements have been collected, the KPI has to be calculated according to the KPI_DE_02 formula. Additional detail will be provided in D1.2.
Reporting Period	M24 with the D5.4 – Use Case 1 Technical Report

4.3 KPI 3 - Increase in self-consumption

KPI Name	Increase in self-consumption
KPI ID	KPI_DE_03
Project's Objective	To improve customers' engagement and facilitate their fair participation to market. To unlock flexibility to address local congestion and voltage stability issues.
DEMO where KPI applies	☐IT ☐GR ☒DE
Owner	Avacon
KPI Description	UC 1 is targeting the reduction of power exchanges along the MV/LV grid connection point. The balancing algorithm shall maximize the consumption of locally generated energy by storing generated surplus in local battery storages (BESS and household energy storages) and make use of stored generation surplus in times of higher demand. This KPI measures the increase of self -consumption in times of UC 1 is applied by comparing the energy export in the period dt with the application of UC 1 and in for the time period of investigation T without the application of UC 1.
KPI Formula	Increase of self-consumption $$IoSC = \frac{\sum_{t=1}^{T_0} \lvert Energy\ Export\ no\ Islanding \rvert_{i;t} - \sum_{t=1}^{T} \lvert Energy\ Export\ Islanding \rvert_{i;t}}{\sum_{t=1}^{T} \lvert Energy\ Export\ Islanding \rvert_{i;t}} * 100$$ **Description**: The KPI will be determined for different season of the year winter spring, summer, autumn and for different periods of investigation of 2, 6, 12, 24 and 96 hours. $\lvert Energy\ Export\ no\ Islanding \rvert$ - is the cumulative value of energy exported out of the energy community LV network

	into MV network in the time of investigation T_0 when UC1 is not applied. The resulting value is defined as the **baseline**. $\lvert Energy\ Export\ Islanding \rvert$ - is the absolute value of energy in kWh exported out of the energy community into MV network in the period of investigation T while UC1 is applied. Where: $$Energy = \sum_{t=1}^{T} U * I * (t_{t-1} - t_t)$$ U – Voltage [V] measured at grid connection point I – Current [A] measured at grid connection point $(t_{t-1} - t_t) -$ Duration of time between two subsequent timestamps of measurement T **–** Is the period of investigation for which measurements will take place considered for evaluation (2h, 6h, 12h, 24h, 48h, 96h).
Unit of measurement	[%]
Target / Thresholds	The KPI target value is set at 80%. Assuming that sufficient storage capacity is available for the storage of generation surplus, the self-consumption during UC 1 application should reach be almost 100% compared to a situation UC is not applied. Due to delays in the measure-switching-measure cycle of the EMS IT-infrastructure a real time synchronization of generation and storage charging will not be possible. It is therefore expected that a certain amount of energy will be unintentionally exported out of the local grid leading to a reduction of self-consumption from 100 % to 80 %.
Measurement Process	The KPI will be evaluated for different seasons of the year (winter, spring, summer, autumn) and different durations T (2h, 6h, 12h, 24h, 48h, 96h) of application of the UC 1. For the calculation of the KPI two measurements have to be done:

	1.) Determination E_{EXP_1} - One measurement to determine the baseline at which the UC 1 is not applied. The baseline $E_{Export,\ no\ Islanding}(T)$ or for this KPI is defined as the cumulated energy that has been exported out of the community along the grid connection point from the EC LV network into the MV network during for the time period of investigation T. Relevant measurement are implemented by sensors located in the secondary substation sending measurements values to the EMS for documentation and evaluation. 2.) Determination E_{EXP_2} - A second measurement has to be done when UC 1 is applied to determine the amount of energy that is exported along the grid connection point $E_{Export,\ Islanding}(T)$ within the same period *T.* The environmental condition, such as temperature, solar radiation, cloudiness should be similar in order to create comparable scenario. Therefore, measurements will be done at the same time, at the same point of measurement but at a different day with comparable weather conditions. After the data of measurements have been collected, the KPI has to be calculated according to the KPI_DE_03 formula. Additional detail will be provided in D1.2.
Reporting Period	M24

4.4 KPI 4 - Maximization of Islanding Duration

KPI Name	Maximization of Islanding Duration
KPI ID	KPI_DE_04
Project's Objective	To improve customers' engagement and facilitate their fair participation to market. To unlock flexibility to address local congestion and voltage stability issues.
DEMO where KPI applies	☐IT ☐GR ☒DE
Owner	Avacon
KPI Description	Use Case 1 is targeting to maximize the total duration or number of times in which the load exchange along the grid connection point is zero or close to zero. This KPI measures the success of maximizing the duration of time at which a load exchange along grid connection point is avoided.
KPI Formula	$$\text{Maximization of Islanding Duration} = \text{MoID}$$ $$\text{MoID} = \frac{\sum_{t=1}^{T} t_{Islanding;\, P_{Breaker} \approx 0}}{\sum_{t=1}^{T} t_{No\ Islanding;\, P_{Breaker} \approx 0}} * 100$$ **Description**: The KPI will be determined for different season of the year winter spring, summer, autumn and for different periods of investigation of 2, 6, 12, 24 and 96 hours. $\sum_{t=1}^{T} t_{Islanding;\, P_{Breaker} \approx 0}$ - Is the sum of duration of times within the period *T* at which the power exchange along the grid connection point (grid breaker) is close to zero (P = ~ 10 kW).

	$\sum_{t=1}^{T} t_{No\ Islanding;\ P_{Breaker} \approx 0}$ - During the UC 1 application it is the sum of duration of time within the period *T* in which the power exchange along the grid connection point is kept about zero (within ± 10 kW). T – Is the period of investigation for which measurements will take place considered for evaluation (2h, 6h, 12h, 24h, 48h, 96h). Constraint: For a comparison, the same environmental conditions must exist. • The measurement takes place at the LV/MV grid connection point. • Constraint: For a comparison, the same environmental conditions must exist.
Unit of measurement	[%]
Target / Thresholds	The KPI target is to increase the duration of islanding by 19.2 hour (≈1,152 minutes) that equals 19,200.00 % per day compared to a scenario at which UC 1 is not applied. The average duration of time at which the power exchange along the grid connection point is in the range of ± 10 kW is expected to be maximum 6 Minutes within 24 hours of an average day. Household load demand during night hours as well as PV generation during the day hours will lead to load flows higher than 10 kW in positive or negative direction at the grid connection point. With the application of UC 1 it is expected that in 80 % (=1440 minutes) of the time of the day the load flow along the grid connection point will be kept between ± 10 kW.
Measurement Process	The KPI will be evaluated for different season of the year (winter, spring, summer, autumn) and different durations of investigations *T* (*T* - 2h, 6h, 12h, 24h, 48h, 96h). For the calculation of the KPI “MoID” two separate measurements are necessary. 1.) Determination of baseline t_{Island} 1:

	In the first step, the baseline $\sum_{t=1}^{T} t_{No\ Islanding;\, P_{Breaker}\approx 0}$ has to be determined. During baseline determination, UC 1 is not applied. The baseline is the sum of durations of time within the time of investigation T at which the active power exchange (P) along the grid connection point (grid breaker) is less than +- 10 kW. 2.) Determination of t_{Island} 2: A second measurement has to be carried out at the same point of measurement during the UC 1 application. $\sum_{t=1}^{T} t_{Islanding;\, P_{Breaker}\approx 0}$ is the sum of duration of times within a period *T* at which the active power exchange (P) along the grid connection point (grid breaker) is close to zero (less +- 10 kW). The environmental condition, such as temperature, solar radiation, cloudiness should be similar in order to create comparable scenario. Therefore, measurements will be done at the same time, at the same point of measurement but at a different day with comparable weather conditions. After the data of measurements have been collected, the KPI has to be calculated according to the KPI_DE_04 formula. Additional detail will be provided in D1.2.
Reporting Period	M24 with the D5.4 – Use Case 1 Technical Report

4.5 KPI 5 - Responsiveness

KPI Name	Responsiveness
KPI ID	KPI_DE_05
Project's Objective	To improve customers' engagement and facilitate their fair participation to market. To unlock flexibility to address local congestion and voltage stability issues. To support cooperation with the TSO.
DEMO where KPI applies	☐IT ☐GR ☒DE
Owner	Avacon
KPI Description	This KPI focuses on the assessment of response times of requests request for flexibility and latencies of the IT infrastructure. The promptness of the implementation of a triggered setpoint ($P'_{Breaker}$) into a measurable value ($P_{Breaker}$) is an important indicator of the value of flexibility provided by local network or energy communities. **Background**: A user sets a setpoint that defines the load exchange at the grid connection point of the field test community. The setpoint will be forwarded to the EMS, which will determine setpoint for individual DER to increase or decrease local consumption in order to reach the requested value of load exchange at the grid connection point ($P'_{Breaker}$). The KPI evaluates the duration of time from setting the setpoint $P'_{Breaker}$ until the successful fulfilment, at which $P_{Breaker}$ = $P'_{Breaker}$. A sensor located in the secondary substation monitors the load exchange along the grid connection point and provides the value of $P_{Breaker}$.
KPI Formula	$$\mathrm{Responsiveness} = \mathrm{t}_{(\mathrm{P'}_{\mathrm{Breaker}} = \mathrm{P}_{\mathrm{Breaker}})} - \mathrm{t}_{\mathrm{Setpoint\ trigger}}$$ **Determination**: $t_{(\mathrm{P'}_{\mathrm{Breaker}} = \mathrm{P}_{\mathrm{Breaker}})}$- Timestamp at which the target setpoint is measurably reached after the setpoint has been

	triggered. $t_{\text{Setpoint trigger}}$ - Timestamp at which the target setpoint is triggered. $\mathrm{P}_{\text{Breaker}}$ – Active power of load exchange along the MV/LV grid connection point. $\mathrm{P'}_{\text{Breaker}}$ –Setpoint value describing the target value of active power of load exchange along the MV/LV.
Unit of measurement	T [seconds]
Target / Thresholds	The KPI “Responsiveness” shall reach a value of maximum 5 Minutes. With the ability to provide a predefined value of power within 5 minutes, an important criterion is fulfilled for the participation on tertiary and secondary balancing power markets. The ability to provide a predefined value of power also add additional value to the flexibility of EC for the use of congestion management measure of the DSO.
Measurement Process	$\mathrm{t}_{\text{Setpoint trigger}}$ – The timestamp at which UC 2 is triggered will be noted right away and documented in protocols. $\mathrm{t}_{(\mathrm{P'}_{\text{Breaker}} = \mathrm{P}_{\text{Breaker}})}$ – The timestamp will be noted in the first moment, when the measured load exchange at the grid connection point (P_{Breaker}) equals the triggered target setpoint (P'_{Breaker}) set to the EMS. The measurement data will be provided by the sensors located in the secondary substation.
Reporting Period	M30 - with the D5.5 – Use Case 2 Technical Report

4.6 KPI 6 - Accuracy of the achievement of a given setpoint

KPI Name	Accuracy of the achievement of a given setpoint
KPI ID	KPI_DE_06
Project's Objective	To improve customers' engagement and facilitate their fair participation to market. To unlock flexibility to address local congestion and voltage stability issues. To support cooperation with the TSO.
DEMO where KPI applies	☐IT ☐GR ☒DE
Owner	Avacon
KPI Description	The accuracy of reaching and maintaining a defined setpoint is a quality feature of flexibility that can be provided by local networks and communities. The ability to achieve and maintain a setpoint exactly helps to avoid power fluctuations in medium voltage network. This KPI is intended to evaluate the precision of balancing consumption with generation of a hole energy community in order to achieve an given active power setpoint defining the load exchange at the grid connection point. During the application of UC 2 the KPI shall measure the relation between the reached (measured) active power exchange ($P_{Breaker}$) along the grid connection point and the target value ($P'_{Breaker}$).
KPI Formula	$$\text{Accuracy of Setpoint reaching} = \frac{\bar{P}_{Breaker}(dt)}{P'_{Breaker}(dt)} * 100$$ **Determination:** $\bar{P}_{Breaker}(T)$ - Average measured peak load exchange along grid connection point during the time period of investigation T while UC 2 is applied.

	$P'_{Breaker}(T)$ - Triggered Setpoint for load exchange along the grid connection point in the time period of investigation T while UC 2 is applied. T – Is the period of investigation for which measurements will take place considered for evaluation (2h, 6h, 12h, 24h, 48h, 96h). **Where:** $\bar{P}_{Breaker}(T) = \lvert\bar{P}_{Breaker}\rvert = \frac{1}{n}\sum_{i=1}^{m} \varnothing\widehat{P_{15Min}}\ i$ $\hat{P}_{Breaker;15Min}$ –Maximum value of P of a 15 minute interval, $\bar{P}_{Breaker}$ – Arithmetic mean of 15 minutes values of maximum active power, $P'_{Breaker}(T)$: Is defined in the setpoint/setpoint set by a user for the period of investigation T.
Unit of measurement	[%]
Target / Thresholds	The KPI target value is set at 80%. Due to delays in the measure-switching-measure cycle of the EMS IT-infrastructure a real time synchronization of generation and storage charging will not be possible. It is therefore expected that the average deviation between target active power and reached active power flow will be 20 %.
Measurement Process	$\varnothing\ P_{Breaker}(T)$ – For the measurement period *T* the maximum peak load value $\widehat{\hat{P}_{Breaker;15Min}}$ will be determined for every 15 minutes $P_{Breaker}$. The arithmetic mean of all 15 minutes peak load values will be then calculated by applying the formula $\lvert\bar{P}\rvert = \frac{1}{n}\sum_{i=1}^{m}\varnothing\widehat{\hat{P}_{Breaker;15Min}}_i$. The values $P_{Breaker}$ are measured by a sensor located in the secondary substation measuring U and I at the grid connection point to determine the active power exchange between the MV grid and LV network of the EC.

	T: Will be set 2, 6 and 12 hours. Therefore 3 measurements will have to be applied $P'_{Breaker}(dt)$: Is defined in the setpoint/setpoint set by a user.
Reporting Period	M30 - with the D5.5 – Use Case 2 Technical Report

4.7 KPI 7 - Success of energy supply/export in bulk

KPI Name	Success of package based energy supply/export
KPI ID	KPI_DE_07
Project's Objective	To unlock flexibility to address local congestion and voltage stability issues. To ensure reliable and secure power supplies in the context of increasing DER penetration.
DEMO where KPI applies	☐IT ☐GR ☒DE
Owner	Avacon
KPI Description	During the application of UC 3, the success of delivery of energy packages shall be documented. This KPI evaluates the success of delivery of energy packages to an EC/ the success of export energy packages of energy an EC. The KPI is determined by comparing the total number of energy packages provided successfully and the number of packages initially triggered for delivery.
KPI Formula	$$\text{Success of energy supply; export in bulks } = \frac{Total\ number\ of\ successful\ deliveries\ (\mathrm{T})}{Total\ number\ triggered\ deliveries (T)} * 100$$ **Determination** $Total\ number\ of\ successful\ deliveries\ (T)$: The total number of energy packages delivered in the time of investigation T. $Total\ number\ triggered\ deliveries(T)$: The total number of energy packages triggered by a user via a setpoint schedule in the time of investigation T. T – Is the period of investigation for which measurements will take place considered for evaluation (2h, 6h, 12h, 24h, 48h,

	96h). Constraint: For a comparison, the same environmental conditions must exist. The KPI will be calculated for different investigation periods T = 2, 6, 12, 24, 48 and 96 hours.
Unit of measurement	[%]
Target / Thresholds	The Target value for the KPI is set 70%.
Measurement Process	**Baseline:** $Total\ number\ triggered\ deliveries(T)$ defines the baseline which is set by a user. The user is defining a setpoint schedule P (t+1) that is defining different power values and their duration, including the starting time t_{Start} and the time of end t_{End}, for the load exchange along the MV/LV feeder. For most of the time P will be set to “0”. In this case, the community has to be operated by the EMS in an islanding mode and any load exchange along the MV/LV feeder should be avoided. In case P is a positive value, e.g. of 10 kW, that hast to be maintain from 10 am to 11 am, then 10 kWh shall be imported into the community during the period of time of investigation. Each period of the setpoint schedule at which P is ≠ 0 is defined as a single energy package. $Total\ number\ triggered\ deliveries(dt)$ is equal to the number of energy packages defined in the setpoint schedule. A visualized example of a setpoint schedule with 2 energy packages is shown in Figure 3.

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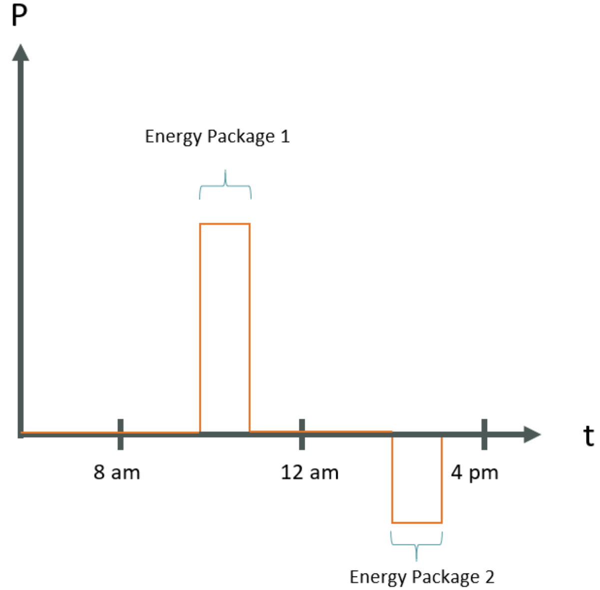

Figure 3: Visualized setpoint schedule with 2 energy packages

Measurement:

The delivery of an energy package is defined successful when following criteria are fulfilled:

1.) The energy package is provided between t_{Start} and t_{End} as defined in the baseline set by a user in a setpoint schedule.
2.) The amount of energy exchanged between t_{Start} and t_{End} equals the amount of energy ± 20% defined in the baseline.

For the calculation, measurement values from sensors located at the grid connection point measuring U, I, P and taking a time stamp will be used. The KPI will be determined for different measurement periods of dt 2, 6, 12, 24, 48 and 96 hours.
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4.8 KPI 8 - Forecast of total Energy Demand

KPI Name	Forecast of total Energy Demand
KPI ID	KPI_DE_08
Project's Objective	To unlock flexibility to address local congestion and voltage stability issues. To ensure reliable and secure power supplies in the context of increasing DER penetration.
DEMO where KPI applies	☐IT ☐GR ☒DE
Owner	Avacon
KPI Description	The forecast of generation and load for an EC is a fundamental function for the EMS to increase the quality of strategy of activation of DER. It enables the EMS to balance generation and demand with a higher quality in order to maintain a given setpoint defining the load exchange along the LV/MV grid connection point and enables to forecast generation deficits or generation surplus within a an given period of time. The KPI aims to evaluate the accuracy of algorithm to forecast the total net energy demand as result of local generation and demand by comparing the amount of energy imported into the local network of the EC or exported out of the local network of the EC with the forecasted amount of energy to be actual exchanged within a given period of time.
KPI Formula	Forecast of Energy Exchange = FEE $$FEE = \frac{\sum_{t=1}^{T} \lvert Energy\ Exchange\ Measured \rvert_{i;t}}{\sum_{t=1}^{T} \lvert Energy\ Exchange\ Forecasted \rvert_{i;t}} * 100$$ **Determination**:

	$\sum_{t=1}^{T}\lvert Energy\ Exchange\ Measured\rvert_{i;t}$ – Is the total amount of energy that has been exchanged along the grid connection point for the period of investigation T. $\sum_{t=1}^{T}\lvert Energy\ Exchange\ Forecasted\rvert_{i;t}$ - Total amount energy forecasted to be exchanged along the grid connection point for the period of investigation T. Where: $$\sum_{t=1}^{T}\lvert Energy\ Exchange\ Forecasted\rvert_{i;t} = E_{forecasted\ demand}\ (T) - \ E_{forecasted\ generation}(T)$$ $\sum_{t=1}^{T}\lvert Energy\ Exchange\ Measured\rvert_{i;t} = \sum_{t=1}^{T}\lvert U\rvert * \lvert I\rvert * (t_{t-1} - t_t)$ U – Voltage [V] measured at grid connection point I – Current [A] measured at grid connection point $(t_{t-1} - t_t)$ – Duration of time between two subsequent timestamps of measurement T – Is the period of investigation for which measurements will take place considered for evaluation (2h, 6h, 12h, 24h, 48h, 96h). Constraint: For a comparison, the same environmental conditions must exist.
Unit of measurement	[%]
Target / Thresholds	The Target value for the KPI is set FEE = 80%.

Measurement Process	The KPI will be evaluated for different season of the year (winter, spring, summer, autumn) and different durations (2h, 6h, 12h, 24h). For the calculation of the KPI "FEC", a baseline will be determined. For evaluation, measurement values will be collected from sensor located in the secondary substation. 1.) Determination of baseline E_{EF}_1: The baseline equals the forecasted net energy demand of the EC, which results from the sum of the forecast energy consumption and the forecast energy generation. The baseline will be determined for the period of time dt under consideration. $$\sum_{t=1}^{T} \lvert Energy\ Exchange\ Forecasted \rvert_{i;t} = E_{forecasted\ demand} d(t) - E_{forecasted\ generation} d(t)$$ $E_{forecasted\ demand} d(t)$ and $E_{forecasted\ generation} d(t)$ are determined by forecasting algorithm. Data are documented for evaluation by the EMS. 2.) Determination of E_{EM}_1 : A sensor located the secondary substation provides voltage (U) and current (I) measurement values with a time stamp. All 3 phases of the grid connection point will be metered. For each measurement the active power will be determined by applying the formula P = U * I. The Energy will be calculated by applying E = P * △t. The value P will be multiplied with the time interval between the time stamps of individual measured value. E.g. in case a measurement takes place every 60 seconds, P will be multiplied by 0,017. All values that have accrued in the period T will be summed to determine$\sum_{t=1}^{T} \lvert Energy\ Exchange\ Measured \rvert_{i;t}$. After the data of measurements have been collected, the KPI has to be calculated according to the KPI_DE_08 formula. Additional detail will be provided in D1.2.
Reporting Period	M43 with the D5.5 – Use Case 3 & 4 Technical Report

5 Outlook

5.1 Expected Results

UC 3 is aiming to enable a local community to maximize consumption of local generation. Avacon will implement a local large-scale Battery Energy Storage System with a rated capacity of 300 kW and a storage capacity of 600 kWh. Regardless of the success of customer involvement and the integration of additional household batteries and flexible loads provided by participating customer households, it is expected that the BESS will provide sufficient capacity to balance the local grid and avoid a load flow exchange with the feeding grid for several hours. The virtual islanding mode is expected to be maintained for at least 2 hours in case of very high generation and to be maintained for one to two days in case of optimal weather conditions.

In order to get a better visibility of the current situation of generation and demand of the targeted network section chosen for the field test trial, Avacon has installed a measurement device in a local secondary substation to measure the net-generation and load demand of the local network. Measurements were made for 7 days during a sunny summer week. The measurement device tracked the power exchange between the local low voltage grid and the feeding medium voltage grid. The evaluation of the measurements shown in Figure 4 display astonishing values. The residual generation in the network turned out to be much higher than expected and exceeds local consumption remarkably. The expectation was that exporting peaks would equal load peaks.

The graphic indicates the measurement values from Thursday 25th of June 2020 7:50 am to Thursday 2nd of July 2020 2:00 pm. Each phase is indicated in a different color. Blue, green, and purple indicate phase I, II and III, whereas yellow indicates the summation of phase I, II and III. The load flow from the medium voltage level into the low voltage level is indicated as positive value and power flows in the other direction as negative value. During the nighttime, when generation of PV is zero, the average demand is in between 20 and 25 kW, whereas during daytime net feedback peaks reaching up to 240 kW, exceeding the demand by factor 8. The average net generation of the local network during one day is approximately at 1440 kWh. Putting the net-generation in relation to the BESS storage capacity of the at least 600 kWh it turns out that the net-generation exceeded the storage capacity by factor 2.4.

For the application of UC 1 to 4, the measurement results indicate that during sunny summer days the islanding of the local grid could be maintained for maximum 10 hours in case the local implemented ALF-C in conjunction with communication infrastructure and BESS operate as planned. With the participation of customers providing additional storage capacity of household energy storages and flexible loads, the islanding duration is expected to increase with each such household asset.

The high proportion of production comes exclusively from local photovoltaic systems and, as shown in Figure 3: Visualized setpoint schedule with 2 energy packages, has a high fluctuation as results from passing clouds. Since all producers are located in close proximity to one another, the entire local generation operates with a high degree of coincidence, which is why the fluctuation is particularly strong. This will pose a challenge for UC2 as short-term drops in performance need to be compensated for by local battery storage. At this point, the responsiveness of the local balancing mechanism will be crucial to achieve and maintain a specified performance value as accurately as possible.

For UC 3 and 4, the local network offers ideal conditions for testing the package-based energy delivery approach and package-based energy export approach. It is to be expected that, during the field test phase, the network will show both energy deficits and surpluses that have to be imported or exported. Depending on the local weather conditions and seasons, it can be expected that UC 3 can be successfully applied for at least 4 hours, perhaps up to 48 hours. In winter months, when the residual power consumption of the community will increase, it can be expected that the duration of UC 3 will be shorter. The opposite is expected for UC 4: with respect to the given storage capacity, the duration of successful application of UC 4 is expected to be maintained for maximum 10 hours in summer on sunny days with a high share of generation. In the transition times between summer and winter, when generation and consumption in the network are balanced over the course of a day, it can be expected that the UC 4 can be applied for up to 48 hours.

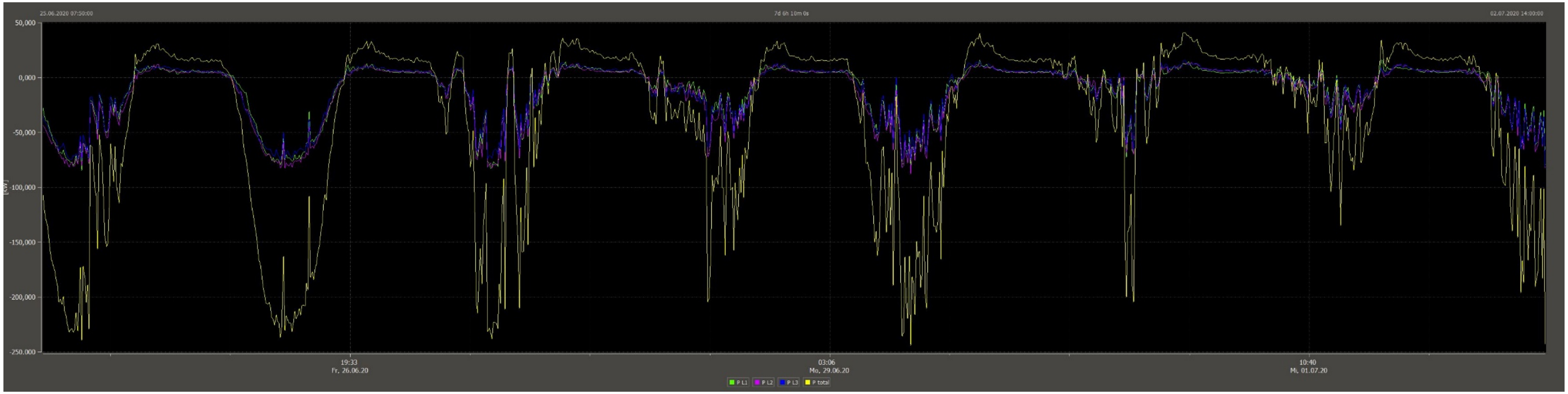

Figure 4: Net Load Demand of Selected Field Test Network

5.2 Impact on Future Operation

Mechanisms developed and tested within the frame of UC 2 provide an opportunity to integrate the flexibility of a community into mechanisms to ensure safe and reliable power grid operation. The ability of a community to provide flexibility on external request provides a potential means for the DSO to increase system performance, reliability and to secure system stability and maintain efficient operation. This can be accomplished with the integration of LEC into DSO’s congestion management mechanism such as feed-in management, redispatch mechanisms and load management. The integration of the community’s storage capacities can contribute to the reduction of amount of RES generation curtailed in the frame of feed-in management and consequently contribute to a reduction of grid fees to be paid by customers.

In the future UC 3 could contribute to a more efficient use of MV networks’ transmission capacity by shifting energy demands of communities into periods of times at which the network is under low stress. Demand peaks can be avoided by applying a staggered provision of predicted energy deficits to the communities located in the low-voltage network. In addition, the UC 3 mechanism helps to reduce uncertainties in grid planning. Uncertainties about load configuration may lead to over-dimensioning of cables and transformers of medium-voltage networks. With the help of the UC 3, these planning uncertainties can be reduced and the network can be dimensioned closer to the real physical limits of the worst-case scenario.

In regions with a high share of generation from RES, the application of the UC 4 supports the avoidance of generation peaks caused by photovoltaic feed-in during the daytime. Energy generated in the communities can be stored locally and exported later. The transport capacities of the medium-voltage network are kept free for the transmission of energy generated by large scale generators directly connected to the MV network. During times of low generation, e.g. nighttime, the energy stored in the low-voltage networks can be discharged staggered along the medium-voltage line. The shifting of the energy export from the local LV grids also helps to reduce the number of network congestion events and amount of network congestion that have to be remedied by curtailments over the course of a year.

6 Conclusion

The present deliverable provides a detailed description of Use Cases and KPIs to be implemented in the German demonstration field test trial. The document provides an overview of relevant actors, systems and components and their connection to each other, a step-by-step analysis, exchanged information and functionalities. All relevant information is provided in templates according the IEC 62559-2 standard for the description of UC.

Together with D5.1 [3], this deliverable contains relevant details for the development of the ALF-C and the way of integration into the Platone framework. Further, it gives a first overview of functionalities, which require capable algorithms to be developed by RWTH Aachen in Task 5.3 and be described in detail in D5.3 [10] in M18.

Based on the discussion in section 5.1, the conclusion is that the PV generation in communities is already higher than expected. The battery storage provides sufficient storage capacity to maintain the UC 1-4 for approximately 10 hours at summer times with very high generation. However, this only applies to a hot sunny summer season and for the one week period of measurement. Outside the summer months, when generation and consumption are more balanced, it is expected that islanding will be maintained for a much longer duration. More detailed information is expected during the field test phase of UC 1 as well as UCs 2 - 4. Results will be evaluated and reported in Deliverables D5.4 [11], D5.5 [12] and D5.6 [13].

With four Use Cases building upon each other, the German demo presents an opportunity to investigate the implementation of Energy Communities in rural areas with a high degree of local generation and their interaction with the distribution network. Use Case 1 provides the basis for an EC and demonstrates the ability of a community to reduce its dependency on outside energy supply to near zero for a limited duration. Avacon and the consortium expect an increase in islanding-duration to have a positive impact on the stress on the relevant mid voltage feeder. KPI 1 – 4 serve to measure and evaluate the success of Use Case 1 and the extent of the demo's islanding-capabilities. Reaching the ambitious goals for these indicators would mean that the German demo successfully created a functioning Energy community with islanding-capabilities.

Use Case 2 targets to apply the inherent flexibility of the EC for purposes beyond the community. Under certain conditions the EC might be incentivized to modulate its behavior in response to an outside request, e.g. to support the distribution grid or to take advantage of favorable conditions on emerging flexibility markets. With Use Case 2, the demo demonstrates the community's ability to adhere to a fixed value for its power exchange with the MV feeder. KPIs 5 and 6 provide the basis for evaluating the success of this Use Case by measuring the time it takes the system to respond to a new setpoint request and the precision of adherence to the setpoint. In a different view, the combination of these two KPIs can serve as a metric to judge the quality of the flexibility that can be provided by the EC.

By combining Use Cases 1 and 2, Use Cases 3 and 4 present a novel approach to energy supply in rural distribution networks. In times when the EC cannot remain in self-sustained balance, the distribution grid will have to supply the remaining energy deficit or accommodate an energy production surplus. In Use Case 3 and 4, the DSO abandons the paradigm of real-time energy exchange and pursues a supply or export of energy in bulk at predefined timeslots. This could allow the DSO to stagger these timeslots along any given feeder and as a result reduce the bidirectional peak load on the feeder and primary substation. Use Case 3 and 4 represent a scheduled switch between Use Cases 1 and 2 – The EC remains in Island-mode whenever possible and only deviates from it during energy exchange slots, which are practically a switch to Use Case 2 at a setpoint that covers the required energy supply. As such all KPIs apply, KPI1 – 4 measuring the quality of the island-operation during times of non-exchange, while KPI 5 and 6 measure the adherence to predefined timeslots of energy exchange. In addition, KPI 7 measures the overall success of energy-package delivery.

7 List of Tables

8 List of Figures

9 List of References

[1] European Union. (2018, December 11th). DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. Official Journal of the European Union. Brussels, Belgium

[2] European Commission, “2050 long-term strategy”, [Online]. Available: https://ec.europa.eu/clima/policies/strategies/2050_en

[3] “D5.1 Solution Design and Technical Specifications”, Platone EU Horizon 2020 Project, 2019

[4] “D1.1 General Functional Requirements and specifications of joint activities in the Demonstrators”, Platone EU Horizon 2020 Project, 2020

[5] “D4.1 Report on the definitions of KPIs and UCs”, Platone EU Horizon 2020 Project, 2020

[6] “D3.3 Delivering of technology (v1)”, Platone EU Horizon 2020 Project, 2020

[7] “D2.1 Platone Platform requirements and reference architecture (v1)”, Platone EU Horizon 2020 Project, 2020

[8] European Union. (2019, June 5th). DIRECTIVE (EU) 2019/944 - OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL Article 46. Official Journal of the European Union

[9] “D1.2 Project KPIs definition and measurement methods”, Platone EU Horizon 2020 Project, 2020

[10] “D5.3 Definition of Use Case algorithms”, Platone EU Horizon 2020 Project, 2020

[11] “D5.4 Use Case 1 Demonstration Report”, Platone EU Horizon 2020 Project, 2021

[12] “D5.5 Use Case 2 Demonstration Report”, Platone EU Horizon 2020 Project, 2022

[13] “D5.6 Use Case 3 and 4 Demonstration Report”, Platone EU Horizon 2020 Project, 2023

10 List of Abbreviations

Abbreviation	Term
ALF-C	Avacon Local Flex Controller
BAP	Blockchain Access Platform
BESS	Battery Energy Storage System
BMS	Battery Management System
CEC	Citizen Energy Community
DER	Distributed Energy Resources
DG	Distributed Generation
DSO	Related Term
DSOTP	DSO Technical Platform
EC	Energy Community
ECO	Energy Community Operator
EMS	Energy Management System
KPI	Key Performance Indicator
LEC	Local Energy Community
LV	Low Voltage
MV	Medium Voltage
PMU	Phasor Measurement Unit
PV	Photovoltaic
RES	Renewable Energy Sources
SOC	State of Charge
SOE	State of Energy
TSO	Transmission System Operator
UC	Use Case
UI	User Interface