Platone

PLATFORM FOR OPERATION OF DISTRIBUTION NETWORKS

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PLATform for Operation of distribution NEtworks

D5.1

Solution Design and Technical Specifications

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Abstract

The German Demonstrator will develop, implement and test a fully functional system, that integrates decentral distributed energy resources (DER) located in low voltage grids into a decentralised flexibility management mechanism able to operate on the border of the network according to the edge computing paradigm. The decentral controller operates fully automatically, to monitor and forecast local generation, demand and available flexibility and builds a bridge between the customers' local flexibility, DSO grid operation systems and markets. In the frame of the Platone project, the "Local Flex Controller" (LFC) will be able to maximize consumption of local generation, apply a new mechanism of package-based energy supply and be able to coordinate the provision of flexibility by balanced local energy communities, to provide flexibility on the request of grid connecting DSO or flexibility markets.

This deliverable 5.1 describes a technical solution concept and technical design of the LFC as well as field test environment, software and hardware components, communication channels, interfaces and data and how these are integrated in the Platone Platform framework.

Keyword list

Local flexibility; Local balancing, Energy Supply, Grid Automation, Blockchain technology; Customer-involvement; DSO.

Executive Summary

The electrical power network is currently experiencing a tremendous change in the way electricity is supplied and how actors are characterized. The paradigm of energy supply is moving from one with centralised generation, fixed loads and uniform power flow to one with networks which contain decentralised generation, controllable devices and bi-directional power flow in low voltage grids (in the case where the nominal power rating is exceeded downstream of the network). The increase in the penetration of renewable energy sources (RES) has caused an increase in the number of challenges for Distribution System Operators. Traditional methods, such as network reinforcement, used to address these concerns have proven to be cost and time intensive and do not always keep up with the rising number of new RES connected to the grid. At the same time the roles of the actors in future low voltage grids will change significantly. Private customer households with flexible generators, storages or loads will become active members in the energy sector and be organized in energy communities aiming to produce, consume, store and share renewable energy and requesting access to energy markets to sell flexibility.

To secure system stability and maintain efficient operation in this changing environment the DSOs' systems for grid operation have to become smarter, more interconnected and much more capable in acquiring and processing local field data. The German demonstrator, under the guidance of Avacon, aims to conceptualize, implement and test a control instance according to the edge computing paradigm that is able to operate as a decentral SCADA/ADMS and provide the necessary functionalities to adapt to current developments and future requirements of flexibility management in low voltage grids.

This deliverable describes the solution design and technical specification of the "Local Flex Controller (LFC). The LFC will be fully integrated into the Platone framework and provides following advantages to the System Operator (SO):

1.) Collect, process and store a vast amount of data acquired by assets located in private customer households, enabling the DSO to monitor and forecast of local generation, load demand and available flexibility,

2.) Provision of KPI of real time and forecasted generation, demand, storage capacity and availability flexibility to higher grid control instances of the DSO or market platform,

3.) A coordination mechanism between centralized and decentralized instances of grid control that enables the provision of flexibility out of energy communities and

4.) A full integration into the Platone framework, communicating via a blockchain communication infrastructure and connecting flexibility located within the community to the market.

The following document details the architecture of the Local Flex Controller in the Platone framework as well as the field test environment, hardware and software components, communication channels, interfaces, the data and use cases which will be applied in frame of the field test trial to test the functionalities of the system.

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1 Introduction

The distribution grid of Avacon is characterized by high penetration of renewables on all voltage levels. Large windfarms and solar farms connected to high, medium and low voltage networks grid put a huge strain on the network and require frequent intervention by the grid operator. Particularly in the rural regions, Avacon is managing low- and medium voltage networks that are exporting a significant surplus of locally produced energy. This influx of decentral generation has been a challenge for the existing networks, to an extent where investments in additional network capacity could not always keep up with the growth of decentral generation. Additional challenges for these grids may arise with the expected increasing share of electric vehicles and charging stations. Possible hot spot areas in which a high share of private customer households own an electric vehicle have a high potential to stress the grid in medium and low voltage grid levels. Avacon is continuously seeking new technical solutions tested in different projects to improve DSO operations and to ensure a safe and reliable energy supply while supporting the integrations of DER and maximize the share of renewables in the grid.

Small scale generators and flexible loads owned by private customers in the low voltage grid are becoming increasingly interesting for DSOs for integration into grid-stabilizing mechanisms, since they provide a potential source of flexibility. In Avacon's service grid, the number of private customer households owning a roof top photovoltaic system is continuously increasing. Some households are even using photovoltaics systems in combination with a residential battery storage system. Also, the number of customers that are using heat pumps for domestic heating is increasing. Additionally, many households in rural areas are still using night storage heaters of past times. In some areas of Avacon's distribution grid, the generation of energy from photovoltaic systems connected to the low voltage grid exceeds the local demand. The surplus gets exported into to the medium voltage (MV) grid and additionally stresses lines and transformers, which already burdened from direct connected renewable feed-in.

The upcoming smart meter rollout and current visions of a control box becoming an integrated component capable of controlling small flexible DER, will introduce a smart, interconnected and capable infrastructure for acquiring and processing local generation and demand field data. The system has the potential to bring new opportunities for the DSO to monitor generation and demand in low voltage grids and to control local consumption for better integration of renewables into the grid. The expected high number of meters and controllers will provide large amounts of data in close to real time, exceeding processing capacities of current DSO grid control SCADA/ADMS systems. To make efficient use of data and determine appropriate measures for optimization of grid operation and better integration of renewables processing, storage and controlling mechanisms will have to be done by outsourced decentral flexibility management instances according to the edge computing paradigm. Decentral flexibility management platform will be able monitor, control and forecast local generation and demand and provide flexibility on request of the DSO via existing network management mechanisms and provide flexibility to other SOs via market-based approaches of flexibility provision.

1.1 Task 5.2

Task 5.2 focuses on the design of technical solution of the German Demonstrator of the Platone project. The technical solution shall meet all requirements to execute UC 1 to 4 in the frame of the German field test trial. The concept will describe IT-architecture, including all communication channels, components, interfaces, data and formats with particular focus on the integration of new solutions with existing systems. A description and proper dimensioning of equipment, particularly the batteries located at the substations and those located in customer households will be done. Detailed specifications of the solution to be implemented, functionalities of the system and definition of data collection capabilities and data base requirements will be made. Results of T5.2 will serve as the basis for the installation and implementation of the demonstrator and provide a blueprint for the replication of the demonstrated concept. Task 5.2 starts in month 1 of the project and ends in month 12.

1.2 Objectives of the Work Reported in this Deliverable

This deliverable 5.1 describes the latest version of a concept of the IT architecture to be implemented in frame of the German demonstrator. The deliverable will give a description of the motivation, a generic concept for a decentral flexibility management mechanism and describe the IT and hardware components, the architecture, interfaces, data and functionalities.

1.3 Outline of the Deliverable

The deliverable 5.1 “Solution Design and Technical Specifications” is the first deliverable of the German Demo. The scope of the document is to give a description of:

- A generic concept of decentral flexibility management, including Avacon’s motivation for implementation of a decentralized flexibility management mechanism;
- A description of use cases (UCs) to be applied in the German field test trial;
- A system architecture: An overview of architecture describes what is planned to be implemented in frame of the Platone field test, including a high-level description of components and communication channels;
- Customers’ role and available flexibilities: A description of the role of customers in future grid and the project, as well as different technologies of flexible DER owned by private households located in LV-grids;
- Large Battery Energy Storage: A description of the role, technical requirements and way of integration into the IT-architecture, including interfaces;
- Local Flex Controller: This section describes the central component of the German Demo, the Local Flex Controller (LFC) fully integrated in the Platone framework. The section describes the architecture of the platform, functionalities, communication channels, interfaces, exchanged data and gives an overview of the complete architecture components, interconnection and interfaces in a single line diagram.

2 Generic Concept

For a greener future of energy supply, the integration of small generators and consumers into the DSO grid operation mechanism will be imperative. To achieve the delicate balance between generation and demand the system has to become smarter, more interconnected and much more capable at acquiring and processing local field data. Thousands of smart meter and control boxes soon will applied in low voltage grids providing large amount of metering data and being able to receive control setpoints. The arising large amount of data to be exchanged will stress the processing capacities of Avacon's grid control SCADA/ADMS. A demand for a decentralized flexibility management instances according to the edge computing paradigm arises, making use of metering data for monitoring and controlling the RES on a local level.

A generic concept of future flexibility management for DSOs foresees a central grid control SCADA/ADMS and several decentralized Decentral Flexibility Management Platforms (DFMP) distributed in the wide geographical area of the DSO. Decentral flexibility management instances will relieve the DSO grid control centre from handling large amounts of data, reduce data exchange over long distances, increase redundancy of grid operation, while still providing the DSO with visibility into low voltage grids and the capability to balance local generation and demand via an automated mechanisms.

Multi stage flexibility management based on centralized and decentralized instances unlocks flexible generation and consumption in low voltage grid, allows integration of more renewable energies while maintaining electricity grid stability and makes flexible devices a tradeable good on market platforms. On the local level of a low voltage network, the DFMP monitors generation and demand for assets from private customer households, building energy communities. The platform fully automatically monitors and balances generation and demand on the local level, gives the SO full transparency of the status of the grid and provides flexibility if requested by DSO or markets.

Addressed Challenges

- The need for DSOs to secure power supplies in the context of ever-increasing DER penetration, decreasing network outages;
- The need for DSO's to gain near real-time insight into the operation of the networks and to optimize them in near real-time;
- The need to unlock local markets of flexibility to address local congestions and voltage stability issues;
- The need to effectively support DSO and TSO system-level of operation through providing flexibility for ancillary services.

Components

An indicative architecture of a generic concept of a multistage stage flexibility mechanism based on central and decentral instances is shown in Figure 1. The architecture allows the DSO to access flexibility located in the low voltage grid provided by private customer households of a local energy community. The aim is to integrate flexible generators, loads and storage systems into a flexibility management mechanism to optimize grid operation on a local level in the low voltage grid and provide flexibility out of LV grids to higher demands from MV or even HV grids, e.g. to the DSO, TSO or market agents. The concept consists several components and interfaces described in the following.

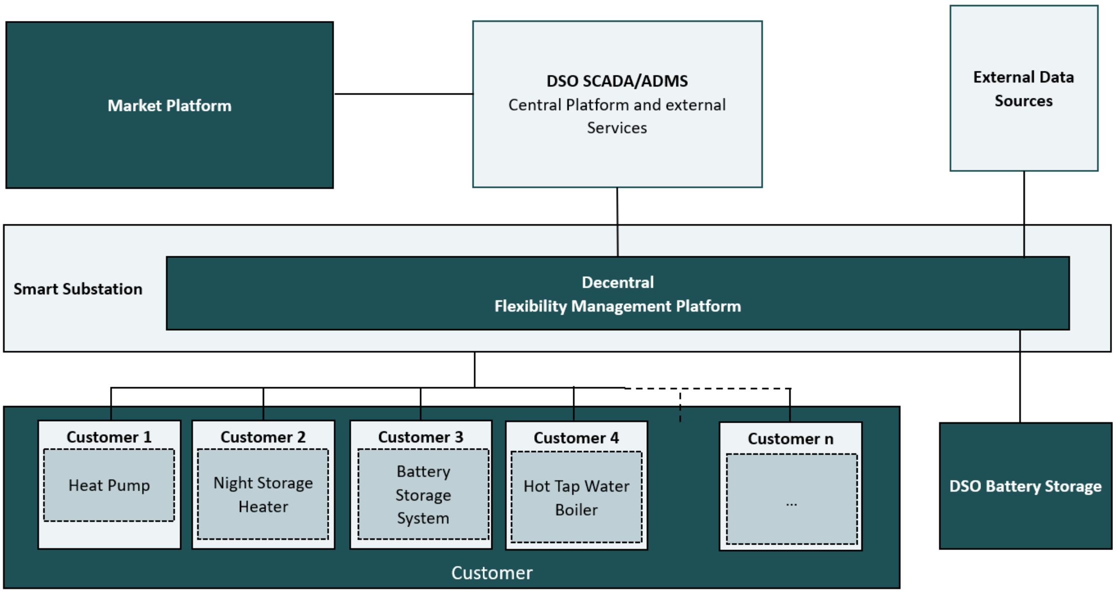


Figure 1: Indicative Architecture of a generic concept for decentralized flexibility management

Decentral Flexibility Management platform

The platform balances generation and demand within the local energy community in such a way that the power exchange along the feeding MV transformer will be minimized or even avoided, allowing physical disconnection from the public energy supply. This mechanism leads to a reduction of stress on mediums voltage grids caused by the export of energy surpluses generated from photovoltaic systems located in the low voltage grid. Transportation capacities of the existing lines and transformers of the MV- or HV-grid can be instead used for energy generated by renewable energy resources from wind turbines or photovoltaic systems connected to the MV-grid. The decentral platform provides flexibility out of the balanced LV grid on request of external demands coming from DSO, TSO, aggregators or others. The provided flexibility can be integrated into mechanisms for optimization of grid operation, such as congestion management, or other measures to increase reliability and efficiency of grid operation. The systems enable making maximum use of renewables and keep the number of interventions in the grid to a minimum level.

The DFMP can be implemented as an on-premises system located inside a secondary substation or be located elsewhere operating remotely. The DFMP will be responsible for monitoring and balancing of single or multiple energy communities providing flexible generators, loads and batteries connected to the low voltage grid. Communications channels and interfaces connect the DFMP and meters and actuators for the exchange of metering data of generation and demand of the community and of single devices in close to real time. The infrastructure also enables the DFMP to send controlling commands to individual available flexible loads, batteries and generators. The platform will be able to process all relevant data of the local grid. The interaction between data and energy management instance enables monitoring, forecasting and control capabilities. The data management components have access to relevant asset data, grid data and external weather forecasts provided by 3rd-party service providers.

The algorithm enables local balancing of the grid, the provision of flexibility out of the grid on external request and coordinates flexibility provision with DSO SCADA/ADMS systems. Controlling commands will be dispatched individually in the most economical and efficient way without affecting the customers' comfort. On external request, the platform can provide relevant grid status KPIs, as well as forecasts of generation and demand.

Smart Substation

Local network stations are located at the grid connection point of the MV/LV grid and house primary technology for transmission and transformation of electrical energy. Secondary substations commonly are equipped with power transformers for the transformation of electrical energy from medium-voltage of 10 kV, 20 kV or 30 kV to the low voltage 400/230 V. It further contains a control panel with busbar for each phase with breakers. Such substations generally do not contain meters or any communication connection. Therefore, in a wide range of Avacon’s distribution grid, the low voltage grids behind the stations are currently operated without the ability for monitoring of generation, demand or status of the grid.

Smart Substations provide advanced functions for the DSO for grid monitoring and operation. Stations are equipped with metering devices, transformers with remote tap changers, data transmission and telecontrol equipment. A connection to glass fibre or DSL communication network allows a communication connection between the substation and the grid control centre. Sensors located in the substation monitor the local grid status via measurement of active power (P), reactive power (Q) and cos (Phi) and measures the total consumption or export of generation of the underlying grid. DSOs’ SCADA/ADMS have direct access to real time measured values and is able balance the voltage the grid in case of high loads or generation via direct control of an adjustable transformer. This allows the DSO to observe low voltage grids and enhance the safe operation of grids with high penetration of DER, even in times of high generation. Due to the numerous advantages, the number of this type of substation in Avacon’s distribution grid is increasing.

Such substations provides potential housing for edge nodes hosting flexibility management mechanisms, such as the DFM platform. Using smart substations for housing of flexibility management edge nodes has several advantages. First, future smart substations will be located in many low voltage networks, providing necessary housing and infrastructure for communication. No additional investments for housing and physical cable-based communication infrastructure is necessary for the connection to SO’s SCADA/ADMS or other external data service providers. Second, since every customer household and flexible generator or feeder of the low voltage grid is connected to the same MV/LV grid connection point along the electricity lines, a communication connection via power line communication (PLC) can be established directly. Third, smart substations provide communication to a high-speed infrastructure, with high availability, short latency and high bandwidth enabling the exchange of large amounts of data in real time with short latencies.

Customer

Due to the increasing number of private owned generators and flexible loads in LV grids, private households in rural areas will increasingly become important players of the future energy supply system. The changing behaviour of energy demand of customers will bring new challenges to the DSO in operating the grid, particularly regarding the expected increasing number of electrical-vehicles in the mobility sector and the consequently increasing number of charging stations in LV grids. However, small-scale residential generators and loads in LV grids are also becoming smarter and more flexible, which makes them a potential source of flexibility for the DSO to integrate into a balancing mechanism on local level. At the same time, against the background of climate change, the pressure is rising to further increase the share of renewable energies on the total electricity consumption. Private households, and owners of PV generators and flexible loads will tend to maximize the consumption of regionally generated electricity and organize themselves with the support of municipalities into energy communities in order to be more independent as regards energy from the public electricity supply and to benefit from lower cost of energy supply. However, the supply of energy from the public grid cannot be completely dispensed with, since balancing would require very high storage capacities of battery packs as well as connectable or disconnectable consumers on a scale that would not be economically viable.

In this scenario, the DSO’s task will be to coordinate generation and consumption within the local grid in such a way that consumption is maximized. In case of imbalances, the remaining energy will be provided by the public power grid. In this framework, the DFMP will have a direct peer-to-peer access to the meter data of households and be able to individually control flexible devices, such as night storage heaters, heat pumps, hot tap water boiler, charging stations of e-vehicles, small scale or even large-scale battery storages.

Large Battery Energy Storage

In future networks with high penetration of DERs, battery storage will be become increasingly important. Large battery energy storage systems (LBES) can store energy and charge, discharge energy at any time. Energy can be provided instantly on request. This gives them a high degree of flexibility, which can be used to avoid power peaks in networks with a high penetration of RES. The number of batteries in distribution grids is likely to increase in future. Local energy communities may own and make use of such device in grids with high RES penetration for balancing generation and demand to be more independent of public energy supply, participate on flexibility markets or other balancing markets. The DFMP will be able to connect LBES to integrate the storage to DSO balancing mechanisms on a local level, to integrate into a package-based energy supply, to provide ancillary services to higher grids and to connect to markets.

Central Platform and external Services

The multi-stage flexibility management approach of Avacon foresees a centralized instance of the DSO (e.g. DSO's SCADA/ADMS) optimizing grid operation for the MV and HV grid and decentralized instances monitoring and maximizing consumption of local generated renewable energies. Requests for the provision of flexibility out of the local grids have to be dispatched into individual control commands in order to provide the demanded request in most efficient way without affecting customers comfort. Flexibility provided by the local communities can be integrated into congestion management mechanisms of the SO, such as feed-in management or redispatch mechanisms, making the technical solution more efficient by avoiding curtailment of too much renewable feed-in due to a higher granularity of control.

Market Platform

The Market Platform allows the support of wide-area geographical flexibility requests from system operators. These are matched with offers coming from aggregators, resolving conflicts according to pre-defined rules of dispatching priorities. This platform will simulate all the different system operator flexibility and congestion requests and behaviours, will collect the DSO's local requests for flexibility and will manage the aggregators' and customers' offers of flexibility.

3 Use Cases

The following chapter gives a description of the latest design status of the use cases 1 to 4. A detailed description of Use Case will be provided with deliverable 5.2.

3.2 Use Case 1 – Local Balancing

Use case 1 aims to maximize the consumption by energy community of local generation in a defined low voltage grid, to reduce the load exchange along the feeding MV/LV-transformer down to zero. Necessary flexibility will be provided by a large-scale battery energy storage systems and residential flexible loads or storages. UC 1 simulates the characteristics of generation and consumption of future private customer households, which will be organized in energy communities aiming to produce, consume, store and share renewable energy and creating requests to access energy markets to sell flexibility. UC 1 will built the functional basis to UC 2, 3 and 4.

3.3 Use Case 2 – Coordination of multiple flexibility management platforms

Avacon envisions future distribution networks consisting of centralized and decentralized control instances for flexibility management. UC 2 aims to coordinate decentrally and centrally organized flexibility management systems in such a way, that system stability and performance remain at a high quality while still enabling customers to choose new ways of power supply. UC 2 shall demonstrate an example showing how a central flexibility management can be coordinated with a local balancing mechanism as developed under UC 1. Under this task, the potential conflicts arising out of flexibility activation shall be investigated and documented, leading to a set of rules for flexibility allocation and prioritization of control signals and an example of how to implement these rules in the demonstrator.

3.4 Use Case 3 – Package-based energy supply (energy download)

This UC concerns supplying energy to the local network in bulk in advance at suitable times. Among the biggest challenge for DSOs with high shares of DERs is the stochastic nature of network demand that is interfered with by local production. While demand-only networks 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. One way to reduce uncertainty, and hence increase 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 packet-based approach to power supply. The residual demand of a network after local production can be forecast and be 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. The control algorithm for UC 3 contains a forecasting element to predict the load and expected generation in a given LV-network. It further calculates the residual energy need of the network and the best time of delivery, taking into account the available load on the feeder, interactions between secondary substations and the storage capacity in the network, and dispatches energy delivery for the next day. The goal is to time energy delivery in such a way, that the load on the MV-feeder remains uncritical and to enable a cascading coordination of all secondary substations on a MV-feeder to minimize feeder load

The UC 3 approach will be described using an example of a medium/low-voltage grid shown in Figure 2. Along a medium voltage line, secondary substations 1 and 3 are connected. A MV/LV-transformer at each local substation feeds a local energy community consisting of private customer households. In the context of UC 3, local generation, consumption and residual demand of e.g. substation 1 must be forecasted, as well as the stress of assets in the feeding medium voltage grid. If a congestion on medium voltage assets is predicted, as highlighted in red, which prevents to supply substation 1 to 3, the forecasted demand of energy will be delivered as energy packages in advance. The time and duration of the package delivery will be done at suitable times for the grid, which will be determined by an algorithm. The energy packages will be stored in battery storages located under the feeding MV/LV-transformer. In times of congestion, the local demand of substation 1 will be covered by discharging the battery storage. Energy packages for different substations will be delivered time-shifted to ensure a consistent load along the feeding MV transformer and lines. Additionally UC 3 aims to enable a cross-substation supply of energy packages, e.g. an energy package delivery from substation 2 to 1. An algorithm needs to be developed for the dispatching of supply of different energy packages.

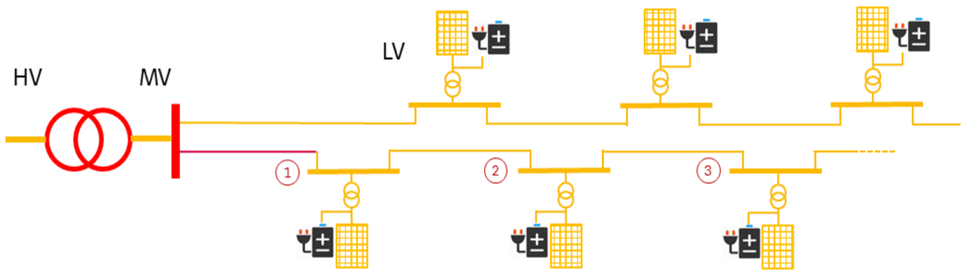


Figure 2: Scheduled Example of Application of Use Case 3

3.5 Use Case 4 – Package based energy export (energy upload)

Use Case 4 aims to reduce stress on MV-feeders by enabling a coordinated cascading power-exchange between the feeder and the connected secondary substations. In areas with high shares of DERs, local networks can reach a point where they export power to the MV network. This backward power flows cumulate along a feeder and usually coincide with each other, creating a situation where the DSO is facing high feeder power backflow during relatively few hours of a year. Still, this leads to the need to account for these situations in grid planning and operation. Instead of uncontrolled power export, Use Case 4 aims at deploying a packet based approach, where surplus energy in a given LV network is stored in a battery, to be delivered to the MV-feeder at non-critical times. If employed grid-wide, this approach would also allow for a staggered power-export along a given feeder, reducing the coincidental backward power flows and in turn also the need for grid expansion. The algorithm includes a forecasting element for local load and expected power production and a scheduler for power-export, taking into account storage capacity and MV-feeder loading.

4 Technical Design of the field test trial

The following sections describes the solution concept and technical specification of the system to be implemented in frame of the German Demo of Platone. First a description of the solution architecture gives an overview of the field test architecture components, actors and communication channels. For each component, a detailed description of targeted technical characteristics, interfaces and exchanged data is presented.

4.1 Solution Architecture and Components

Avacon aims to implement a real live demonstrator with the Local Flexibility Controller (LFC) integrated in the Platone platform framework that consists of a DSO Platform and Market Platform. The LFC integrates flexible generators and loads of an energy community connected to the low voltage grid into a communication infrastructure for monitoring and controlling. The consumption of local generation shall be maximized in order to balance generation and demand and minimize the load exchanged along the feeding MV/LV feeder. An energetic islanding of the energy community will be targeted. The platform will be able to provide available flexibility out of the balanced grid to meet higher grid demands. Flexibility requests can be triggered via setpoints from external instances such as Platone Market platform or Avacon's SCADA/ADMS environment. Flexibility located within an energy community provides necessary capacity for ramp up, ramp down of load or generation and storage capacity to store energy. Figure 3 gives an overview of the components of the field test trial.

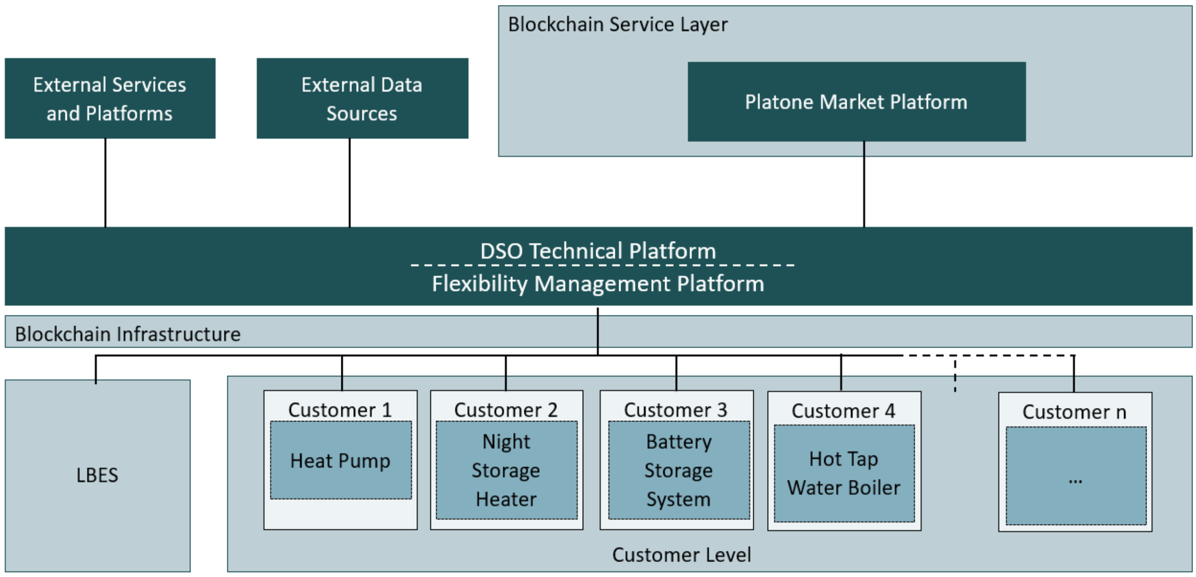


Figure 3: Indicative Architecture of a generic concept in the Platone framework

4.2 Private Customers

The goal of the demonstrator in Germany is to establish a complete integration of residential customers with the LFC to make dormant flexibility in private household accessible and controllable. To maximize the effect of the Use Cases 1 to 4, it is also necessary to identify a region that is characterized by a high share of renewable generation and suitable residential structures that maximize the chances of recruiting pilot customers. The acquisition process that is planned to be started in August 2020 will provide a clearer picture of what types of assets, interfaces and technical solution have to be implemented to integrate the assets into the field test trial. The following section therefore describes different types of generators, loads and batteries potentially available in the grid, gives a description of the technical solution of how to integrate them into the field trial architecture, including the interfaces targeted to be used and data to be exchanged.

The following type of flexible assets are commonly in use by private customers in Avacon's low voltage grid and could potentially provide flexibility for integration into the LFC infrastructure:

- Roof top photovoltaic systems;
- Battery storage systems;
- Night storage heaters;
- Heat pumps;
- Hot tap water boilers.

Due to the large variety of plant types and the year of manufacture, the plants can vary widely in terms of measurability and external controllability. Customers who are willing to participate will be equipped with sensors and controllers, if no alternatives are available on site.

4.2.1 Customer photovoltaic and battery storage systems

Roof top photovoltaic systems offer private households an opportunity to be more self-reliant and reduce the feed-in from the grid. The generation of energy depends on the installed capacity of each individual device and can be reduced by external environmental factors such as global radiation, radiation angle, temperature and cloudiness. A large number of customer households own a combination of photovoltaic systems and a battery storage to make use of the generated energy surplus and optimize the household's energy consumption. The integration of such devices to the LFC will provide additional sources of flexibility for the UC applications. In the context of local balancing, the energy surplus stored in the battery can be discharged at a later point of time, when the load demand in the local grid exceeds the power supply or is needed to be utilized for grid balancing services. Due to the increasing number of battery storage systems connected to the DSOs' grids and their versatile applicability, they will become a vital part of the future energy system. Based on the availability of devices and customer response for the invitation for participation, Avacon aims to connect assets to LFC and integrate them into the use case application.

Manufacturers of modern photovoltaic and combined battery storage systems offer IoT services to customers via cloud-based platforms. The inverters of such PV systems are equipped with an integrated data management system with a gateway. The gateway is connected to customer's Wi-Fi for communication via household internet connection. The cloud service enables the customers to access measurement data in real time via smart phone or tablet. Customers make use of it to monitor system status and control devices manually remotely. PV systems with combined battery storage systems are equipped with an integrated controller allowing the customer to control when to charge or discharge the battery via the IoT cloud access. Such cloud platforms also offer interfaces for connection of external instances to access data and exchange control signals in real time. Such interfaces will be targeted to use to connect LFC to customers generators for measurement and controlling.

Interfaces

The communication along the interfaces are realized via an API using standard protocols such as Modbus or TCP via TCP/IP. For the connection of an external platform, such as LFC, vendors generally provide web access via API (JSON) for the exchange of real time values and for controlling. The inverter of smart systems commonly provides following interfaces:

- Ethernet (RJ 45 socket): - LAN, 10/100 Mbit, API (JSON)
- Wi-Fi: - Wireless standard 802.11 b/g/n, Modbus TCP, API (JSON)
- Digital inputs: - Interface to ripple control receiver
- Digital inputs: - Interface for load management
- RS485: - Modbus RTU or meter connection

Figure 3 schedules the targeted way for connection of PV systems with IoT functionalities to the LFC.

Data

For the use case application, the provision of active power (P) of generation of PV will be a minimum requirement. Battery storages have to provide data of state of charge (SOC) or state of energy (SOE).

IoT services generally enable access to even more data such as measurement values of reactive power (Q), voltage (U), phase (cos Phi) and can receive steering commands (ON/OFF). The communication will have to be encrypted with secure virtual private network (VPN) set up in order to prevent unauthorized access. Table 1 gives an overview of the minimum requirements of data to be provided by the system including the rate of provision.

Photovoltaic systems not providing internal integrated measurement functionalities, or whose integrated systems lack reliability or precise measurement, will be equipped with a Phasor Measurement Unit (PMU). A detailed description will follow in section 4.4.

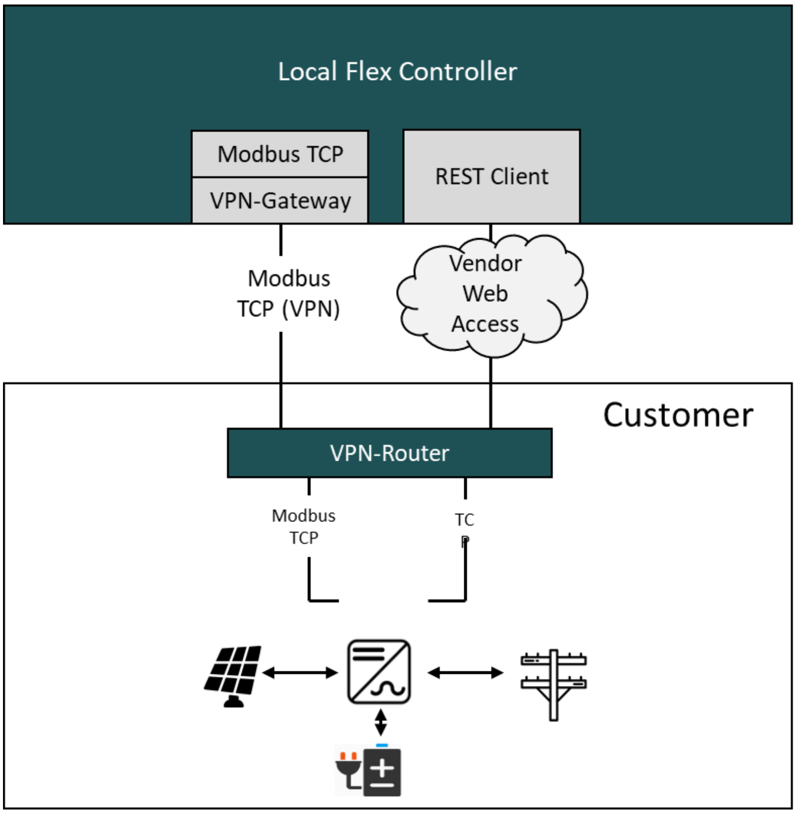


Figure 4: Communication interfaces of photovoltaic and battery storage systems

Table 1: Measurement data from photovoltaic system with combined battery storages

	Value	Unit	Frequency
PV Generation Power	$P_{P,\ Generation}$	kW	≥ 15 Min
SOC of Battery	E	%	≥ 15 Min
Battery Peak Power	$P_{B,\ Peak}$	kW	≥ 15 Min.

4.2.2 Customers Flexible Loads

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. Night storage heaters and heat pumps are preferably used as electrical heat for domestic hot water provision of private customers located in Avacon's electricity network. Control actions on devices are commonly carried out via clock timers installed locally on customers' installations, via long wave radio signals carried by third parties or via acoustic ripple control by DSOs for high level demand response. The current controlling mechanisms do not provide any advanced data processing capabilities, nor any metering data nor any possibility of confirmation of execution of controlling commands send by DSO. Therefore, current applied technologies in the grid provide limited options for dynamic load control and do meet the necessary requirements to be integrated into the measurement and controlling infrastructure of the LFC.

However, manufacturers of electrical heaters are aware of the rising demand of customers to have a remote access to heaters for monitoring and controlling purposes. Vendors provide IoT cloud solutions to provide data to customers for mobile control and visualization of the state of operation. Even retrofit solutions for remote monitoring and controlling of old assets are available.

4.2.3 Heat Pumps

Heat pumps are becoming increasingly important as sources of heat in private customer households. Generally, heat pumps are used as central heating or for domestic hot water provision. Due to the special tariff systems and the high efficiency, they became competitive to oil and gas heating systems. Most systems are equipped with a heat storage system, which allows customers to use the heat generated in the night also during day times. Due to the thermal inertia it is possible to turn a heat pump off for a long period of time without dropping the indoor temperature immediate and effecting customer comfort. In combination with their instant start-up and turn off ability, electrical heat pumps became a potential source of flexibility for the DSO to help stabilizing the grid. Heat pumps can provide both negative and positive flexibility since it is possible to both increase and decrease heat demand. However, the available flexibility is largely dependent on the outdoor temperature.

Smart-Grid-Ready Heat Pumps

Since the introduction of the "smart-grid-ready" certification for heat pumps, more assets are being equipped with a dedicated interface enabling external control by 3rd parties such as via IEC 61850 OpenADR protocol, which are open, highly secure and allow bi-directional communication for the exchange of temperature measurement values and setpoints. Certified devices provide four operations modes that can be triggered from external:

Operation Mode I:	System shut down triggered by SO;
Operation Mode II:	Standard operation;
Operation Mode III:	Increased operation;
Operation Mode IV:	Startup command, independent of other control signals.

Interfaces of Smart-Grid-Ready Heat Pumps

Heat Pumps with IoT cloud access enable customers to monitor system status, heat values and provide functions to control the heat pump via smart phones, tablets or PCs. Measurement data provided by internal sensors are stored on vendors' cloud-based platforms. Interfaces provided by the vendor enable 3rd party platforms to build a connection via API interfaces using TCP/IP protocols. Heat pumps are connected to customers' internet connections, commonly via Wi-Fi. The integration of devices can be established by making use of the vendor's provided API. The interface allows sending of control signals from the LFC to the heat pumps and monitoring of the heat pumps through their network as shown in Figure 5. The devices can receive temperature setpoint.

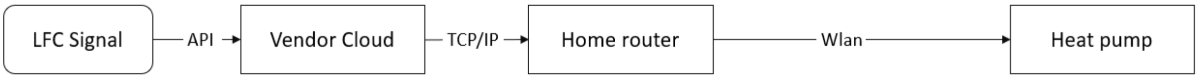


Figure 5: Communication with heat pump via cloud connection

Data provided by Smart-Grid-Ready Heat Pumps

Many heat pump systems only measure and make temperature flow data setpoint calculations. Power (kW) mostly cannot be used as a setpoint and in some cases devices do not even measure power values. In this case, the system will be equipped with a PMU to provide data of power consumption of P (kW) (see section 4.4.). Temperature values, listed in Table 2, can still be used by LFC to estimate the state of charge of the heater storage as well as to forecast available storage capacities if static key figures of the system are available, such as storage capacity and coefficient of performance (COP).

Heat Pumps with such remote solutions are commonly able to provide following measurement data.

Table 2: Measurement values from heat pumps Measurement values from heat pumps

Sensor	Value	Unit	Frequency
Room temperature	T	°C	≥ 15 Min.
Outdoor temperature	T	°C	≥ 15 Min.
Hot water temperature	T	°C	≥ 15 Min.
Flow temperature	T	°C	≥ 15 Min.
Return temperature	Temperature setpoint	°C	≥ 15 Min.
Heat medium flow	Temperature setpoint	°C	≥ 15 Min.
Power (or by PMU)	P	kW	≥ 15 Min.

Retrofit Solution

Older-generation Heat Pumps are equipped with internal controlling units enabling setting of the temperature control circuit, flow temperature, setpoints, operation mode, etc. To make the devices remotely accessible for monitoring and controlling, several manufacturers offer retrofit solution. Commonly available solutions provides a bundle of devices consisting of a central gateway, wireless indoor sensor and a control box.

Devices enable customers to monitor and control the heater remote via smart phone or tablet. Real time and historic data of heat demand, hot water, cold water, and ambient and outdoor temperatures can be monitored and visualized in charts. Setpoints and timers can be set. Systems provide an energy management system with machine learning algorithms which adapt the control of the heating according to the thermal inertia of the room and heating system. This enables increasing the heating efficiency and reducing cost without influencing customers' comfort. Retrofit systems are even able to adapt heating according to the electricity spot price in case customers have a price-per-hour agreement with the energy provider. The individual components are able to communicate via Bluetooth or wireless LAN with a central gateway provided with system. The gateways commonly are connected with customers' home network internet connections, from where data are sent to IoT cloud platform commonly operated by the vendor. With a smart phone, tablet or PC, the customer can access measured data, setpoints and status of the system online via a provided dashboard. Adjustments of the target domestic temperature set by the customer online requires a change of heat generation of the heat pump. The desired temperature setpoint schedule is communicated from the cloud platform to through the gateway to the control box, which is directly connected to the temperature sensor of the heat pump. The control mechanism is based on a control box with a smart thermostat that manipulates the temperature sensor, pretending higher or lower temperature to make the heat controllable. Vendors of such systems in most cases provide a public API to enable connection to the vendor's IoT cloud from external instances to access devices for measurement and steering purposes. In many cases such APIs accept JSON in the HTTP request body. API interfaces enable establishment of a connection from the LFC-platform to the thermostats and control box for measurement and control.

Figure 6 shows the communication path of a setpoint sent from LFC to the heat pump via retrofit solution.

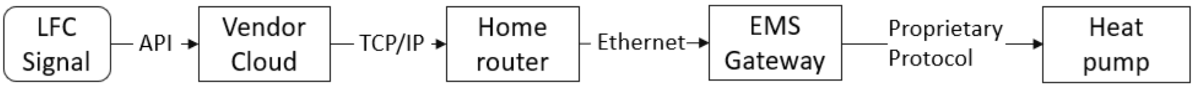


Figure 6: Communication path from retrofit control devices for heat pumps

Potential retrofit solutions can provide following data:

Table 3: Send and read values of retrofit meter/controller for heaters

Sensor	Value	Unit	Frequency
Warm water temperature	T	°C	≥ 15 Min.
Cold water temperature	T	°C	≥ 15 Min.
Indoor temperature	T	°C	≥ 15 Min.
Outdoor temperature	T	°C	≥ 15 Min.
Target water temperature	Temperature setpoint	°C	≥ 15 Min.
Hot water availability	Temperature setpoint	°C	≥ 15 Min.
Power demand	P	kW	≥ 15 Min.
Humidity	-	%	≥ 15 Min.
Sunlight	-	-	≥ 15 Min.

A PMU will be used as an optional meter to be installed on customers' premises for the measurement of the load demand of the heat pumps. A detailed description the PMU will be described later in section 4.4.

4.2.4 Hot Tap Water Boiler

Water heaters have been very common water heater in private customers' households in the past. In some few households, such heaters are still in use for the generation of hot water for sinks and showers. Since hot tap water boilers convert electrical energy to heat for storage, these devices provide potential flexibility for the balancing mechanism in the local grid. During periods of surplus energy generation in the local grid of the energy community, hot tap water boilers can be triggered to reduce heat generation. Generated hot water can be stored, reducing the demand of heating energy at other times when the local community has a deficit of energy generation.

Generally, devices are temperature driven and almost no older-generation device provides a possibility for external control. Comparable to older generation of heat pumps, hot tap water boilers can be equipped with retrofit solution to make them measurable and controllable for the LFC. Potential technical solutions available on the market can disconnect the current circuit of boilers while providing measurement values of the generated hot water temperature and cold-water temperature fed into the boiler. Temperature sensors of retrofit solutions are connected to the water connection of the boiler, providing temperature values through a gateway connected with customer Wi-Fi internet connection to an IoT cloud-based data management platform of retrofit vendor. Measured values are available to be retrieved from external platform via REST API. The LFC will be able make use of such an API to collect data and to send setpoints. Figure 7 shows the way communication is performed for the connection of the LFC to collect measured data and to send setpoint for controlling devices. Table 4 gives an overview of potential data provided by the retrofit solution. In case the provision of measurement values of retrofit solutions lack reliability or precise measurement, a PMU will be an additional option for the provision of measurement values of consumption. In this case the retrofit controller will only be used to switch the device ON and OFF. A detailed description the PMU and provided values will be described in in section 4.4.

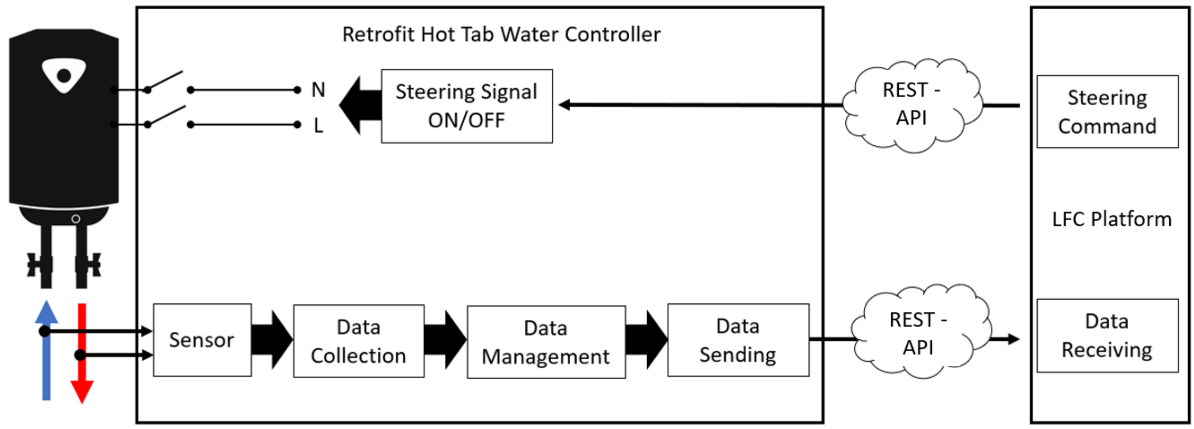


Figure 7: Hot Tap Water Heater Retrofit Controller

Table 4: Send and control values of a hot tap water boiler retrofit solution

Sensor	Value	Unit	Frequency
Warm water temperature	T	°C	≥ 15 Min.
Cold water temperature	T	°C	≥ 15 Min.
Target water temperature	Temperature setpoint	°C	≥ 15 Min.
Hot water availability	Temperature setpoint	°C	≥ 15 Min.

4.3 Large Battery Energy Storage

The implementation of use cases 1 to 4 requires a high degree of flexibility in the local energy provision, to supply power instantly for ramp up and ramp down as well as storage capacity. A large battery energy storage (LBES) is essential for Avacon's real live demonstrator since it will provide necessary power and storage capacity to balance the grid even in case customer households will not be available to provide any flexibility. Excess energy generated from local rooftop photovoltaic system will be stored in real time and fed back in times when demand of the community exceeds supply. In the frame of use case 1 – 4 the LBES will have to fulfil following tasks:

- **UC 1 - Local Balancing/Islanding:** LBES will act as an additional load or source of power to draw or withdraw energy in order to balance the grid and operate the local network in a virtual island mode.
- **UC 2 – Coordination of decentralized and centralizes flexibility management instances:** not applicable
- **UC 3 – Package Based Energy Supply:** Storage of energy packages. The forecasted demand of an energy community will have to be provided at uncritical times for the network before the actual

demand of the targeted energy community increases. The energy package will be stored in the LBES and provided to the community via discharging of the battery later, when the demand in the community increases.

- **UC 4 – Export of Energy Packages:** Energy surpluses of an energy community will be stored in the LBES and exported out of the local grid to MV- grid level at uncritical times. If in the meantime the community has a higher electricity demand than generation, the temporarily stored energy package can also be returned to the community in order to balance local grid energy consumption in accordance with use case 1.

For the calculation of an appropriate dimensioning of LBES (power and storage capacity) the load demand of three preselected communities have been monitored and analysed. In each community a power logger has been installed in the secondary substation for the measurement of power exchange along the MV/LV grid connection point in order to measure the total energy consumption during a period of 3 days. The results visualized in Figure 8. During the period of measurement a maximum peak of consumption between 75 kW and 130 kW has been recorded. Based on the results and the maximum amount that could be purchased within the budget constraints, an installed capacity of 600 kW and a storage capacity of 600 kWh has been determined to be sufficient for the field test trial.

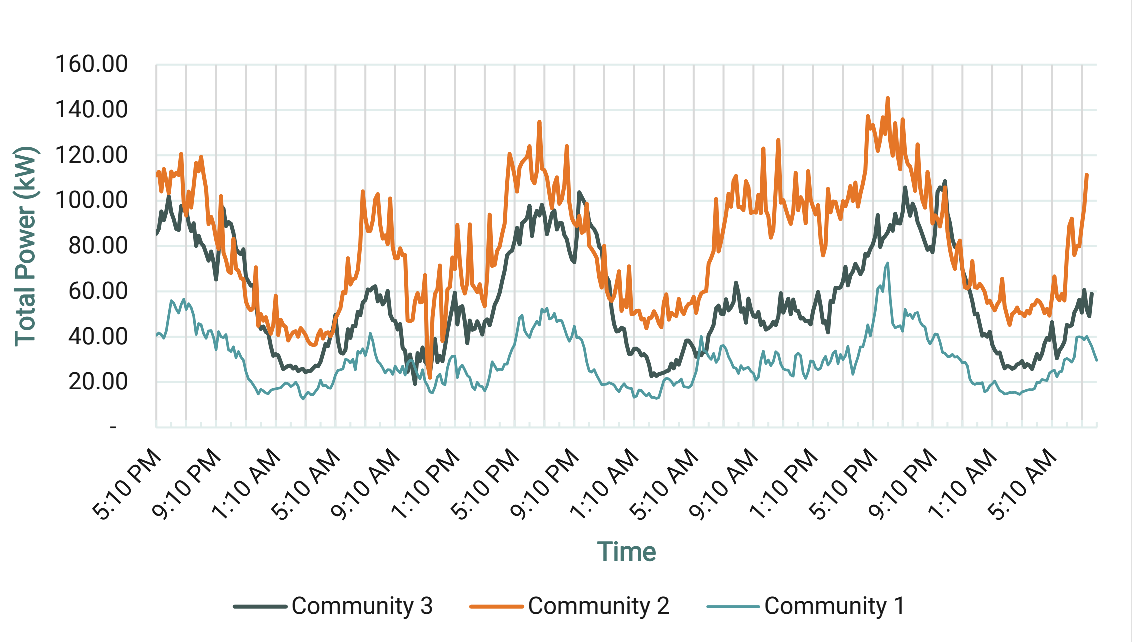


Figure 8: Total load demand of three exemplary energy communities (measured December 2019)

For a seamless integration of the LBES into the local energy management of the LFC, the following components have to be provided:

1.) The system must be provided with a battery management system (BMS) responsible for state of charge estimations and safe operation within system limits.

2.) The storage must be equipped with an automated system for disconnection of the battery from the grid in case of critical situations.

3.) The system must provide a gateway for real time data exchange with high frequency of data provision (up to ≤ 1 sec) to LFC for provision of system data, such as of state of charge (SOC), state of energy (SOE), maximum available power (P_{max}) and for charge/discharge control commands and measurement data for each phase of active power, reactive power, apparent power, voltage, current phase angle cos (Phi).

4.) The LBES has to be equipped with a power conversion system for the control of the inverter. An integrated switch must enable the external control that implements external control signal or set points in real time.

5.) The controller of BMS must be able to receive and execute setpoints sent from LFC in real time (≤ 1 sec), enabling battery storage to compensate even the smallest power fluctuations in the local grid. The local control of the battery will have to be realized via an external control-box that connects directly to the inverter. The setpoint for charging/discharging must of battery must be controllable.

6.) Communication channels should be established in short time with low latencies.

7.) Communication channels should be encrypted, e.g. by VPN.

Architecture overview

LBES systems will be provided in a containerized system. This considerably simplifies the transportation, installation on premises and dismantling and transportation after the project. A comparable system with required capacity of 616 kWh and 630 kW inverter power will be delivered in 2 containers. One container for the inverter section with 30 units with a size of 3,2 m x 1,9 m x 2,5 m and one container with 6 battery racks in size of 4,3 m x 1,9 m x 2,5 m (L x W x W). A BMS to be provided with the system to monitor the status of battery racks during operation and send alarm signals and be able to disconnect the storage from the system in case of critical system status. A controller will build the connection to the LFC for exchange of measured data, system status, operation mode and setpoints. The controller will be able to receive read and write setpoints for full control of the device. Figure 9 schedules the system architecture of BES.

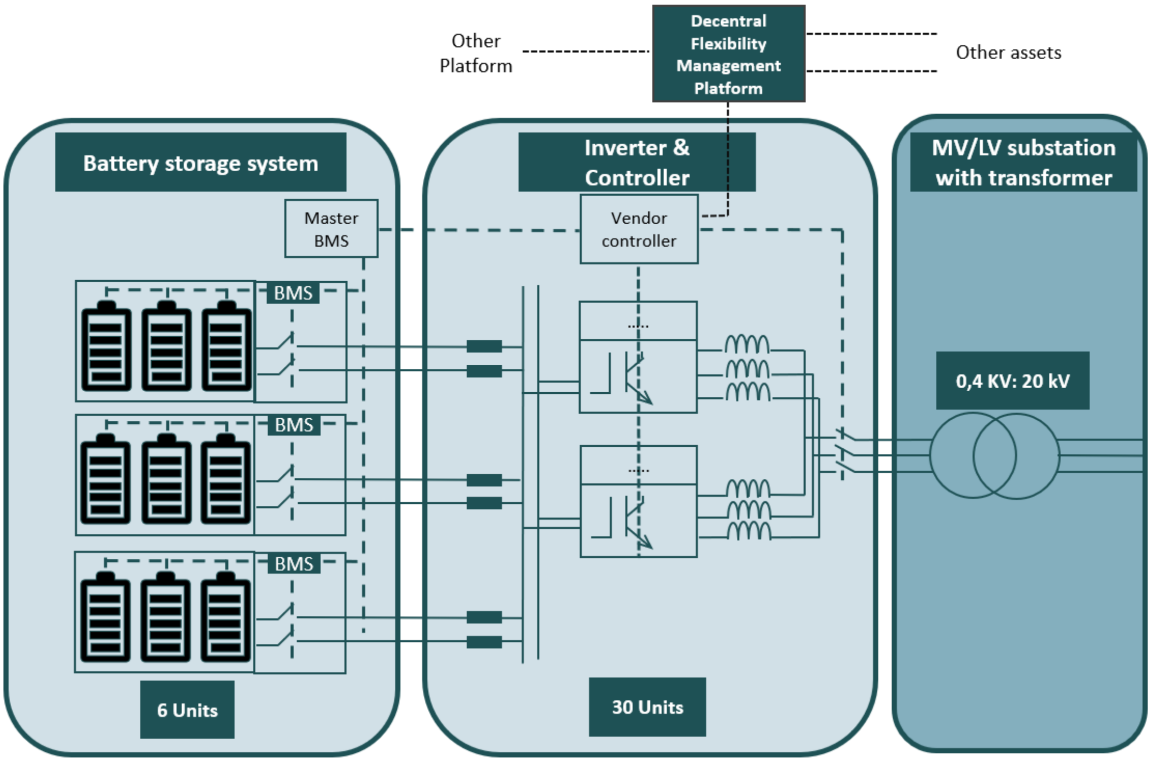


Figure 9: Overview of LBES components

Exchanged Data

The BES system will have to provide measurement values active power (P), reactive power (Q), cos (Phi), voltage (U) and current (I) of feed or demand of each phase of the grid connection point as well as battery SOC/SOE to the AFCL every second. A detailed list of read and write values that can be provided from BES of comparable targeted LBES is attached in Annex B.

The system provides multiple channels for real time data exchange. The following lists gives an overview of standard protocols and interfaces:

- Ethernet to BMS;
- CAN-BUS for connection to battery racks;
- Analog Signals 4 to 20 mA for operation of heating, conditioner and ventilators;
- Protocols: Modbus TCP/IP, RTU over RS485 and other on request;

- Encryption: Virtual Private Network (VPN) and certificate-based communication.

An example of a configured system with appropriate size is shown in Figure 10.

Figure 10: Example of an outdoor Large Battery Energy Storage System

4.4 Substation

The substation contains all components to connect the LV 400 V with MV 20 kV grid. Load flows to different households converge at this single point. Sensors for power measurement will be installed providing real time data to the LFC. The provision of measurement data from the grid connection point is critical for the application of the UCs, since it triggers the decision and control command dispatching processes of the LFC.

PMU

For that purpose, a phasor management unit (PMU) will be provided by RWTH Aachen. The PMU will provide active and reactive power, voltage, current and frequency per phase. The units will be connected to each of the 3 phases of LV grid connection. The communication is performed by the Raspberry PI 3[1]. It includes the communication libraries to send and receive data messages in sampled values (SV) format, according to the IEC [2] standard. A library will be provided with the unit as well as a set of algorithms to calculate synchrophasors, frequency and rate of change of change of frequency. Active and reactive power can be calculated. As recommended by the IEC standard for PMUs, the measurements are encapsulated in Sampled Value (SV) messages and into UDP-IP packets at a later stage. The RPI runs the operating system Raspbian[3], which can operate the open source libraries libiec6850 for applying the IEC 61850 standard. Messages from the device can be sent via Open VPN to ensure encryption and authentication features. The PMU can exchange measurements via Ethernet, Wi-Fi and wireless adapters such as 3G/4G modem devices and can alternatively be used for metering customers' household energy consumption at the household grid connection point.

Table 5: Send data from PMU located in secondary substation

Sensor	Value	Unit	Frequency
Power per Phase	P	kW	≤ 1 Sec
Reactive per Phase	Q	Var	≤ 1 Sec

[1] Raspberry PI is a series of single-board computers that feature a system with integrated central processing unit, on-chip graphics processing unit, RAM and USB and Ethernet hub

[2] IEC – International Electrotechnical Commission is an international standards organization that prepares and publishes international standards for all electrical, electronic and related technologies.

[3] Raspbian – Computer operating system for Raspberry Pi

Voltage per Phase	U	V	≤ 1 Sec
Cos (Phi)	-	-	≤ 1 Sec

The state-of-the-art substation will be implemented in the field test trial providing potential connection to public communication infrastructure via DSL or fiber optic communication. A gateway installed in the substation can provide a connection to the public communication grid on the one side and an Ethernet connection to the battery storage and the PMU sensor on the other. The data potentially can be exchanged with lower latencies, closer to real time.

4.5 Local Flex Controller

The LFC will the main component to be developed, implemented and tested in frame of the German demo. The platform will be integrated into the Platone framework and acts as an own SCADA/ADMS of the local small voltage grid. The controller optimizes the synchronization of consumption and generation inside the field test LV grid and provides flexibility on external request such as from the Platone Market Platform or directly from the DSO in frame of mechanisms that maintain safe and reliable operation of the distribution grid. The following section gives a detailed description of LFC functions.

4.5.1 Local Flex Controller Functions

Monitoring

The platform continuously monitors the available flexibility of local generation and demand, 24 hours a day, as well as the load exchange over the grid connection point. Sensors and assets in the field provide measurement data from generators and domestic heaters of private customer household and battery storage system.

Based on given values, the status and available flexibility of private assets and LBES will be determined. Data will be stored locally on the platform. Aggregated KPI of operation state of the network will be provided to external platforms.

Data Analysis & Forecasting

Algorithms to be defined in deliverable 5.3 will analyze and evaluate historic measurement data on a time series-based level to profile energy demands, identify recurring characteristics of consumers and respect individual behaviour to forecast consumption of individual domestic heaters and the whole grid. External data sources will provide additional weather forecast values such as temperature, solar radiation, cloudiness, humidity and wind speed in order to forecast the demand of heat and generation from photovoltaics. Based on the forecast estimations, the system will continuously forecast customer demand, local generation, and available flexibility individually and for the whole network in 15-min intervals up to 24 hours ahead.

Local Balancing, Islanding

The LFC maximizes energy consumption of local generated energy based on measurement and forecast values. With individual control of available flexible devices and batteries, the load exchange along the MV/LV feeder shall be reduced enabling to operate the local network in a virtual island. A real-time control of LBES twill enable the compensation of even small fluctuations. The balancing process will be supported by flexibility from private customer households.

Setpoint Dispatching for Package Based Energy Supply

A local Energy Management will enable to provide flexibility out of the balanced grid on request of external instances coming from external instances such as the DSO SCADA/ADMS, TSO or Platone market agents. Setpoints are defined as a value for the momentary power exchange between the local system and the MV feeder. Setpoints will be disaggregated into individual setpoint schedules for LBES and flexible loads to maintain the given setpoint.

Reporting

The platform will provide an interface for the exchange of aggregated data of generation, load, the state of charge, the available flexibility and KPI in order to extend service to system operators and provide necessary data to Platone platforms such as the market platform.

4.5.2 Local Flex Controller Layers

The LFC will be implemented as an IoT cloud platform running on MS Azure. The platform concept consists of multiple layers. The top layer is divided into a front-end and a communication interface with external parties and platforms. The front end provides GUI monitoring and reporting functions such as live data and charts of historic data. External interfaces provide aggregated data of generation, demand and available flexibility to other platforms such as Platone market platform or central grid control instances of the DSO. In the middle layer, an energy manager with smart algorithms enables the described function and application of use cases 1 to 4. Data will be analysed, stored and provided by a local data management instance. The bottom layer provides the backbone that establishes the connections to flexible assets to collect measurement data and sends controlling commands/setpoints.

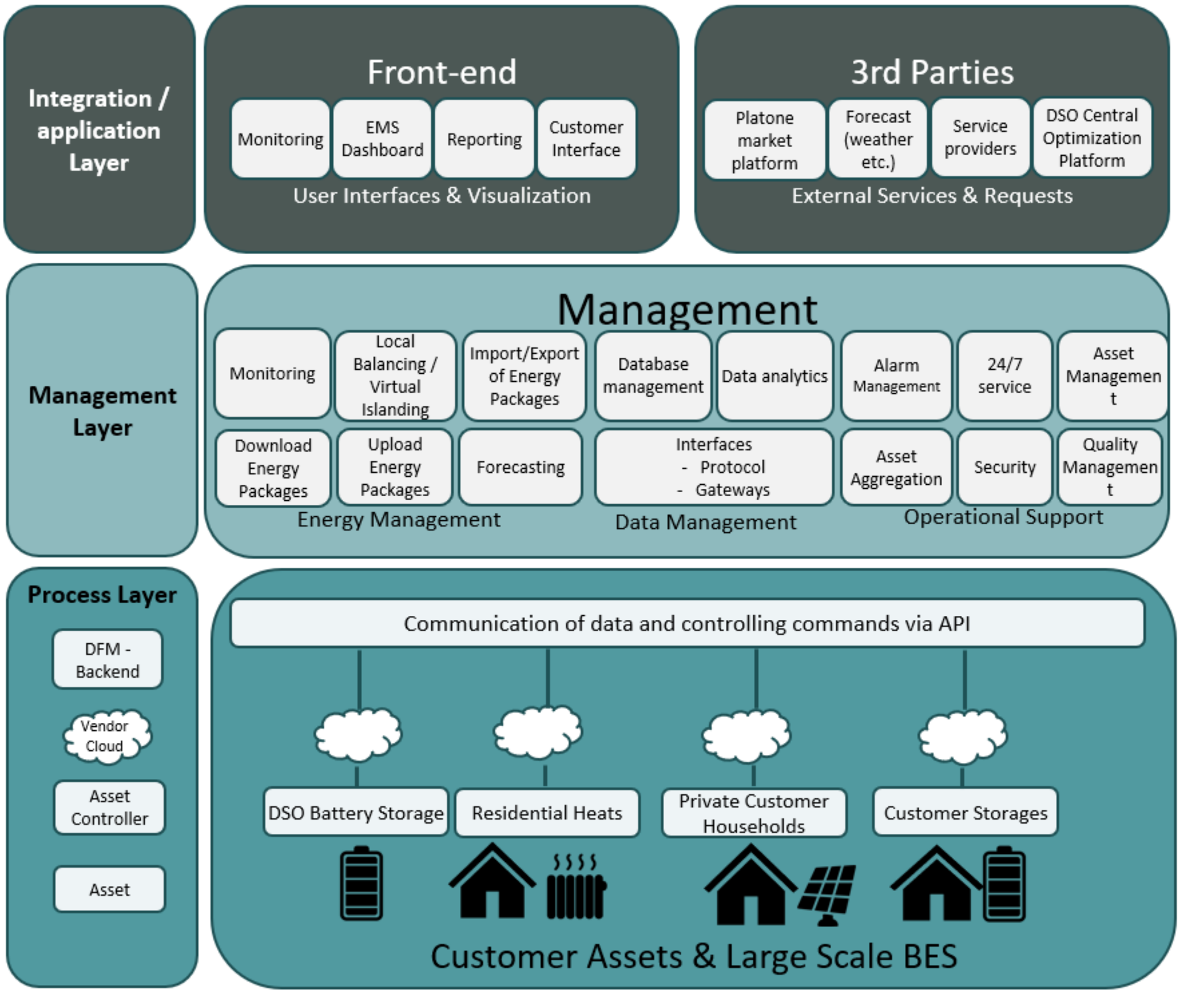


Figure 11: Overview of Local Flex Controller components

4.5.3 Interfaces

A peer-to-peer communication from LFC to different flexible assets in the field will be established via IoT cloud computing services. Many flexible devices or retrofit solutions enable remote access via REST

API using open-standard file format such as Java Script Object Notation (JSON). The platform enables communication via any protocol that is necessary for the integration of assets provided by customers in the field test. The most common communication protocols used for IoT devices are web services (REST/JSON), Modbus via TCP/IP and RTU. In case other protocols are in use, a corresponding implementation will be made in order to access the assets for measurement and control. The LFC will provide a backbone enabled to establish connections with each device in the field for the exchange of data. Communication to different devices will be encrypted, e.g. via a Virtual Private Network VPN. An API provided by WP 2 of the Platone project will enable the connection to the Platone market platform through a blockchain communication infrastructure. The connection to the LBES will be established directly via a gateway integrated in the system. Communication over the WAN takes place via radio via 4G, 3G or similar or cable-based up to the secondary substation over fiber optic cable or DSL cable.

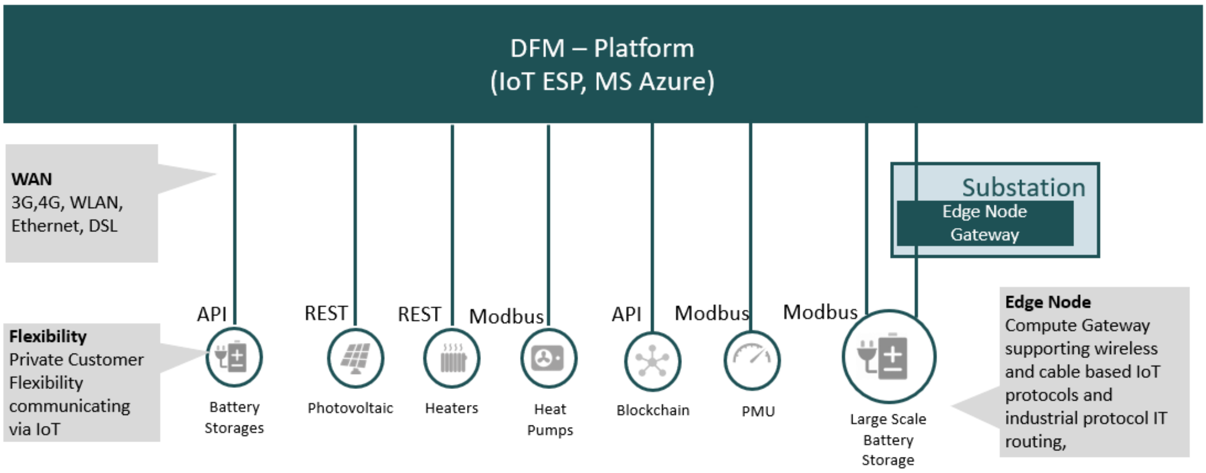


Figure 12: Overview of potential LFC interfaces to field test components

4.5.4 Data & Formats

Assets in the field provide measurement data to the LFC. Measurement data will be provided by sensors or directly by flexible smart assets, including measurement data of generation, demand and thermodynamic data of heaters such as heat water temperature of generated heat or outdoor temperature. Data of status of operation or system status such as temperature of asset components can be provided to LFC. The LBES provide an even wider set of data, such as state of charge, state of energy or operating status. The controller processes the collected data and generates corresponding steering signals. Weather forecast data will be provided by external instances to forecast generation as well as demand, enabling the LFC to derive suitable measures for optimization of operation. Table 6 gives an overview of potential data that can be collected from field test assets described in previous sections 3.2., 3.3 and 3.4. Table 7 gives an overview of data to be received and sent from the LFC to different components in the field test.

Table 6: Data Input for LFC

Technology	Input from		Value	Unit
LBES				
	SOC - State of Charge	-	-	%
	SOE - State of Energy	-	-	%

	Active Power (+/-)[4]	3 Phase	P(t)	kW/MW
	Reactive Power (+/-)	3 Phase	Q(t)	VAr
	Voltage (per Phase)	3 Phase	U (t)	V
	cos(Phi)	3 Phase	-	-
	Temperature	-	T (t)	°C
	Alarm	-	-	-
Customer				
I Customer Loads	Active Power	3 Phase/Single Phase	P(t)	kW
	Setpoint Status	-	-	ON/OFF
II Photovoltaic				
	Power	3 Phase/ Single Phase	P(t)	kW
	Voltage	3 Phase	U (t)	V
	cos(Phi)	3 Phase	-	-
	Temperature	-	T (t)	°C
	Reactive Power	3 Phase	Q(t)	VAr
	Setpoint Status	-	-	ON/OFF
III Customer Battery Energy Storage System				
	SOC - Sate of Charge	-	-	%
	SOE - State of Energy	-	-	%
	Power (+/-)	3 Phase	P(t)	kW/MW
	Reactive Power (+/-)	3 Phase	Q(t)	VAr
	Voltage (per Phase)	3 Phase	U (t)	V

[4] (+/-) – (+) Feed into the grid, (-) Demand from the grid

	cos(Phi)	3 Phase	-	-
	Temperature	-	-	-
	Alarm	-	-	-
Smart Substation (PMU				
	Power (+/-)	3 Phase	P(t)	kW/MW
	Reactive Power (+/-)	3 Phase	Q(t)	VAr
	Voltage	3 Phase	U (t)	V
	cos(Phi)	3 Phase	-	-
External Data Sources				
	Solar radiation	-	P/m2 (t)	W/m2
	Temperature	-	T (t)	°C
	Wind	-	V (t)	m/s
External Platforms				
	Setpoint P(t)		P(t+1)	kW/MW
	further to be defined D.2			

Table 7: Data sent from LFC

Technology	Input from		Value	Unit
Setpoint send to LBES				
	Power	3 Phase	$P_{+-}(t)$, $P_{+-}(t+1)$	kW
	Reactive Power	3 Phase	$Q_{+-}(t)$, $Q_{+-}(t+1)$	VAr
	SOE	-	Min, Max	%
	SOC	-	Min, Max	%
Setpoint sent to Customer				

I Customer Loads	Active Power	3 Phase/Single Phase	P+ -(t), P+ -(t+1)	ON/OFF
II Customer Battery Energy Storage System	Power - setpoint	-	P+ -(t), P+ -(t+1)	ON/OFF
Setpoint sent to Market Platform				
To be defined by WP2				

4.5.5 External Services and Platforms

The LFC will provide interfaces that enable communication with the Platone market platform and centralized instances of Avacon's grid control centre. The interface allows the transmission of setpoints for the provision of flexibility from the local network. Setpoints may be sent from higher-level instances of network management from Avacon or from the Platone market agents selling flexibility.

Avacon's SCADA/ADMS is responsible for the operation of the high and medium voltage networks. If a demand for flexibility for the support of higher-level networks arises, a setpoint for flexibility provision can be transmitted to LFC. A setpoint describes the value of the power and duration that should be exchanged via the grid connection point. Conversely, the platform provides grid status KPI and forecasts for generation and consumption to Avacon´s centralized instances if requested.

On the market platform, bid offers of flexibility will meet demands bits by SO. Traded flexibility will be used to resolve potential congestions and voltage issues. The communication will take place via a blockchain communication infrastructure for a secure and transparent communication. An API for the exchange of relevant data with LFC will be provided by WP 2. The interfaces can also be used to provide predictions of available flexibility for trading on the market platform, as well as setpoint to control traded flexibility. A detailed overview of the communication channels of system components in the Platone framework in a single line diagram in Annex A.

5 Conclusion

In this deliverable the solution design and technical concept of Avacon's LFC has been described. The system aims to enable the operation of a decentralised flexibility management instance following the edge computing paradigm. The LFC is fully integrated into the Platone framework enabling flexibility located in the bounded low voltage grid to be accessed.

The LFC is an integrated part of the overall concept of Platone. In the next step components connected to the LFC will have to be further specified. This applies in particular to the market platform to be developed in frame of Task 2.2, of which a first release will be provided in month 12. The specification of the market platform has to include a detailed description of functionalities, data and formats, so that adaptations in the concept of the LFC can be implemented accordingly and functional requirements can be met. Meanwhile the use case will be further developed and specified. Avacon aims to finalize the conceptualization of the technical solution of the LFC and field test design by month 12, according to the original time schedule of the project plan.

6 List of Tables

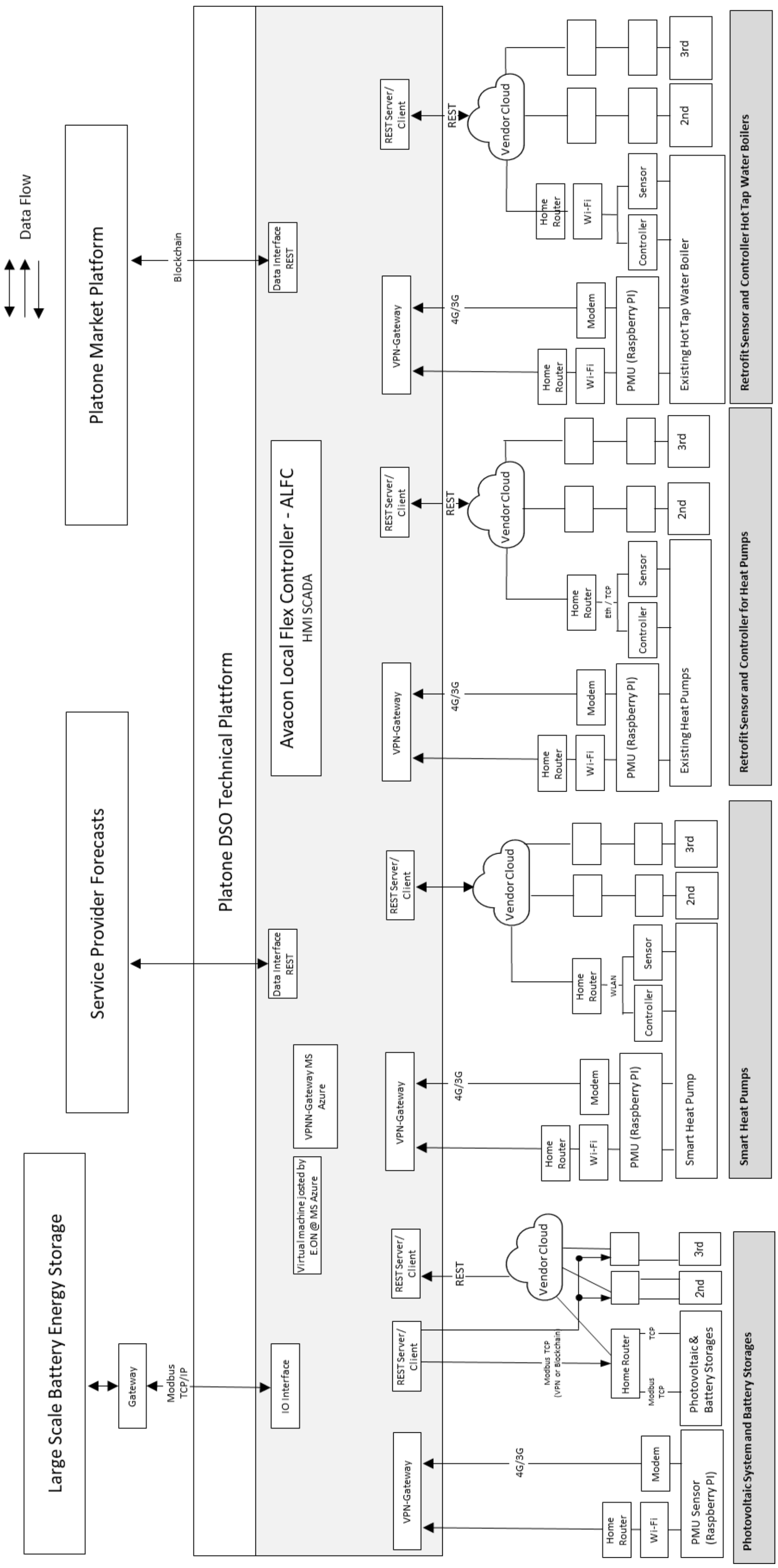
7 List of Figures

8 List of Abbreviations

Abbreviation	Term
ADMS	Advanced Distribution Management System
API	Application Programming Interface
BMS	Battery Management System
DER	Distributed Renewable Energy
DFMP	Decentral Flexibility Management Platform
GUI	Graphical User Interface
LBES	Large Battery Energy Storage
DSO	Distribution System Operator
KPI	Key Performance Indicator
LFC	Local Flex Controller
LV	Low Voltage
MV	Medium Voltage
HV	High Voltage
PC	Personal Computer
PLC	Power Line Communication
PMU	Phasor Measurement Unit
PV	Photovoltaic
RES	Renewable Energy Sources
SCADA	Supervisory Control and Data Acquisition
SO	System Operator
SOC	State Of Charge

SOE	State Of Energy
TSO	Transmission System Operator
UC	Use Case
UI	User Interface
VPN	Virtual Private Network

Annex A Single Line Diagram of System Architecture



Annex B Overview of Data provided by of LBES Energy Management System to external system via API

Name	Register (protocol based)	Data type	Size (in WORD)	Minimum value	Maximum value	Unit	Description
Cmd_Start	0	WORD	1	0	5		0=Idle, 1=Start, 2=Stop AIP, 3=Stop AIP and BMS, 4=Reset AIP Fault , 5= Reset BMS Fault
Cmd_Auto	1	WORD	1	0	1		0=use of Cmd_Target_P and Cmd_Target_Q, 1=Peakshaving Active
Cmd_Target_P	2	REAL	2			kW	Active power setpoint of the BESS when in "Remote_Manual" Mode; positive=discharge
Cmd_Target_Q	4	REAL	2			kVar	Reactive power setpoint of the BESS when in "RemoteManual" Mode
Cmd_Islanding	6	WORD	1	0	1		0=Stop Islanding, 1=Start Islanding
Cmd_Anti_Islanding	7	WORD	1	0	1		0=Anti-Islanding Disabled, 1=Anti-Islanding Enabled
WatchDog	9	WORD	1	0	65536		A changing value needs to be written here every second
Param_pk_HighLimit_Power	10	REAL	2			kW	High limit of the hysteresis of peak shaving
Param_pk_LowLimit_Power	12	REAL	2			kW	Low limit of the hysteresis of peak shaving
Param_pk_HighLimit_SOC	14	REAL	2	0	100		High limit of the State of charge to activate the peak shaving [%] max 98
Param_pk_LowLimit_SOC	16	REAL	2	0	100		Low limit of the State of charge to activate the peak shaving [%] min 0
Param_Self_Comp	18	WORD	1	0	1		0= no compensation of the consumption of the auxiliaries, 1=compensation of the consumption of the auxiliaries (except for target P = 0) (*)
Param_Self_Comp_0	19	WORD	1	0	1		active only if Param_Self_Comp is equal to 1 0=no compensation of the consumption of the auxiliaries

Name	Register (protocol based)	Data type	Size (in WORD)	Minimum value	Maximum value	Unit	Description
							when Target P = 0 1= compensation of the consumption of the auxiliaries when Target P = 0 (*)
Grid_P	40	REAL	2			kW	Active power of the grid meter (**)
Grid_Q	42	REAL	2			kVAR	Reactive Power of the grid meter
Grid_S	44	REAL	2			kVA	Apparent power of the grid meter
Grid_Cos_Phi	46	REAL	2				Cos Phi of the grid meter
Grid_I1	48	REAL	2			V	Line 1 current of the grid meter
Grid_I2	50	REAL	2			V	Line 2 current of the grid meter
Grid_I3	52	REAL	2			V	Line 3 current of the grid meter
Grid_IN	54	REAL	2			V	Neutral current of the grid meter
Grid_U_L1_N	56	REAL	2			V	Line 1 to neutral voltage of the grid meter
Grid_U_L2_N	58	REAL	2			V	Line 2 to neutral voltage of the grid meter
Grid_U_L3_N	60	REAL	2			V	Line 3 to neutral voltage of the grid meter
Grid_U_L1_L2	62	REAL	2			V	Line 1 to Line 2 voltage of the grid meter
Grid_U_L2_L3	64	REAL	2			V	Line 2 to Line 3 voltage of the grid meter
Grid_U_L3_L1	66	REAL	2			V	Line 3 to Line 1 voltage of the grid meter
(*) Only applicable for PQpluS Outdoor							
(**) Mandatory for peak shaving applications							
(***) Registers not shown are either in use or reserved							

Name	**Register (protocol based)**	**Data type**	**Size (in WORD)**	**Unit**	**Description**
PQpluS Status	0	WORD			0=Stopped 1=Run 2=alarms
Mode	1	WORD			0=OFF 1=Remote 2=Local
Battery string Status	2	WORD			0=Stopped 1=Run 2=alarms
BESS Max Charge	3	REAL		kW	Max allowed charging power
BESS Max Discharge	5	REAL		kW	Max allowed discharge power
BESS Battery room temperature	7	REAL		°C	Ambient temperature of the battery room
Islanding Status	9	WORD			0=Grid 1= Islanding 2=Resynchronising
Battery string Communication Status	10	WORD			0=Disconnected 1=Connecting 2=Connected 3=Disconnecting 4=Resetting
RESERVED	11				
RESERVED	12				
RESERVED	13				
RESERVED	14				

Name	Register (protocol based)	Data type	Size (in WORD)	Unit	Description
RESERVED	15				
RESERVED	16				
RESERVED	17				
RESERVED	18				
RESERVED	19				
RESERVED	20				
BESS_P	21	REAL		kW	BESS total active power to/from grid
BESS_Q	23	REAL		kVAr	BESS total reactive power to/from grid
BESS_S	25	REAL		kVA	BESS total apparent power to/from grid
BESS_I1	27	REAL		A	BESS line 1 current
BESS_I2	29	REAL		A	BESS line 2 current
BESS_I3	31	REAL		A	BESS line 3 current
BESS_IN	33	REAL		A	BESS neutral current
BESS_U_L1_N	35	REAL		V	BESS line 1 to neutral voltage
BESS_U_L2_N	37	REAL		V	BESS line 2 to neutral voltage
BESS_U_L3_N	39	REAL		V	BESS line 3 to neutral voltage
BESS_U_L1_L2	41	REAL		V	BESS line 1 to line 2 voltage
BESS_U_L2_L3	43	REAL		V	BESS line 2 to line 3 voltage
BESS_U_L3_L1	45	REAL		V	BESS line 3 to line 1 voltage
BESS_COS_PHI	47	REAL			BESS Cos Phi
BESS_PF	49	REAL			BESS power factor
BESS_E_P_POS	51	REAL		kWh	BESS Positive active energy

Name	Register (protocol based)	Data type	Size (in WORD)	Unit	Description
BESS_E_P_NEG	53	REAL		kWh	BESS negative active energy
BESS_E_Q_POS	55	REAL		kVArh	BESS Positive reactive energy
BESS_E_Q_NEG	57	REAL		kVArh	BESS Negative reactive energy
BESS_E_S	59	REAL		kVAh	BESS Apparent energy
AUX_P	70	REAL		kW	Auxiliaries total active power to/from grid
AUX_Q	72	REAL		kVAr	Auxiliaries total reactive power to/from grid
AUX_S	74	REAL		kVA	Auxiliaries total apparent power to/from grid
AUX_I1	76	REAL		A	Auxiliaries line 1 current
AUX_I2	78	REAL		A	Auxiliaries line 2 current
AUX_I3	80	REAL		A	Auxiliaries line 3 current
AUX_IN	82	REAL		A	Auxiliaries neutral current
AUX_U_L1_N	84	REAL		V	Auxiliaries line 1 to neutral voltage
AUX_U_L1_N	86	REAL		V	Auxiliaries line 2 to neutral voltage
AUX_U_L1_N	88	REAL		V	Auxiliaries line 3 to neutral voltage
AUX_U_L1_L2	90	REAL		V	Auxiliaries line 1 to line 2 voltage
AUX_U_L1_L2	92	REAL		V	Auxiliaries line 2 to line 3 voltage
AUX_U_L1_L2	94	REAL		V	Auxiliaries line 3 to line 1 voltage
AUX_COS_PHI	96	REAL			Auxiliaries Cos Phi
AUX_PF	98	REAL			Auxiliaries power factor
AUX_E_P_POS	100	REAL		kWh	Auxiliaries Positive active energy
AUX_E_P_NEG	102	REAL		kWh	Auxiliaries negative active energy
AUX_E_Q_POS	104	REAL		kVArh	Auxiliaries Positive reactive energy

Name	Register (protocol based)	Data type	Size (in WORD)	Unit	Description
AUX_E_Q_NEG	106	REAL		kVArh	Auxiliaries Negative reactive energy
AUX_E_S	108	REAL		kVAh	Auxiliaries Apparent energy
BAT_SOC	120	REAL		%	State of charge of the batteries
BAT_SOH	122	REAL		%	State of Health of the batteries
BAT_CHARGE_LIM	124	REAL		kW	Maximum charge allowed by the batteries
BAT_DISCHARGE_LIM	126	REAL		kW	Maximum discharge allowed by the batteries
BAT_U_STACK_AVERAGE	128	REAL		V	Batteries voltage (average)
BAT_I_STACK_SUM	134	REAL		A	Batteries current (total)
BAT_TEMP_MAX	142	REAL		°C	Batteries temperatures (Maximum)
BAT_TEMP_MIN	144	REAL		°C	Batteries temperatures (minimum)
BAT_U_CELL_MAX	148	REAL		V	Batteries Cells voltage (Maximum)
BAT_U_CELL_MIN	150	REAL		V	Batteries Cells voltage minimum)
ESI_P	170	REAL		kW	PQStorI total active power to/from grid
ESI_Q	172	REAL		kVAr	PQStorI total reactive power to/from grid
ESI_S	174	REAL		kVA	PQStorI total apparent power to/from grid
ESI_U_L1_L2	176	REAL		V	PQStorI line 1 to line 2 voltage
ESI_U_L2_L3	178	REAL		V	PQStorI line 2 to line 3 voltage
ESI_U_L3_L1	180	REAL		V	PQStorI line 3 to line 1 voltage
ESI_U_THD_L1_L2	182	REAL		%	PQStorI Line 1 to Line 2 voltage harmonic distortion [%]
ESI_U_THD_L2_L3	184	REAL		%	PQStorI Line 2 to Line 3 voltage harmonic distortion [%]
ESI_U_THD_L3_L1	186	REAL		%	PQStorI Line 3 to Line 1 voltage harmonic distortion [%]

Name	Register (protocol based)	Data type	Size (in WORD)	Unit	Description
ESI_FREQ	188	REAL		Hz	PQStorI frequency
ESI_I_L1	190	REAL		A	PQStorI line 1 current
ESI_I_L2	192	REAL		A	PQStorI line 2 current
ESI_I_L3	194	REAL		A	PQStorI line 3 current
ESI_I_THD_L1	196	REAL		%	PQStorI Line 1 current harmonic distortion [%]
ESI_I_THD_L2	198	REAL		%	PQStorI Line 2 current harmonic distortion [%]
ESI_I_THD_L3	200	REAL		%	PQStorI Line 3 current harmonic distortion [%]
ESI_PF	202	REAL			PQStorI Power factor
ESI_TEMP_CONTROL	204	REAL		°C	PQStorI temperature (control board)
ESI_TEMP_IGBT	206	REAL		°C	PQStorI IGBT temperature
BESS_ALARMS_1	230	WORD			see alarms and warnings descriptions
BESS_ALARMS_2	231	WORD			see alarms and warnings descriptions
BESS_ALARMS_3	232	WORD			see alarms and warnings descriptions
BESS_ALARMS_4	233	WORD			see alarms and warnings descriptions
BESS_ALARMS_5	234	WORD			see alarms and warnings descriptions
BESS_ALARMS_6	235	WORD			see alarms and warnings descriptions
BESS_ALARMS_7	236	WORD			see alarms and warnings descriptions
RESERVED	237	WORD			see alarms and warnings descriptions
RESERVED	238	WORD			see alarms and warnings descriptions
RESERVED	239	WORD			see alarms and warnings descriptions
BESS_WARNING_1	240	WORD			see alarms and warnings descriptions
BESS_WARNING_2	241	WORD			see alarms and warnings descriptions

Name	Register (protocol based)	Data type	Size (in WORD)	Unit	Description
BESS_WARNING_3	242	WORD			see alarms and warnings descriptions
RESERVED	243	WORD			see alarms and warnings descriptions
RESERVED	244	WORD			see alarms and warnings descriptions
RESERVED	245	WORD			see alarms and warnings descriptions
RESERVED	246	WORD			see alarms and warnings descriptions
RESERVED	247	WORD			see alarms and warnings descriptions
RESERVED	248	WORD			see alarms and warnings descriptions
RESERVED	249	WORD			see alarms and warnings descriptions