D6.1 - Phase 1 Test Site Plans

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Review Date	Reviewer	Summary of Comments
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Related Documents

ID	Title	Reference	Version	Date
D2.1	Initial Storage Scenarios and Use Cases	[1]	V1.1	2017-06-08

Table of Contents

Executive Summary

This deliverable summarizes the **Initial Test Site Plans** in all the three S4G test sites. It uses the S4G vision from "D2.1. Initial Storage Scenarios and Use Cases" [1]. It describes each test site in terms of the two superposed layers: electrical energy transfer (PV, loads, storage, inverters, energy meters), and a combined information (real time measurements, infrastructure descriptors, set-points, local restrictions etc.) and data communication (including data secure transfer using primordially the SMX component) layer. The description is the first view and exemplification for the implementation, to be adapted and refined during next phases, based also on the outcomes of the D3.1 deliverable addressing the system architecture, to be issued in M9.

1 Introduction

This deliverable summarizes the **Initial Test Site Plans** in all the three S4G test sites, resulting from the analysis activities performed by task T6.1 "Test Sites and Cases Planning".

WP6 integrates project outcomes in the test sites in Bucharest, Bolzano and Fur. Evaluation activities were planned to leverage the test sites taking into account scenarios, use cases and business models designed in WP2 and documented in D2.1 [1] as well as the key functional requirements identified by the project and documented in deliverable D2.5 "Initial Lessons Learned and Requirements Report". It has also to be observed that T6.1 also builds upon the Architecture and Components specifications developed in WP3 which will be released in deliverable D3.1 "Initial S4G Component Interfaces and Architecture Specification" in M9.

Starting from scenarios, use cases, business models and requirements defined in WP2, concrete test and evaluation cases to be deployed in each test site have been designed. For each case, appropriate boundary conditions to be monitored are proposed. To ensure relevance of tests and demonstrations, each test case is mapped to at least one reference business case.

Based on the work reported in D2.1[1], description of scenarios and use-cases, and following the requirements derived from JIRA, the expected role and performance of the most important components associated with the specific test site has been considered. An updated architecture and components will be provided in D3.1.

The demonstrators will focus on testing the communication between main components, as part of the use cases associated with each of the three demo sites. Figure 1 shows the preliminary diagram of the main components from HLUCs, which will be tested in, Bolzano, Fur and Bucharest.

For example, one of the components in all layers is the Unbundled Smart Meter (USM) [2]. However, the functionalities of Smart Meter eXtension (SMX) [3] as process interface and communication modules are different in Bucharest (where the SMX proxy will be the Energy Router) and Bolzano, where 3rd party modules will directly control both the storage and the EV charger.

To recall the use cases associated with each demonstrator please see D2.1 [1]**.**

At the moment of preparing this deliverable, the S4G architecture and components overview is presented in Figure 1.

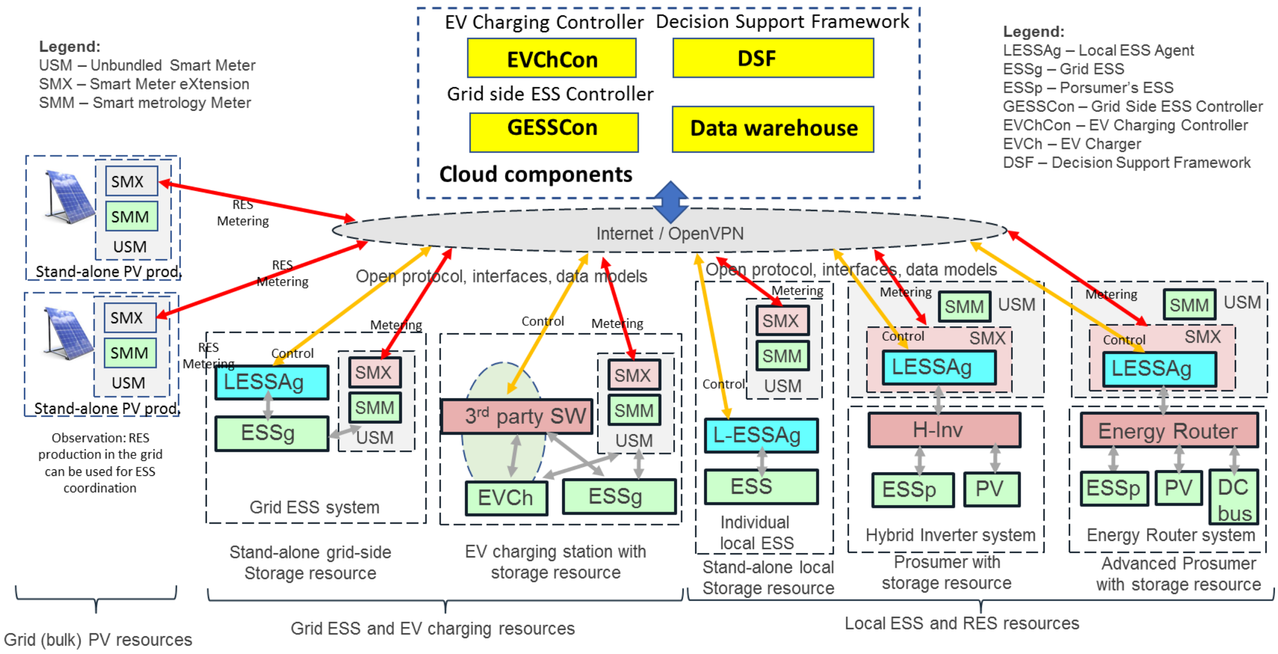

Figure 1 - Architecture and Components diagram

This shall be considered as an example and first view of implementation, as the real implementation will be described in D3.1 and will evolve and improve during the project implementation.

1.1 Deliverable Scope

This deliverable documents the results generated by Work Package 6 "Integration, Test Sites and Evaluation", and more specifically by task T6.1 "Test Sites and Cases Planning". This document describes technical steps for evaluation of phase 1 demonstrators, included in general plans of the test sites analysed until M8 of the project (July 2017). Two future versions are expected to update and replace the information documented in this deliverable, namely D6.2 "Phase 2 Test Site Plans" (due in M20, July 2018) and D6.3 "Phase 3 Test Site Plans" (due in M32, July 2019).

A general view of all the uses cases is presented in Figure 2, where the use cases are structured according to the scenarios and high level use case to be demonstrated in the three test sites:

Resilient and efficient local ecosystem - HLUC-1: test site UPB;
Cooperative EV charging - HLUC-2: test site Bolzano;
Grid simulation - HLUC-3: test site Fur

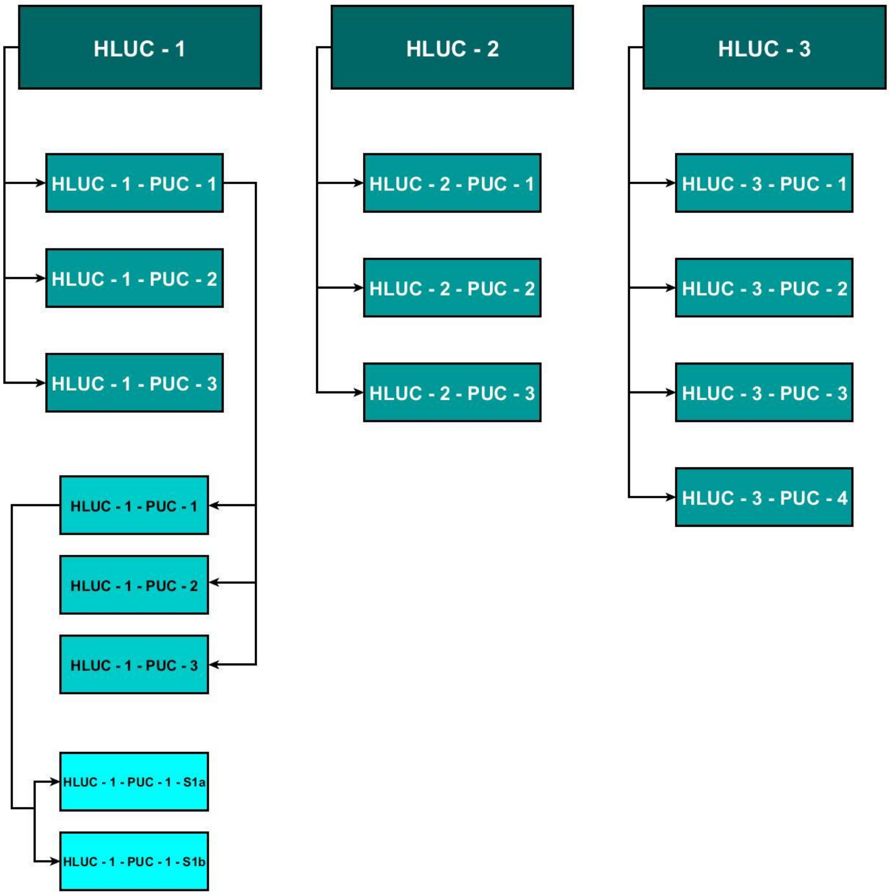

Figure 2 - Use cases diagram

The use cases are briefly presented below:

Resilient and efficient local ecosystem - HLUC-1

Grid strengthening and ancillary services simulation (providing services for the DSO)

- **HLUC-1-PUC-1** (Advanced Prosumer – AP)
  Handle over-generation from RES into the grid (avoid curtailment orders from DSO) –
  - **HLUC-1-PUC-1-S1**
    - **HLUC-1-PUC-1-S1a** – Handle over-generation from RES into the grid (avoid curtailment orders from DSO), when surplus energy cannot be completely stored locally, thus being sent to the network, where it will be redirected to available storage. Prosumer will generate into the grid P<=0, with |P|<=Pmax.
    - **HLUC-1-PUC-1-S1b** – Handle over-generation from RES into the grid (avoid curtailment orders from DSO), when there is identified a local storage that can absorb surplus energy from the grid. Prosumer will consume from the grid P>0, with |P|>=Pmin.
  - **HLUC-1-PUC-1-S2** – Serving peak demands on DSO-level: the prosumer will consume from the grid P>=0, with |P|<=Pmax, where the supplementary needed energy (for the local loads) comes primarily from the local storage.
  - **HLUC-1-PUC-1-S3** – Provide ancillary services (black start) on DSO-level. The ER has to operate without frequency signal from the external network and act as grid former. The prosumer will generate into the grid P<=0, with |P|>=Pmin, where the energy comes primarily from the local storage.
- **HLUC-1-PUC-2** (Advanced self-resilient prosumer)
  Battery management in such a way that the prosumer will act always as a consumer from the grid side. It needs only local information for optimal energy management. It does not receive set points from the DSO.
- **HLUC-1-PUC-3** (Resilient hybrid cooperative ecosystem)
  Battery management in such a way that the prosumer will act always as a consumer from the grid side. The local load will include the remote load of the neighbour and the local generation will include local PV, local storage in discharge mode and potentially the neighbour storage also in discharge mode. It does not receive set points from the DSO.

Cooperative EV charging - HLUC-2
Growing shares of intermittent power generation from RES while facing with increasing diffusion of EVs

- **HLUC-2-PUC-1** (Residential prosumer with storage)
  Installation at the residential prosumer of ESS (USM, DSF and GUI) for power flow management (data related to PV generation, SoC, electrical consumption of the household, voltage and currents levels) and for two EV charging in order to complete the charge within the next morning.
- **HLUC-2-PUC-2** (Cooperative charging in the parking lot of a commercial test site)
  Installation at the prosumer parking lot of ESS (USM, DSF and GUI) after the POD at customer level, for PV energy storage in order to avoid a rise of the available power needed at his point of delivery (POD).
- **HLUC-2-PUC-3** (Simulation of high penetration of EV chargers and of prosumers with storage and residential EV charging)
  With respect to a future scenario with higher EV penetration, the DSF will simulate the maximum possible amount of EV's and charging stations which can be supported by the existing grid (without additional grid strengthening). The outcomes will show the potential and limits of storage and cooperative charging in today's grid topology.

Grid simulation - HLUC-3
Simulations necessary from the perspective of more DER production from RES and added consumption of electrical energy was taken into consideration in this high level use case.

- **HLUC-3-PUC-1** (Traditional grid strengthening simulation)

Simulation of the baseline will be run and interactions with customers are only necessary if there is the need to rent more land for transformers or if the cables need to be replaced. The tariffs are computed based on the consumer's consumption.

- **HLUC-3-PUC-2** (Simulation of private households investing in residential storage)
  Simulation with local storage and BMS which runs independent of the grid.
- **HLUC-3-PUC-3** (DSO investing in larger systems at substation level)
  Simulation for evaluation if the battery systems can be placed in the low voltage grid. and where to place it. Due to either/or high local consumption or production it may be feasible to place storage at local feeder lines to overcome increasing or decreasing voltage levels and/or to control the flux, especially up-wards flow in the grid. The optimal position of where to place the storage to gain the most positive effect will be addressed.
  HLUC-3-PUC-4 (Deploying and enforcing distributed controllable storage at various levels)
  The S4G simulation engine is used to model the situation of the grid when private storage and the storage on grid level is jointly operated and coordinated. In this situation, also ancillary services will be taken into consideration, depending on the regulatory environment.

1.2 Preliminary business cases approach

S4G will develop a viable and sustainable business framework for controllable storage solutions that align with global business conditions, and in particular, to develop realistic business models and cases for deploying the S4G outcomes. While a number of technical capabilities and features of S4G control solutions can be operated by single business entities (e.g. private prosumers), the real value of such solutions lies in the use of S4G solutions as an enabler of complex business and market configurations. Therefore, services by different stakeholders and partnerships are dynamically involved and integrated with the energy market in a specific regulatory environment.

An initial analysis of already established models for deployment and operation of storage systems will be performed in D2.3 "Initial S4G Business Models" (deadline in month 12), initially focusing on simpler business cases with a shorter time perspective of realization. Such initial activity will include referencing to current market configurations and regulations.

The developed business cases build on knowledge gathered and reported in **D2.1. "Initial Storage Scenarios and Use cases"** [1], which describes different actors or stakeholders in all use cases considered for S4G. The stakeholders' business cases are being explored in business conditions, investments and cost, marked perspective and regulation issues.

1.3 Planning overview

General boundary conditions for test site components

In order to ease the performance assessment in the first phase test cases, specific boundary conditions for test site components will be identified and addressed. These conditions will be classified according to the following structure and adapted to each test case and site:

I. Completeness of measurements;
II. Requirements for data synchronization;
III. Communication.

Evaluation methodology

The applied evaluation methodology consists of the following steps:

- Establishing the studied scenario;
- Realizing a simulation (for example using Matlab-Simulink or other numerical program) for one data set which is needed to be exchanged between the tested component and another interacting component (for example the generation of data collected each 15 minutes from the PV), depending on the use case studied;
- Emulating the transfer of data between components used in each test site;
- Testing the functionality of components used in the test site
- Experimenting with all the components from each test site;
- Comparing testing results with numerical simulation;
- Repeating all steps for other data set (typical for one day.)

2 Test site Bolzano: Cooperation EV charging

The "Cooperative EV charging" scenario will be set up in Bolzano and operated by S4G partner Edyna jointly with Alperia Smart Mobility and Alperia. The three companies are part of the same Group, being Alperia the holding company.

Bolzano is the capital of Alto Adige – Sudtirol , an alpine region in northern Italy characterized by the presence of two medium cities (Merano and Bolzano), with strong seasonal changes in electricity demand and use of EVs due to the touristic nature of the site. As of today (July 2017) approx. 250 EVs are already active in the area, using a charging network of 31 slow charging stations (average power absorbed during charging: 22 kW AC) and 3 fast charging stations (average power absorbed during charging: 45 kW AC). The diffusion of EVs is currently growing significantly in this area; therefore, Alperia Smart Mobility, as e-mobility provider, has already scheduled investments to activate 51 overall charging stations (45 slow and 12 fast) in the area, before the end of 2017. The current EV charging infrastructure is monitored and controlled in real-time by Alperia Smart Mobility through a dedicated SIEMENS backend management system. The number of charging stations is possible to raise during the project lifetime, considering the high interest for e-mobility in this area.

This test site features **two scenarios**: a **residential** case and a **commercial** case.

2.1 Residential case

For the **residential case** Edyna will use as test site a single-family house in a rural village close to Bolzano that is already equipped/fitted with a PV installation on the roof (10 kW) and with an EV private charging station. At the moment, the house does not have a storage system, but it will be equipped during the next couple of months, in order to fulfil the requirements of the test site. The supplier of the storage system has already been identified and the purchasing process is ongoing. The house will have a main USM to be mounted at the Point of Common Coupling (PCC) between the DSO and the prosumer internal network. Different types of smart meters are being evaluated for purchase and the compatible SMX is to be designed and developed within the S4G, as part of the WP4 – T4.1. and T 4.4. activities, integrated with the residential ESS and a dedicated local GUI. The preferred meter type is 3-phase ZMG310 meter form Landis+Gyr, which has good characteristics in terms of flexibility and dynamics of real-time data reporting (down to each 1 second), but other types of meters will be also analysed, such as MT831 from Iskraemeko, which is widely used in the utility, but not yet proven to have similar characteristic in terms of USM flexibility.

Edyna will regulate the installation and utilization of USM, charging station (a SMART type with communication to a backend system will be installed) and storage system contractually with the owners of the house.

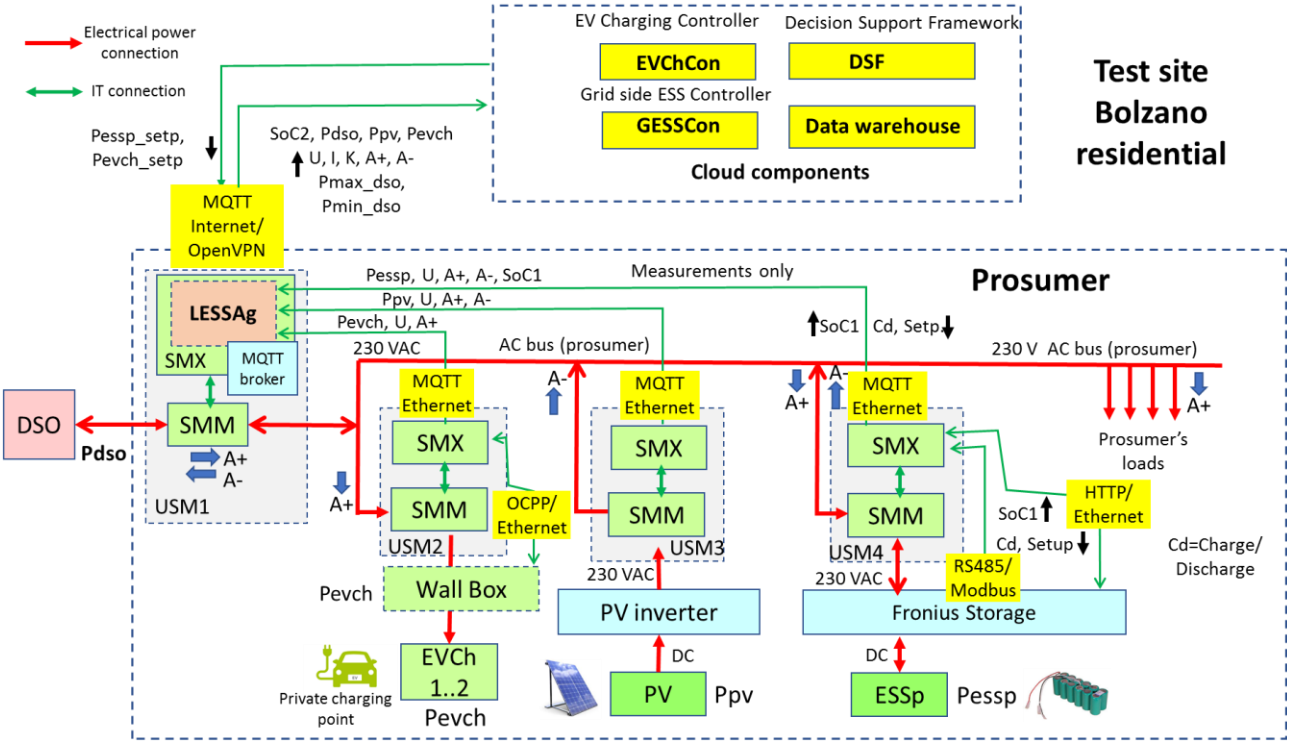

Figure 3 - Preliminary details of the residential part of the test site Bolzano (example of implementation)

Legend for the annotations can be found in Table 1:

Table 1 - Legend – Residential Test Site Bolzano

Name	Description
SoC1	State of Charge of the local Energy Storage System of prosumer (information given by the Fronius Storage to the Smart Meter eXtensions)
SoC2	The value of State of Charge which is sent to Decision Support Framework (it is not mandatory that this value and SoC1 to be equal)
Pdso	Active power received from or injected to the DSO, measured by USM1 (main USM)
Pmax_dso	Maximum active power required/provided from/to the DSO sent to the cloud components
Pmin_dso	Minimum active power required/provided from/to the DSO sent to the cloud components
Ppv	Active power provided by the PV, measured by USM3; this power has usually negative value, as it is mainly generating power; USM3 is also providing the energy consumed (A+) and produced (A-)
Pevch	Active power consumed by the Electrical Vehicle Charging point through the Wall Box (WB); the SMX of USM2 regulates the power value by communication with the WB
Pevch_setp	The value of active power provided by Electrical Vehicle Charging point to EV, decided to be sent from the cloud components to the Smart Meter eXtension as a

	set point for WB
Pessp	Active power provided by Energy Storage system of prosumer
Pessp_setp	The value of power provided by the local Energy Storage System of the prosumer (consumption or generation), decided to be sent to Smart Meter eXtensions from the cloud components, as a set point; the SMX of USM4 regulates the power value by communication with the Fronius Storage inverter
U	Root Mean Square phase voltages delivered with a reporting rate Tu
I	Root Mean Square phase currents delivered with a reporting rate Ti
A+	Energy consumed by the prosumer
A-	Energy produced by the prosumer
Cd, Setp	Control Actions (commands and setup values)

To be noted that TU will have a value between 1 and 10 seconds, to be decided based on implementation details, such as SMM, WB and Fronius inverter characteristics.

As an example, in Figure 3 are presented two layers (networks) corresponding to:

- Power / energy flow (lines depicted in red colour), related to the power network:
  - From the prosumers 230 V AC bus to the charging point; the real-time active power Pevch and active energy A+ are measured with an individual USM2. Based on the metrology meter (SMM) characteristics, the real-time active power will be available with the reporting rate TU = 1 .. 10 seconds
  - From PV to the prosumer's 230 V AC bus, via Fronius converter system, the real-time active power Ppv as well as the active energy A+ are measured and exchanged with an individual USM3. Based on the metrology meter (SMM) characteristics, real-time active power will be available with the reporting rate TU = 1 .. 10 seconds
  - Between the prosumer's 230 V AC bus and the available storage ESSp, the active power Pessp is measured and exchanged by using an individual USM4;. Power Pessp, exchanged between the AC bus and the storage unit ESSp, will have positive values in battery charging mode (acting as energy consumption) and negative values in battery discharging mode (acting as energy production). Moreover, energies A+ and A- will be available, corresponding to charging and discharging mode of the battery.
  - Power and energy exchanged by the prosumer with DSO is are metered by an individual USM1, acting as main USM. Active power Pdso exchanged between DSO and prosumer will have positive values when the prosumer is equivalent to a load and negative values when the prosumer injects energy in the DSO grid, acting as a generator. Based on the meter characteristics, real-time active power will be available with the reporting rate TU = 1 .. 10 seconds. Moreover, energies A+ and A- will be available, corresponding to load and generator mode of the battery.
  - On the prosumers premises there are other AC loads with active power consumption P_loads or P_Σload. There is no individual meter associated with them. Information on power

delivered to these loads will be calculated from power balance P_Σload =Pdso-Pessp-Pevch-Ppv.
    - As a general rule, USM is delivering the A+ as energy consumed by the prosumer and A- as energy sent to the grid by prosumer.
- Information flow (lines depicted in green colour), related to the information network:
    - Measurements from local devices:
        - Delivered by USM: Pdso, Pevch, Ppv, Pessp, Pmax_dso, Pmin_dso, Pevch U (rms phase voltages delivered with a reporting rate Tu), I (rms phase currents delivered with a reporting rate Ti), A+, A- (A+ is measured energy in the consumption mode and A- is measured energy in the production / inject back to the system mode)
        - Delivered by Fronius system: Soc1 (updated at the highest rate of reporting, e.g. each 1 to 10 seconds)
        - Other data: number of partial charging/discharging cycles of ESSp etc.
        - Calculated: SoC2, P_∑load, storage capacity.
    - Set points from the cloud applications: Pessp_setp, Pevch_setp.
    - Control actions from the cloud applications: Cd for charging/discharging ESSp and for WB action mode

The red lines correspond to the power bus (power wiring in the prosumer's premises, for energy transfer between different components at 230 V AC) and the green lines are IT information exchanged between the different parts (physical media for information transmission will be decided in the next stage).

LESSAg is the Local ESS Agent, which is considered to run in the SMX part of the main USM. The cloud components are EVChCon (Electric Vehicle Charging Controller) and GESSCon (Grid side ESS Control), which have support components the DSF and the Data warehouse.

To be noted that all details should be considered as an example and first view of the implementation, for the good of describing some first KPIs related to the communication between different components of the system. This situation applies to all further descriptions of on-site demonstrator implementations.

A clear description of information exchange and of software modules will be provided in D3.1.

2.2 Commercial case

The **commercial case** will be tested in the parking place of Edyna in the Bolzano area. The parking place is provided with several charging points (CP) for EVs. Alperia Smart Mobility will install SMART charging stations in each of the charging points, to enable fine-grained monitoring and control of the charging process. The test site will be completed by installing a substation level ESS compliant with S4G interfaces and models.

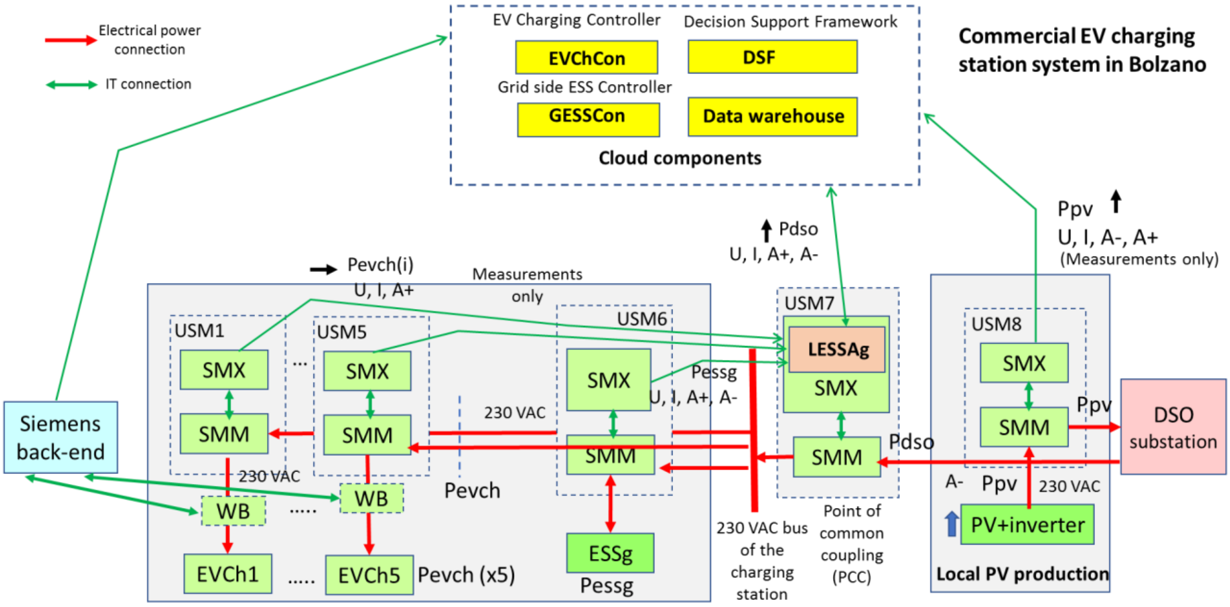

Figure 4 - Preliminary details of the commercial part of the test site Bolzano (example of implementation)

Legend for the annotations can be found in Table 2:

Table 2 - Legend – Commercial Test Site Bolzano

Name	Description
Pdso	Power received from the DSO, measured by USM7
Ppv	Power provided by the PV and measured by USM8
Pevch	Power provided by Electrical Vehicle Charging points (the sum of powers measured by USM1 to USM5)
U	Root Mean Square phase voltages delivered with a reporting rate Tu
I	Root Mean Square phase currents delivered with a reporting rate Ti
A+	Energy consumed by the different components: charging stations, grid ESS and PV inverter when energy production is not possible.
A-	Energy sent to the grid by the different components

In Figure 4 are again represented two layers corresponding to:

- Power / energy flow
  - From the DSO to the charging station Pdso; the power is measured with USM7 at the point of common coupling (PCC); the energy A+ and A- are also measured by USM7.
  - From the charging station bus to the charging points Pevch = Σ Pevch(i); the power is measured with individuals USMs (USM1…USM5); the energy A+ is also measured by each USM1 to USM5.
  - From the PV to the DSO Ppv; the power Ppv and energy in both directions A+ and A- are measured with individual USM7

  - Power Pessg and corresponding energy A+ and A- exchanged from the ESSg system and the grid, metered by USM6. For practical reasons related to implementation, the ESSg is physically placed on the charging station bus, but its functionality is equivalent with being physically placed on the DSO substation, which is electrically equivalent. For computational point of view, the ESSg can be considered on both sides of PCC, seen as grid-connected resource.
- Information flow:
  - Measurements
    - Delivered by USM: Pdso, Pessg, Ppv, Pevch, U, I, A+, A- for each USM
    - Other: number of partial charging/discharging cycles of ESSg, PV production prognosis based on meteorological information, … etc.
  - Set points: to be described in later deliverables, including D3.1.
  - Control actions: Cd, to be described in later deliverables, including D3.1

LESSAg is the Local ESS Agent, which is considered to run in the SMX part of the main USM. The cloud components are EVChCon (Electric Vehicle Charging Controller) and GESSCON (Grid side ESS Control), which have support components the DSF and the Data warehouse.

To be noted that all details presented in this deliverable should be considered as an example and first view of the implementation, for the good of describing some first KPIs related to the communication between different components of the system. This situation applies to all further descriptions of on-site demonstrator implementations.

A clear description of information exchange and of software modules will be provided in D3.1.

2.3 Demonstrator test cases

In order to allow utilities like Edyna to pursue their ambitious EV charging infrastructure deployment plans while avoiding heavy investments in strengthening the grid, Storage4Grid will study methodologies for planning, evaluating and controlling storage installations communicating and cooperating with EV charging systems

In the residential case (HLUC-2-PUC-1) the initial test will demonstrate the ability of the system to measure the flux of electrical energy produced by the PV plant exchanged with the local storage unit and with the local loads (EVs), by operating remote start/stop in the charging station. At the same time it will be necessary to monitor the [residual] available power (to be potentially delivered to the grid) in the connection node in order to estimate the benefit of the proposed scenario. In this case the trigger consists in acquisition of the EV and the need to charge it in addition to the existing loads of the house and the montage of local storage, use of EMS and communication with DSF.

The commercial case will be tested in the parking place of Edyna in the Bolzano area. The parking place is provided with several charging points (CP) for EVs. Alperia Smart Mobility will install SMART charging stations in each of the charging points, to enable fine-grained monitoring and control of the charging process. The test site will be completed by installing a substation level ESS compliant with S4G interfaces and models. The trigger for the commercial case consists in charging request from the EVs parked in the fleet garage (up to simultaneous charging requests from all the charging stations).

2.4 Specific boundary conditions for Bolzano test site components

In order to ease the performance assessment in the first phase test case Bolzano, specific boundary conditions for Bolzano test site components will be identified and addressed in the first phase of test site planning.

I. Completeness of measurements: the quantities delivered by the USM (Pdso, Pevch, Pessg, Ppv U, I, A+, A-), both aggregated and individual (phase) values, time granularity for all measurements, availability of Siemens back-end system measurements, availability of Fronius system measurements.
II. Requirements for data synchronization: measurements with time stamp of at least 1 to 10 seconds resolution; requirements for control signals
III. Communication: Requirements for communication medium (wireless/ cable/) and interfaces (Wi-Fi, Bluetooth, RS232, RS485, ...), security (VPN), provider (public, LAN),...

2.5 Specific methodology

Firstly Alperia will establish the studied scenario- HLUC–2–PUC–1, “Residential prosumer with storage”.

The applied specific methodology consists on the following steps:

- New contract with house owner (prosumer) about installing a local energy storage system
- Purchase and installation of the storage system
- Adjustment of the electrical circuit (Italian Technical Standard CEI 0-21)
- Management of the administrative practice for the grid connection (Edyna, GSE, Terna)
- Installation of specific meters in connection with USM extension
- Implementation of DSF connectors
- Access to local ESS managing system
- Installation of gateway for communication
- Introduction to local GUI for residents
- Monitoring of available residential components deployed in the test site, using USM and DSF connector implementations.

Simultaneously Alperia will start to develop the test site for the HLUC–2–PUC–2 ”Cooperative charging in the parking lot of a commercial test site”.

The applied specific methodology consists on the following steps:

- New contract between parking lot owner (Edyna) and Alperia Smart Mobility about installing new wall boxes for EV charging
- Management of the administrative practice for the grid connection (Edyna)
- Purchase and installation of the charging boxes
- Installation of specific meters in connection with USM extension in one or more boxes
- Implementation of DSF connectors
- Access to the managing system of the charging points
- Installation of gateway for communication
- Monitoring of available components deployed in the test site, using USM connector implementations.

The first set of tests for the Bolzano use case will focus on the communication between components. The KPIs will be therefore related to successful communication between the following components:

- Smart Meter (USM) and the Smart Meter eXtension (SMX), at rates of 1 to 10 seconds
- SMX and cloud applications: MQTT messages between SMX client and simulated remote MQTT client, with messages at rates of 10 seconds to one minute
- SMX driver for inverters, in communication with inverter, at rates of 1 second to 10 seconds, with maximum accepted one minute, if the inverter interface does not allow higher rates.

3 Test site Fur: Storage coordination

The “Storage Coordination” scenario will be addressed in conjunction with the deployment in the Fur test site, and led by partner ENIIG. The Island of Fur is placed in Northern Denmark in a fjord. A more detailed description can be found in D2.1. “Initial Storage Scenarios and Use cases” [1]**.**

This test site features **5 residential Fur houses** which are already provided with storage units paired with PV installations of various sizes (ranging from 3 to 6 kW sizes). The batteries already installed are Solar Batteries Li-ion 4.5 from Fronius.

The houses will be provided with an USM, integrated with the residential ESS and a dedicated local GUI. The project will investigate in phase 1 whether it is feasible to install batteries at premises of private households (space availability, owners’ concerns regarding safety in operation etc.) and how to prioritize and control this set-up (preliminary); the scenario and the use cases are in progress and will be fully documented in D2.2. as HLUC-3-PUC-4 and a new HLUC-3-PUC-5: Operation in private households, access to local GUI.

In phase 2 (see D6.2. Phase 2 test site plans) the project will investigate whether it is feasible to install batteries at substation-level; the corresponding use cases are HLUC-3-PUC-3 and an extended version of HLUC-3-PUC-4; it will be investigated whether it is feasible to install batteries both at sub-station level and in private households and how to prioritize and control such set-ups.

This test site features **two scenarios**: a local case and a grid case.

3.1 Local case

The best option from the end user point of view (and associated in a business case) is to store surplus local energy production as close as possible to the production site and to use it locally in order to avoid grid losses. A specific business case to be deployed in phase one is “Autonomous voltage control in residential houses” where voltage set-points are set and controlled by the DSO. The house-owner will get access to information via a local GUI (to be developed in Task 6.3 and D6.7. Initial Interfaces for Professional and Residential users (M9), followed by D6.8 Updated Interfaces for Professional and Residential users (M21) and D6.9 Final Interfaces for Professional and Residential users (M33)). Using the local GUI, the residential user can get relevant system information, and explore reasons for deviations from the optimal voltage (rms) level from the rated values ensured by local standards and regulations. In phase 2, this business case will be extended further, by introducing grid side battery and more actors, such as aggregators and investors.

In this business case the DSO will make contracts with the house owners about

- Installation of the USM (with two components: smart meter and associated SMX)
- Getting access to the local BMS, i.e. the existing Battery Management System
- Integrating the ESS system
- Installing the local GUI.

It is considered the process of getting permission to control the local voltage level, which may mean the export of PV-production when the battery is not fully loaded, caused by the demand of electricity in other parts of the local grid which decrease the voltage level.

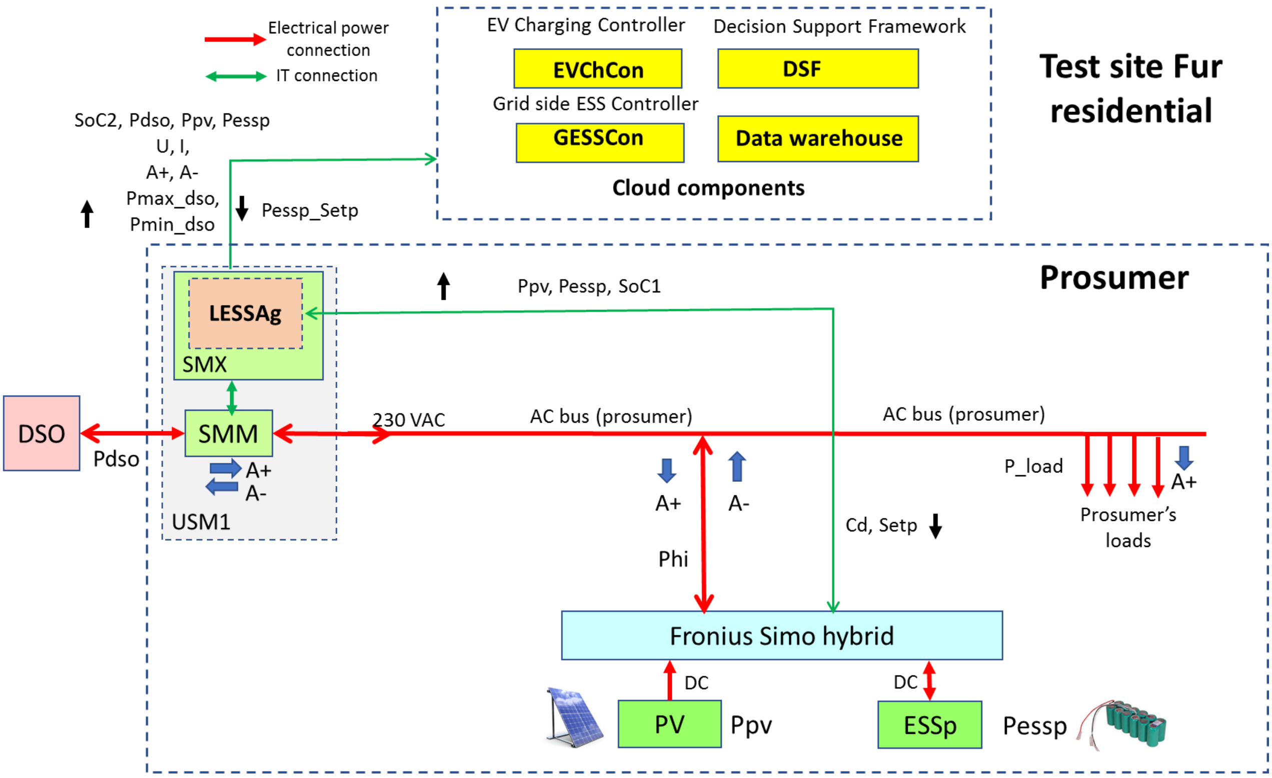

Figure 5 - Preliminary details of the residential (local) part of the test site Fur (example of implementation)

Legend for the annotations can be found in Table 3:

Table 3 Legend – Residential (local) Test Site Fur

Name	Description
SoC1	State of Charge of the Energy Storage System of prosumer (information given by the Fronius Simo hybrid to the Smart Meter eXtensions)
SoC2	The value of State of Charge 1 sent to Decision Support Framework (it is not mandatory that this value and SoC1 to be equal)
Pdso	Power received from or injected to the DSO
Pmax_dso	Maximum power required/provided from/by the DSO sent from the cloud components
Pmin_dso	Minimum power required/provided from/by the DSO sent from the cloud components
Ppv	Power provided by the PV
Pessp	Power provided or absorbed by Energy Storage system of prosumer
Pessp_setp	The value of power provided Energy Storage System of prosumer decided to be sent to Smart Meter eXtensions by the cloud components
Phi	Power exchanged by Fronius Simo hybrid
P_load	Total active power of the prosumer's AC loads
U	Root Mean Square phase voltages delivered with a reporting rate Tu

I	Root Mean Square phase currents delivered with a reporting rate Ti
A+	Energy consumed by the component
A-	Energy sent to the grid by component
Cd, Setp	Control Actions

Figure 5 has two layers corresponding to:

- Power (energy) flow:
  - From DSO to the AC bus the active power Pdso and energy A+ and A- are measured with an individual USM1.
  - From PV and ESSp to the AC bus, via Fronius Simo hybrid inverter (HI) system, the power and energy A+ and A- are exchanged and measured with information coming from Fronius Simo hybrid inverter and read by LESSAg of SMX. The power delivered by the PV system is considered to be available directly from Fronius HI as a metered variable.
  - Similar with PV energy, for the available storage related active power is exchanged and measured based on Fronius HI information.
  - On the prosumers premises there are also AC loads with active cumulated power P_load There is no individual meter associated with them. Information on the active power delivered to these loads will be calculated from power balance P_load = Pdso - Phi = Pdso – Ppv - Pessp.
  - USM is delivering the A+ as energy consumed by the prosumer and A- as energy sent to the grid by prosumer.
- Information flow:
  - Measurements
    - Delivered by USM: Pdso, Ppv, Pessg, P_load, U (rms phase voltages delivered with a reporting rate Tu), I (rms phase currents delivered with aa reporting rate Ti), A+, A-
    - Delivered by Fronius HI system: Soc1 (updated at intervals of 10 seconds to one minute)
    - Other: number of partial charging/discharging cycles of ESSp etc.
  - Set points: SoC2, Pessp_setp.
  - Control actions (generic at this stage, to be detailed in further project work): Cd

LESSAg is the Local ESS Agent, which is considered to run in the SMX part of the main USM. The cloud components are EVChCon (Electric Vehicle Charging Controller) and GESSCon (Grid side ESS Control), which have support components the DSF and the Data warehouse.

To be noted that all details presented in this section should be considered as an example and first view of the implementation, for the good of describing some first KPIs related to the communication between different components of the system.

A clear description of information exchange and of software modules will be provided in D3.1.

3.2 Grid case

The Fur grid storage diagram is presented Figure 6.

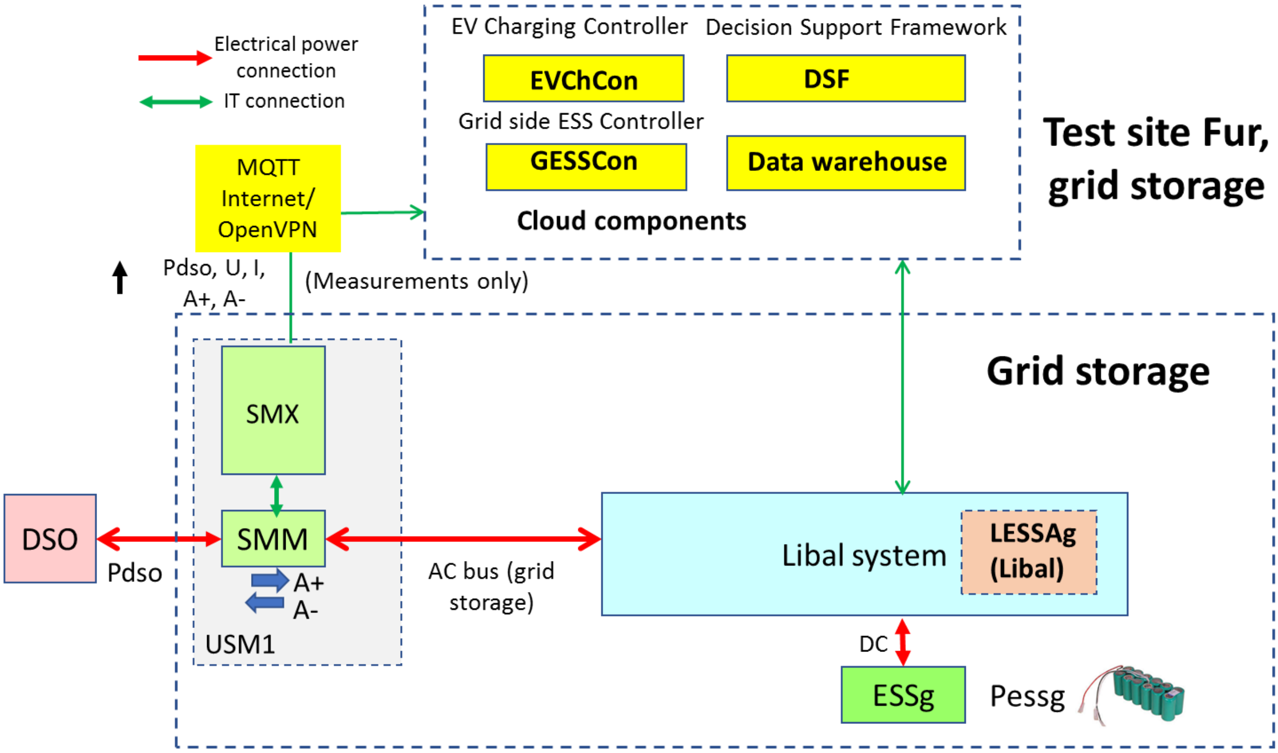

Figure 6 - Preliminary details of the grid storage of the test site Fur (example of implementation)

Legend for the annotations can be found in Table 4:

Table 4 Legend – Grid Test Site Fur

Name	Description
Pdso	Power received from or injected to the DSO
Pessg	Power provided by Energy Storage system of the grid
U	Root Mean Square phase voltages delivered with a reporting rate Tu
I	Root Mean Square phase currents delivered with a reporting rate Ti
A+	Energy consumed by the prosumer
A-	Energy sent to the grid by prosumer

In Figure 6 one has two layers corresponding to:

- Power (energy) flow
    - From the DSO to the proprietary Libal charging system the energy is measured with an individual USM1; the active power Pdso and energy A+ and A- are exchanged and measured with the same USM1.
    - There is no prosumer consumption, however small consumptions of ESSg and different measurements in USM and in ESSg system may give different values between Pdso and Pessg;

- Information flow:
    - Measurements
        - Delivered by USM: Pdso, A+, A-, U (rms phase voltages delivered with a reporting rate Tu), I (rms phase currents delivered with aa reporting rate Ti), A+, A-
        - Delivered by Libal system: to be described in later deliverables
        - Other: number of partial charging/discharging cycles of ESSp etc.
    - Other information will be detailed in later deliverables, such as D3.1.

LESSAg is the Local ESS Agent, which is considered to run in the SMX part of the USM.

The cloud components are EVChCon (Electric Vehicle Charging Controller) and GESSCON (Grid side ESS Control), which have support components the DSF and the Data warehouse.

To be noted that all details presented in this section should be considered as an example and first view of the implementation, for the good of describing some first KPIs related to the communication between different components of the system.

A clear description of information exchange and of software modules will be provided in D3.1.

3.3 Demonstrator test cases

This initial test case will demonstrate voltage (U, rms value) control at household level by controlling the charging/discharging mode of the local batteries. The target is to keep the voltage (rms) deviation from the rated value (ΔU) within +/- 10% of 230 V (single phase connection point PCC) due to legislation and regulation demands. Different control bands can also be considered in answer to the operation conditions of the DSO.

The impact of storage availability on the voltage deviation ΔU will vary from day to day and from installation to installation depending on production and consumption locally and in the local feeder lines. It is also a function of the grid conditions (substation voltage control) and therefore set points might vary according to the actual grid operation. In this phase, it is considered a fix set point for ΔU of +/- 10%.
In general (currently), during sunny days, the storage control will not help the voltage regulation since sun-peak will come after battery is fully charged, when the battery is self-managed. Therefore, PV production is often being injected into the grid on random times and not at optimal times (Figure 7).

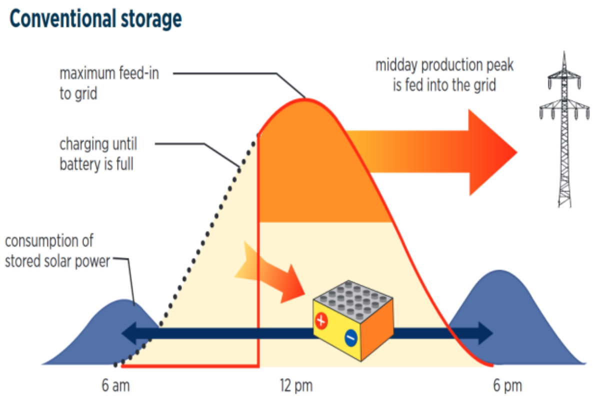

Figure 7. Self-managed battery system

When introducing voltage-level-control, the [positive] impact will increase on the local feeders (for example, the system will postpone the charging until the sun-peak), see Fig. 8. This means that the control algorithm also gets information from weather forecast. The impact is defined as the possibility of installing more energy generation units in local feeders.

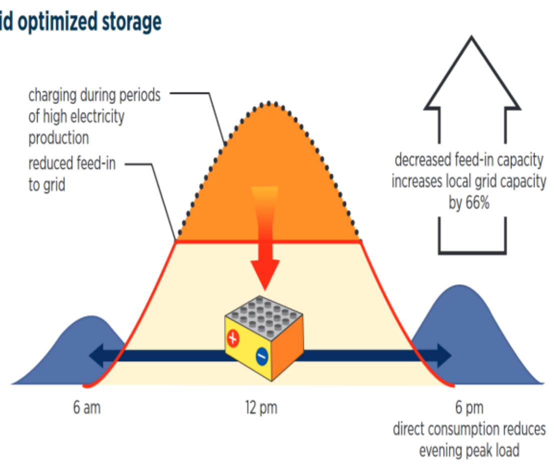

Figure 8. Grid optimized storage

Distributing electricity around and/or to a higher voltage level causes more grid losses due to higher energy flux. This requires that the battery never will be able to discharge into the grid but only to deliver electricity to local loads.

3.4 Specific boundary conditions for Fur test site components

In order to ease the performance assessment in the first phase of testing the use case Fur, specific boundary conditions for Fur test site components will be identified and addressed in the first phase of test site planning.

I. Completeness of measurements: the quantities delivered by the USM (Pdso, Pessp, Peesg, P_load, U, I, A+, A-), both aggregated and individual (phase) values, time granularity for all measurements of 10 seconds to one minute, availability of Fronius system and Libal system measurements.

II. Requirements for data synchronization: measurements with time stamp of 1s accuracy, requirements for control signals

III. Communication: Requirements for communication medium (wireless/ cable/) and interfaces (Wi-Fi, bluetooth, RS232, RS485, …), security (VPN), provider (public, LAN),…

In Fur, beyond the residential users, the aim is to address so-called professional users, (e.g. DSO planning engineers, but also ESCOs professionals interested in evaluating storage investments, etc.).

3.5 Specific methodology

The applied specific methodology consists on the following steps:

- New contracts with house-owners about controlling voltage level
- Installation of specific meter in connection with USM extension in one house
- Implementation of DSF connectors
- Installation of SMX as gateway for communication
- Introduction to local GUI for residents
- Introduction to professional GUI for DSO employees
- Set-points for voltage level set by the DSO
- Monitoring voltage level and controlling the battery
- Monitoring the combined PV and storage information given by the Fronius HI (Hybrid Inverter)

In the first phase, the system will be up and running in one house for preliminary test before installation in other houses.

The first set of tests for the Fur use case will focalize on the communication between components. The KPIs will be therefore related to successful communication between the following components:

- Smart Meter (USM) and the Smart Meter eXtension (SMX), at rates of 1 to 10 seconds
- SMX and cloud applications: MQTT messages between SMX client and simulated remote MQTT client, with messages at rates of 10 seconds to one minute
- SMX driver for inverters, in communication with the hybrid inverter, at rates of 1 second to 10 seconds, with maximum accepted one minute, if the inverter interface does not allow higher rates.

4 Test site UPB: Cooperative Storage System Scenario

The "Advanced Cooperative Storage Systems" scenario will be addressed in conjunction with the deployment in the Bucharest test site and be led by partner UPB. A detailed description can be found in D 2.1 Initial Storage Scenarios and Use cases [1]**.**.

This test site is executed in a laboratory setting and features a **home DC bus** which will support the DSO operation. The energy exchange in point of common coupling (PCC) is monitored 24/7. The equipment to be deployed are **SMX** [2]**, energy router, and communication equipment (for example, local Wi-Fi router)** which may even allow for future black-start support for isolated grids. To ensure that the local DC grid will be able to supply its critical (local) loads also during small AC voltage interruptions or during black-outs (the connection to the grid will be kept open during this period) it needs to be compatible with existing network codes. Additionally, it will also allow new services in the future, e.g. for black-start inside a micro-grid set-up.

The installed demonstrator components are as follows:

- RES-PV
- Batteries
- Converters
- SMX
- ER
- DC bus with local loads (directly connected to DC) for ensuring local resilience
- Neighbour DC bus to supply naturally dc loads remotely (200m)
- ESS Software

In the first phase, the UPB test site will focus on the scenario **HLUC - 1 - PUC – 2**, where the Advanced Self Resilient Prosumer (ASRP) is only seen as a load (consuming as much as possible from his RES energy production) and will not back-generate surplus energy. This will be accomplish based on the optimal management of all components or actors implicated: ER, PV panels, DSO, batteries, DC loads, and AC loads. The energy management will be implemented in such a way that the energy consumed (Pconsumed) by the DSO will always be either null or higher than zero (≥0).

The parameters are the following:

- PV power (Ppv) generated by PV and estimated as the 15 minutes average (from the energy delivered to the ASRP via the ER in 15 minutes);
- State of Charge of the batteries (SoC) estimated every 15 minutes and compliant with the allowed interval [SoCmin ... SoCmax] tested;
- Energy exchanged with the batteries (Eexch.bat) integrated over 15-minute cycle,
- Power delivered to the DC loads estimated as the 15 minutes average (from the energy delivered to the DC loads via the ER in 15 minutes (P_{DC}) and
- Power of the AC loads estimated as the 15 minutes average (from the energy delivered to the AC loads via the ER in 15 minutes (P_{AC})

Because the PV generation cannot be influenced, the controllable parameters remain: the energy exchanged with the batteries (Eexch.bat), power delivered to the DC loads (P_{DC}) and power delivered to the AC loads (P_{AC}).

The use case **HLUC - 1 - PUC – 2** will be emulated in a numerical program for a set of variables emulating 24 hours of operation (96 scenarios).

4.1 Specific business cases

The ideal business case will always be to store surplus production as close to the production site as possible to avoid grid losses. Moreover, as there are several AC loads (mostly residential type) which accept "direct DC" connection, the feasibility of 230V DC bus mediating the energy transfer at direct voltage from/to storage, from PV and to loads will be demonstrated.

Due to the low-TRL nature of many S4G outcomes and the small-scale of the test-site, a complete validation of business models is out of scope for S4G. Nevertheless, S4G will perform significant preparatory work in studying potential business cases and models where cooperative storage is involved. Moreover, evaluation activities will specifically consider economic feasibility aspects, so to provide important inputs (including e.g. the most potentially valuable cases) to future pilot projects willing to perform full-scale validation of the proposed methodology. **Scenario 1**, being used as a test bench to devise other innovative market and grid services, will address this issue.
The preliminary business cases associated with the test site in UPB (low TRL) are further summarized.

HLUC-1-PUC-1-S1 is for testing Storage as a Service between two prosumer entities connected to the same low-voltage network. If one prosumer has spare storage capacity, it can absorb surplus energy from another prosumer, which otherwise will be curtailed by the DSO due to grid constraints reasons.

HLUC-1-PUC-1-S2 is for testing also Storage as a Service between the grid operator and prosumer entities connected to the low-voltage network. If there is a high consumption which may require for consumption reduction due to network constraints, the prosumer can use its energy stored in his local ESS in order to inject energy in the LV network, thus being able to reduce the power requested on the MV/LV transformer. This is a service for enhancing network capacity and also can be seen as a transaction between two actors connected on the same LV grid. In fact, it can be a stacked business case, combining peer-to-peer energy transaction and also network capacity enhancement.

HLUC-1-PUC-1-S3 is for testing a grid service, seen as an ancillary service in case of microgrid operating in isolated mode. The prosumer which is able to deliver such black-start and grid-former service is expected to be paid for the system service. The tests will be simulated by a small grid with consumption only and the grid will be supplied based on frequency provision and necessary power needed to preserve a certain voltage level at the grid former node.

HLUC-1-PUC-2 is for testing resilient prosumers with hybrid solution in the prosumer area, having a DC bus for all sensitive loads (as prioritized by the user: for example Wi-Fi router, lights, computer, cooking device etc.). It is a resilience by design service.

HLUC-1-PUC-3 is for testing more advanced resilient prosumers, with hybrid solution in the prosumer area, having a DC bus for all sensitive loads and with DC exchange of energy with the neighbourhood. It is a cooperative resilience by design service.

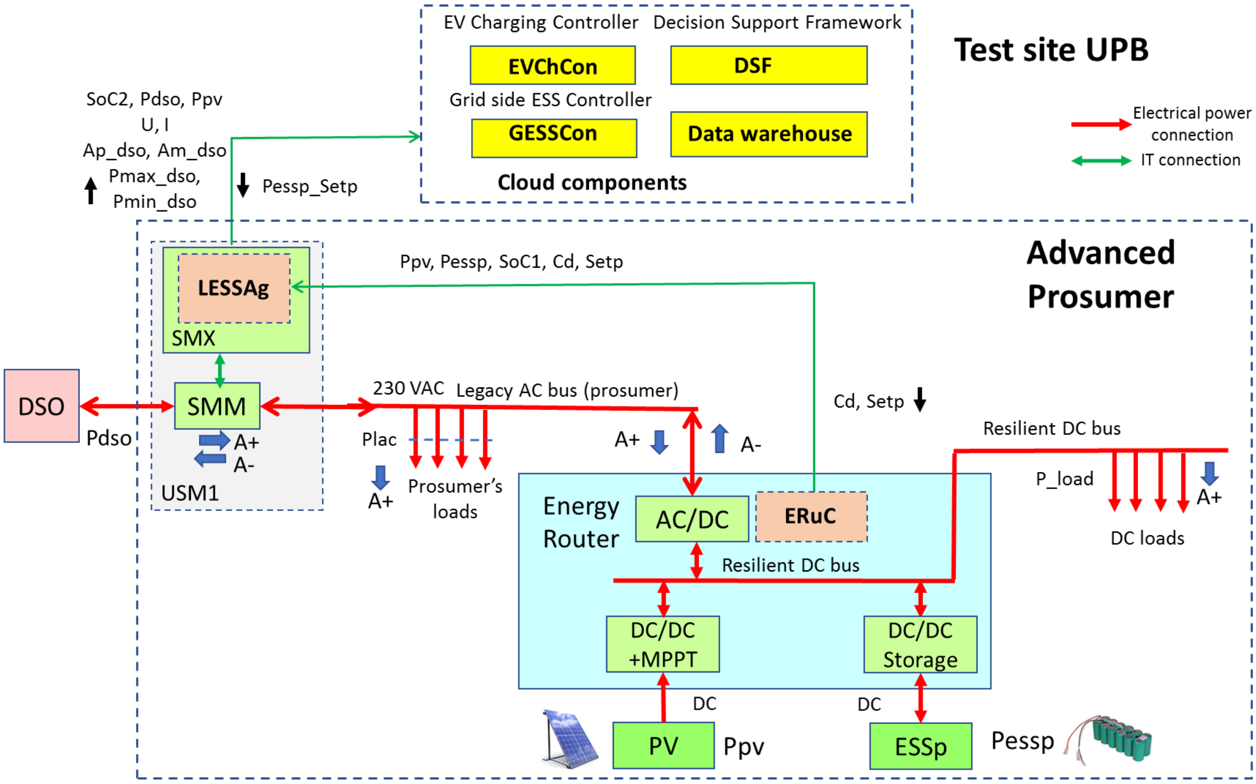

Figure 9 - Preliminary details of the advanced prosumer in UBP laboratory (example of implementation)

Legend for the annotations can be found in Table 5:

Table 5 Legend – Test Site Bucharest

Name	Description
SoC1	State of Charge of the Energy Storage System of prosumer (Energy Router)
SoC2	The value of State of Charge 1 sent to Decision Support Framework (it is not mandatory that this value and SoC1 to be equal)
Pdso	Power received from or injected to the DSO
Pmax_dso	Maximum power required/provided from/by the DSO sent from the cloud components
Pmin_dso	Minimum power required/provided from/by the DSO sent from the cloud components
Ppv	Power provided by the PV
Pessp	Power provided or absorbed by Energy Storage system of prosumer
Pessp_setp	The value of power provided Energy Storage System of prosumer decided to be sent to Smart Meter eXtensions by the cloud components
U	Root Mean Square phase voltages delivered with a reporting rate Tu
I	Root Mean Square phase currents delivered with a reporting rate Ti
A+	Energy consumed by the DSO/prosumer/ER

A-	Energy sent to the grid by DSO/prosumer/ER
Cd, Setp	Control Actions
ERuC	Energy Router's microController

Figure 9 presents two layers (networks) corresponding to:

- Power (energy) flow
  - From the DC bus to the PV; the power is measured via Energy Router;
  - Between the DC bus and the available storage ESSp, the power is exchanged and measured via Energy Router; the power exchanged between the DC bus and storage unit ESSp will have positive values in battery charging mode and negative values in battery discharging mode.
  - Power exchanged by the prosumer with DSO is Pdso and is metered by USM.. Active power exchanged between DSO and prosumer Pdso will have positive values when the prosumer is equivalent to a load and negative values if the power is injected in the grid.
  - On the prosumers premises, there are other (AC, DC, neighbour) loads with active total power P_load or P_∑load. There is no individual meter associated with them. Information on the power delivered to these loads will be calculated from power balance:

    P_∑load = Pdso – Pessp - Ppv.
- Information flow:
  - Measurements
    - Delivered by USM: Pdso, Ppv, Pessg, Soc1, U (rms phase voltages delivered with a reporting rate TU), I (rms phase currents delivered with a reporting rate TI), A+, A-
    - Other: number of partial charging/discharging cycles of ESSp etc.
    - Calculated: SoC, $P_{\sum load}$ (DC, AC, neighbour loads), storage capacity.
  - Set points: SoC2, Pessp_setp, Op.mode.
  - Control actions: Cd

LESSAg is the Local ESS Agent, which is considered to run in the SMX part of the USM.

The cloud components are EVChCon (Electric Vehicle Charging Controller) and GESSCON (Grid side ESS Control), which have support components the DSF and the Data warehouse. The commands from these components will be simulated during all use-cases, as they are laboratory based and not real-grid situations.

To be noted that all details presented in this section should be considered as an example and first view of the implementation, for the good of describing some first KPIs related to the communication between different components of the system.

A more clear description of information exchange and of software modules will be provided in D3.1.

4.2 Demonstrator test cases

Resilient and efficient local ecosystem - HLUC-1

The solution proposed in this high-level use case is considering an architecture which increases the efficiency of energy produced, stored and used locally while enabling self-resilience and empowerment of citizen and its local community. Such empowered ecosystems can serve as well the grid with distribution-related services (ancillary services for distribution) and can better use the available energy from the European energy market.

This target is served by using the functionality provided by the Advanced Prosumer (AP) and by the ASRP. The architecture of today prosumers with hybrid inverters compared with the Advanced Prosumers with an energy router is presented in Figure 10.

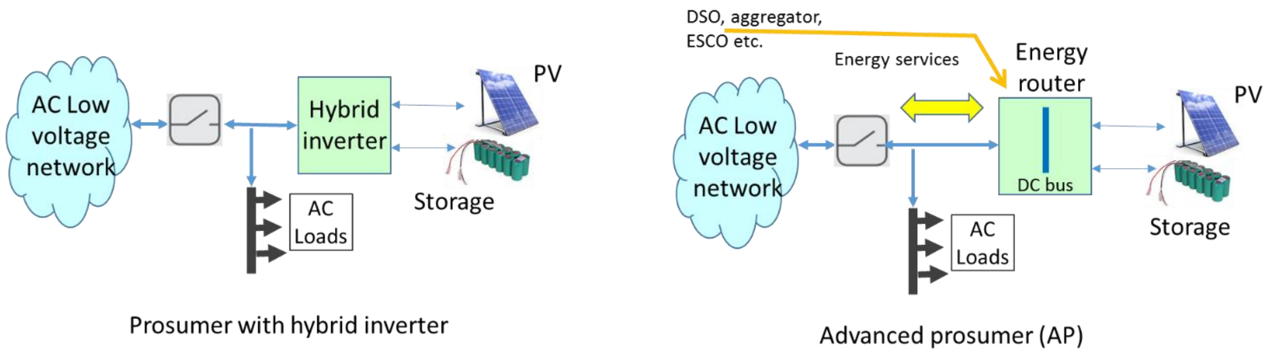

Figure 10 - Prosumer with hybrid inverter, and advanced prosumer (AP) having an energy router

The main difference is in fact that due to the more flexible solution, the advanced prosumer is also able to provide energy services requested by DSO, ESCO or aggregator. The advanced prosumer is then able to ensure grid strengthening and to provide different ancillary services on request. This will be subject of primary use case (PUC-1).

The resilience of the prosumer with hybrid inverter as well as of the advanced prosumer is ensured only after the breaker disconnects the prosumer from the AC network.

A more resilient prosumer is the one which uses the energy router's internal bus to supply resilient DC loads at the prosumer local premises. These loads make the prosumer even more resilient, and for the resilient local loads it is not needed that the network is disconnected.

Figure 11 gives an advanced variant comparing with ASRP, when the energy router has only consumption behaviour on DSO side and which is able to balance prosumer internal energy through an additional DC bus to connect to neighbours.

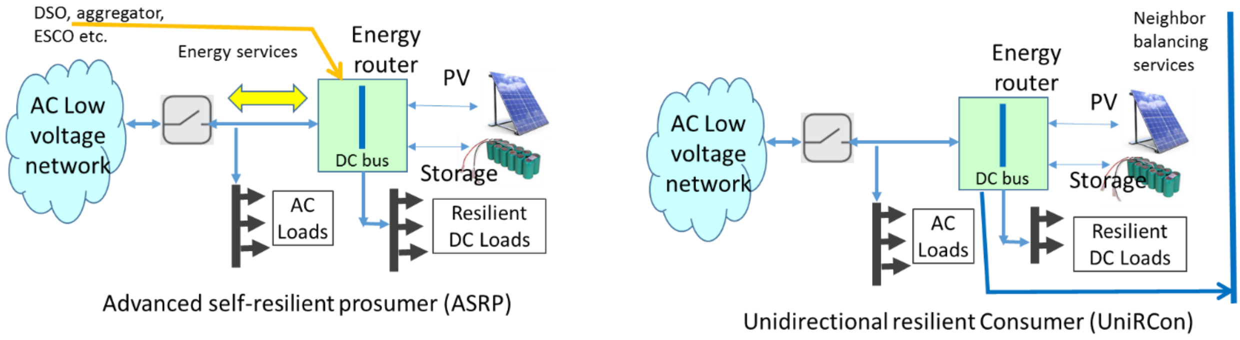

Figure 11 - Advanced self-resilient prosumer (ASRP); b) Unidirectional resilient consumer (UniRCon)

Advanced self-resilient prosumer – HLUC-1-PUC-2

The advanced self-resilient prosumer (ASRP) has an Energy Router with a resilient DC bus available for connecting resilient DC loads. This modular Energy Router is the core interface designed for optimal usage of advanced prosumer energy resources (PV, storage). ASRP is an extension of AP which has in addition the local DC bus which can be used by the consumer.

The ASRP (having an S4G Energy Router-based local energy architecture) wants to consume as much as possible his RES energy production. He also wants his activities to remain resilient to main grid outages. Therefore, he is using the local intelligence of the EMS to control energy production, storage and consumption such that he always has some spare energy in the batteries in case that there is a short interruption on the AC network or in case it is a complete blackout.

To do that, the EMS software is continuously trying to maximize the use of locally produced energy and keeps a dynamic level of minimal stored energy, which is based on the estimated consumption in the next hours, such that the consumption is resilient for the consumption connected to the DC bus of the ER.

In the case that the connection of the ER to the DSO grid is designed or programmed to be uni-directional, the advanced self-resilient prosumer becomes an UniRCon, meaning that he is adapting the internal strategies in order to appear as consumer-only when seen from the DSO side. This is transforming the prosumer in a pure consumer on DSO side, which simplifies the responsibilities and requirements of connection and allows a complete control of internal resources.

4.3 Specific boundary conditions for Bucharest test site components

In order to ease the performance assessment in the first phase test case Bucharest, specific boundary conditions for Bucharest test site components will be identified and addressed in the first phase of test site planning.

I. Completeness of measurements: the quantities delivered by the USM (Pdso, Ppv, Pessg, U, I, A+, A-), both aggregated and individual (phase) values, time granularity for all measurements being one to 10 seconds.

II. Requirements for data synchronization: measurements with time stamp of minimum 1 minute resolution; requirements for control signals

III. Communication: Requirements for communication medium (wireless/ cable/) and interfaces (wifi, Bluetooth, RS232, RS485, …), security (VPN), provider (public, LAN).

4.4 Specific methodology

The applied specific methodology consists on the following steps:

- First UPB will establish the studied scenario- HLUC - 1 - PUC – 2;
- Then a simulation will be made for one data set (generation data collected for 15 minutes from the PV), will be executed;
- Emulation of the transferred data between equipment – UPB will ensure that the information exchange channels are functional;
- All the components (PV, Converters, Batteries, DC and AC loads) will be connected;
- The final results will then be compared to the results obtained from the simulation;
- In the end, UPB will repeat all steps for other selected data sets typical for one day (set of variables emulating 24 hours of operation containing 96 intervals of 15 minutes).

The first set of tests for the Bucharest use case will focus on the communication between components. The KPIs will be therefore related to successful communication between the following components:

- Smart Meter (USM) and the Smart Meter eXtension (SMX), at rates of 1 to 10 seconds
- SMX and cloud applications: MQTT messages between SMX client and simulated remote MQTT client, with messages at rates of 10 seconds to one minute
- SMX driver for the energy router (ER), in communication with the energy router, at rates of 1 second to 10 seconds. This rate of communication will be possible based on the fact that ER is developed in the project and can fulfil high level requests as requirements for the ER design.

The S4G methodology and parts of the tools will be published as licensed, free and/or open software and will therefore be published for broad communities (both industrial, RTD and academia), using common licensing schemes. This enables the usage of the results for realizing commercial products.

5 Conclusions

The very first test site plans are developed according to the S4G vision and scenarios considered for the three main high level use cases. The components and associated requirements are set in correlation with findings reported in D2.1 [1] and in D3.1 (in progress). The test sites planning considers simultaneously the energy flow, the real time and context-based information (need of specific measurement quality and reporting rate) and the communication infrastructure (and requirements), thus bringing an overall picture of the entire system.

This deliverable will be updated according to the findings during the project developments and will have two subsequent versions: D6.2 “Phase 2 Test Site Plans” (due at M20, July 2018) and D6.3 “Phase 3 Test Site Plans” (due at M32, July 2019).

Acronyms

Acronym	Explanation
AP	Advanced Prosumer
ASRP	Advanced self-resilient prosumer
BMS	Battery Management System
BTM	Behind The Meter
CP	Charging Points
DER	Distributed Energy Resource
DSF	Decision Support Framework
DSO	Distribution System Operator
Eexch.bat	Energy exchanged by the batteries
EMS	Energy Management System
ER	Energy Router
ESCO	Energy Service Companies
ESS	Energy Storage System
EV	Electric Vehicle
GUI	Graphical User Interface
HLUC	High Level Use Case
IT	Information Technology
KPI	Key Performance Indicator
LV	Low Voltage
PAC	Power of the AC loads
PCC	Point of Common Coupling
PDC	Power of the DC loads
POD	Point Of Delivery
PPV	PV power
PUC	Primary Use Case
PV	Photovoltaic
RES	Renewable Energy Sources
RMS	Root Mean Square
S	Scenario

SMX	Smart Meter eXtensions
SoC	State of Charge
SoCmin	Minimum State of Charge
SoCmax	Maximum State of Charge
SUC	Secondary Use Case
UniRCon	Unidirectional resilient consumer
USM	Unbundled Smart Meter

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References

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