D6.6 - Phase 3 Test Site Platforms and Deployments Report

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Executive Summary

This deliverable evaluates the phase 3 (M25-M34) deployment status in all three S4G test sites (Bolzano, Bucharest, and Fur/Skive) based on the plans detailed in D6.3 – "Phase 3 Test Site Plans" [S4G-D6.3]. It is an update version of D6.5 – "Phase 2 Test Site Platforms and Deployments Report" [S4G-D6.5].

Several prototypes were developed for the phase 3 test site platforms, namely:

- D4.3 – "Final User-side ESS control system" [S4G-D4.3];
- D4.5 – "Final Grid-side ESS control system" [S4G-D4.5];
- D4.7 – "Final Cooperative EV charging station control algorithms" [S4G-D4.7];
- D4.10 – "Final USM extensions for Storage Systems" [S4G-D4.10];
- D4.12 – "Final Energy Router" [S4G-D4.12];
- D5.2 – "Final DSF Hybrid Simulation Engine" [S4G-D5.2];
- D5.5 – "Final DSF Connectors for external systems and services" [S4G-D5.5];
- D5.7 – "Final DSF Predictive Models" [S4G-D5.7];
- D6.9 – "Final Interfaces for Professional and Residential users" [S4G-D6.9].

With the completion of these prototypes, Milestone 14 (M33) – "Components ready for integration in Phase 3 Test Site Platforms" has been accomplished and their deployment could proceed in all three test sites, to further evaluate the following three scenarios:

- Storage Coordination (Fur/Skive)
- Cooperative EV Charging (Bolzano)
- Advanced Cooperative Storage Systems (Bucharest)

During phase 3 were accomplished the following:

- An Unbundled Smart Meter (USM) was installed at the grid site storage in Skive test site;
- the single-phase Energy Router (ER) was mounted and pre-tested,
- the cabinet for a second laboratory set-up was finalized and the connection between the two laboratories was energized and preliminary tests were done on the 400 V DC energy transmission line in Bucharest test site;
- an Energy Storage System was installed and more Electrical Vehicles chargers were installed in the Bolzano test site.

Final components have been deployed, such as final Cooperative Electric Vehicle (EV) charging station control algorithms, final Grid Energy Storage System Controller (GESSCon) algorithm, final Decision Support Framework (DSF) predictive models, final USM extensions for Storage Systems and final DSF Hybrid Simulation Engine, with complete description in section 2.

Details of deployed components and of lessons learned in phase 3 are presented for each scenario in sections 3, 4 and 5. Conclusions related to phase 3 deployments are presented in chapter 6.

1 Introduction

This document reports the final deployment of the Test Site Platforms documenting the integration of developed tools and components in the three S4G's test sites.
The document is the third and last yearly iteration report of the outcomes of Task 6.2 – Test Sites Integration and Task 6.4 – Test Sites Deployment and Execution. The present deliverable grounds on the deliverable D6.3 – "Phase 3 Test Site Plans" [S4G-D6.3].

Deployment activities were performed in order to ensure the final technical integration of components on the platforms thus allowing the final evaluation of operating S4G test sites and S4G outcomes. Starting from scenarios, use-cases, plans, requirements and KPIs, concrete deployments have been done in demonstrators.

WP6 integrates project outcomes in the test sites in Bucharest, Bolzano, and Fur/Skive, as follows:

- **Advanced Cooperative Storage Systems** (Bucharest): a dedicated lab-scale technical scenario, emulating a residential electricity system, to test the project developments in a controlled environment.
- **Cooperative EV Charging** (Bolzano): a test site who features two scenarios:
  - *Residential case* - a house owned by a private customer with Storage, Photovoltaic (PV) installation and EV.
  - *Commercial case* - a EVs' parking lot with several EV charging stations.
- **Storage Coordination** (Fur/Skive): a test site who features two scenarios:
  - *Residential case* – 5 residential Fur houses provided with storage units and PVs installations;
  - *Grid case* – a combined sport and cultural arena with a large PV plant on the roof and one grid-side battery near the transformer station

1.1 Scope

This deliverable presents the final (phase 3) results of Task 6.2 – "Test Sites Integration" [based on the plans documented in S4G-D6.3] and Task 6.4 – "Test Sites Deployment and execution". It is describing the deployment of the S4G platforms needed to demonstrate the use cases selected in the three test sites

1.2 Related documents

ID	Title	Reference	Version	Date
D3.3	Final S4G Component Interfaces and Architecture Specification	[S4G-D3.3]	1.0	2019-10-04
D4.3	Final User-side ESS control system	[S4G-D4.3]	1.0	2019-06-13
D4.5	Final Grid-side ESS control system	[S4G-D4.5]	1.0	2019-09-13
D4.10	Final USM Extensions for Storage Systems	[S4G-D4.10]	1.0	2019-09-30
D4.12	Final Energy Router	[S4G-D4.12]	1.0	2019-08-29
D5.2	Final DSF Hybrid Simulation Engine	[S4G-D5.2]	1.0	2018-09-23
D5.5	Final DSF Connectors for external systems and services	[S4G-D5.5]	1.0	2019-09-10
D5.7	Final DSF Predictive Models	[S4G-D5.7]	1.0	2019-09-16
D6.3	Phase 3 Test Site Plans	[S4G-D6.3]	1.0	2019-10-25
D6.5	Phase 2 Test Site Platforms and Deployments Report	[S4G-D6.5]	1.0	2019-01-02

2 Phase 3 S4G components

This section presents the S4G components developed during phase 3. Table 1 summarizes where the S4G components were deployed, integrated, tested, and evaluated according to the D6.3 test sites plans [S4G-D6.3]. The Layer column represents the architectural layer the component belongs to, i.e. communication, service, edge, device or physical layer. For a better reading of the table: "✓" deployed with success, "×" deployment not finished/ongoing, and "-" means that a specific prototype was not planned to be deployed in that test site during phase 3.

Table 1. Phase 3 S4G components.

Phase 3 S4G components	Layer	Phase 3 S4G prototypes	Bucharest (RO), HLUC-1	Bolzano (IT), HLUC-2	Fur/Skive (DK), HLUC-3
Control broker	Communication	D5.5 [S4G-D5.5]	✓	✓	✓
Data broker	Communication	D5.5 [S4G-D5.5]	✓	✓	✓
OGC Sensor Things	Communication	D5.5 [S4G-D5.5]	✓	✓	✓
DSF DSO SCADA System connector	Service	D5.5 [S4G-D5.5]	-	✓ (commercial)	-
DSO EV connector	Service	D5.5 [S4G-D5.5]	-	✓	-
DSF-SE Hybrid Simulation Plug-in	Service	D5.5 [S4G-D5.5]	✓	-	-
Professional GUI	Service	D6.9 [S4G-D6.9]	-	✓	✓ (grid)
DSF-SE	Service	D5.2 [S4G-D5.2]	-	✓	✓ (grid)
DSF Predictive Models (Load)	Service	D5.5 [S4G-D5.5]	-	✓	-
DSF Predictive Models (ESS)	Service	D5.5 [S4G-D5.5]	✓	✓	✓
DSF Predictive Models (PV)	Service	D5.5 [S4G-D5.5]	✓	✓	✓
DSF Economic Engine (DSF-EE)	Service	D5.2 [S4G-D5.2]	-	✓	✓
DSF Electric Vehicle Analytics (DSF-EVA)	Service	D5.5 [S4G-D5.5]	-	✓ (commercial)	-
ESS Life-time estimation	Service	D5.5 [S4G-D5.5]	-	✓ (commercial)	✓ (grid)
GESSCon	Service	D4.5 [S4G-D4.5]	-	✓	✓ (grid)

Phase 3 S4G components	Layer	Phase 3 S4G prototypes	Bucharest (RO), HLUC-1	Bolzano (IT), HLUC-2	Fur/Skive (DK), HLUC-3
DSF-DWH	Service	D5.5 [S4G-D5.5]	✓	✓	✓
DSO Grid Models connector	Service	D5.5 [S4G-D5.5]	-	✓	✓
Energy price connector	Service	D5.5 [S4G-D5.5]	✓	✓	✓
Weather forecast connector	Service	D5.5 [S4G-D5.5]	✓	✓	✓
Geolocation connector	Service	D5.5 [S4G-D5.5]	✓	✓	✓
Solar radiation connector for PROFESS or PROFEV	Edge	D5.5 [S4G-D5.5]	-	✓	✓ (residential
Residential GUI	Edge	D6.9 [S4G-D6.9]	-	✓ (residential)	-
Residential GUI (back-end)	Edge	D6.9 [S4G-D6.9]	-	✓ (residential)	-
Aggregator broker	Edge	D5.5 [S4G-D5.5]	✓	✓	✓
OGC wrapper	Edge	D5.5 [S4G-D5.5]	✓	✓	✓ (residential)
PROFESS	Edge	D4.3 [S4G-D4.3]	-	-	✓ (residential)
PROFEV	Edge	D4.7 [S4G-D4.7]	-	✓	-
SenML connector (PROFESS/PROFEV)	Edge	D4.3 [S4G-D4.3] D4.7 [S4G-D4.7]	-	✓	✓ (residential)
Aggregator DWH	Edge	D5.5 [S4G-D5.5]	-	✓	✓
Technical GUI	Device	D4.10 [S4G-D4.10]	✓	✓	✓
Data Dispatcher	Device	D5.5 [S4G-D5.5]	✓	✓	✓
LESSAg	Device	D4.3 [S4G-D4.3]	✓	-	-
SMX broker	Device	D4.10 [S4G-D4.10]	✓	✓	✓

Phase 3 S4G components	Layer	Phase 3 S4G prototypes	Bucharest (RO), HLUC-1	Bolzano (IT), HLUC-2	Fur/Skive (DK), HLUC-3
SMX core	Device	D4.10 [S4G-D4.10]	✓	✓	✓
ER SMX SB connector	Device	D4.10 [S4G-D4.10]	✓	-	✓ (residential)
Hybrid Inverter SMX SB connector	Device	D4.10 [S4G-D4.10]	-	✓ (residential)	✓ (residential)
EV SMX SB connector	Device	D4.10 [S4G-D4.10]	-	✓	-
SMM	Physical	-	✓	✓	✓
Single-phase ER	Physical	D4.12 [S4G-D4.12]	✓	-	-
EV charging point	Physical	-	-	✓	-
Hybrid Inverter (Fronius)	Physical	-	-	✓ (residential)	✓ (residential)
LiBal System	Physical	D4.5 [S4G-D4.5]	-	-	✓ (grid)

Several prototypes were developed during the phase 3 test site platforms, namely:

- D4.3 – "Final User-side ESS control system" [S4G-D4.3];
- D4.5 – "Final Grid-side ESS control system" [S4G-D4.5];
- D4.7 – "Final Cooperative EV charging station control algorithms" [S4G-D4.7];
- D4.10 – "Final USM extensions for Storage Systems" [S4G-D4.10];
- D4.12 – "Final Energy Router" [S4G-D4.12];
- D5.2 – "Final DSF Hybrid Simulation Engine" [S4G-D5.2];
- D5.5 – "Final DSF Connectors for external systems and services" [S4G-D5.5];
- D5.7 – "Final DSF Predictive Models" [S4G-D5.7];
- D6.9 – "Final Interfaces for Professional and Residential users" [S4G-D6.9].

With the completion of these prototypes, Milestone 14 (MS14) – "Components ready for integration in phase 3 Test Site Platforms" is accomplished in all three test sites (Bucharest, Bolzano, and Fur/Skive). The following sub-sections described where each prototype was deployed or it is available.

2.1 Final User-side ESS control system

D4.3 [S4G-D4.3] describes the Professional Realtime Optimization Framework for Energy Storage Systems (PROFESS) and Local Energy Storage System Agent (LESSAg). PROFESS was successful deployed and integrated in the **Fur/Skive** test site, while LESSAg was successful deployed and integrated in the **Bucharest** test site.

2.2 Final Grid-side ESS control system

D4.5 [S4G-D4.5] describes the Grid Energy Storage System Controller (GESSCon) and its connectors to other components within the S4G system. During phase 3, GESSCon has been deployed in **Bolzano and Skive grid site**. It will be also integrated with Decision Support Framework Simulation Engine (DSF-SE) for the Skive/Fur site simulation study.

2.3 Final Cooperative EV charging station control algorithms

D4.7 [S4G-D4.7] describes the optimization model developed for the control of the EV charging stations at EDYNA premises, to be used by PROFEV which was deployed in phase 3 in the **Bolzano** test sites.

2.4 Final USM extensions for Storage Systems

D4.10 [S4G-D4.10] is composed by several software components, namely:

- *ER SMX SB connector:* deployed in the **Bucharest** test site;
- *Hybrid Inverter SMX SB connector:* deployed in the **Bolzano** and **Fur/Skive** test sites.
- *Extension connector for receiving grid-side storage services requests:* deployed in **Bucharest** test site
- *Local Technical GUI SMX South-bound connector:* deployed in **Bucharest**, **Bolzano** and **Fur/Skive** test sites.
- *EV SMX SB connector:* deployed in the **Bolzano** test site.

2.5 Final Energy Router

D4.12 [S4G-D4.12] describes the single-phase ER, that was successfully deployed and integrated in the **Bucharest** test site.

2.6 Final DSF Hybrid Simulation Engine

D5.2 [S4G-D5.2] describes the architecture of the Decision Support Framework Economic Engine (DSF-EE), which is deployed into a docker container on a server at Fraunhofer FIT. An API-Gateway called Linksmart-Border Gateway together with an Identity Provider (Keycloak) were also deployed for achieving authorisation and authentication for the DSF-SE. It was integrated with the S4G components and prototypes for the **Bolzano and Fur/Skive** test sites.
Furthermore, it describes the DSF-EE, which is deployed into a docker container on a server at LINKS premises. A reverse proxy (nginx) and a load balancer (uwsgi) have been integrated with the DSF-EE for enabling security and robustness aspects.
Finally, the DSF-SE - Plug-in for Hybrid-Simulation was described and tested to demonstrate the hybrid simulator capabilities of the DSF-SE within the **Bucharest** test site. It is a Python code running on demand, executing an OpenDSS instance on Linux and interacting with deployed hardware devices through the ER.

2.7 Final DSF Connectors for external systems and services

D5.5 [S4G-D5.5] is composed by several components, namely:

- *DSF-DWH*: available in the cloud to the three test sites.
- *Data Dispatcher*: deployed in all three test sites within Smart Meter eXtensions.
- *OGC Wrapper*: deployed in all three test sites within Aggregators.
- *DSO SCADA System connector*: available to the **Bolzano** test site.
- *DSO Grid Models connector*: available in the cloud to the **Bolzano and Fur/Skive** test sites.
- *DSO EV connector*: available in the cloud to the **Bolzano** test site.
- *Geolocation connector*: available in the cloud to the three test sites.
- *Weather Forecast connector*: available in the cloud to the three test sites.
- *Energy Price connector*: available in the cloud to the **Bolzano and Fur/Skive** test sites.
- *PROFESS/PROFEV Solar Radiation connector*: deployed inside PROFESS and PROFEV in the **Bolzano and Fur/Skive** test sites.

- *ER Control Connector*: deployed in the **Bucharest** test site (presented in section 2.4).
- *LiBal System Control Connector*: deployed in the **Bolzano and Fur/Skive** test sites (presented in section 2.2).
- *LESSAg Control Connector*: deployed in the **Bucharest** test site (presented in section 2.1).
- *Hardware in the Loop (HIL) control Connector*: deployed in the **Bucharest** test site for Advanced Prosumers (AP) demonstrations
- *DSF-SE Hybrid Simulator connector*: available in the cloud to the **Bucharest** test site.
- *DSF Predictive Models connector*: available in the cloud to the three test sites.

2.8 Final DSF Predictive Models

D5.7 [S4G-D5.7] describes the developed predictive models to empower S4G DSF and GESSCon with reliable forecasts and estimations, that in turn would optimize the Energy Storage System (ESS) and Renewable Energy Sources (RES) exploitation.
GESSCon relies on Remaining Useful Life (RUL) and State-of-Health (SoH) estimation pattern to adapt the estimation result for each individual Energy Storage System (ESS) to provide better operational instruction improving efficiencies for ESS systems. These models were designed, developed and implemented within LiBal's Battery Management System (BMS) product. In the S4G project, since Bolzano commercial site and grid-side storage in Skive are using LiBal's energy storage, this feature is available [D2.2] to High Level Use Case 2 Primary Use Case 2 (HLUC2-PUC-2) - Cooperative charging in the parking lot of a commercial test site and High Level Use Case 3 Primary Use Case 3 (HLUC3-PUC-3) - Simulation of high penetration of EV chargers and of prosumers with storage and residential EV charging.
DSF relies on PV, load, ESS forecast to support storage analysis and planning. Distributed generation is correlated with the environmental aspects, load (electricity consumption) is bound directly to the human behaviour and storage status is related to a combination of both.

2.9 Final Interfaces for Professional and Residential users

D6.9 [S4G-D6.9] is composed by two components, namely:

- *Residential GUI:* deployed in the **Bolzano** test site within the Aggregator to monitor RES, ESS and EV systems at home.
- *Professional GUI for GRID Planner:* available in the cloud to **Fur/Skive** test site.

2.10 Prototypes deployment status

Table 2 summarizes the deployment status of the S4G prototypes developed during phase 3. For a better reading of the table: "✓" deployed with success, "×" deployment not finished/ongoing, and "-" means that specific prototype will not be deployed in that test site during phase 3.

Table 2. Deployment status of phase 3 prototypes.

Prototype	Bucharest (RO)	Bolzano (IT)	Fur/Skive (DK)
D4.3 – Final User-side ESS control system	✓	✓	✓
D4.5 – Final Grid-side ESS control system	-	✓	✓ (grid)
D4.7 – Final Cooperative EV charging station control algorithms	-	✓ (commercial)	-

D4.10 – Final USM extensions for Storage Systems	✓	✓	✓
D4.12 – Final Energy Router	✓	-	-
D5.2 – Final DSF Hybrid Simulation Engine	✓	✓	✓
D5.5 – Final DSF Connectors for external systems and services	✓	✓	✓
D5.7 – Final DSF predictive models	-	✓	✓
D6.9 – Final Interfaces for Professional and Residential Users	-	✓	✓

With the deployment of the above mentioned prototypes during phase 3, and their integration in the S4G infrastructure, the project has achieved the envisaged S4G approach for the use cases selected for demonstration, which further enables the execution and evaluation of the planned tests.

3 Cooperative EV Charging Scenario: Bolzano (IT) test site

This scenario is composed by the residential and the commercial case. It is intended to support large deployments of EV charging stations and we have designed *the methodologies for planning, evaluating and controlling storage installations communicating and cooperating with EV charging systems for both settings: commercial and residential*. The latter is a private house near Bolzano, which has PV panels, an EV charging station, and an ESS with its respective inverter. The commercial case is in the EDYNA's headquarters garage, where 22 EVs can be charged. There are also PV panels which are directly connected to the distribution grid. The phase 2 deployment diagram is available in D6.2 [S4G-D6.2] and the phase 3 diagram can be found in D6.3 [S4G-D6.3].

3.1 Summary of phase 1 deployments

During phase 1, several installations in the residential case were made, namely:

- 1 ESS and its inverter
- 1 single-phase EV charging station
- 4 Landis+Gyr meters
    - 1 for PV panels
    - 1 for the ESS
    - 1 in the EV charging station
    - 1 for the other loads of the house
- Dedicated internet connection
- Data dispatcher (described in [S4G-D5.3])
- Fronius cloud connector (described in [S4G-D5.3])

As for the commercial case, the main activities were:

- Connection to Distribution System Operators (DSO) grid using a DSO meter
- Installation of cables switchboxes and utility pole's protection
- Installation of 3 single-phase and 2 three-phase EV charging stations
- Evaluation of the ESS to be installed on the site
- Installation of 10 Landis+Gyr meters
    - 1 per EV smart charging station – 5 in total
    - 1 for 3 dummy charging stations (the only ones present in phase 1)
    - 1 in the interconnection point (EDYNA loads + 1 PV plant)
    - 1 for the ASM interconnection point (total of EV chargers + future ESS)
    - 1 per PV panels installation – 2 in total
- Installation of the garage's internet connection

3.2 Summary of phase 2 deployments

During phase 2, the S4G software prototypes deployed in Bolzano test site were D4.2 [S4G-D4.2], D4.4 [S4G-D4.2], D4.9 [S4G-D4.9], D5.4 [S4G-D5.4], D5.6 [S4G-D5.6], and D6.8 [S4G-D6.8].

No new hardware components were deployed in phase 2.

3.3 Phase 3 deployments

During phase 3, the S4G software prototypes deployed in Bolzano test site were D4.3 [S4G-D4.3], D4.5 [S4G-D4.5], D4.7 [S4G-D4.7], D4.10 [S4G-D4.10], D5.2 [S4G-D5.2], D5.5 [S4G-D5.5], D5.7 [S4G-D5.7] and D6.9 [S4G-D6.9] as shown in Table 1 in D6.3.

During phase 3 the commercial test site is completed with the installation of an ESS in the ASM grid. The ESS has an energy capacity of 79 kWh. It is provided by LiBal, and the connection with the alternative current (AC) grid is performed by a 33 kW inverter of Socomec. For the measurements of the energy parameters in the ESS another USM11 will be installed. Due to the expected increase of EVs in Edyna fleet, ASM is installing more EV chargers. They will not be monitored by a dedicated USM, but their measurements are available in USM12 installed at ASM PCC.

3.4 Phase 3 issues and lessons learned

The commercial site demonstrator in EDYNA garage requires deployment of high capacity ESS in a closed environment. This resulted into meeting the conditions of an accident involving both people and storage deterioration. The project team concluded that an updated risk assessment and financial planning has to be performed in similar cases, in order to overcome such criticalities related to safety and security in places with higher fire hazard (increased due to ESS placement in a garage).

During phase 3 the reliability issues of the Raspberry® PI was continued. To solve them, 13 SD-cards have been changed. For some reasons, not fully clarified but with a potential mix of causes (poor power quality in the field, higher electromagnetic compatibility issues in the test site, temperature boundaries exceeded, excessive use of the SD card during some periods etc.), the content written in these cards appeared as been corrupted and the only solution was to change the SD-card.

To be noted that this maintenance has a cost, and probably would be better to use a more reliable device as SMX than a simple Raspberry® PI, which has been used as a research tool. To be noted that RPI has been still chosen for its flexibility and extensive use in many research projects, also in case of low TRL situations. The above recommendation relates to decide on higher initial investment as to avoid future maintenance costs in full commercial deployments.

Finally, also in this phase 3, like before, some changes in the internet network and communications systems in the test sites are been made to have a more stable and more efficient communication. The problem is that the requests of these changes come ever one after the other, not all together, which is however usual in innovative projects, based on various loops of development. Even a commercial product used in the project, as being one of the routers used in the test site, faced sometime communication reconnection problems after power outages. These situations have led to high implementation costs, due to the numerous interventions of people inside and outside EDYNA and ALPERIA.

It would have been better to have a clear specification from the beginning on the characteristics of the communication system to be implemented, to make all the job in one only time. This is a general recommendation for solutions deployment, and it is related to the general risks of innovative projects.

4 Storage Coordination Scenario: Fur/Skive (DK) test site

This scenario features a residential test site (Fur), a grid-side ESS (Skive), and the deployment of the ER at ENIIG premises (Skive). It demonstrates how to maximize both self-consumption and RES exploitation at prosumer' level. The residential case is composed by 5 houses already fitted with PV panels, ESS and its respective inverter. The grid case is one grid-side ESS installed behind the meter in the sports arena. S4G has demonstrated how the tool we designed for both *control and planning is able to optimally use the storage as a buffer for fluctuations in either generation or loading conditions. This coordination shows its advantage in case of large number of already installed RES-based generation and it is of direct benefit of DSOs which have to handle less unpredictability.*

The phase 2 deployment diagram is available in D6.2 [S4G-D6.2] and the phase 3 diagram can be found in D6.3 [S4G-D6.3].

4.1 Summary of phase 1 deployments

During phase 1, the USM was installed in one house at Fur/Skive. The USM in Fur/Skive is composed by the SMX and one Landis+Gyr E550 meter. Moreover, the Fronius cloud connector [S4G-D5.3] and the data dispatcher connector [S4G-D5.3] were also deployed and is also providing information about the ESS.

4.2 Summary of phase 2 deployments

During phase 2, the S4G software prototypes deployed in Fur/Skive test site were D4.2 [S4G-D4.2], D4.4 [S4G-D4.4], D4.9 [S4G-D4.9], D5.4 [S4G-D5.4], D5.6 [S4G-D5.6], and D6.8 [S4G-D6.8], as shown in Table 2. The three-phase ER was installed in the residential test site, as described in D4.11 [S4G-D4.11]. 5 USMs were also installed during phase 2, one near the three-phase ER (Figure 1), and the other ones of the Fur residential houses that participates in the S4G project (Figure 2).

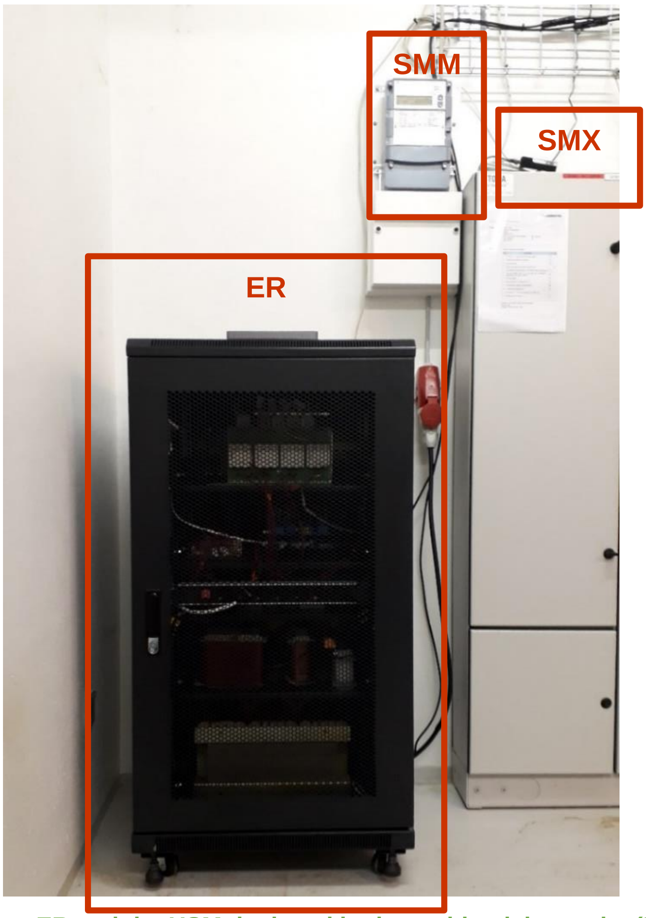

Figure 1. Three-phase ER and the USM deployed in the residential test site (Eniig, Skive, DK).

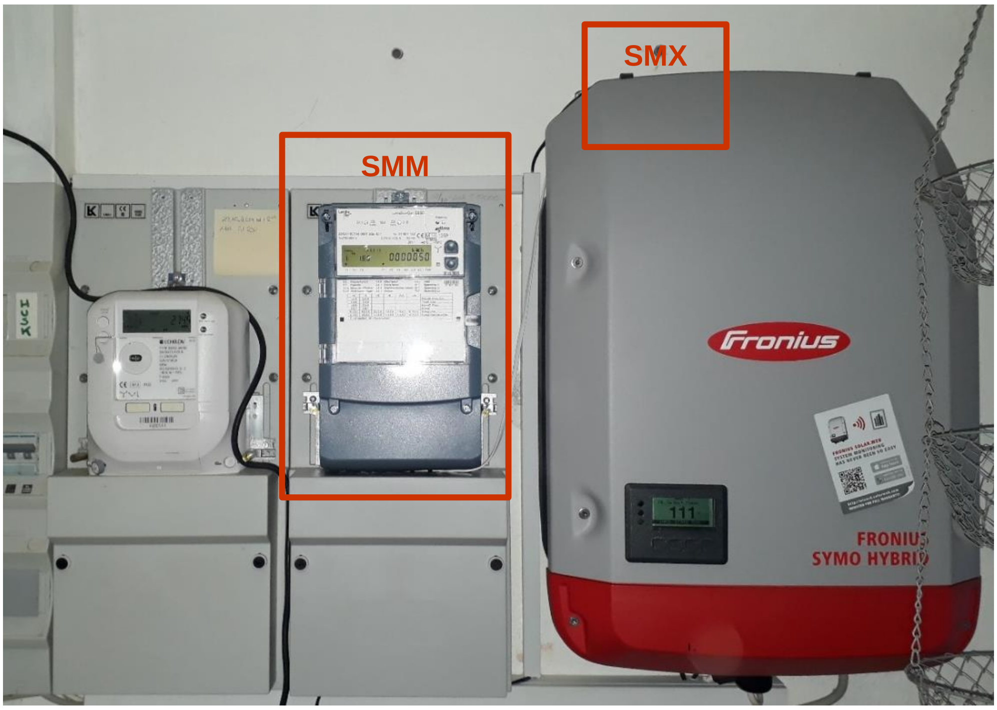

Figure 2. USM deployed in the residential test site (Fur, DK).

4.3 Phase 3 deployments

During phase 3, the S4G software prototypes deployed in Fur/Skive test site were D4.5 [S4G-D4.5], 1 USM was installed during phase 3 at the grid site storage in Skive, as it can be seen in Figure 3.

Figure 3. USM deployed in the Grid-side ESS test site (Skive, DK).

4.4 Phase 3 issues and lessons learned

Four *ZMD310CT44.07 S3a B31* Landis+Gyr meters were installed during phase 2 in the Fur/Skive residential test site. The connection with these meters required a different metering mapping and some updates in the SMX in phase 3.
Moreover, due to local equipment arrangement, it was not possible to install other USM in the Skive building Point of Common Coupling (PCC), because this would have required cutting the switchboard busbar. During phase 3 it will be studied the possibility to connect the SMX with the already available Smart Measurement Meter (SMM), or the installation of a different SMM.

During the three-phase ER deployment it was observed that the ER transformer had suffered a mechanical deformation during the transportation to the test site. However, this did not affect its deployment nor the on-site tests [S4G-D4.11]. Due to this deformation, there is a very small possibility that in the transformer creates a hot spot that may cause a fire in the room. Since the security of the persons in the building is the top priority, the ER was left disconnected from the grid. The ER correct operation can be verified at any time, with human supervision in the ER room. In order to achieve continuous operation, it is planned to replace the ER transformer with a new one in the very near future. For grid-side ESS installation, it is noticed that a good communication with site owner is very critical for the success of the installation process. A clearer instruction of prerequisite is also needed, such as internet connection and 230V power plug, etc.

5 Advanced Cooperative Storage System Scenario: Bucharest (RO) test site

This scenario is composed by a laboratory test site where some S4G prototypes are evaluated before the field deployment. This demonstrator integrates innovative S4G solutions in a pre-existing DC microgrid where an internal DC bus is used for direct energy transfer from/to storage units and to selected loads directly connected to DC supply. This scenario allows in real life 24/7 functionality of energy flow for both DSO and prosumer, and, in addition, provides survivability during lack of DSO supply for the selected loads. It is leveraging on the Energy Router capabilities and further improved control of DC buses in the MicroDERLab facilities in Bucharest (RO).

The tested scenario for "Advanced Cooperative ESS" is also addressing the home hybrid energy system including a direct current (DC) bus.

The phase 2 deployment diagram is available in D6.2 [S4G-D6.2] and the phase 3 diagram can be found in D6.3 [S4G-D6.3].

5.1 Summary of phase 1 deployments

During phase 1, several installations were made, namely:

- 2 SMXs
- 2 Landis+Gyr ZMG310 meters
- 8 PV panels (Kyocera KC130GHT-2)
- 4 valve-regulated lead-acid (VRLA) batteries (Ultracell KC130GHT-2)
- 1 Steca Tarom hybrid charge controller
- DC bus with local loads
- Neighbour laboratory
- Subcomponents to be used in modules for transmitting energy in DC
- ER connector (described in [S4G-D4.1])
- SMM connector (described in [S4G-D4.8])

5.2 Summary of phase 2 deployments

During phase 2, the S4G software prototypes deployed in Bucharest test site were D4.9 [S4G-D4.9], D5.4 [S4G-D5.4], and D5.6 [S4G-D5.6], as shown in Table 2. A control board (Figure 44) was realized in order to have a central point for optimizing the energy flow in the UPB test site. It connects to PVs, batteries, DSO, neighbour and to the ER (in phase 3).

Figure 4. UPB Physical Control Board.

5.3 Phase 3 deployments

During phase 3 it has been mounted and pre-tested the single-phase energy router. Details are given in D4.12. A picture of the ER cabinet connected to the control board is given in Figure 5.

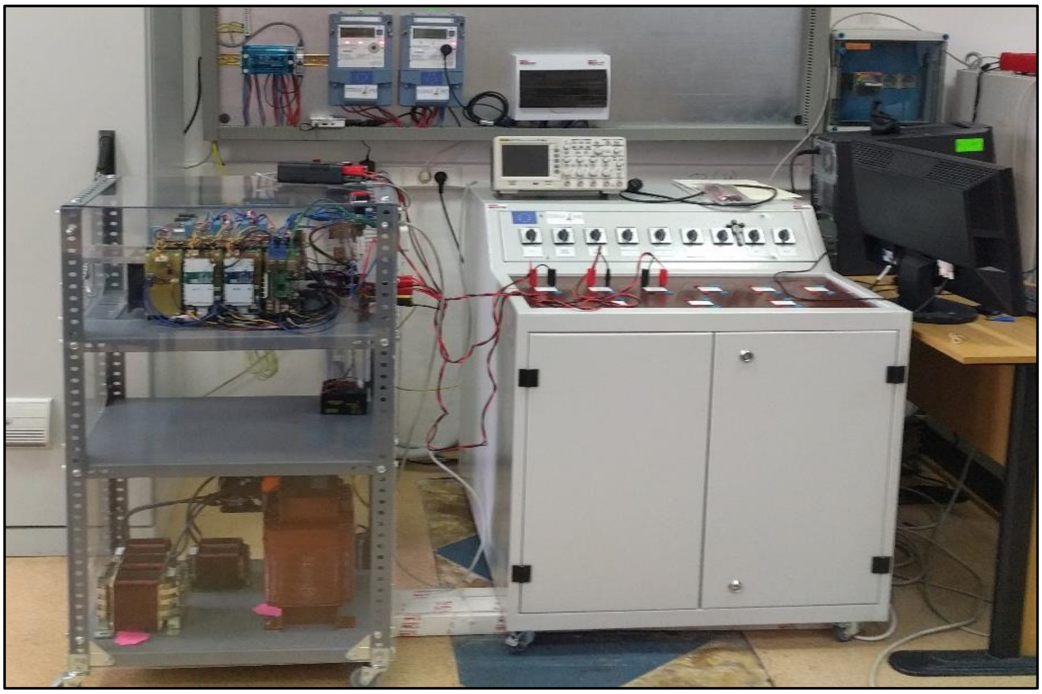

Figure 5. Single-phase ER deployed is EB105 at UPB's premises.

Moreover, during the phase 3 has been finalized the cabinet for the second laboratory (EG111), acting as neighbour which receives energy through a DC connection at 400 V DC and converts it in 220 V DC through a buck converter scheme. Figure 6 shows the EG111 cabinet acting as a neighbour of the energy community, which received energy from the Advanced Prosumer and Figure 7 shows the DC connection cable.

Figure 6. Neighbour cabinet deployed in second laboratory EG111 at UPB's premises.

The connection between the two laboratories has been energized during the 3rd phase and preliminary tests have been done on the 400 V DC energy transmission line.

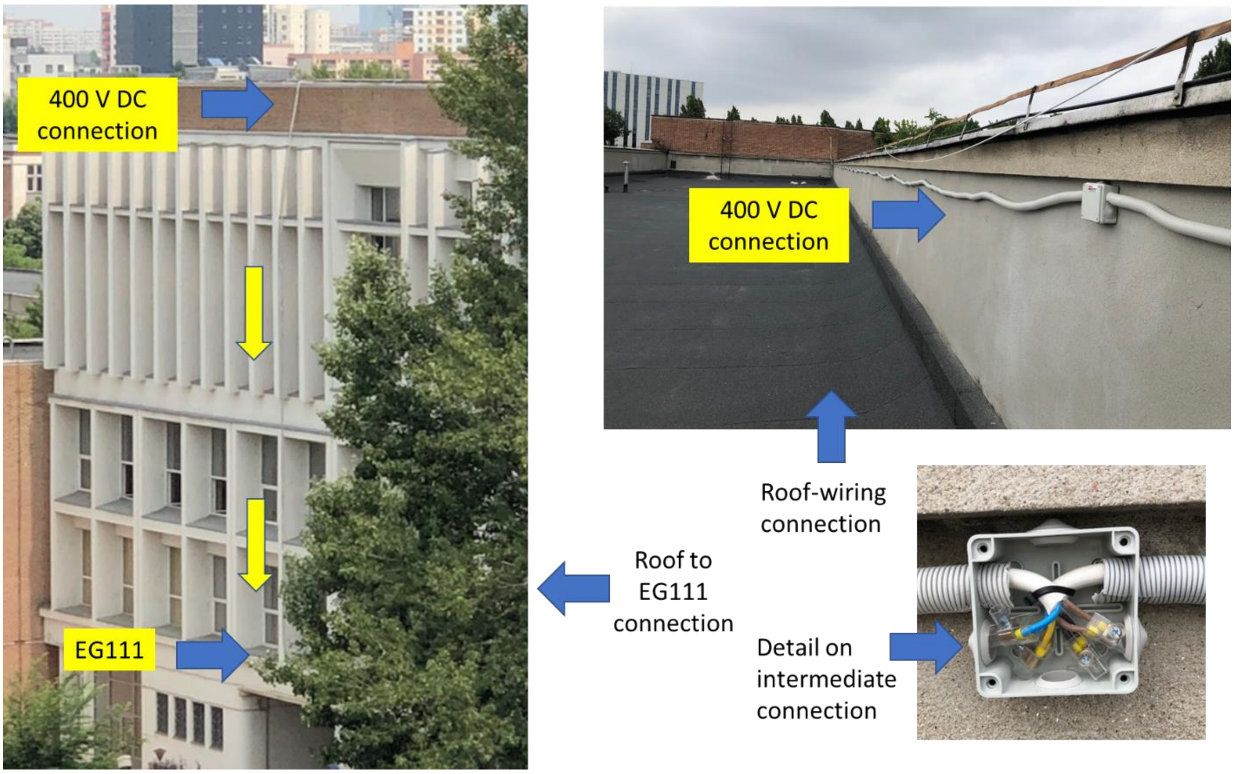

Figure 7. Connecting cable between the main laboratory (EB105) and second laboratory (EG111) at UPB's premises.

Moreover, in the 3rd phase has been also made the necessary communication / internet connection of the neighbour laboratory and have been made preliminary tests with loads connected on the 220 V DC bus-bar of the EG111 laboratory. To be noted that the voltage level (220V) has been selected as to comply with previous (now obsolete) standards for the emergency supply of protection cabinets in HV power station, while current standards are not existing and work on new standardization for LVDC grids is ongoing.

5.4 Phase 3 issues and lessons learned

During phase 3 the integration lessons learned can be summarized as following:

- For finalisation of inter-laboratory connections in DC, it was needed to use specialized electricians for DC components integration, while rules for connecting the components to continuous voltage are not yet in the practice of electricians; finally, the experience from substations works, where batteries can have a voltage level of 110 or 220 V DC has been a useful experience for finalizing the works;
- DC circuit protection to short-circuits has been a challenge (and it is still al challenge for the DC grids in general); a combination of DC fuse protection devices and measures for the limitation of short-circuit current has been applied, such that the protection trips before power components (especially IGBT) become non-operational; the short circuit protection is still a challenge in DC, as there is no zero-crossing current, thus making difficult for traditional protection devices to always operate safely to protect the main power circuits;
- The DC circuit protection to overvoltage has been also a challenge; it has been found that in some transitory situations it happened to be damaged the switching power electronics, so it was needed to take additional measures; a final protection approach with varistors at around 500 V DC showed to be appropriate for the operational 400 DC voltage level, while power components have been chosen with nominal voltage in the range between 600 and 650 V DC, in order to keep an acceptable margin towards the varistor protection parameters, as well as compared with the operational 400 V level;
- During the buck converter final design some changes in the implementation solution have been made, in order to find a simpler and cost effective design, especially at the IGBT drivers level; the new setup needed however a higher protection level from disturbances, which has been solved with appropriate capacitors used to mitigate short-time bursts at sub-microsecond level, in addition to electrolytic capacitors used as default;
- Disturbances have been spotted also during the developments in the PC USB connection with the buck converter, during program updates which were made with energized power circuits; it has been found that a proper wiring and positioning of power parts, being physically more distant from the USB connection to the PC, was able to solve acceptably the communication problem;
- Because the UPB test sites are also laboratories where the students have classes, a clear delimitation has been shown to be mandatory in all critical places, in order to teach in a safe environment;
- Details of design, especially critical aspects such as the inductors used for the boost and buck converters and detailed specifications for other components showed to be a learning process during entire design and tests activity, thus has been decided to elaborate technical sheets with essential information and to promote the knowledge by preparing laboratory activities for the teaching process.

6 Conclusions

The deployment report of each scenario was presented in this deliverable. The deployments were made according to the test site plans of phase 3 in D6.3 – "Phase 3 Test Site Plans" [S4G-D6.3]. Table 2 summarises the prototypes deployment status during phase 3. Some issues happened in the test sites during phase 3, namely:

- **Cooperative EV Charging Scenario (Bolzano, IT):**
    - The presence of an ESS represent a risk for safety of people and security of the places. Moreover, increase the fire risk:
    - The SMXs Secure Digital (SD) cards are continued to fail. A lot of SD cards are being changed, and a thorough study of the electromagnetic compatibility levels in the field to match the equipment declared immunity is needed, while other causes, such as temperature range, excessive use of SD cards in some periods etc. could also lead to the need to change them, asking in a future full commercial deployment for more reliable solutions
    - Further work has been done to improve communications and the internet network in the test sites. It seems very difficult to achieve the requirements of the project in the test sites.

- **Storage Coordination Scenario (Fur/Skive, DK):**
    - A new SMM mapping was incorporated in the SMXcore, to enable the integration of the Landis+Gyr SMM used in the Fur/Skive test site;
    - The ER transformer suffered a mechanical deformation during the transportation to the test site and may need to be replaced, however, the three-phase ER operation can be demonstrated at any time.

- **Advanced Cooperative Storage System Scenario (Bucharest, RO):**
    - DC connection rules should be written and available to electricians;
    - A safe environment is mandatory in the laboratory since the space is shared between students and researchers;
    - The neighbourhood DC link required an approval from both Electrical Engineering Faculty and Power Engineering Faculty authority, taking some time to solve the necessary administrative requirements. An explained request and persuasion speech were needed for connecting the two points;
    - A higher students' engagement regarding the DC bus and its components can be achieved through animation techniques.

During phase 3, the main components to be installed are the ESS in the Bolzano commercial test site, the grid-side ESS in the Skive Grid-side ESS test site, and the single-phase ER in the Bucharest test site. D6.6 – "Phase 3 Test Site Platforms and Deployments Report" is the final version of this document.

Acronyms

Acronym	Explanation
AC	Alternative Current
BMS	Battery Management System
DC	Direct Current
DSF	Decision Support Framework
DSF-DWH	Decision Support Framework Data Warehouse
DSF-EE	Decision Support Framework Economic Engine
DSF-SE	Decision Support Framework Simulation Engine
DSO	Distribution System Operator
ER	Energy Router
ESS	Energy Storage System
EV	Electric Vehicle
GESSCon	Grid Energy Storage System Controller
GUI	Graphical User Interface
HIL	Hardware In the Loop
HLUC	High Level Use Case
LESSAg	Local Energy Storage System Agent
MS	Milestone
OGC	Open Geospatial Consortium
PCC	Point of Common Coupling
PROFESS	Professional Realtime Optimization Framework for Energy Storage Systems
PROFEV	Professional Realtime Optimization Framework for Electric Vehicles
PUC	Primary Use Cases
PV	Photovoltaic
RES	Renewable Energy Sources
RUL	Remaining Useful Life
SB	South Bound
SCADA	Supervisory Control and Data Acquisition
S4G	Storage 4 Grid
SD	Secure Digital
SMM	Smart Metrology Meter

SMX	Smart Meter eXtension
SoH	State of Helth
USM	Unbundled Smart Meter
VLRA	Valve-Regulated lead-Acid

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