D5.4 – Updated DSF Connectors for external systems and services

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0.2	2018-08-20	UNINOVA	Inputs regarding DSO Scada connector
0.3	2018-08-21	ALPERIA	Minor adjustments and editing
0.4	2018-08-28	ISMB	Updated and inputs for Grid, Weather, Price, DWH, OGC wrapper
0.5	2018-08-29	ALPERIA	Ready for internal review
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Internal Review History

Review Date	Reviewer	Summary of Comments
2018-08-30 (v0.6)	Yini Xu (LIBAL)	Approved • Minor Corrections • Comments
2018-08-29 (v0.6)	Marta Sturzeanu (UPB)	Approved • Minor Corrections

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Executive Summary

This deliverable presents the updated results of the task 5.2 whose main goal is to develop a set of connectors to allow the Decision Support Framework to operate with 3rd party and DSO systems.

It provides first an overview of the S4G Data Warehouse implementation with its component set-up which enables the data collection of all S4G test sites. Secondly, it describes the various connectors developed in the project till now: the Data Dispatcher, the OGC wrapper, DSO connectors, the DSF-DHW connectors, the DSF DSO Scada connector, solar radiation connectors and hybrid simulation connectors

Information regarding installation and deployment of the connectors as well as their software dependencies and requirements is given. A preliminary API reference is presented.

This is a prototype document which reports updated results. The number of connectors will increase, as Figures 4 and 5 of D3.1 show. D5.5 will report on final implementation results.

1 Introduction

The deliverable D5.4 – Updated DSF Connectors for external systems and services documents the updated results of T5.2 whose main goal is to develop a set of connectors to allow the Decision Support Framework (DSF) to operate with 3rd party and DSO systems.

Chapter 2 presents the structure of the DSF Data Warehouse before describing the prototype of the various DSF connectors and their structure. The installation and deployment of the connectors are presented in chapter 3. Chapter 4 shows the software dependencies and requirements, whereas chapter 5 presents a preliminary API reference. Finally, chapter 6 discusses the conclusions and next steps.

1.1 Scope

Following the project work-plan, the effort of WP5 in the first 1.5 years of the project has been focused on the development of various components necessary to gather data from the test sites in Fur and Bolzano. In its second version, therefore, this deliverable describes mainly the updated outcomes of Task T5.2 DSF Interoperability with 3rd party and DSO systems.

Future issues of this deliverable, will be refined according to results of T5.2 as well as of T5.3 – DSF Hybrid Simulation Support, resulting in "D5.5 Final DSF Connectors for external systems and services" at M33. The work in T5.2 and T5.3 is largely intertwined with the work in WP3.

1.2 Related documents

ID	Title	Reference	Version	Date
[D2.1]	Initial Storage Scenarios and Use Cases	D2.1	1.1	2017-06-08
[D2.2]	Final Storage Scenarios and Use Cases	D2.2	1.0	2018-07-31
[D3.1]	Initial S4G Components, Interfaces and Architecture Specification	D3.1	1.0	2017-08-31
[D4.8]	Initial USM Extensions for Storage Systems	D4.8	1.0	2017-08-31
[D5.3]	Initial DSF Connectors for external systems and services	D5.3	1.0	2017-09-04
[D6.1]	Phase 1 Test Site Plans	D6.1	1.0	2017-08-31

2 Connectors Prototype Overview

This chapter provides a high-level overview of the implementation of the S4G Data Warehouse, i.e. the main component set-up to collect all the test sites data in Storage4Grid, together with a description of the first DSF connectors developed by S4G.

The list of connectors, further explained in the following section, is the following:

- Data Dispatcher; it is an instantiation of a North-bound SMX Connector, as seen in USM's high-level architecture depicted in Figure 4 of D3.1 as well as in one of the USM configurations in Figure 5 of D3.1.
- OGC wrapper; it is installed on each Aggregator and extend the compatibility of the device layer by providing functionalities of the OGC SensorThings standard.
- DSF Connectors, including:
  - DSO connectors, including:
    - Grid connector; to enable the propagation of Grid data;
    - Price connector; to enable the propagation of Price data;
    - Fronius Cloud connector; to enable the Fronius system.
  - Third party connectors, about:
    - Weather forecast;
    - PV production data.
- DSF-DWH connectors, regarding the set of plugins related to the influx database.
- DSF DSO Scada connector
- Solar radiation connectors, to enable PROFESS and PROFEV.
- Hybrid Simulation connectors, regarding the set of plugins related to the influx database.

The purposes of these connectors are mainly to enable the feeding of data into the data warehouse, to provide external services information to other software components of the DSF and to enable the forwarding of control messages towards the Physical layer devices.

2.1 Basic Information – Data Warehouse

The DSF Data Warehouse (DSF-DWH) is the central system used to store data from all test-sites in the Storage4Grid project. Its structure is depicted in Figure 1.

The development of a Data Warehouse is not within the core objectives of the project. Nevertheless, this is a key component supporting the S4G test site, as well as a key test-bench where all data and information model developed by S4G must be reflected.

In order to match the project requirements, the DWH is implemented using existing open-source solutions for industrial-scale real-time data processing and storage, namely the TICK suite[1]. In the first phase of the project, only the basic components (Telegraf and Influxdb) are adopted. Further components (e.g. Kapacitor, Chronograf) may be adopted in subsequent phases, e.g. to support development of more advanced processing and visualization features.

[1] https://www.influxdata.com/

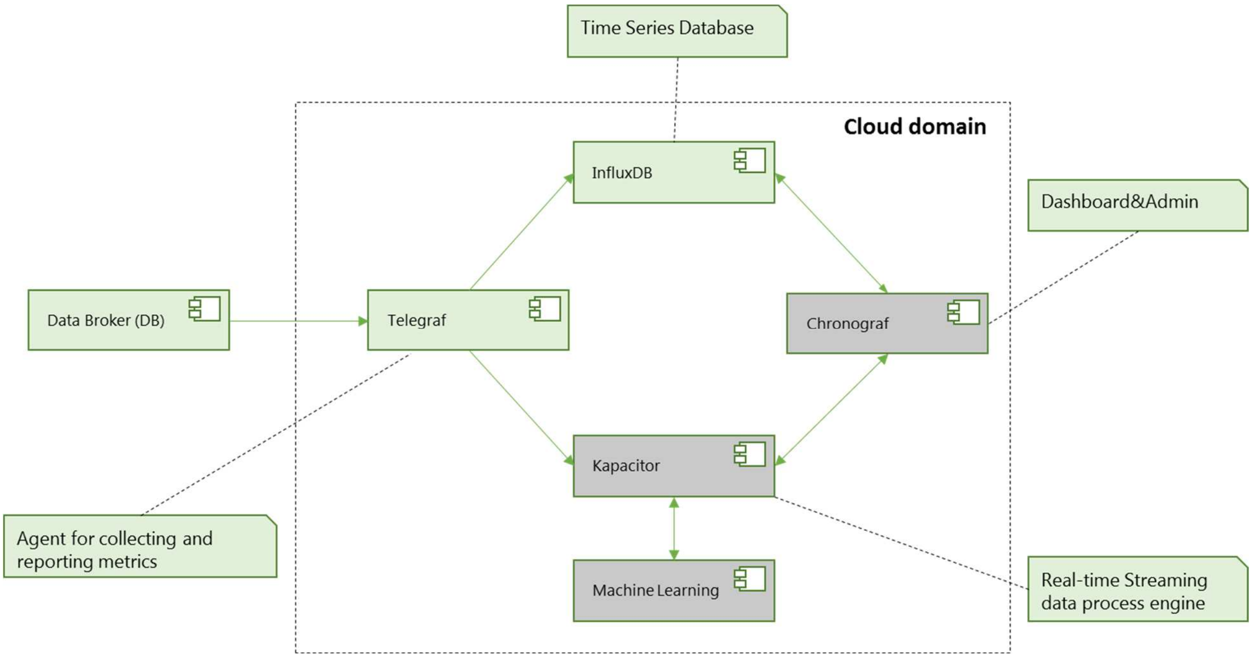

Figure 1 - Data Warehouse (DWH)

2.2 Data Dispatcher

The Data Dispatcher component resides in the SMX box. It feeds data from the SMX to the Aggregator in charge of managing it exploiting the Aggregator Broker. The Data Dispatcher is expected to upload local data batches periodically. The interval should be configurable. At the same time, it should be able to resend local data batches whenever sending failures occurred due to e.g. network connection downtime. This component is also in charge of forwarding control messages coming from the Residential GUI and from the Service layer components towards the Physical layer devices by means of the SMX Broker.

The interfaces of the Data Dispatcher are shown in Figure 2.

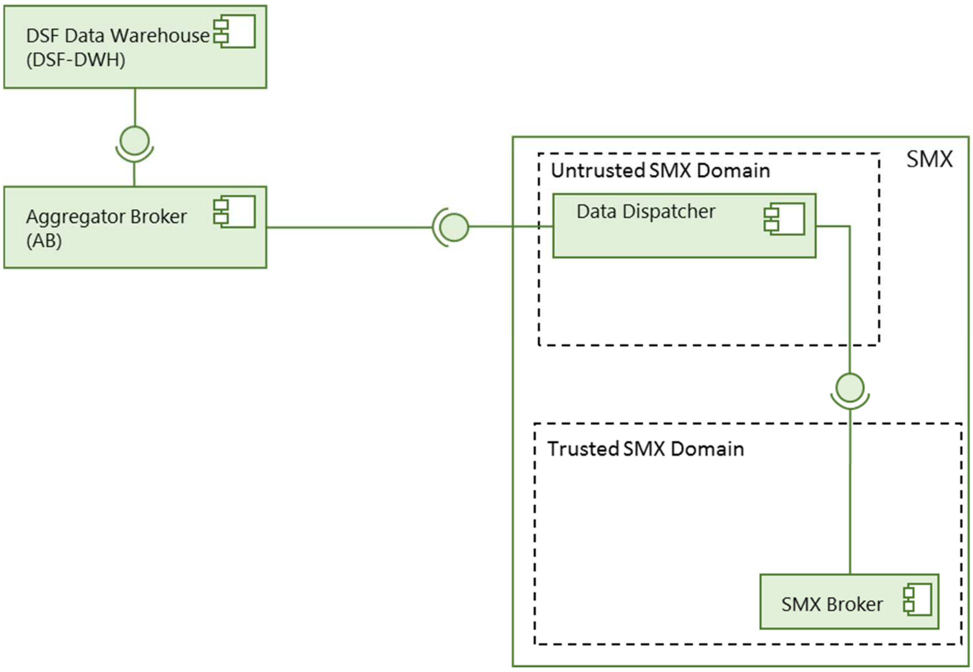

Figure 2 - Data Dispatcher

2.3 OGC wrapper

The OGC wrapper component resides in the SMX box. It feeds data from all the SMXs located on a single site to the Aggregator-DWH and simultaneously forward these data towards the Service layer. By maintaining a logical mapping between each SMX and the required cloud services, it propagates the messages, connecting the Device layer to the Service layer.

The resulting managed paths are:

- from the Device layer (involving the SMXs managed by the current Aggregator) to the Service layer;
- from the Service layer to the Aggregator;
- from the Aggregator to the Device layer (by targeting a specific SMX);

At the same time, this component can detect time drifting values between device layer components and the local system. To improve the overall stability, it will automatically send an email to all the IT involved technicians with some debug information's and the related warning.
The interfaces of the OGC wrapper are shown in Figure 3.

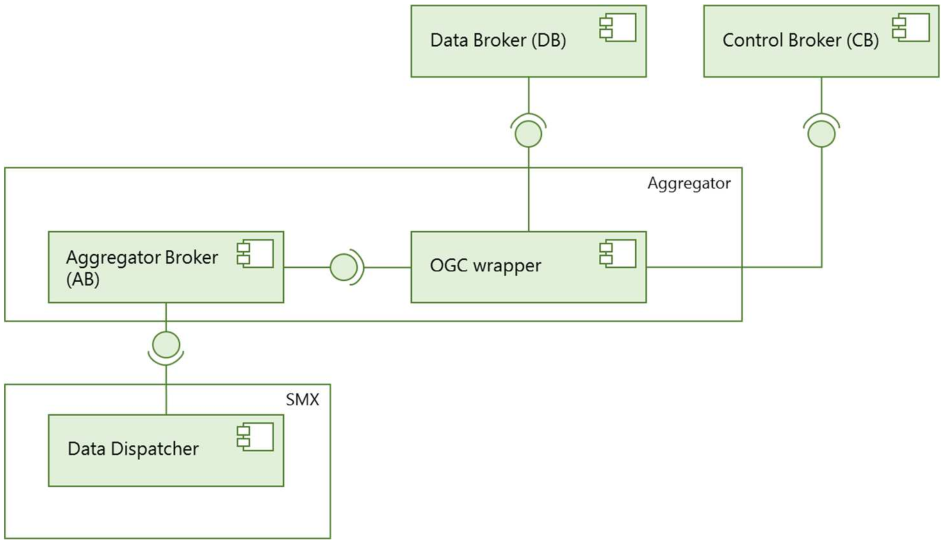

Figure 3 - OGC wrapper

2.4 DSO connectors (GridDB connector, Energy Price connector)

At the present stage of the project, two connectors have been dedicated to the data extraction from DSO premises. These data include Physical Electricity Distribution Grid data and Energy Price table, both read-only from DSF side and are being updated/changed/modified by the DSO authenticated members.
Both the connector described resides in the DSF-DWH cloud machine. These such component provide via RESTful APIs third party data to all the authorized services in the S4G environment.

2.4.1 GridDB connector

The GridDB is a connector designed to access and read distribution network model from DSO database. Due to security reasons, the accessed database is a backup copy (located on the DSF) of the DSO ones. The configuration of the distribution feeder of Bolzano's test site is demonstrated in Figure 4.

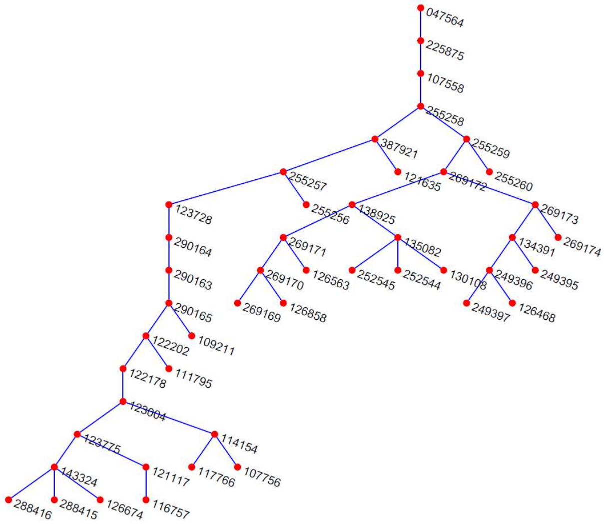

Figure 4 - Bolzano test site feeder

These data essentially contain buses and lines as the configuration definition and in an objective framework describes the nodes' connected elements such as transformers, loads and generators.
The grid related data have been stored in a *json* format in the database.
Below an example of hierarchical grid object in the database can be seen.


```
{
  "hv_mv_substation": {
    "mv_substations": {
      "substation_001": {
        "feeders": {
          "feeder_001": {
            "nodes": {
              "bus_047564": {
                "tech_id": "047564",
                "latitudine": 0,
                "longitude": 0,
                "from_root": 1,
                "parent": "substation_02",
                "children": {
                  "TR1": {
                    "tech_id": "TR1",
                    "phases": 3,
                    "windings": 2,
                    "xhl": 0.014,
                    "parent": "substation_02",
                    "bus1": "047564",
                    "kva1": 400,
                    "conn1": "delta",
                    "kv1": 16,
                    "r1": 0.5,
                    "bus2": "225875",
                    "kva2": 400,
                    "conn2": "wye",
```

```
        "kv2": 0.4,
        "r2": 0.5
      }
    }
  },
...
```


Such data are being used by DSF for simulation purposes, in a particular format adapted to the DSF-SE. As a result, the GridDB connector reads the json formatted grid information and convert them in a second phase to the DSF-SE adapted format.

2.4.2 Energy Price connector

Energy price within S4G perspective is planned to be provided as a static data in a human-assisted way. This means, given that none of the DSOs are going to use spot market directly for the pricing scheme, the prices will be provided as kind of price table in which various contractual and timing framework determine the specific price contents.

An *EnergyPrice* connector has been developed to access and get the mentioned table. For instance, the tables contain various prices for the timing slots, for determined contract type, as in Figure 5 can be seen.

Priser inkl. moms	Spændings-niveau	Kundetype	Transport N1	Abonnement	
				Timemålt	Skabelon-afregnet
			øre/kWh	kr/år	kr/år
A-kunder	150 kV	Detail	0,94	1.321,25	
	60 kV	Detail	3,86	1.321,25	
	10-20 kV	Detail	5,69	1.253,75	
		Egen netbevilling	4,75	1.253,75	
B-kunder	10-20 kV	Detail	11,49	1.253,75	
		Egen netbevilling	10,55	1.253,75	
	0,4 kV	Detail	14,13	921,25	368,75
		Egen netbevilling	13,19	921,25	
C-kunder	0,4 kV	Detail	23,91	921,25	368,75
Onlinemåling for alle kundetyper				5.922,50	
Impuls fra måler, uanset målertype				150,00	150,00

Figure 5 - Contractual pricing scheme in ENIIG premises

Other table may contain information about the contract type, such as commercial, residential, etc. and also various offer types.

2.5 Fronius Cloud Connector

The Fronius Cloud Connector component runs in the cloud and is used for fetching information from Fronius hybrid systems installed in the Bolzano and Fur test-sites. It can access data from the whole population of Fronius systems from all test-sites and make it available to the DSF-DWH via the DB. The interfaces of the Fronius Cloud Connector are shown in Figure 6.

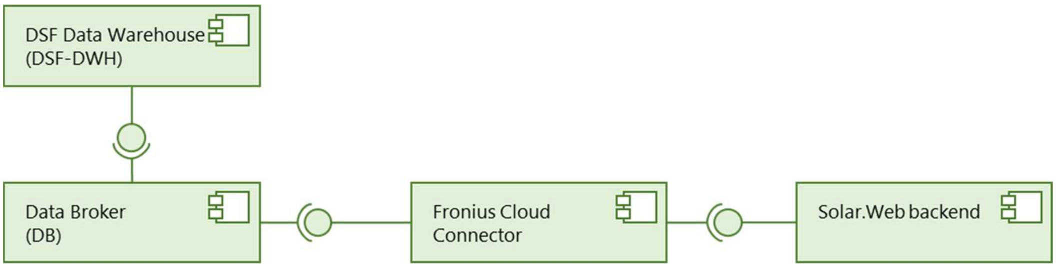

Figure 6 - Fronius Cloud Connector

The functionalities of the Fronius Cloud Connector partially overlap with the functionalities of the local SMX adapter for Fronius ESS described in deliverable D4.8. The main difference is that the Fronius Cloud Connector relies on the internet-based data infrastructure provided by Fronius, and it is therefore not indicated for applications where local control loop must be established.

While S4G use cases normally require more direct interaction with ESS, and therefore the local SMX adapter is the preferred solution, the key advantage of the Fronius Cloud Connector component is the possibility to quickly interconnect to the existing Fronius-based installations – so that operational data can be collected without deploying additional infrastructure, which is a key requirement in the early stage of the project, so that more data can be collected.

2.6 Weather forecast for PV production connectors

Given a fixed operational condition (switching on/off, inverter efficiency etc.) and position (panel tilt and azimuth angle), the PV output power is a function of season, time, cloud density and temperature. For the Predictive Models related to the PV production we get use of two connectors. The first one to get cloud presence (density) and temperature, the second connector is only intended to provide visualization features to be used eventually in GUI.

2.6.1 Weather connector

This connector is built upon a free API offered by weatherunlocked that provides necessary information for solar irradiation calculation such as cloud density and temperature. The data is available for seven days in three hours' intervals. This information then will be combined with other static calculation to provide the solar irradiation forecast.

Partial results of a request are imported in the Figure 7 .

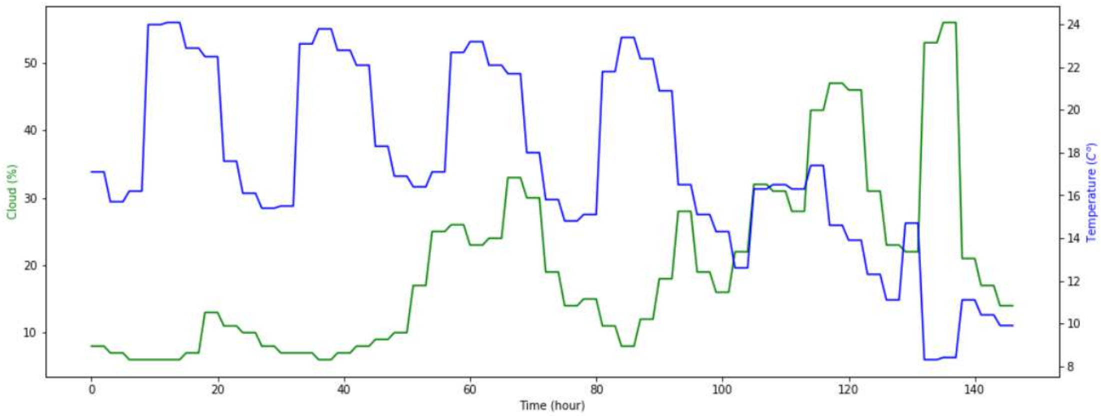

Figure 7 - Cloud and temperature for seven days in Bolzano test site

2.6.2 WeatherImage connector

The WeatherImage is a connector for visualization purposes in case of user-interface compatibility, return the animated GIF image for the last hour observation above the area of interest. This gets an intuitive impression of the cloud presence and movement and can be offered as an additional feature for the user. The service is provided by [en.sat24.com](en.sat24.com) and the contents are being received as html extension, visible in any web application.

The Figure 8 shows this visualization feature in a frame in which the sun rising alongside with the cloud presence can be seen.

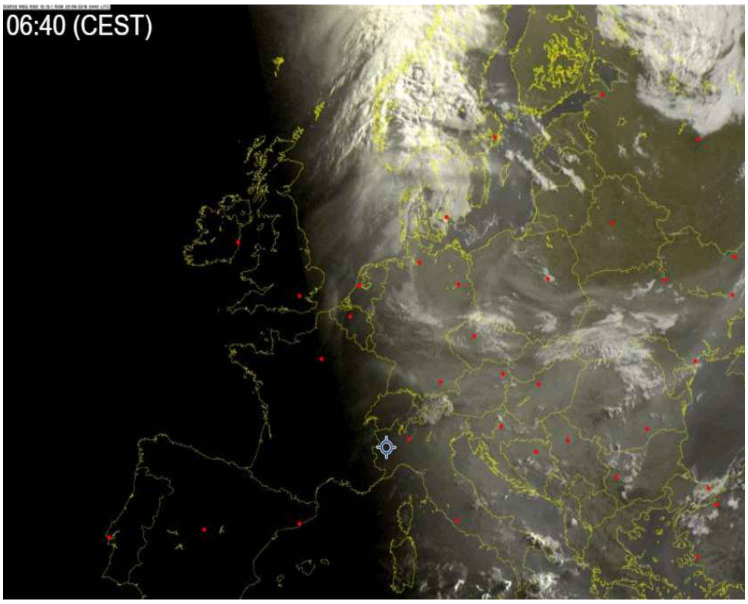

Figure 8 - Last hour sunshine and cloud movements.

2.6.3 DSF Solar Irradiation connector

Once DSF PV production predictive model received the request for solar irradiation forecast for specific time and geographical area, gets use of the information received from 3rd parties as mentioned above and calculates the day-ahead irradiation. The process of this calculation method is explained in the D5.6. An example of such prediction result can be found in the Figure 9 Figure 9 - Normalized solar irradiation forecast by DSF predictive model.

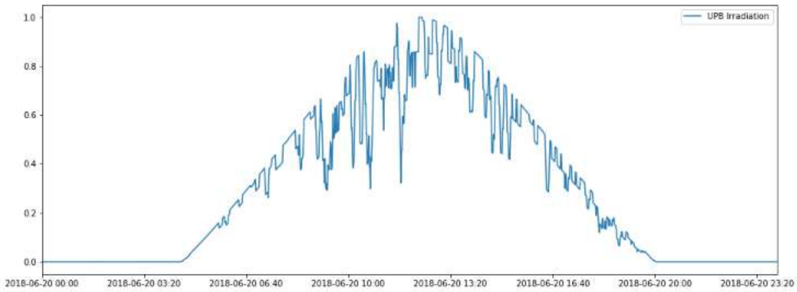

Figure 9 - Normalized solar irradiation forecast by DSF predictive model.

This irradiation then will be accessed from the service caller by DSF Solar Irradiation connector.

2.7 DSF-DWH connectors

These connectors enable the DSF to expose the historical data collected in the selected time-series database towards the authorized services requiring it. For privacy and security reasons, the web access will be limited to a group of users and services with enough rights.
The TICK Influx suite include a set of plugins that enables authenticated users to interact with the database exploiting a SQL-like query language via web.
Furthermore, it provides monitoring functionalities such as the possibility to define rules and reactions about irregular behavior of the data streams injected into the database. Currently, an agent verifies periodically if data reception is constant, concerning the known open data streams. The reaction selected in case of no more incoming data, for a defined amount of time, is to send an email with warnings to all the IT technicians in charge of managing the network.

2.8 DSF DSO Scada connector

This connector enables the DSF to receive grid information from the DSF. Moreover, it also allows the control of S4G devices through the DSF. This connector is implemented using the IEC 60870-5-104 standard[i], using the master defined in this standard. At the moment of this deliverable, only the control part is implemented. In the final version the DSO SCADA monitoring, and the retrieval of information will be detailed.

2.9 Solar radiation connector for PROFESS or PROFEV

The connector uses the services of photovoltaic geographical information system (PVGIS), which is an open source tool of the European commission. PVGIS provides information about solar radiation and photovoltaic (PV) system performance. It can give information about the energy generated by a PV in several places of the world. This information is free and there is no restriction for the use of it.

The connector developed in S4G project makes uses of the API provided by PVGIS. Through this API, the connector receives information of solar radiation and PV generation of a defined place. The place is entered in the present development with the name of the city. Moreover, some PV parameters are necessary to send to the API for getting the PV power generation at that place. These parameters are the following:

- PV technology: it is possible to choose between following PV material technologies: crystalline silicon cells; thin film modules made from CIS or CIGS and thin film modules made from Cadmium Telluride (CdTe) for estimating the losses caused by temperature and irradiance effects.

- Peak power: Maximal power that the PV can generate under standard test conditions declared by the manufacturer.
- Losses: All losses in the system that causes that the power delivered to the grid is lower than the power generated by the PV.
- Mounting position: there are two possibilities. The first one is "free-standing" with air flowing freely behind the modules. The second one is "building-integrated" without air movement behind the module.
- Slope of PV: Angle of the PV from the horizontal plane.
- Azimuth of PV: angle of the PV relative to the direction to South.

PVGIS makes use of different solar radiation databases, where solar radiation from satellite images is calculated. The three main databases are:

- PVGIS-CMSAF: covers Europe and Africa and parts of South America. Our connector selected this database for getting the solar radiation profile inside PROFESS or PROFEV.
- PVGIS-SARAH: Covers Europe, Africa, most Asia and parts of South America
- PVGIS-NSRDB: covers North and South America

The connector also selected the option of using horizon information for the calculation of solar radiation and PV generation. PVGIS uses the information of the local horizon for including the effects of shadows caused by mountains into the solar radiation calculation.

The PV generation and solar radiation data is obtained hourly from PVGIS. Depending on the time step in which the optimization inside PROFESS or PROFEV has to be calculated, the PV generation data is expanded inside the connector as needed.

2.10 Connector enabling Hybrid Simulation

The Hybrid Simulation will integrate physical devices (ER and ESS) in test sites as hardware-in-loop elements. The ESS and ER are being monitored and controlled trough already developed interfaces with the LiBal Site Controller and SMX. Enabling Hybrid simulation needs publish-subscribe messaging pattern that handle measurements and set points from hybrid simulator.
A general overview of S4G Hybrid Simulation is depicted in the Figure 10.

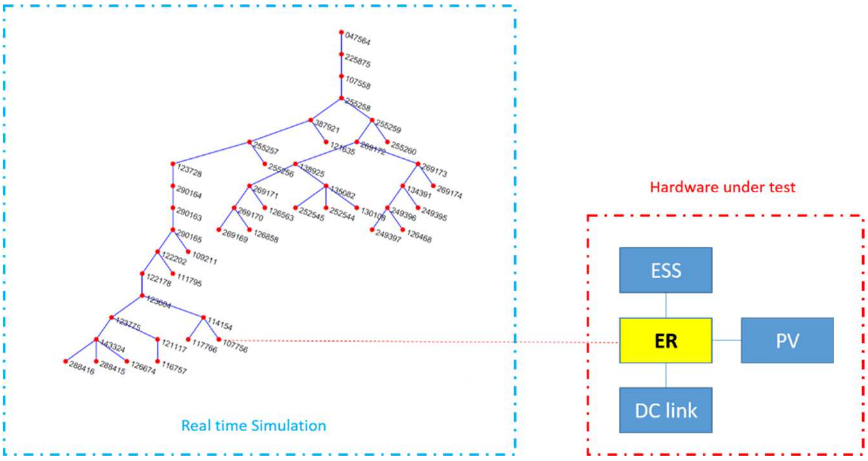

Figure 10 - Hybrid (hardware-in-loop) simulation

A set of connectors named *RealTimeConnectors* is under development to accommodate the requirement for a successful hardware-in-loop simulation.
This connector is being called at each single step of simulation by *RealTimeSimulator* and a set point found from simulator analysis which indicates the next state of ER/ESS is being published trough that. The physical device(s) follow the instruction accordingly as the rest of electric network is still virtual.

3 Installation/Deployment instructions

3.1 Data Dispatcher

This extension is designed to be deployed as part of a standard USM installation, and therefore no specific installation or configuration instructions are needed specifically to use this extension.

3.2 OGC wrapper

This extension is designed to be deployed as part of a specific USM installations, previously called USM0. In particular, these installations are the ones referred to the edge layer (Aggregators). Therefore, no specific installation or configuration instructions are needed to use this extension.

3.3 DSO connectors (GridDB connector, Energy Price connector)

This extension is designed to be deployed uniquely on the cloud domain. This is installed inside the DSF machine together with the database collecting the related information. Therefore, no specific installation or configuration instructions are needed specifically to use this extension.

3.4 Fronius Cloud Connector

The Fronius Cloud Connector is currently deployed as a standard Linux system service on the cloud domain, but is also possible to install it as a docker[2] component.

3.5 DSF-DWH connectors

The DSF-DWH connectors are installed into the DSF-DWH cloud machine. These agents are dockerized together with the Influx database to provide an easy and scalable solution for the deployment.

3.6 DSF DSO SCADA Connector

The DSF DSO SCADA software used in this prototype can be found in the Storage4Grid Git official repository. Place the software in the DSF and start the application using the bash file.

4 Software dependencies and requirements

The connectors are designed to be lightweight, and therefore do not have special requirements in terms of RAM or processing power.

Table 1 – Software Dependencies

Dependency	License	Role
influxdb[3]	MIT License	Part of Data warehouse: Scalable time-series database for metrics, events, and real-time analytics
telegraf[4]	MIT License	Part of Data warehouse: The plugin-driven server agent for collecting & reporting metrics.
j60870	GPLv3	This software is used to connect to the DSO SCADA enabling the data exchange with the DSF using the IEC 60870-5-104 standard.

5 API Reference

5.1 Data Dispatcher

In each of the SMX present on the Device layer domain, is installed a MQTT broker that connects Physical layer devices streams to it.
By exploiting local configuration files, the connection between the SMX and the Aggregator is automatically configured at boot, by using a different topic for each Physical device. The current connector is installed as a system service exploiting the systemctl functionalities offered by the OS where this code is executed.

[2] https://www.docker.com/
[3] https://www.influxdata.com/time-series-platform/influxdb/
[4] https://www.influxdata.com/time-series-platform/telegraf/

5.2 OGC wrapper

In the cloud domain, a MQTT broker is running which allow to link all the Aggregators streams to the DSF-DWH. By exploiting a global OGC SensorThings server (GOST), this component is autonomously able to setup the required channels (in compliance with the OGC SensorThings standard) with the DSF-DWH. The current connector is installed as a system service exploiting the systemctl functionalities offered by the OS where this code is executed.

5.3 DSO connectors (GridDB connector, Energy Price connector)

These connectors enable the DSF to propagate grid and price information from the DSF towards the authorized services requiring it.
In order to extract DSO information residing on the DSF, RESTful APIs are exposed. A more detailed description of the APIs exposed will be finalized in the next version of the deliverable.

5.4 Fronius Cloud Connector

The connector wraps the internal API provided by Solar.Web [1]. It works as a client, fetching data from Solar.Web.

- GetData(): This function will return a JSON message with following parameters:
    - P_Grid: Active power transferred from the grid to the local customer (house). A negative value means that power is generated into the grid.
    - P_Load: Home load, i.e. the active power transferred into the local loads. A positive value means that the house is in load mode, i.e. consuming active energy.
    - P_Akku: Active power transferred from the battery to the local loads (home). A negative value means that the battery is charging, i.e. in load mode, positive means discharging, i.e. in generation mode.
    - P_PV: Active power being generated by the PV (always positive or zero)
    - SOC: State of Charge, i.e. energy percentage of the rated capacity which is available in the battery

In principal, developers could integrate this client easily by setting intervals and credentials for Solar.Web.

5.5 DSF-DWH connectors

The DSF-DWH connectors component is composed by a time series database together with a set of agents to enable different interaction with it. This database collects all data sources from the distributed environment. Telegraf agent is used to connect the DB to the MQTT broker by using the MQTT consumer plugin in Telegraf. The MQTT consumer plugin reads data in InfluxDB format from the configured topics and forward it to InfluxDB. The available web APIs to extract information from the DSF are exposed via HTTP and allow to interact with the database in a SQL-like query language.
These connectors comprehend also weather forecasts data propagations.

5.6 DSF DSO SCADA Connector

Currently, the connector enables two commands:

- C_SC_NA_1: to switch on/off a relay in a specific slave
- M_SP_NA_1: to request the relay status of the slave

These commands work as a proof-of-concept. Other commands can be implemented, extending the functionalities of this connector, if necessary.

6 Conclusions and next steps

This deliverable presents the first updated results of T5.2 whose main goal is to develop a set of connectors to allow the Decision Support Framework to operate with 3rd party and DSO systems.

It describes the first DSF connectors which enable the feeding of data into the DSF-DWH and provide ways to retrieve third party service information.
As previously described, the software components in charge of feeding data into the DSF-DWH are performed by: the Data Dispatcher, the OGC wrapper and the Fronius Cloud Connector. The Data Dispatcher makes data available from the SMX into the Aggregator and the OGC wrapper will forward towards the DSF-DWH; whereas the Fronius Cloud Connector fetches information from Fronius hybrid systems at a global scale.
The software component in charge of providing third party information and the access to both historical and real time data about the DSF-DWH are respectively DSO connectors and DSF-DWH connectors.

The number of connectors could increase throughout the project. A preliminary idea about the number of connectors foreseen in the course of the project can be gotten from D3.1 *Initial Components, Interfaces and Architecture Specification* as in Figures 4 and 5 which show USM's high-level architecture.

The results will be further described in D5.5 *Final DSF Connectors for external systems and services* at M33.

Acronyms

Acronym	Explanation
DSF	Decision Support Framework
DSF-DWH	DSF- Data Warehouse
DSF-SE	DSF – Simulation Engine
DSO	Distribution System Operator
DB	Data Broker
CB	Control Broker
CIS	Copper Indium Selenium
CIGS	Copper Indium Gallium Selenium
GOST	Global OGC Sensor Things
JSON	JavaScript Object Notation
MQTT	MQ Telemetry Transport or Message Queue Telemetry Transport
OS	Operating System
PVGIS	Photovoltaic Geographical Information System
PROFESS	Professional Realtime Optimization Framework for Energy Storage Systems
PROFEV	Professional Realtime Optimization Framework for Electrical Vehicles
S4G	Storage4Grid
SCADA	Supervisory Control and Data Acquisition
SMX	Smart Meter eXtensions
SOC	State Of Charge
SQL	Structured Query Language
USM	Unbundled Smart Meter
OGC	Open Geospatial Consortium
EV	Energy Vehicle
PV	Photovoltaic System

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References

[1] Fronius International GmbH, „Fronius Solar.web," Fronius International GmbH, 2017. [Online]. Available: https://www.solarweb.com/. [Accessed on August 2017].

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[i] IEC 60870-5-104:2006 - Telecontrol equipment and systems - Part 5-104: Transmission protocols - Network access for IEC 60870-5-101 using standard transport profiles, https://webstore.iec.ch/publication/3746, Accessed 20 August 2018.