



Small or medium-scale focused research project (STREP)

# Energy Demand-Aware Open Services for Smart Grid Intelligent Automation

## SmartHG

EU FP7 Project #317761



### Deliverable D4.3.2

## Third Year Prototype of Grid Intelligent Automation Services

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# Contents

<b>Executive Summary</b>	<b>1</b>
<b>1 Retrospect</b>	<b>2</b>
<b>2 Introduction</b>	<b>3</b>
<b>3 DAPP Web Service</b>	<b>4</b>
<b>4 Conclusions</b>	<b>7</b>
4.1 Impact . . . . .	7
<b>Bibliography</b>	<b>8</b>

# List of Acronyms

**DAPP** Demand Aware Price Policies

**DAPP-H** Demand Aware Price Policies for Homes

**DB&A** Database and Analytics

**DSO** Distribution System Operator

**EDN** Electric Distribution Network

**ESS** Energy Storage System

**EUMF-K** Energy Usage Modelling and Forecasting for Control

**EVT** EDN Virtual Tomography

**GIAS** Grid Intelligent Automation Service

**HIAS** Home Intelligent Automation Service

**IAS** Intelligent Automation Service

**PPSV** Price Policy Safety Verification

**RESTful** REpresentational State Transfer

**SaaS** Software as a Service

# Executive Summary

The main objective of the SmartHG project is to develop effective Intelligent Automation Services (IASs) to minimise users energy bill for end residential users while optimising operation on the grid for Distribution System Operators (DSOs). This deliverable, together with Deliverable D3.3.2, describes the third year effective implementation of such IASs. Namely, in this deliverable we focus on the IASs working on the DSO side, i.e., on the Grid Intelligent Automation Services (GIASs). Instead, Deliverable D3.3.2 focuses on the Home Intelligent Automation Services (HIASs), which work on the residential user side. Following the design described in Deliverable D4.3.1, the GIASs developed in the third year are the following: the Database and Analytics (DB&A), Demand Aware Price Policies (DAPP), Price Policy Safety Verification (PPSV) and EDN Virtual Tomography (EVT) services. The implementation of the GIASs is based on the GIASs design described in Deliverable D4.3.1.

In the second year, for each of such GIASs we developed a Web service (for human users) and a REpresentational State Transfer (RESTful) service (for automatic communications between IASs), basing on a common and unified software architecture. In this third year, we integrated such architecture in the SmartHG Platform Technical Section, by also simplifying and clarifying the user interaction.

The effectiveness of the prototypes described here is evaluated, together with the HIAS prototypes, in the third year iteration of the SmartHG IASs evaluation (Deliverable D5.3.1).

# Chapter 1

## Retrospect

In this section we briefly recall the main achievements obtained in the second year version of the SmartHG Grid Intelligent Automation Services (GIASs) prototype implementation, which was described in Deliverable D4.2.2. The detailed list of all advancements of the second year version of such prototypes (described in this deliverable) w.r.t. the first year version (described in first year Deliverable D4.1.2) is instead reported in Section 4.

First of all, in the second year we defined an overall architecture of the prototypes, which was the same as the Home Intelligent Automation Services (HIASs) architecture. Within such architecture, all GIAS prototypes were accessible from a Web service, which allowed either a Software as a Service (SaaS) usage (submit an execution and wait for completion) or software download (for services with real time requirements). Furthermore, the second year implementation of all GIAS prototypes also changed to reflect the changes in the design (described in Deliverable D4.2.1).

The effectiveness of the second year prototypes was evaluated, together with the HIAS prototypes, in the second year iteration of the SmartHG Intelligent Automation Services (IASs) evaluation (Deliverable D5.2.1).

# Chapter 2

## Introduction

This deliverable describes the third year version of the prototypes for the SmartHG Grid Intelligent Automation Service (GIAS). To this aim, we recall that, during the second year activities, we defined a common architecture for all SmartHG Intelligent Automation Services (IASs) (see Figure 2.1). Within such architecture all IASs have a Web service and a REpresentational State Transfer (RESTful) service, in order to be used by both human users and by other (automatic) IASs. During the third year, we mainly worked in integrating such services in the SmartHG Platform developed during the third year, and most notably in the SmartHG Technical Section described in Deliverable D7.3.2. Moreover, we also updated the Demand Aware Price Policies (DAPP) service in order to reflect the changes in the DAPP design described in Deliverable D4.3.1. In this deliverable, we outline the work done on the DAPP Web service, as the other services have been modified in a very similar way.

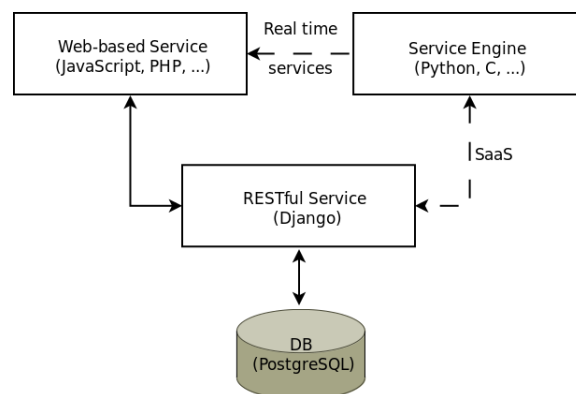


Figure 2.1: Software architecture for real-time services and for SaaS. Communications which take place for both SaaS and real-time services are shown with arrows. Dotted arrows show communications which take place either only for SaaS or only for real-time service (to allow service download). For the DB&A service, only the first two layers are used.

# Chapter 3

## DAPP Web Service

In this section, we describe the Demand Aware Price Policies (DAPP) Web service [1], which shares many features with the Web services of the other Software as a Service (SaaS) Grid Intelligent Automation Services (GIASs). The DAPP Web service has been obtained by simplifying and making more usable the second year version of the Demand Aware Price Policies for Homes (DAPP-H) Web service. For the design of the service and the nomenclature used, we refer the reader to Deliverable D4.3.1. Once the user visualises the starting Web page [1], by choosing a link in the left sidebar (see Figures 3.1–3.2) the DAPP Web service allows the user to perform the following actions.

**New Execution** Request a new execution (see Figure 3.2). In order to submit an execution request, a complete input must be provided. To this aim, the input is organised in two *scenarios*:

- The *substation scenario* contains all substation-related information required by DAPP. That is, the substation scenario is a collection of  $(t, P_s(t))$  pairs, where  $t$  is a time-slot (represented by the starting and ending time-stamps) and  $P_s(t)$  is the desired substation maximum aggregated demand (in kW) in  $t$ .
- The *home scenario* contains all homes-related information required by DAPP. That is, the home scenario is a collection of  $(u, P_u, C_u, t, p_u(t), d_u(t), Q_u(t), R_u(t))$  tuples, where  $u$  is the identifier of an home connected to the substation,  $P_u$  (resp.,  $C_u$ ) is the electricity production (resp., consumption) contract for user  $u$ ,  $t$  is a time-slot,  $p_u(t) < P_u$  (resp.,  $d_u(t) < C_u$ ) is the power production (resp., consumption) of electricity (in kW) of user  $u$  in time-slot  $t$ , and finally  $Q_u(t), R_u(t)$  is the flexibility of user  $u$  at time-slot  $t$  (expressed as the capacity and the power rate of an Energy Storage System (ESS) needed to follow the output power profile).

In order to create a new execution request, it is possible to choose already uploaded scenarios (i.e., scenarios already present in the REpresentational State Transfer (RESTful) service). It is possible to check the actual profiles contained in the selected scenarios by downloading them as text files. (see Sections 1.1 and 1.2 of the second year D4.2.2.Annex for the format).

- Starting date of the execution validity, that is, from which time-stamp the price polices output by DAPP will be applied. Choosing a time-stamp  $t$  for such starting date will also set the ending date to  $t$  plus one day.



- The fixed length (in minutes) of the input and output time-slots.
- The maximum speed  $\beta$  for users flexibility (in kW). If we model users flexibility as an ESS, then  $\beta$  is the maximum charge/discharge speed (i.e., in one hour the ESS may be charged/discharged at most  $\beta$  kWh).

**Submitted Executions** Search and retrieve for already submitted executions (default choice after login, see Figure 3.1). For all execution, it is possible to check status and other information. For completed executions, it is possible to download both the complete input and the complete output. Namely, the service creates and allows the user download a zip file for the input, containing two text files representing the home and the substation scenario (again, see Sections 1.1 and 1.2 for the format), and one zip file for the output, containing the following 4 files:

- one file for the output power profiles (see Section 1.4 for the format); thus, the file must contain a collection of  $(u, t, P_u^-(t), P_u^+(t))$ , where  $u$  and  $t$  are the same as in the home scenario (see above), and  $P_u^-(t), P_u^+(t)$  define the low tariff area for  $u$  in time-slot  $t$ ;
- one file for forecasting (computed by the same algorithm of Energy Usage Modelling and Forecasting for Control (EUMF-K)); such file has the same format of the home scenario file (see Sections 1.1), and provides, for each time-slot, the forecast for the consumption and the forecast for the power usage (in kW) and the forecast for the power production (in kW);
- one file for DAPP collaborative profiles (see Section 1.5 for the format); thus, the file must contain a collection of  $(u, t, \tilde{d}_u(t), a_u(t), b_u(t))$ , where  $u$  and  $t$  are the same as in the home scenario (see above),  $a_u(t)$  is the charge/discharge action in  $t$  (in kW) for the ESS representing user  $u$  flexibility,  $b_u(t)$  is the remaining capacity in  $t$  (in kWh) for the ESS representing user  $u$  flexibility, and  $\tilde{d}_u(t)$  is the resulting power demand after charge/discharge action  $a_u(t)$  (i.e., if  $d_u(t)$  is the forecasted demand in  $t$ , then  $\tilde{d}_u(t) = d_u(t) + a_u(t)$ );
- one file containing the input capacities for the ESSs representing users flexibility (see Section 1.6 for the format); thus, the file must contain a collection of  $(u, B_u(t))$ , where  $B_u(t)$  is the maximum capacity (in kWh) for the ESS representing user  $u$  flexibility.

**New Scenario** Submit a new home and/or a new substation scenario to be then selected when submitting a new execution (see Figure 3.3). Such combined scenario is provided as a text file (see Section 1.3 for the format).

Figure 3.1: DAPP service: search an already requested execution

Figure 3.2: DAPP service: requesting a new execution

Figure 3.3: DAPP service: adding a new scenario

# Chapter 4

## Conclusions

In this deliverable we described the third year versions of the prototypes for the SmartHG Demand Aware Price Policies (DAPP) Grid Intelligent Automation Service (GIAS). W.r.t. the second year version of the DAPP prototype, we removed the login page (to ease reviewers access to the service), we removed the figures visualisation (as this is offered by the SmartHG Platform Technical Section) and finally we adapted the input required by the DAPP service to the changes in the design (see Deliverable D4.3.1).

### 4.1 Impact

The Web services of each GIAS are important in order to allow users (mainly Distribution System Operators (DSOs)) to actually invoke such services in a clear and user-friendly way. On the other hand, the REpresentational State Transfer (RESTful) services behind such Web services are important to allow any Intelligent Automation Service (IAS) to directly and automatically communicate with other IASs. Thanks to this architecture, the SmartHG Platform may be directly used in an effective way by its final users, thus allowing all benefits described in Deliverable D4.3.1.

# Bibliography

- [1] “Demand Aware Price Policies (DAPP) Web Service: `mclabservices.di.uniroma1.it/dapp/`,” 2014.