*Smart system of renewable energy storage based on **INtegrated** E**V**s and b**A**tteries to empower mobile, **D**istributed and centralised **E**nergy storage in the distribution grid*

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Abbreviations and Acronyms

Acronym	Description
WP	Work Package
WPL	Work Package Leader
API	Application programming interface
BMS	Battery Management System
BPL	Business Process Layer
BRP	Balance Responsible Party
DES	Distributed Energy Storage
DMS	Distribution management system
DSO	Distribution System Operator
EV	Electric Vehicle
FO	Flexibility Operator
IED	Intelligent Electronic Device
OCPP	Open Charge Point Protocol
OSCP	Open Smart Charging Protocol
RTU	Remote Terminal Unit
SCADA	Supervisory control and data acquisition
SGAM	Smart Grid Architecture Model
SM	Smart Meter

Executive summary

This document describes the results of the feasibility analysis and the field devices integration work between field devices and the INVADE platform, starting from the SGAM architecture defined in other work packages and deliverables.

Different elements involved in communications platform from field devices to business layer have been studied and analyzed.

In later chapters, it is documented different preconditions for the systems involved:

- Customer Communications Interface – related to INVADE platform members status and control plan execution
- External information Providers – regarding flexibility on demand and metering data from DSO
    - In example, what type of factors are influenced in consumption or generation prediction, such as weather forecast, flexibility contracts or metering data of the DSO´s among other type of factors (market precies, etc.).
- Field devices – related to INVADE members and field devices integration
    - All field devices communicate with the INVADED system but these devices communicate directly through other systems. a continuation of the difference in the case of direct connection, as well as members of INVADE or other systems such as Pilot member. in the first cases, there should be a contract between this invade member and INVADE, but in the other case, the contracts are established between INVADE and pilot owners or DSO´s

1 Introduction

The objective of this document is to define the minimum viable product (MVP), a product that has just enough features to gather validated information about the product and its continued development.

It is also important to define all the preconditions needed and what is required in all the different actors of the project regarding field devices and INVADE platform.

This feasibility study is an analysis used to measure the ability to successfully complete the INVADE project, including all relevant factors involved in it. There are a number of important factors that affect the achievement of the project, such as technical factors (compatibility between systems), external factors (for example, weather forecasting) or some legal factors, such as the provision of user data in the INVADE system.

Some of these factors are analyzed in the following sections, such as those that affect the user interface both at the device level and at different control plan executions on these field devices.

Likewise, it is important to review those factors not only internal but also external to the project and to the systems that are part of INVADE, that act on its results, such as environmental factors or flexibility services from external DSOs.

2 System description

In order to have an overview of the whole project, it is good to know which is the general architecture of the systems that are described in the next sections.

The INVADE project, technically is focused around the INVADE platform that has been developed to collect all the data coming from the field devices of each pilot, as well as to establish a bidirectional communication between them and the upper layers (business and market layers) .

The following figure shows a general architecture of the project including all possible scenarios, from households with photovoltaic generation, storage, electric car and smart home devices to those technologies independently (EV parks, solar generation or storage for electrical substations for example) .

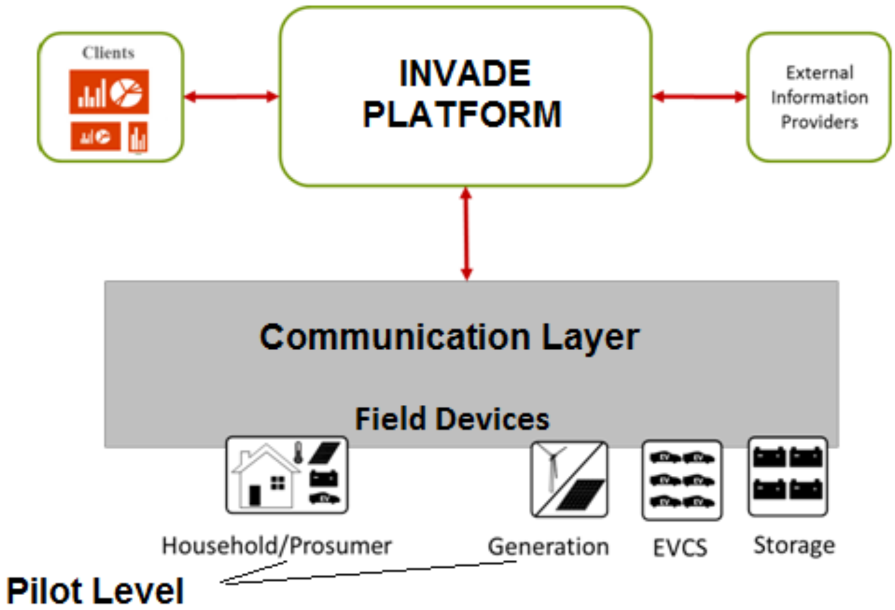

Figure 1.General INVADE architecture

The INVADE platform communicates with other higher layers to exchange electrical data from the field devices as well as to transmit the control commands to them.

Although every pilot is quite different from the others, it is possible to summarize them into a generic architecture.

In order to provide two-way communication between field devices and BPL (business Process Layer) layer, where the INVADE platform receives all the information from field devices as well as information from applications located in the business layer, various methods have been evaluated.

1. In the case of the system referred to the devices located in household sites, both Norwegian and German cases are included.
    a. Norway smart homes
    b. German smart homes – Hybrid case
2. For the rest of pilots, the main functionalities are focused on Storage, and EV use case (V2G, EV smart charging, Smart Substation and PV Generation)

2.1 Smart Home Use Cases

There will be smart devices installed at household level (with EV chargers, PV panels, and smart plugs), as it is detailed in the Norwegian pilot.

Norway:

- **Main Meter**

  All smart homes in Norway will use main meter data and integrate these data into the Smartly Cloud. The integration will be a cloud to cloud solution to provide the end customer data into the INVADE platform and otherwise.

- **EV Charger**

  Home EV chargers are manufactured by Schneider. The only integration with the Smartly cloud solution is done through the INVADE API.

- **PV panel/ inverter**

  Regarding the PV solution for the pilot, inverters from Fronius will be used. The Modbus TCP and Modbus RTU open interfaces are used in this case. The battery is used as a standalone solution.

- **Storage**

  Home batteries will be provided by Nissan/Eaton for residential use and they meet all requirements and regulations for batteries installed in a home environment, including all the flexibility services in the platform: Time of use optimization, KW max control and self-balancing.

Germany

Home Management System

Home management systems play a key role for the use of distributed energy storage. All pilot test sites will use the Sunny Home Manager 2.0 from SMA that enables an efficient use of solar energy as well as control of battery storages, wall boxes for EV charging and household appliances, so it´s opened for connecting different devices from other manufacturers. .

These devices provide a reliable and rapid communication between the meters (or distributed resources) and the INVADE platform about households' network consumptions, generation, etc.

2.2 EV smart charging, storage and generation

Spain

Spanish Pilot is based on a Storage Use case in a substation level.

- **Storage**

All the information exchanged between field device and smart meters and INVADE platform is established through an RTU in the substation that transform all the information from the WEB API to Modbus and IEC protocols to field devices

Bulgaria

Bulgaria has installed different technologies, as batteries, PV panels, and smart devices in the hotels.

These devices are from Schneider:

- **Gateway:** EGX100 as Master RTU (CPU)
- **Field smart meters** –Slaves: Used different models always connected using Modbus RS485 protocol→ PM3255 , PM500, PM9C, PM800, PM5110

The INVADE project architecture will be fully compatible with the already functioning energy and water SCADA StruxureWare Power Monitoring Expert in Albena.

The Netherlands

Dutch pilot is mainly focused in EV charging technology.

Different types of EV smart chargers are being analysed in the project. Different options will be carried out at the end of the project, for example, V2G, which is quite important and there is still not much development about this issue. Also storage is part of this pilot, that although is not part of the project this storage will be used to control and monitor power quality and other factors.

In order to perform bidirectional communication between physical devices and the INVADE Platform, there has been developed a group of web services (deliverable D7.2) that enable real-time communication between BPL and these devices.

These Services are based on OCMP protocol to connect their systems. Elaad will use this protocol, and Greenflux will use their own Cloud App to connect with INVADE platform.

3 Customer communication interface

The communication interface between the INVADE platform and the different devices is independent of the pilot, since only the type of device and the technology is what is being evaluated.

3.1 INVADE member – Controllable units´ status

INVADE platform monitors and logs all activity integrated in this level, where all the information comes from different type of units or systems (gateways, cloud apps, SCADA, etc.)

Definition of smart devices status is the current status of the controllable unit that will be finally part of the pilot, whether the unit is ON or turned OFF (either manually or due to the control plan execution) or what type of execution plan is required.

Apart from the type of connection or systems that the information comes from, these controllable devices will be presented in the INVADE platform indicating current status:

- Generation: production
- Load: consumption
- Charging point: consumption
- If the device is ON/OFF

3.1.1 Minimum Viable Product (MVP) – INVADE platform

- Presenting real time consumption, overall and pr. device
- Presenting real time generation, pr. device
- Presenting if the device is ON/OFF (status)
- Presenting if the charger is ON/OFF (type of charging)
- Optimize energy consumption based on hourly rate.
- Optimize energy consumption based on effect/power.
- Optimize utilization of self-produced energy.

3.2 INVADE – Control plan execution

If an INVADE member has a device which will be engaged in a control plan executed by the INVADE platform, this needs to be notified and presented with all the details of the interval that the device will be “controlled” by the INVADE platform. The end user needs to be aware of this and needs to agree with that.

The control plan execution can be applied to all of the components that are part of the INVADE platform, as EV chargers, smart home devices, storage batteries, etc.

When the execution plan is ACTIVE, the INVADE member’s controllable devices’ status will be updated with ON/OFF or current operation level. Later, it will be able to see a historical of the disconnections that have been executed.

3.2.1 MVP – INVADE Control plan execution

- Receiving push notification regarding the control plan execution, containing: unit, time and date for execution of control command
- THE Status device change to “ON/OFF” when engaged in a control plan.
- Presents historical disconnections
- Decline option. An INVADE user will have the option to manually decline the control plan notification when the notification is sent this user through the app. For example, this user cannot accept to stop charging its vehicle or changing to off the floor heating.
- When the device is under control, the app will indicate whether it is controlled by an INVADE control plan or manually.

3.3 Preconditions

To carry out this control plan execution, some recommendations are required for the end user:

- The user needs to have a smartphone, because the app requires a smart phone - either iOS or Android.
- Smart home devices have to be integrated with a Local Controller / Home automation cloud to be able to send and receive control commands from INVADE Platform

- The customer must be included into the INVADE system
- Dutch EV chargers need to communicate with INVADE platform on real-time due to Greenflux Cloud Software.
- Devices from Spanish/Bulgarian pilots need to communicate with INVADE platform using different types of SCADA systems.
- German Pilot connector is still not clear it is going to use SMA with the Web API defined in D7.2

4 External information providers

4.1 Metering data from the DSO

Metering data from DSO requires firstly that the DSO allows the INVADE platform to receive this information, and secondly that this INVADE platform can integrate it into this system. It will be dependant from different factors as, each country laws or the DSO rules itself.

For those customers who have a contract with INVADE, it should not be a problem of sharing metering data, trough smart home devices or smart meters inside households (not from DSO´s ownership). The main problem of using DSO metering data is time resolution and availability.

4.2 Flexibility control requests

As defined in other workpackages and deliverables, in example, D4.2: Architecture of pilots or WP5 regarding flexibility services integration, different flexibility services have been defined according to the requirements and needs of each pilot. (Deliverable D4.2 – INVADE architecture of pilots)

INVADE platform is capable of providing several flexibility services to prosumers, DSOs and/or BRPs.

Regarding the cases in which the DSO sends the flexibility commands, the DSO will send a flexibility request to the INVADE platform by using the Web API´s defined in D7.2.

The request can be positive or negative. Positive values are defined according to up-regulation, namely - increase in generation or decrease in load. Discharging of batteries also fall into this category. Negative values correspond to down-regulation, namely - decrease in generation, increase in load including batteries charging.

Defined in D4.2: all the flexibility services used in INVADE

Flexibility customer	Flexibility services
DSO	Congestion management
	Voltage / Reactive power control
	Controlled islanding
BRP	Day–ahead portfolio optimization
	Intraday portfolio optimization
	Self-balancing portfolio optimization
Prosumer	ToU optimization
	KWmax control
	Self-balancing
	Controlled islanding

Table 1: Flexibility services to be used in INVADE

These different actors receives orders from the INVADE platform to adapt the consumption/generation of the different devices (EV chargers controllers, PV inverters, smart home gateways, etc.).

4.2.1 MVP – INVADE Flexibility Services

- Presenting a website where flexibility requests can be posted, which will be received by the INVADE platform based on fixed parameters.

4.2.1.1 Preconditions

- Specified contract between INVADE and Flexibility Operator, customer or DSO
- DSO will send requests based on DSO’s own analysis, thus the reasoning behind request is irrelevant for the INVADE

4.3 External Weather forecasting

For different pilots, as Netherlands or Bulgaria, the information provided by external weather companies is quite important for the forecasting of the Energy generation – consumption – balancing, so this is quite a important point to take into account.

Expected external forecasting are:

- Weather forecast and temperature observations
- Solar observations and predictions

4.3.1.1 Preconditions

- Relevant external forecasting systems exist and will be able to integrate towards.

4.4 Market Prices for Energy Consumption

A homogenised market price for the EV chargers is very important in order to provide a correct charging to the customers regarding payments in €/KWh.

- In the case of the **Netherlands** pilot, the market prices from the day ahead market are publicly available via an API. This data will be imported with INVADE platform.

In the case of the other pilots the market prices are sent to INVADE this way:

- **Spain**
  - These market prices are acquired thanks to eSmart. Estabanell will buy weather and price data for the optimization algorithm from an external data provider of eSmart;
- **Bulgaria**
  - In the Bulgarian pilot, the energy prices are important part of the self-optimization process. The energy prices at the day-ahead market are key for the optimization algorithms and therefore will be automatically sent to the IIP by API from the Independent Bulgarian Energy Exchange (IBEX).
- **Germany**
  - EVs are not quite common in Germany today due to insufficient tax subsidies. Therefore, in the German pilot only in two participating households EV-chargers are planned to be installed. Today the energy for loading an EV is charged the same way as the regular consumption of the household. All energy consumption is running over the same (simple) meter and is charged with identical price. The price is calculated in the year before taking into account the forward prices on the European Energy Exchange (EPEX) and the forecasted consumption of all customers. The price is valid for one year. Shorter periods are possible but not usual. Time dependent fees do not exist in

the small customer segment due to the lack of smart meters in Germany. So market prices from the day ahead market could be sent via an API either directly by the European Energy Exchange (EPEX) or by the energy supplier. This data could also be shared with the INVADE platform. But it is not really relevant for the real case

- **Norway**
    - The case of Norway is similar to Netherlands but the prices are established by **Norwegian Power eXchange Norpool**

5 Field devices

5.1 INVADE member – (Actor with a contract with INVADE project)

INVADE member is referred to those customers or entities that have a contract with the project INVADE and eSmart in order to send their data to the platform, in order to be available to other business and market applications.

There are no members with a direct contract with INVADE, as there are no customers that sends their data directly to the platform, because in each of the 5 pilots end customer data are collected and send using pilot owners capabilities.

Data shared with the INVADE platform/eSmart will be anonymized. eSmart will only get information about end customer (household, EV charger, storage, etc.) with random identifier. eSmart will not get any personal or location information.

5.2 INVADE Pilot members

As discussed in the previous section, the possibility of making different tasks of integration between different systems (pilots) involved in the project has been studied and analysed.

Different developments and interface software have been carried out to integrate the end field devices to the final platform in all the pilots.

5.2.1 Norway

The INVADE platform will receive all the customers metering data from the Smart Home Automation Cloud app from Lyse. All devices are connected to the Smart Home automation Cloud and these data will be sent to the INVADE platform.

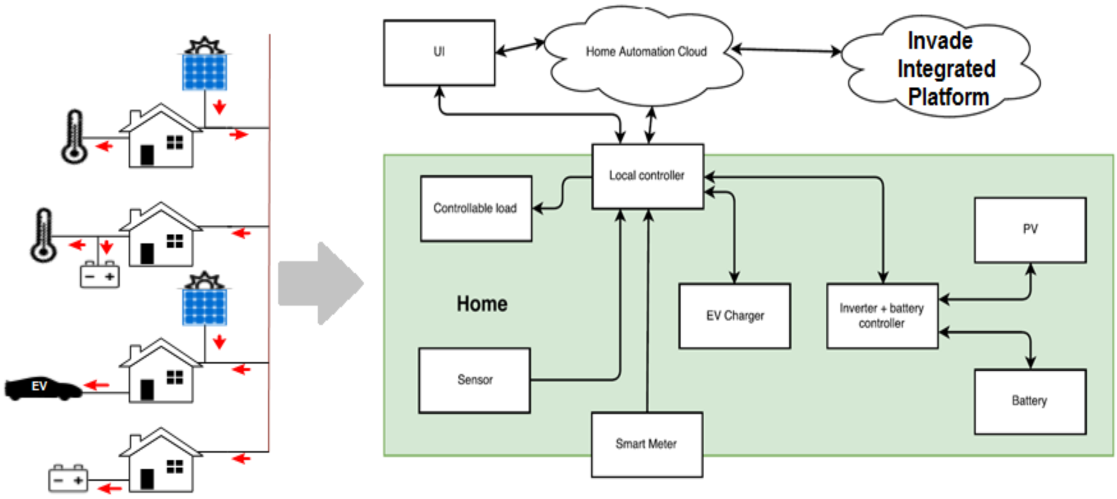

Figure 2. Norway Generic architecture

All the different distributed energy resources are connected to the INVADE platform through the Home Automation Cloud, so no direct connection are available between smart meters and INVADE platform.

5.2.1.1 Preconditions

- End customer has an agreement with Lyse to share its data with INVADE
- Personal customer data will not be shared with INVADE, only consumption data.
- Home Automation cloud establishes a bidirectional connection with INVADE platform using the Web API defined in deliverable D7.2.
- Customers data can come from:
  - Smart home devices
  - PV panels
  - Storage

5.2.2 Netherlands

Dutch Pilot is mainly focused in EV chargers

- Household level
- Private Office Spaces
- Public domain

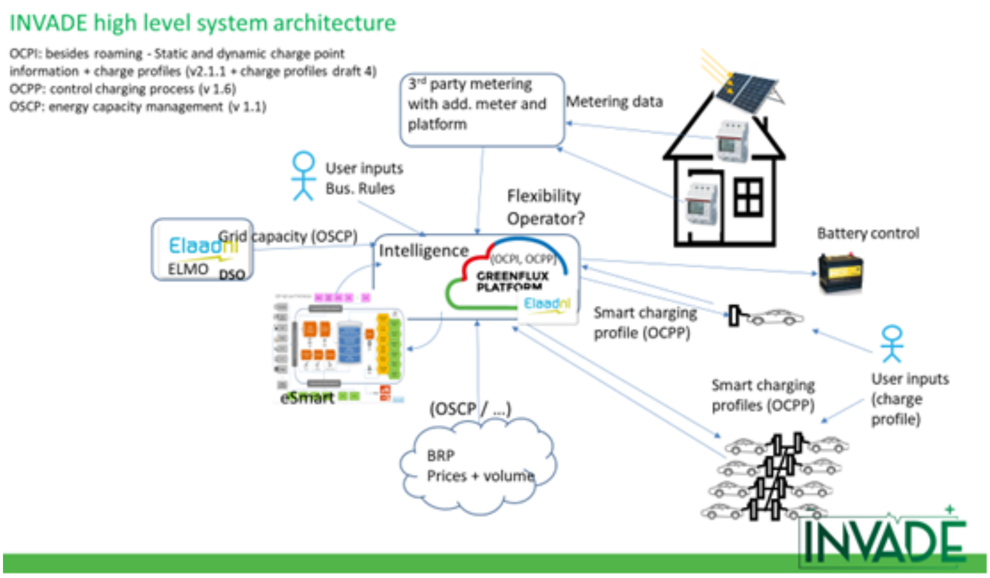

Figure 3. Netherlands Generic architecture

All the electrical information related to the charging will be collected by Greenflux Platform and will be sent in an anonymous way to the INVADE platform.

5.2.2.1 Preconditions

- Charger ID is part of the INVADE
- EV customers will not be shared with INVADE
- Greenflux and ElaadNL will interconnect in a bidirectional way with the INVADE platform using the protocol OCMP

5.2.3 Bulgaria

To integrate field devices in the different hotels, a software installation and development have been required, as well as to connect these devices to the Albena SCADA system via Modbus protocol.

As this is a standard protocol, the SCADA system has integrated a connector to understand the information coming from the different field devices (controllers).

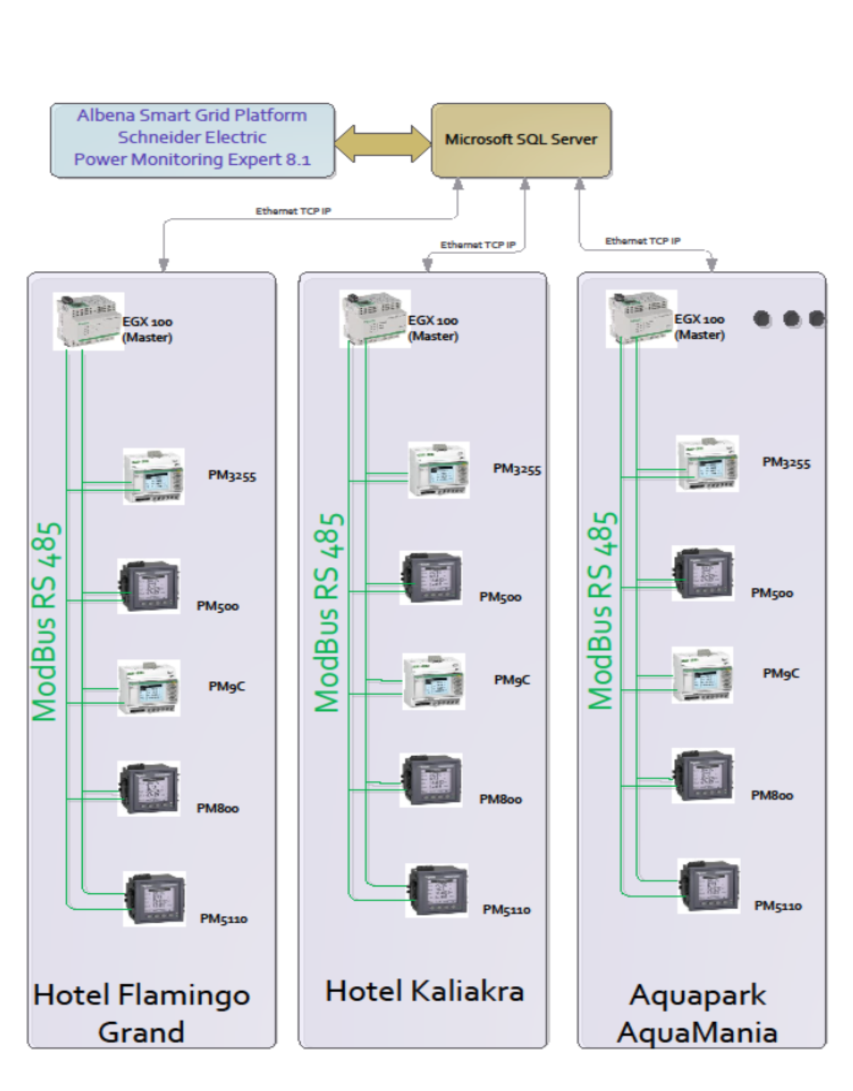

Figure 4. Albena generic architecture

In addition, by utilizing a standard protocol future developments and integrations will be easier to adapt and export which should again be more economical.

5.2.3.1 Preconditions

- For all field devices (EV chargers, storage, generation) the same main functionality is required
- SCADA is connected in real time with every device controller and INVADE.
- The main functionalities required are:
  - Bidirectional communication in real time between the INVADE platform and field devices.

- Periodic sending of electrical measurements
- Real time Command from INVADE to field devices
- Energy values reading on demand, as state of charge, energy, power, etc.
- Minimum logical intelligence within the communication platform
- Operator monitoring tool for smart grid.

Different DER devices are connected to the SCADA communication platform using Modbus TCP.

Within the SCADA, they have developed a series of API connectors (web Services – JSON messages) to communicate in real time with INVADE using the communication bus Event Hub Azure from Microsoft.

All data sent from the SCADA system to the INVADE platform will go through this communication bus.

5.2.4 Germany

The German pilot focuses on a hybrid approach. It will create one centralised energy storage (CES) device on one hand as well as connecting distributed energy storages (DES) in private households on the other hand

1) <u>CES</u>

The communication interface to the INVADE platform will already be installed within the battery system. INVADE will retrieve data not only from smart meters but also from the battery management system.

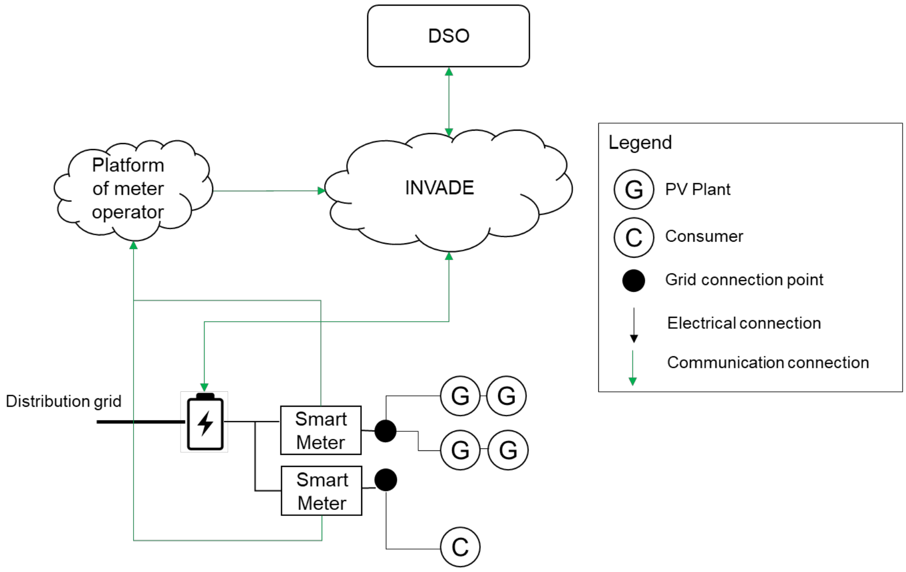

Figure 5. CES Germany Case

2) <u>DES</u>

All components and devices (battery, household devices, PV and possibly charging points) will be controlled by the Sunny Home Manager.

Sunny Home Manager will retrieve commands from the INVADE platform via the newly installed **gateway** to control the energy consumption at the grid connection point as requested by the DSO.

- The DSO sends commands to the INVADE platform, if flexibility is required.
- The INVADE platform enables the DSO to use the flexibility potential of the DES.
- INVADE directly transfers control requests to a newly developed product of SMA, a gateway, which will be installed next to the already existing Sunny Home Manager acting as the local control unit.
- The gateway stands as a communication interface between the INVADE platform and the Sunny Home Manager.
- Control requests are sent from the INVADE platform to the gateway which transfers the commands to the Sunny Home Manager finally executing these commands.

- Information related to the households (PV-systems, battery, maybe wall box for charging an e-vehicle) will be provided via the Sunny Home Manager and an explicit API for INVADE (connection between the SMA Sunny Portal Professional and the INVADE platform).

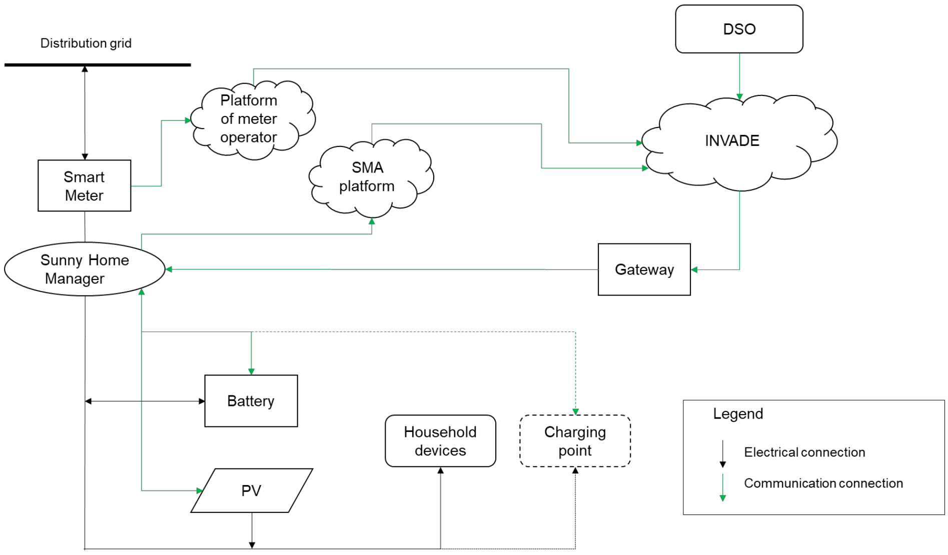

Figure 6. DES Germany Architecture

5.2.4.1 Preconditions

- Households need to be part of INVADE project with some kind of contracts (or contract between DSO and INVADE
- Regarding flexibility services and operations, when INVADE project´s period is over, the home management system takes over again and recalculates the operational scheme of all devices to return to a regular operation mode
- Flexibility requests will always be limited to a certain time frame.
- In all participating customer households, local gateways will be installed for the project
- Personal data will not be shared with INVADE Platform

5.2.5 Spain

The Spanish pilot focuses fundamentally on the installation of a substation as well as all the components that are part of it, such as storage, RTU's relays and other intelligent IEDs that collect all the information of the electrical network and transmit it towards the SCADA, in the control center which communicates with the INVADE system. Inside the Substation, there will be information from:

- Storage – Batteries (Battery Management System)
- Relays – and other IED´s (field devices in substation)
- Power electronics
- Other devices

All these devices are interconnected by using a RS485 Modbus protocol, and all the information and commands are mastered by a gateway – RTU PRX.

This RTU is managed by a SCADA in the operation centre.

The connection between INVADE platform and the field devices is made through the SCADA.

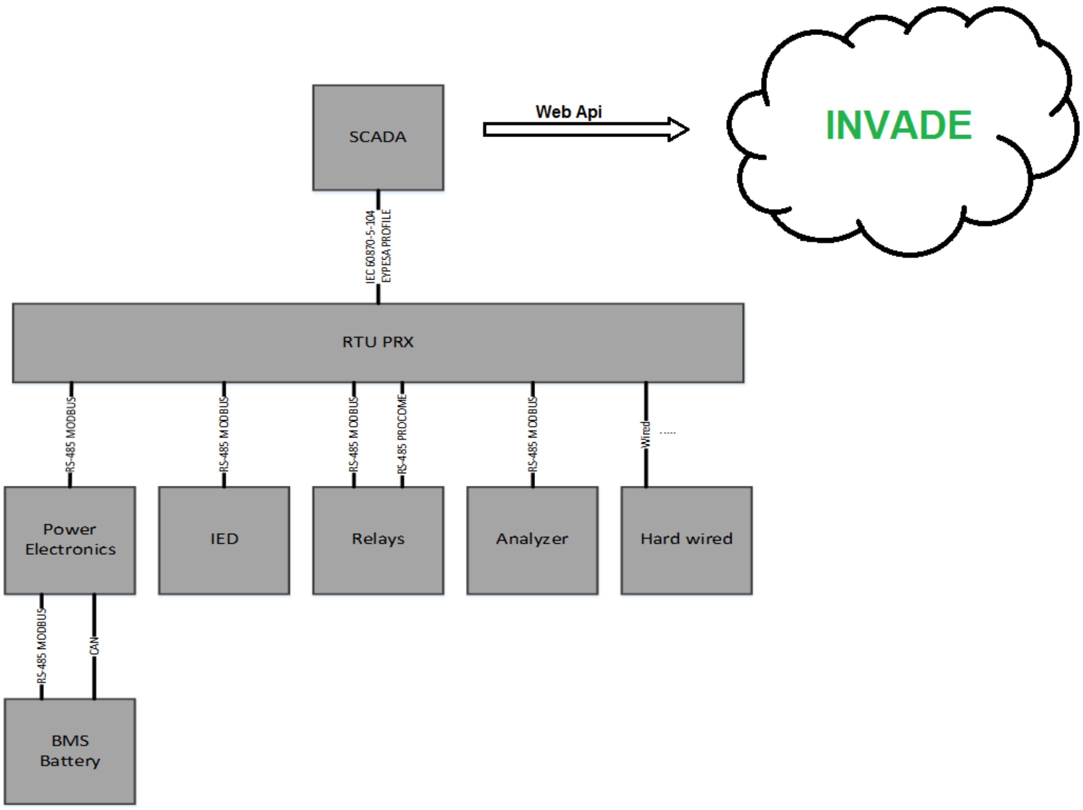

Figure 7. Spanish Architecture

5.2.5.1 Preconditions

- Standard protocols are used in the field devices in order to provide higher level of scalability to the system.

- No personal data from the customers from the substation will be shared with the INVADE
- SCADA and RTU can provide a bidirectional real time communication between field devices and INVADE platform.

6 Conclusions

The aim of D7.3 is to describe and document that the methods of communication and integration between the INVADE platform and the different pilot members (households, EV chargers, storage and generation) have a high reliability and are secure, and thus further supporting the chosen communication and integration methods in the project.

Some factory acceptance tests have been made for these pilots and connectors. However, some improvements will still be necessary until the end of the project according to the final equipment installed on site. These tests will be part of the pilot testing in WP 10.

Connection tests have successful results in establishing a real communication in both ways between field devices (using SCADA, Gateway or other middle systems) and INVADE platform.

For all the pilots and members there need to be defined a list of preconditions but a general one is that no personal data from the pilot customers are shared in INVADE platform and business or market layer in the project. These data belong to countries' DSOs.

7 References

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