UPGRID PORTUGUESE DEMO – MARKET CHALLENGES (IN) THE POWER GRID

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ABSTRACT

With the increasing penetration of market driven distributed resources, namely decentralised generation, in the distribution networks, the operations become increasingly challenging. From the perspective of the DSO, it is of utmost importance to develop the right tools to deal with these challenges, in order to maintain secure, stable and efficient operation of the network, while assuming the role of market facilitator providing data to the market players. The architecture developed in the Upgrid Portuguese Demo will connect prosumers, retailers and the DSO, in order to allow an integrated management and operation of the electric grid with all these actors and the associated resources, thus enabling the growth of decentralised generation and distributed energy resources.

INTRODUCTION

This paper describes a market driven architecture, developed under the Portuguese Demo of the H2020 UPGRID project, which addresses the power grid flexibility challenges, with the integration of Demand Side Management (DSM) and Distributed Energy Resources (DER).

The Portuguese UPGRID demo, which is integrated over the national Smart Grid project InovGrid infrastructure, led by EDP Distribuição, is being tested in the parish of Lisbon, with approximately 14 000 customers, 2 primary substations, over 200 secondary substations and 16 EV charging stations. The project's architecture is composed by the market hub, the retailers' platform, the DSO grid and the customers. This architecture allows the DSO to communicate through the market hub in order to mitigate the constraints of the LV power grid. This is achieved by different tools: 1) a system of dynamic pricing supported in a home energy management system; 2) a load and generation forecasting tool, which provides information about grid constraints and flexibility needs, 3) a low voltage network management system (LV NMS) that includes several tools, such as:

- Optimum Power Flow (calculation of the optimum power flow for a given set of secondary substations – DPLAN UPGRID);
- Grid Infrastructure's Data (constraints due to overloads; maintenance services; asset failure);

As a result of the implemented architecture, the operation of the grid is improved. The outcome of this architecture is a set of additional tools to effectively manage the power grid and optimize the power flows, thus leading to a more efficient, flexible and resilient network. The customers will also benefit from this new architecture, since they will have access to their consumption profiles, the possibility to make load shifting with economic benefits, a better power quality and the possibility to efficiently use a wider set of DER (from PV generation to EV charging).

ARCHITECTURE & CONTROL LAYERS

Smart Grids Infrastructure

The architecture developed in the UPGRID Portuguese demo was built on top of the already existing InovGrid infrastructure [2].

The InovGrid Project Architecture of EDP Distribuição is divided in three parts (when considering the data management):

1. Metering infrastructure (LV network);
2. Secondary Substations (MV-LV);
3. Central systems.

The metering infrastructure, constituted by the EDP boxes, provides a set of functionalities (both technical and commercial) that comprises measurement of the consumption, load curves, control of the contracted power, events and alarms. All these functionalities are available remotely through the PLC PRIME or GPRS technology.

In the secondary substation is located the DTC (Distribution Transformer Controller), which acts at two levels:

1. As a data aggregator (providing access and collecting data from the EDP boxes);
2. Monitoring the secondary substation (measuring the electrical measurements of the sec. substation, events, alarms and automation).

In the third part of the architecture come the central systems, which allow the integration of the InovGrid infrastructure and the associated functionalities in the business processes, such as the technical management of the distribution grid, through the AMI, as well as its integration in the various corporative and technical systems of the company.

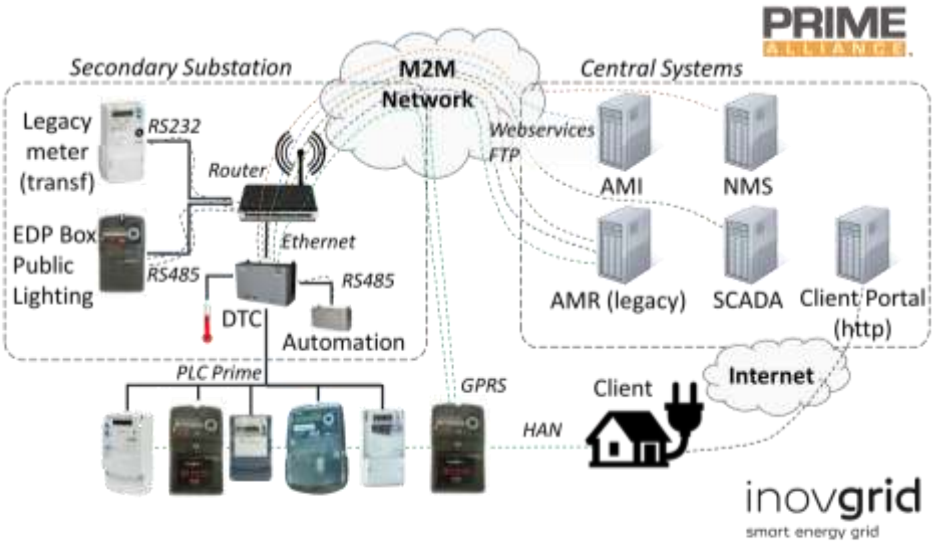

Figure 1 – InovGrid Architecture

DPlan UPGRID

In the context of the UPGRID Portuguese Demo, one of the main tools that has been developed is the DPlan UPGRID, which is a LV network planning tool that aims at supporting the LV network operation, by running the power flows of the network based on real time measurements obtained by the InovGrid Infrastructure. Besides the real time data, (i.e. load curves of EDP boxes or DTCs), forecasting models will also be used to feed the DPlan UPGRID with predictions of consumption/generation.
The integration of these functionalities in a low voltage dispatch centre will allow the operator to anticipate constraints in the LV network, allowing him to act in a preventive way, thus mitigating the risks of power outages and assuring adequate operating conditions for the network.

Market Hub, Retailers Platform and Home Energy Management System (HEMS)

The Distribution System Operators (DSOs) have an important role to foster retail markets. They should operate as facilitators for competitive markets [1]. Therefore, DSOs can provide infrastructures or services that promote new business models. This will make the most of Smart Grid development, increasing operational efficiency and reducing operation and maintenance costs through the promotion of customer engagement.
For this, it is important to develop platforms and systems that enable market agents/customer participation. The market architecture must promote an open and fair access, aiming at cost optimization and market competition.

The *Market Hub* (MH) will be the interface between the DSO and the different market agents (Retailers, Aggregators …)[3]. The platform will provide data and information to the market (e.g.: dynamic tariffs, contracted power), offer the possibility of flexibility requests to be made (e.g.: Load shifting) and will also receive information about available flexibility and post-action load shifting response feedback.

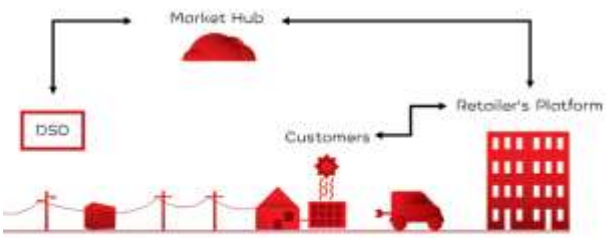

Figure 2 – Market Players

The MH will allow different stakeholders (Regulators, TSO's, Universities and Research Centres, etc.) to access the information with different levels of access. This will contribute to higher transparency and potentiate even further developments of the Smart Grid concept as a market facilitator.
The different market agents will require a platform that can receive all information provided by the MH (client's overall demand, local/regional/national demand), aiming cost reduction through a better portfolio management and energy efficiency and also aggregate the flexibility from customers. This platform is called *Retailers Platform* (RP). Each agent should have its own platform and will have access to the same information from the *Market Hub*. The

agent will define rules and objectives to actively participate in the market, aiming at maximizing customers' benefits. The RP will be configured according to these rules and it will also access the flexibility in its own portfolio of clients to respond DSO requests. In the Demonstrator, a unique RP will be developed.

The *Home Energy Management Systems* (HEMS) will be the hub inside customers' houses. It will communicate with the RP, giving feedback on equipment status/availability. HEMS will also have access to almost real time information from the Smart Meter (e.g.: consumption, active power). It monitors and controls loads, fully taking advantage of customers' engagement.

Integrated architecture

The main challenge of the UPGRID Portuguese Demo is the integration of all the functionalities (with the purpose of monitoring and operating the LV network), using not only the DSO infrastructure, in this case the InovGrid Infrastructure, but also involving other agents in that process, such as the retailers.

To achieve that goal, an integrated architecture was defined based on three pillars:

1. DSO;
2. Retailers;
3. Customers

Despite the fact that already exist interfaces between the DSO and the consumer, UPGRID also aimed at developing an interface between the DSO and the retailers, under the name of Market Hub (see Figure 3). This platform allows to communicate with the market, thus allowing an active involvement of the different agents in the operation of the LV network, always under the coordination of the DSO.

Besides the operation of the LV network, and with the purpose of defining a new approach for market design, this integrated architecture will also allow to share information with several market players, making possible the development of new services.

USE CASES

In order to illustrate the potential applications of UPGRID's Portuguese demo architecture, three use cases are presented.

Dynamic Tariffs

It's in UPGRID's Portuguese Demo scope to test dynamic network tariff schemes of residential customers. For this purpose, an action plan was developed comprising four main steps of analysis. First, an analysis of real-time consumption, using the data provided by the smart meters installed, to identify the peak hours of network use. Based on this information, the second step will be to check which tariff schemes - among Time-of-Use and Critical Peak Pricing options – can give the best response to lower peak consumption and promote load shifting. Thirdly, we will choose the prices for the scheme in a way that ensures the revenue recovery stability for the DSO. To do this, the baseline revenue coming from the sample shall equal the revenues generated under the current tariff schemes adopted by the customers. The customer savings will be related to the levels of load shift and peak consumption decrease. Finally, we will quantify the success of these schemes through a set of KPIs, which will be related to the impact of dynamic tariffs on consumption, mainly in peak hours. On the other hand, a subset of customers will have a Home Energy Management System (HEMS) installed, and the DSO will be able to control the customers' load, in case of network congestion. An important issue is that these experiments will require the acceptance by both the customer and respective electricity supplier (retailer).

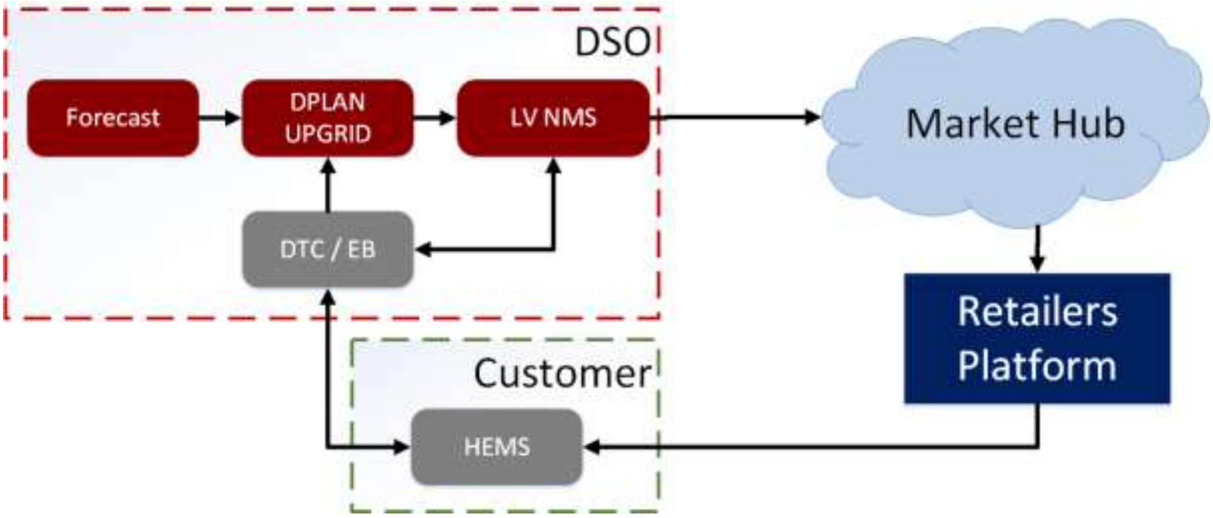

Figure 3 – Integrated Architecture of the UPGRID Portuguese Demo.

Contracted Power

This Use Case will test emergency actions that the DSO may need to take to keep a stable grid operation. The rules for these actions should be clearly defined and should only be taken as last resource.

In this situation, the DSO sends an order to reduce the maximum active power of customers in the affected grid area. A percentage of the total contracted power will temporarily be reduced. The DSO will send the order through its own systems to the Smart Meter. This action is defined in the Smart Meter specifications and will be controlled by DSO systems.

If no additional actions are made customers may be turned off grid, with negative impact for customers.

Leveraging on the designed architecture and in order to reduce the impact of such measure, the DSO can also inform market agents of this action.

The procedure is done by creating a parallel information channel where the DSO sends the same order to the MH.

Having access to the MH, the RP will be able to immediately readjust their client's loads not to exceed the new defined maximum power.

The HEMS will receive the information (both via Smart Meter and RP) and will cut off excessive load. This action needs to be fast to be effective.

When the operations are back to normal, the DSO will reverse to the original situation, informing the MH and market agents of such measure.

Load Shifting

In this use case, an alternative measure to decrease the energy consumption during peak times is proposed.

Facing overloads or technical constraints in a certain area of the grid, it might be critical for a secure and safe operation of the network to reduce the power consumption. Following the architecture developed, the DSO communicates the issues detected to the market hub. As the central data manager, the market hub provides this data to the retailers. The retailers will interact with their clients and act on the HEMS, upon the following:

- The customers establish a set of conditions to define the loads that are flexible, the time frame for this flexibility, and the priority associated with each load;
- The previous information is received by the Retailers Platform and selects the HEM Systems that should be activated, that is, act on their loads, according to the need.
- The information concerning the action taken by the RP is sent to the DSO via the market hub.

Whether the total flexible power available allows to meet the requirements of the DSO, it is up to the Market Hub to confirm it. In case it is enough, the MH sends the command to the RP, which will, accordingly to its customers' conditions, select the loads that should be shifted. The information of the loads that are effectively shifted is then sent to the RP.

The RP receives the information from all the HEMS,

aggregates it and sends it to the Market Hub. After the technical constraints or the overload issue is gone, the loads should go back to the normal operation conditions. This action should be guaranteed by the HEMS, which will receive information from the RP, which receives from the Market Hub, and this last one from the DSO.

CONCLUSION

As an overall conclusion, it is clear that the developed architecture reinforces the central role of the DSO in the future electricity system, and its connection to the market agents and consumers. A true Smart Grid will leverage on: i) knowledge about grid users' capacity to provide flexibility; ii) on the DSO capability to manage on-line data and interact with this grid users, using the flexibility when needed, and iii) facilitate the market, ensuring a neutral data access to relevant agents.

The DSO will thus assume evolving roles as market facilitator and data manager promoting a market driven architecture, having the market hub as the platform that allows to provide flexibility for the grid through the cooperation between the technical side (DSO) and the commercial side (Retailers).

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