AlpEnergy

Tecnologia e ricerca
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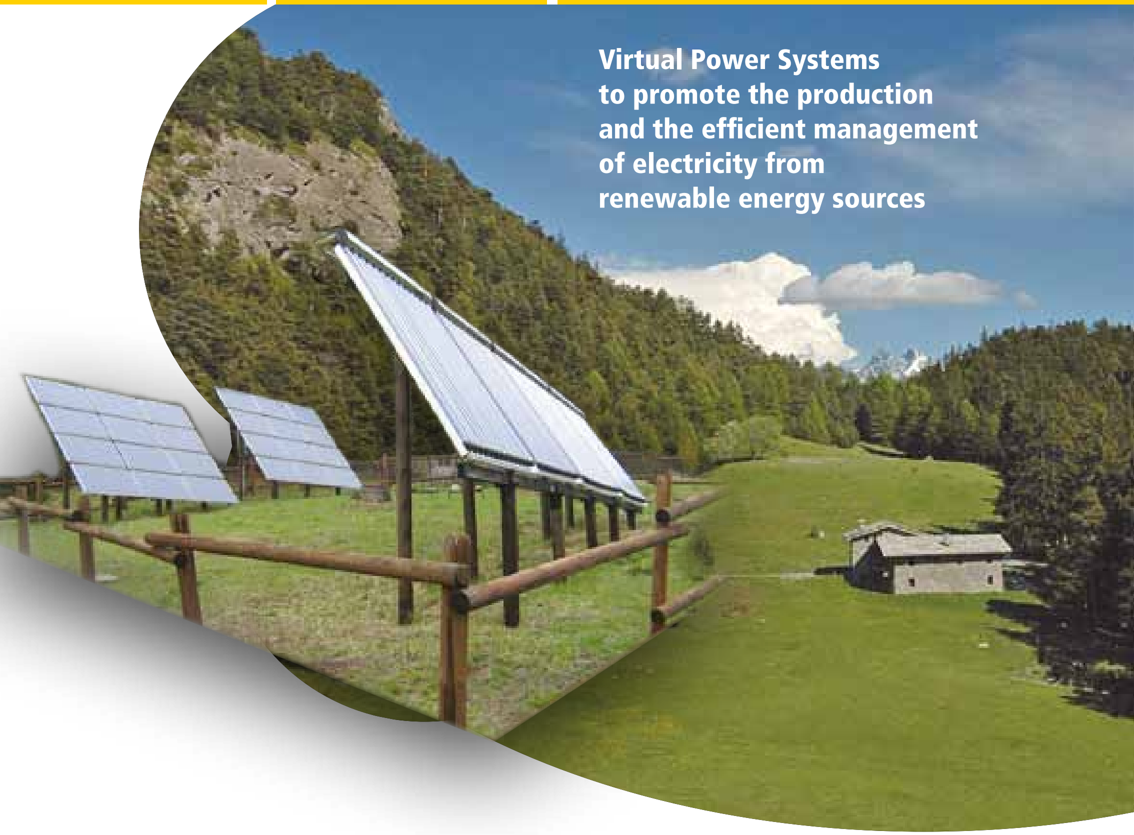

Virtual Power Systems to promote the production and the efficient management of electricity from renewable energy sources

The experience of the partner Valle d'Aosta and the Saint-Denis pilot project: advanced monitoring, "demand side management" and storage systems for the distribution grid of the future

Alpine Space
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Région Autonome Vallée d'Aoste
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ALPENERGY

Summary

Introduction

AlpEnergy is a european territorial cooperation project funded by the Alpine Space Programme 2007-2013. AlpEnergy aims to increase the competitiveness and attractiveness of the regions involved by studying the potential and applicability, in the Alps, of a new technological paradigm in electricity distribution, usually known as "Smart Grids", that the project has framed and redefined with the introduction of a new concept: **Virtual Power Systems (VPS)**.

The regional Ministry of Production activities, project partners from December 2009, has produced this brochure to illustrate the technical issues addressed by the project and the pilot implementation carried out in order to test some advanced technological solutions in the field of VPS.

2.

New challenges for the electrical system

In the last few years, the production of electricity from renewable sources (solar, wind, hydro, biomass, etc..) has grown exponentially and in the near future, under the pressure of the European goals of 20-20-20, is intended to develop further. The existing grid, designed to deliver electricity from large power plants to users (i.e. from high to medium and low voltage), is not prepared to receive a high power production, in the opposite direction, generated by diffuse renewable sources.

Renewable energy sources have, among their characteristics, also that of being discontinuous and non-programmable and, often, the generation of energy is not contemporary with respect to consumption. Considering that electricity can be stored cheaply with difficulty and the long-distance transmission of the surplus generates heavy losses, generation and consumption must be, as much as possible, simultaneous and local. In addition, diffuse generation can cause grid overload problems with failures and risks of mini blackouts.
For the system these aspects introduce new challenges in managing the grid that must adapt to new demands of a more rational use of energy and new rules for buying and selling the surplus produced.

The AlpEnergy project accepts this challenge with the aim of analysing and testing possible technological and economical solutions for the development of electricity distribution networks in an area as difficult as the Alps.

3.

What is VPS?*

VPS is a system of distributed power production and consumption linked by an electricity network (typically a distribution network), suitably completed by a communications system (electronic network). The spatial extension of a VPS may vary from very small settlements to entire countries.
The elements forming a VPS can be concentrated in one area or spread over a larger area, they can determine the whole electricity supply and consumption of an entire area or only the electricity generation in, and consumption of, a few facilities within an area.
The existing electricity supply system is of course also a system of power production and consumption linked by an electricity network and suitably completed by a communications system. The first distinctive feature of a VPS compared to the existing electricity supply system is that the power production is more distributed, i.e. provided by a larger number of smaller units, and mainly based on renewable energy resources including combined heat and power plants (CHP).

- **It is mainly the intermittent nature of solar and wind power**

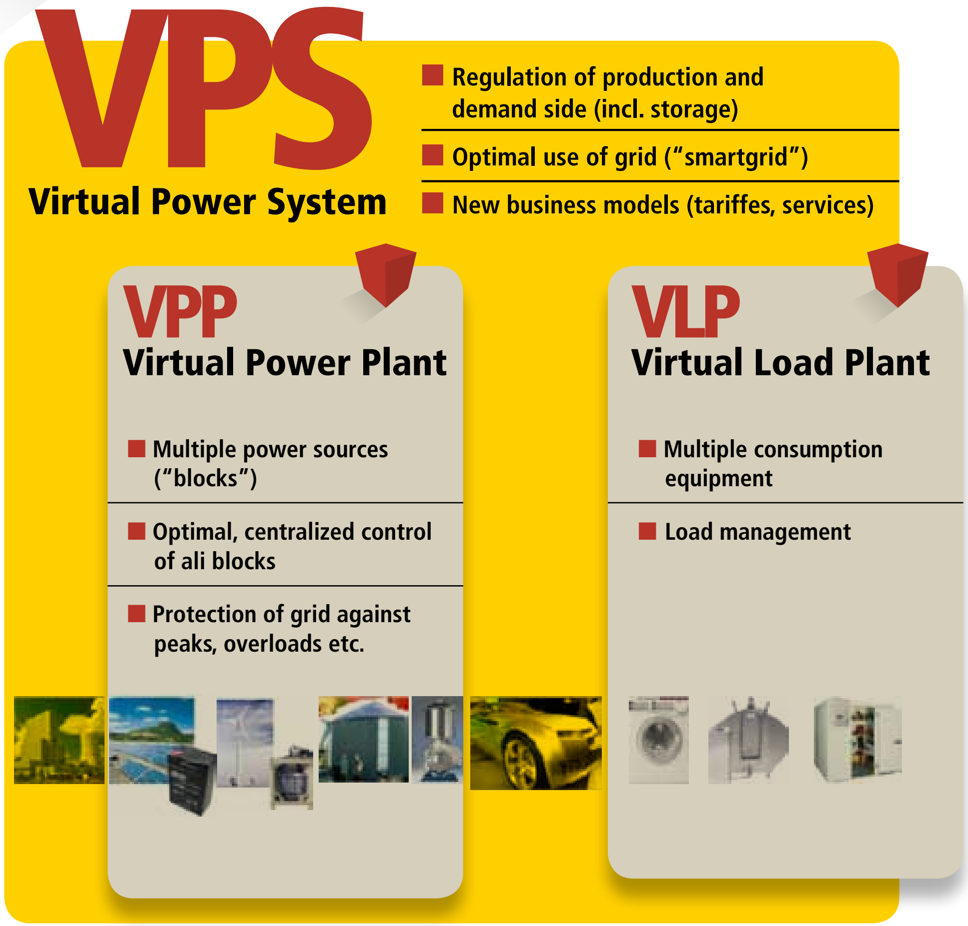
- **and the generally smaller size, and therefore distributed location, of almost all renewable power plants compared to most conventional power plants which make the consideration of VPS necessary.**

Consequently, VPS concerns mainly, but not exclusively, the distribution part of the electricity grid system.
In a VPS, the power supply is typically provided by more than one renewable technology and by more than one power plant. All the generation resources can be summed up in a single energy production profile. If a VPS comprises only production facilities, but no consumption units, it is called a Virtual Power Plant (VPP). A VPP represents a boundary case of a VPS.

* Extract from Chapter 3, paragraph 3.1 of the document "***Virtual Power Systems White Book***", developed within the activity of analysis and modeling (WP4) of the AlpEnergy project and fully downloadable in English language, at the link http://www.alpenergy.net/images/stories/White_Book_VPS.pdf

A Virtual Power System integrates, manages and controls distributed energy generators and storage capacities and links their technical operation to the demand of consumers and the energy market.

A VPS comprises a number of consumption units whose power demand is measured and can be actively controlled. This is the second distinctive feature compared to the existing electricity supply system which is widely lacking communication infrastructure in the distribution grid and does not allow active control of most consumption units. The loads can be aggregated to shape a single power consumption profile. If a VPS comprises only consumption units, but no production facilities, it is called here a Virtual Load Plant (VLP). A VLP represents the boundary case of a VPS opposite to a VPP. In Figure 1 is provided a graphical representation of these concepts.



However, a VPS in the full sense comprises power production and consumption units which are jointly managed (in terms of energy and/ or power balance) in order to get extra benefits. It exploits a proper communications network, in a wider perspective a tailored ICT system, for managing electricity generation and consumption (e.g. for balancing as far as possible generation and load time profiles) in order to maximize these benefits. An additional support for better balancing production and demand can come from the efforts to reduce electricity demand while maintaining the same living comfort.

The VPS may also include energy storage units for improving its performance with regard to synchronizing electricity generation and consumption. Storage units in the proper sense convert electricity after it has been generated into another form of energy (chemical, rotational, pressure, etc.), store the energy in that other form, and reconvert it into electrical energy.

Two other forms of storage options can be identified along the energy conversion and use chain:

- **Storage of energy before conversion into electricity, e.g. in the form of biomass or water in barrages (limited option and already widely used)**
- **Storage of energy service (heat generated by heat pumps, cold generated by cooling de- vices, charged electric vehicle) after provision by electricity.**

The second option is the most promising and up-to-now represents only a very little explored option. It is very attractive because it makes use of storage units which are inherent to the load, such as cold rooms which inherently store cold or heat storage tanks of heat pump systems. Making use of the storage of an already provided energy service requires however that the load can be controlled, i.e. the second distinctive feature of a VPS. For this reason, this form of storage is generally called load management.

[2] In many publications VPP designate not only a system comprising exclusively electricity generation facilities, but also systems including consumption units. However, the definition of VPP is not homogeneous and clear throughout the literature. For this reason, the name VPP is in Alpenergy reserved for systems comprising generation, but no consumption facilities, whereas the new name "Virtual Power System" is introduced for underlining that a combina- tion of generation and consumption is meant.

4.

The project Alpenergy in Aosta Valley

For the implementation of activities, the regional Ministry of Production activities, given the technologically advanced environment that characterizes the VPS, decided to seek the scientific advice of the Laboratory of Mechatronics at the Polytechnic of Turin (CSPP-LIM) that operates in the campus of Verrès in the Aosta Valley. This collaboration has brought into focus the study and experimentation on some technical aspects that underlie the development of the VPS:

1. **the advanced monitoring of loads and production from RES (in particular solar PV);**

2. **the testing of some methods of load management (demand side management);**

3. **The reduction of absorption peaks (peak shaving) through the use of battery storage systems.**

The territory identified for the pilot implementation is the Municipality of Saint-Denis, a typical scattered mountain village with about 370 inhabitants and a territorial extension ranging from 500 m to 1500 m asl.
Starting with an ideal long-term model of VPS focused on the pilot municipalities, the project centres, therefore, on the development of certain parts: from the monitoring and analysis of data consumption and production from RES, up to the implementation of different modes of load management and storage systems.
One of the most important objectives is the social impact of the project, which will ensure the availability of users to embrace a new concept of efficient use of energy resources available locally. The test does not heavily affect the electricity infrastructure in private households and does not require modifications on the existing distribution grid. Rather, it focuses on the interaction with the load that, responding positively to communications given to it, will contribute, together with the energy storage system, to the control of power flows on the network and the coordination between production and consumption of energy at the local level, both functions essential for the operation of a VPS.

4.1 Advanced monitoring

photo 1

Thanks to the cooperation of the municipal Administration and 24 volunteer citizens who have made available their households to the project, a monitoring infrastructure was developed capable to sample, in a detailed and real-time way, the consumption of 2 public facilities (City hall and Lavesé eco-friendly centre), 24 private buildings and the production of four photovoltaic plants (3 public and 1 private).
For this purpose 27 "data logger" - NxN GT-621 - (see photo 1 and 2) were installed, able to sample consumption and production every 2 seconds read by the current transducers connected between the electronic electricity meter and the safety switch of the electricity system. The data were first recorded in the internal memory of the device before being sent to the central server via GPRS. Each module is, in fact, equipped with a SIM data that allows it to use the GSM/GPRS net for transmitting data and SMS. From the analysis of different communications infrastructures available in the area, the cellular network resulted as the one able to ensure the greatest territorial coverage in addition to allowing the use of an instant messaging service for the subsequent phase of load management.

photo 2

The data, sent over the mobile network, are then routed by the telephone operator on the internet with TCP/IP protocol to reach the central server installed in the Verrès campus of the Polytechnic where they are made available for the relative elaborations.
In addition, thanks to cooperation with Deval SpA, the largest electricity distributor in the region, the acquisition, with monthly cadence, of the data consumption of all users (425) within the territory of Saint-Denis equipped with electronic meters is in progress. This monitoring allows the elaboration of some simulations on the long-term VPS scheme planned for Saint-Denis.
Finally, thanks to the data collected, we created a historical data base of consumption of users and production of PV plants, with the aim of creating a model that exemplifies all the facilities connected to the network useful for future simulations.

4.2 Demand side management

After an initial period of sampling and system configuration, on 1 April 2011 the phase of interaction with citizens began. Each module performs, in addition to collection and transmission of data to the server, the following functions:

- **luminous communication regarding the state of consumption;**
- **SMS communication of high consumption.**

In particular each module was fitted with two LEDs in the front part of the module, one green and one red, to notify at the user, visually and in real time, their consumption status. The LEDs are turned on only on command of the central server that analyses, in real time, the data sampled. Moreover, in the case of high consumption, that is consumption that exceeds a specific threshold set according to the time slot, each module sends a notification SMS of high consumption to a configured mobile phone number, typically that of the user involved in the project. In this way the user is informed, even if he/she is not near the module to see the light signals.
Permanently at the service of the citizens who have joined the project a dedicated website has been developed (www.polito.it/alpenergy) where, on entering a protected personal area, they can check, with various display options, their consumption profiles since the project began until the time of consultation (see figure 2).

It is also possible to obtain general information on project status on the website and visualize, in real-time, the production of the three municipal photovoltaic plants monitored (see figure 3). The objective is the study and analysis of user behaviour subjected to various kinds of solicitations, in order to assess the potential of the system implemented in the area of load management, with particular reference to the shift of power absorption peaks and the coordination between consumption and energy production.

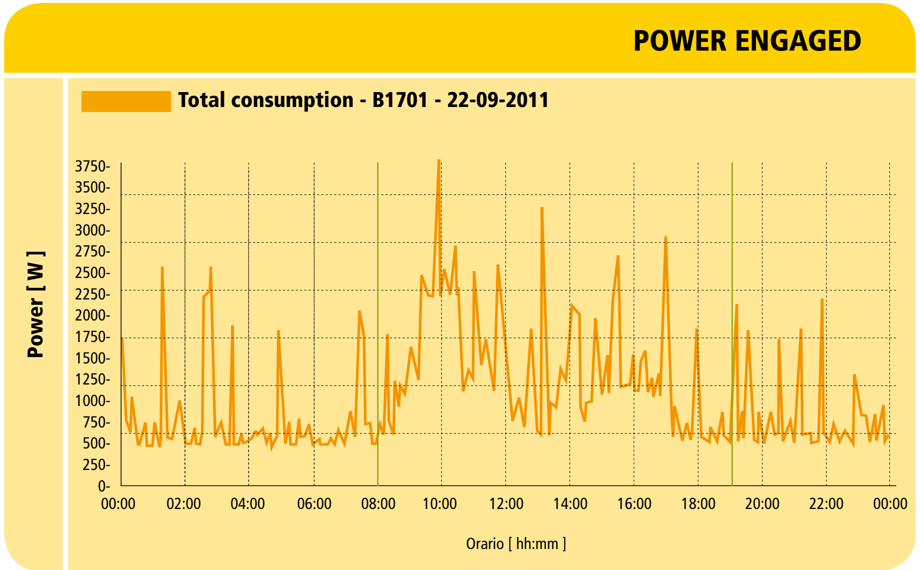


figure 2

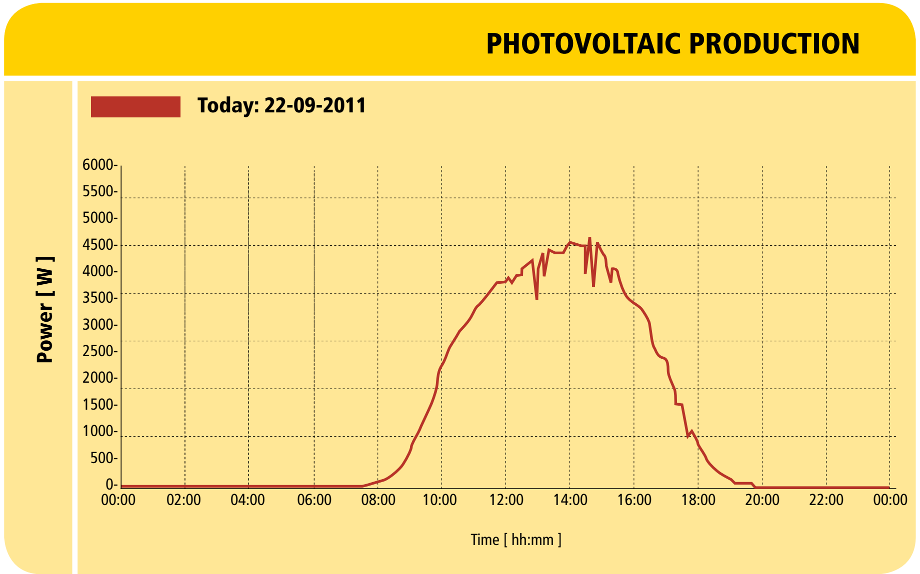


figure 3

4.3 Storage systems

The last step of the project implementation is the installation of storage systems (see photo 3) in ***peak shaving*** mode, or rather for the suppression of absorption peaks due to the normal use of electrical equipment.

Power consumption may vary during the day reaching, in moments of higher consumption, levels that can exceed the maximum threshold contractually ensured by the supplier. Energy storage systems also allow a lower solicitation of the distribution network, ensuring a more homogeneous and efficient power supply.

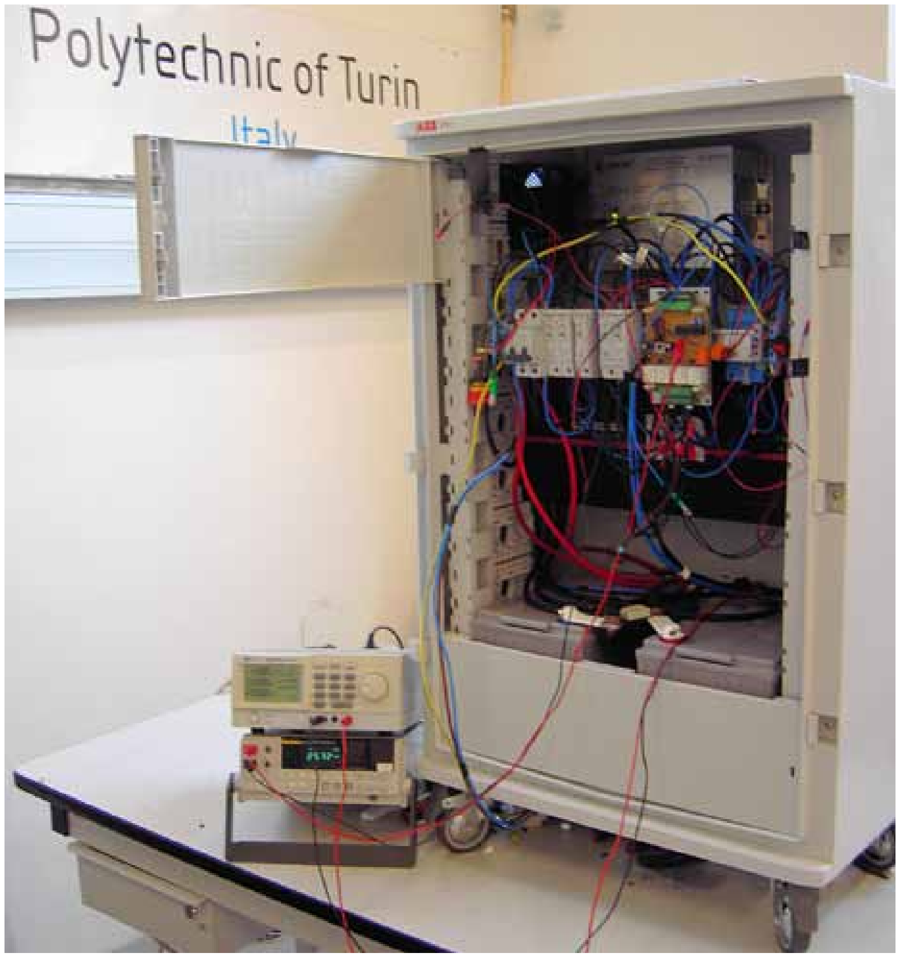


photo 3

This system, interposed between the user and the electronic meter has the ability to lighten the network in case of overload, ensuring a good supply of energy for the citizens, both in continuity and in quality of service. When consumption remains below a predetermined threshold of absorption, programmed through a relay which includes a current monitor, the user is connected directly to the national grid and the energy is drawn directly from this; when the threshold is exceeded, the system switches to the auxiliary system, with the activation of the inverter that compensates the energy requirements above the threshold drawing it from batteries (see figure 4).

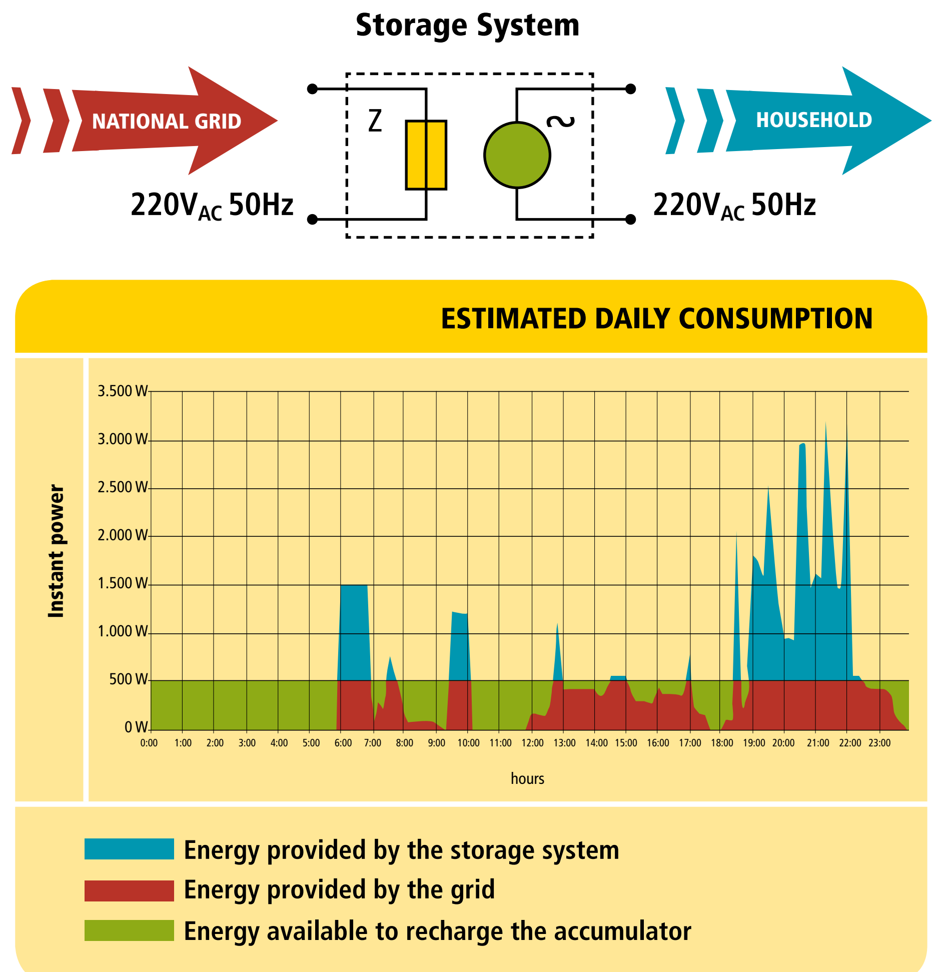
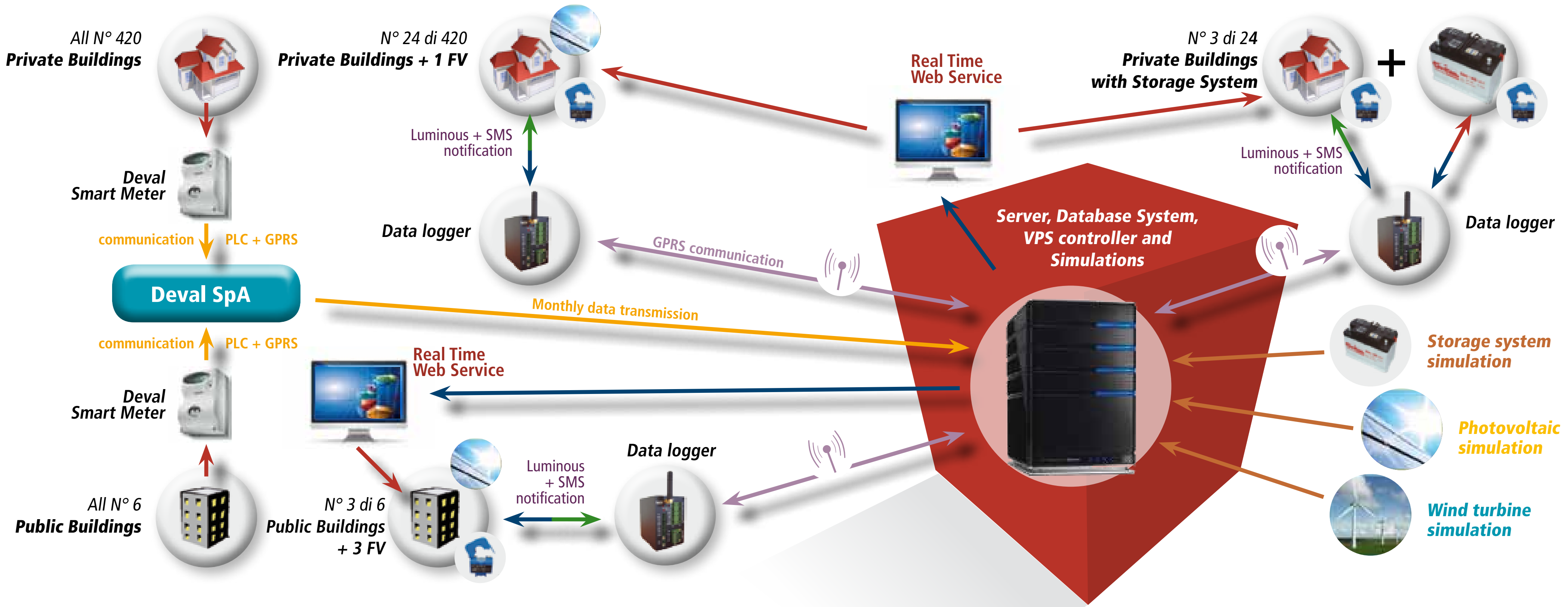


figure 4



If the power consumption falls below the threshold imposed (after a proper choice of hysteresis), the user returns to draw power directly from the network and the batteries are recharged, ideally during lower energy cost hours or when, in the local network, there is a surplus of energy produced from renewable sources.

The general scheme of the implemented system, with the interconnections between the subsystems of monitoring and control highlighted, is shown in figure 5.

4.4 Technical measures

The system implemented, from the data loggers to the storage systems, is composed of commercial devices widely available on the market with reduced cost and timing. This choice allowed the realization, in a short time, of a highly **replicable** system, free from the design of new equipment and from the procedures for certification of apparatus to be installed in the homes of end users. Another important factor is the high **interoperability** of devices that can be used synergistically with other systems.
The only internal component of the storage systems designed specifically for the project is the supervision unit which deals with the user interface, by luminous communication of the state of the system, and with the data loggers' interface, to obtain the operating parameters remotely and to act on the batteries automatically without on-site manual intervention. In addition, the storage systems are assembled inside an electric control panel specially equipped with wheels for easy transport and installation, and with an IP 66 protection level, which allows its use even in a difficult environment such as the alpine one (e.g. temperatures of -20° C to +45° C outdoors partially exposed to the elements).

5. Results

At the date of publication of this booklet, the experimentation, simulation and data analysis activities are still ongoing. At the end of all these activities, it will be possible to assess, in detail, the impact on the distribution gird of the different solutions adopted, both in terms of their potential in the control of power flows on the network and in the coordination between production and consumption of energy locally.
Although the pilot implementation was conducted on a small number of users and, therefore, on a small portion of the grid, the availability of real operating data will allow accurate assessment of the benefits, both technical and economical, of the proposed solutions, as well as provide important information to the function simulations of the VPS in terms of data setting and validation of the results.

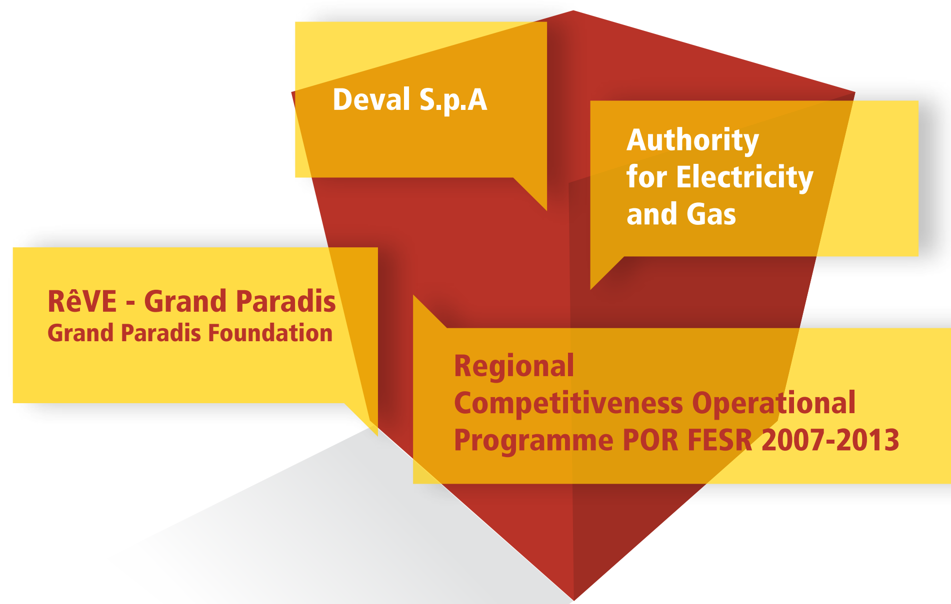
The update to the contents of the booklet and the final results of the project will be available on the official website of the Region of Valle d'Aosta
www.regione.vda.it/energia/alpenergy
and the official websites of the project AlpEnergy
www.polito.it/alpenergy
www.alpenergy.net

6. Synergies

Thanks to AlpEnergy, the regional Ministry of Production activities had the opportunity to involve various actors, operating at local level, interested in the development of the themes addressed by the project: public authorities, research institutes, SMEs and individual citizens/users of the electricity grid.

In addition to the direct involvement of the Mechatronics Laboratory at the Polytechnic of Turin and of Deval S.p.A., a coordination action was carried out that allowed the creation of important synergies between different projects under construction.

The most significant of these synergies is undoubtedly the one between the pilot project "smart grids" of Deval SpA, funded by the Authority for Electricity and Gas, and the project "REVE - Grand Paradis" regarding electric mobility of the Grand Paradis Foundation, funded by the Regional Competitiveness Operational Programme POR FESR 2007-2013. With this synergy, it will be possible to test the impact of electric mobility on the electricity system, also in terms of control and management of vehicles such as distributed storage systems on the grid.



7.

Conclusions

The final objective of the regional Ministry of Production activities is to support, at regional level, a shared vision of the opportunities offered by the advent of "Smart Grids", a vision involving all the actors implicated in the process of modernization of the electric system and able to ensure a greater integration between research centres and production system.

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NEW CHALLENGES FOR THE ELECTRICAL SYSTEM SMART GRIDS THE **PROJECT ALPENERGY** IN VALLE D'AOSTA ADVANCED MONITORING STORAGE SYSTEMS VIRTUAL POWER SYSTEMS PRODUCTION AND **EFFICIENT MANAGEMENT OF ELECTRICITY** FROM RENEWABLE SOURCES

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