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Départmenet fédéral de l'environnement, des transports,
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Ofiice fédéral de l'énergie OFEN

Rapport annuel 25 novembre 2010

AlpEnergy

Virtual Power System (VPS) as an Instrument to Promote Transnational Cooperation and Sustainable Energy Supply in the Alpine Space

Mandant:
Office fédéral de l'énergie OFEN
Programme de recherche Réseaux
CH-3003 Berne
www.bfe.admin.ch

Cofinancement:
Cantone e Republica Tessin, CH-6500 Bellinzona
Office fédéral du développement territorial ARE, CH-3003 Berne

Mandataire:
Università della Svizzera italiana
ALaRI Institute
13, Via Buffi 13
CH-6900 Lugano
www.alari.ch

Auteurs:
Slobodan Lukovic, USI-ALaRI, lukovics@alari.ch
Igor Kaitovic, USI-AlaRI, igor.kaitovic@usi,ch
Umberto Bondi, USI-AlaRI, bondi@alari.ch

Responsable de domaine de l'OFEN: Dr. Michael Moser
Chef de programme de l'OFEN: Dr. Michael Moser
Numéro du contrat et du projet de l'OFEN: 153658 / 102848

L'auteur de ce rapport porte seul la responsabilité de son contenu et de ses conclusions.

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Summary

AlpEnergy (http://www.alpenergy.net) is an **European Territorial Cooperation Project** (http://www.alpine-space.eu/) bringing together power suppliers, development agencies, research institutes and public administrations from five different countries of the **Alpine Space** - France, Germany, Italy, Slovenia and Switzerland - to address the central issue of **renewable energy supplies**.

Even if hydropower, solar and wind energy, wood and other biomasses are richly distributed throughout the area, they are unequally accessible because of many **territorial discrepancies**. The need to balance an increasing production and use of RES (renewable energy sources) requires a stronger and more extended electric grid capable of dealing with high levels of remote power generation. **Virtual Power Systems (VPS)** offer an alternative by using ICT technology for an intelligent combination of load management, storage and demand and their efficient aggregation in a single entity in technical and commercial terms.

AlpEnergy focuses on both **technical** as well as **commercial aspects** to introduce an efficient operational model that aims at a standardizing technologies as well as procedures (i.e. legal, commercial, management and similar). It intends to provide new knowledge-based income sources and business opportunities to local enterprises, traditional as well as innovative, thus supporting the competitiveness of the Alpine regions and making the Alpine space a showcase for other mountain areas in the world.

Project goals

The need to limit climate change implies that global green house gas emissions are quickly and strongly reduced, including a quick and strong decrease of C02-emisions from fossil electric power plants. On the other side, renewable energies and energy efficient measures are expected to be soon deployed in a large scale impacting traditional power systems. To face these challenges, new approaches are necessary. This is where Virtual Power Systems (**VPS**) come into play.

Operators are asked to handle rising shares of renewable electricity in their grids, including those that are coming from fluctuating sources, such as wind and photovoltaic power stations. Technically speaking, this complicates the task of bringing purchase/sale of surplus electricity in pattern with the electric demand. As it is fairly hard to store electrical energy, generation and consumption have to be simultaneous. There is a need for intelligent energy management that coordinates different plants in a way that peaks demands are attenuated. VPS will allow insertion of a larger number of intermittent renewable energy production plants in the grid.

AlpEnergy aims at the analyzing, modeling, and then design and development, the **demonstration and test**, the evaluation and transfer of virtual power systems in **four** distinct **areas** of the Alpine space: the Allgäu region in Bavaria (Germany); the city of Mantua in Lombardia and the province of Belluno (Italy); the Belledonne chain area in the Rhône – Alpes region; and the Gorenjska region in Slovenia.

1. USI-ALaRI participation

ALaRI (Advanced Learning and Research Institute, www.alari.ch) is an institute of Faculty of Informatics and part of Università della Svizzera italiana (USI, Lugano, Switzerland), established in 1999 with the mission of promoting research and education in Embedded Systems Design. ALaRI was created as a joint initiative of a number of Universities, Research Centers and Companies. From 2005 USI-ALaRI is part of the faculty of Informatics (established at USI in 2004). The main areas of the current research activities at ALaRI are: co-design and optimization of pervasive systems, design of optimized hardware cryptographic devices, robustness analysis of cryptographic algorithms, design of hardware and software solutions robust to power analysis attacks; power modeling and optimization of wireless systems; high-level services for on-chip communication (QoS, security, power management, fault tolerance, etc.); multiprocessor reconfigurability; energy efficiency in SmartGrid related fields.
USI-ALaRI role in the project is related to the ICT aspects of the VPS concept in sense of determining and defining functional requirements and accordingly Information flow in VPS. More precisely, our goal is development of an ICT model of VPS according to guidelines adopted and defined by the consortium. USI-ALaRI involvement is conceived as three step engagement. We should:

- Contribute to definition formulation of VPS concepts and models
- Create VPS modeling framework
- Basing on previously developed VPS models define Information flow

These tasks are mapped into project work description in Working Packages four (Analysis and Modeling) and five (Design and Development) as assessing ICT plans of proposed systems. The foreseen milestones according to these phases of the project are:

- The document on state-of-the art of VPS concept in Europe and discussion on exact VPS definition adopted for the project
- Determination of all elements of the Information flow model of VPS in terms of ICT
- Assessment of the ICT plans for the proposed system

The workflow has been logically encapsulated in terms of Work Packages and timelines are provided at the year by year level. In the sequel the USI-ALaRI tasks are provided according to this division.

USI-ALaRI tasks for 2010

The entire AlpEnergy project is partitioned in seven work packages. During the project development it has been detected a need for task rescheduling and extension of certain Work Packages. Due to delay in pilot implementations the entire project is extended for additional six months to the end to 2011. Such scenario has impacted also USI-ALaRI workflow. In 2010 year, USI-ALaRI tasks have been mostly related to Work Package 5 (Design and Development).
Tasks are in general interconnected and based on determining the information flow in the system using system engineering methodology. Our goal is to develop an instrument to embrace the entire context of VPS, determine all the stakeholders involved, define their requirements and develop system ones accordingly. Here are listed single tasks to be performed.

1. Tasks in scope of Work Package three

1.1 Dissemination and promotion

USI-ALaRI has a minor role in this task. It mostly consist of promotion of VPS concept at local level and according to its academic nature at relevant scientific conferences and workshops. Moreover, some additional activities as participation in AlpEnergy related programmes and intiatives is welcome.

2. Tasks in scope of Work Package five

2.1 Definition of VPS Information flow (ICT) model

The task is mapped into Work Package five and it is the most important part of USI-ALaRI role in scope of AlpEnergy project. It represents direct continuation of the work done in scope of Work Package four (Analysis and Modeling). The key aspects are Definition of “Information Flow (ICT) Model” for real VPS implementations in terms of (mapped into WP5): structural and behavioural description of VPS components. The functional requirements and specification for all the components are to be determined.

2.2 General framework for Canton Tessin (delayed from 2009)

The aforementioned general information overview should be scaled and adopted for regional circumstances. The local instances of VPS (pilot implementations) would serve as a prototyping model. The local situation in Canton Tessin should be elaborated and mapped into the framework according to previously developed rules. The task is supposed to be done upon provided inputs (technical and business models) from partners implementing pilot setups the deadline is under revision.

2.3 Organization of AlpEnergy summer school in Lugano

USI-ALaRI has been in charge of organizing a summer school for practitioners, research and technology transfer partners in order to discuss and assess the overall concepts, promote 'clean energy awareness' among young researchers and lead to existing and useable solutions for the pilot implementations

Performed work and obtained results

In this section of the report we provide description of the work performed in 2010. The workflow corresponds to the aforementioned tasks.

1. VPS structure and information flow determination

In scope of task 2.1 the system engineering methodology for structural and behavioral modeling of VPS components has been developed. The information flow in system (i.e. data and control flow between components) is represented in form of different SysML instruments (models). The description of the methodology presented here below is given in details in [1,2].

Due to its novelty, lack of communication and interface standards, descriptive nature of future energy market and lack of full definition of roles of stakeholder in future power system, VPS concept is a subject of constant change and adaptation depending on new rules and results achieved. VPS model has to reflect all the changes and for that reason has to be constantly updated depending on the new stakeholders or requirements identified as well as results obtained from the best practice. For that reason, we have adopted and applied a model-driven approach that is already well known and proven approach in software and complex systems (e.g. avionics) engineering [3].

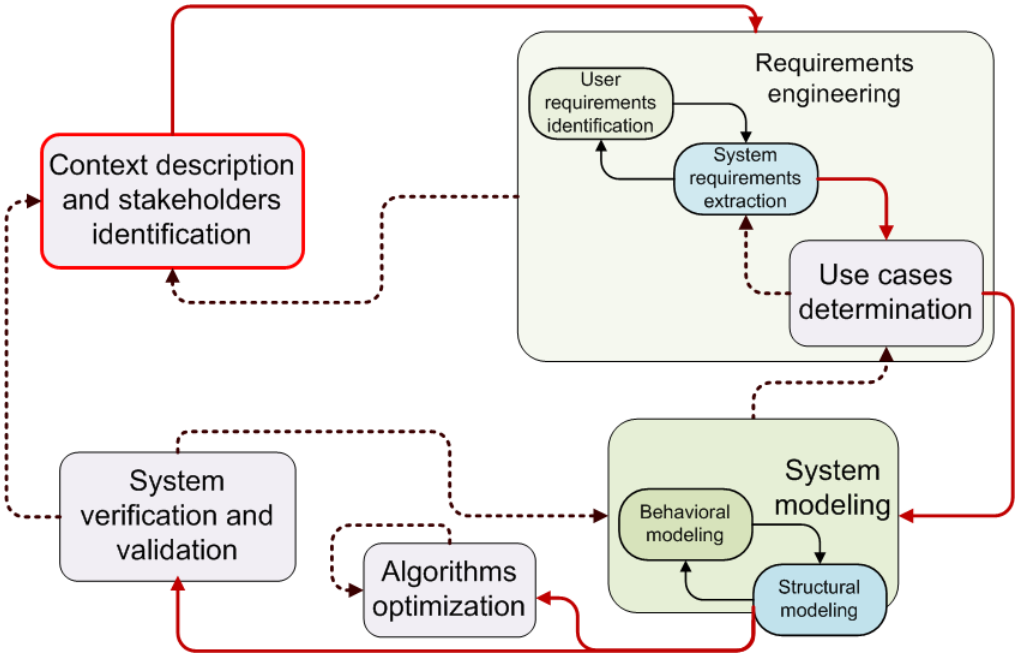


Figure 1 - Model-driven methodology for VPS

VPS and in particular AlpEnergy projects itself, involves many stakeholders/partners that are not ICT/software engineering experts. For that reason it was necessary to propose a very simplified model-driven methodology that is easy to explain and adopt on one hand, but that copes with dynamic model changes on the other hand (Figure 1 - Model-driven methodology for VPS). Moreover, the same methodology has to keep in mind particularities of the AlpEnergy project and be able to accept VPS requirements, results and specifics situation of im-

plementations from different partners. The main benefit of using this methodology is that it supposes an interactive and not a straight-forward process of project deployment and that is fully open to changes and upgrades that are in-fact parts of any research/innovation project. The ultimate result of the methodology application to the VPS is a structural and behavioral model of the system describing VPS components, relation among them, interaction (in terms of control and data flow) and data type to be exchanged.

The methodology starts with *context description* and stakeholder's identification. Context description refers to unambiguous definition of system environment in terms of surrounding systems and it's relation to the system under development. This is the basis for stakeholders' identification that are de facto sources of users requirements. Requirement engineering that includes collecting, tracing, analyzing, qualifying and managing *user requirements* is the next step. The main purpose of this step is the efficient extraction of system requirements and its refinement trough *use cases* that are latter traced to concrete components as identified in next step. For each user requirement collected from stakeholder (or in particular case from some of the project partners), a set of system requirements has been derived. The same set of system requirements has been mapped to use cases describing system functionalities that are finally traced to one or system components presented in the model. Despite the fact that various authors propose structural modeling before behavioral, or vice versa, developing system model is an iterative process. It starts with behavioral modeling of each system functionality presented trough use cases and assumed set of components [4]. In order to keep model as simple as possible interaction based behavioral modeling presented troughs SysML sequence diagrams are suggested. Still, other SysML mean of representing interaction could be used as well (e.g. activity diagrams). While progressing with behavioral models of system functionalities, system structure changes in terms of growing of components number or changing of the component roles. In some cases, structural change will affect additional behavioral change. The final result of this step is consistent structural and behavioral model. Before actual deployment, achieved models have to formally validated and verified. Moreover, very same model or its parts serve as a basis for functional optimization of the system that, in particular case, can be done trough under-development tool whose main purpose is energy balance algorithm optimization.

Applying this methodology and collecting information (requirements and results) from all the project partners (trough project reports, project workshops and conferences) we have obtained a final and highly-level, generic VPS model that describes VPS implementations from various partners. VPS model includes:

- VPS context and stakeholders identification
- A full set of requirements identified
- VPS behavioral model
- VPS structural model
    - VPS components
    - Information flow description

As a complex and highly multidisciplinary system, VPS is seen to include various stakeholders (starting from legal and commercial to technical ones). While identifying stakeholders, we were focusing on a long-term set of stakeholders that are seen to appear in the future rather than a specific set involved in AlpEnergy project. Moreover, we have directly contacted some of the stakeholders (e.g. Smart Meter producer). Still, one should keep in mind that particular stakeholders (e.g. energy market legislation) will just appear or drastically evolve in the future. A full set of identified stakeholders, including individuals and organizations, follows:

- Distribution System Operator (DSO)
- Dispatcher
- Energy Exchange Stock
- Energy market legislation
- Local authorities

- Equipment producers
- VPS shareholders
- Home users
- Industrial users

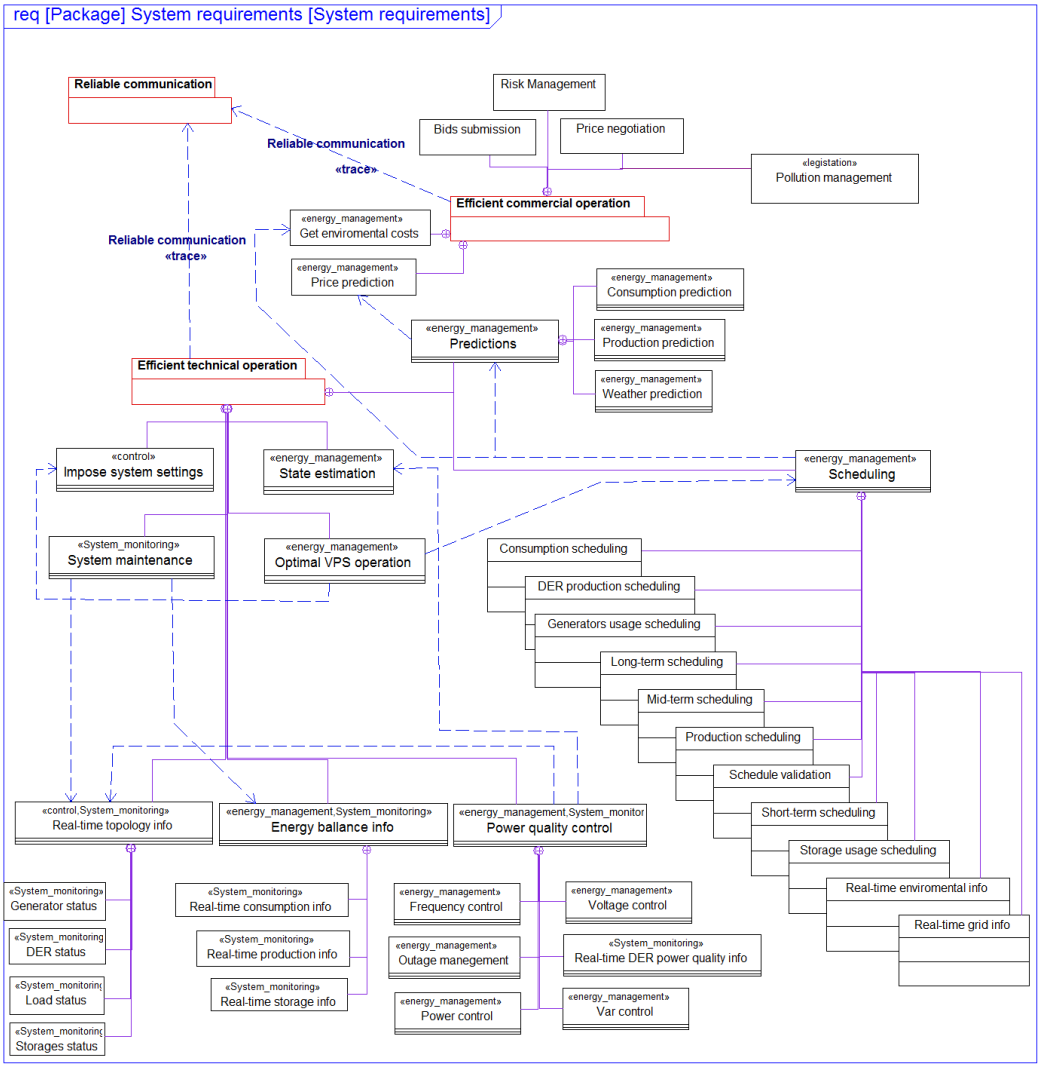


Figure 2 - VPS major system requirements

Diagram on Figure 2, summarizes general VPS system requirements as so far identified. While focusing on functional ones, requirements are organized in tree main packages: efficient technical operation, reliable communication and efficient commercial operation.

Starting with this set of collected/identified requirements and a general definition of VPS concept as well as goals of AlpEnergy project itself, five major VPS functionalities were identified and presented trough use-case diagram in Figure 3. This way, each stakeholder can identify his own position in VPS and latter refer only to the set of diagrams related to a particular use-cases he is interested in. Each use case has been decomposed to a more detailed set of use-cases that are traced to system requirements (or set of system requirements).

In order to keep this report free of details, a fine-grained use-cases diagram as well as other detailed diagrams will not be presented here. For more details please referred to [1,2,20].

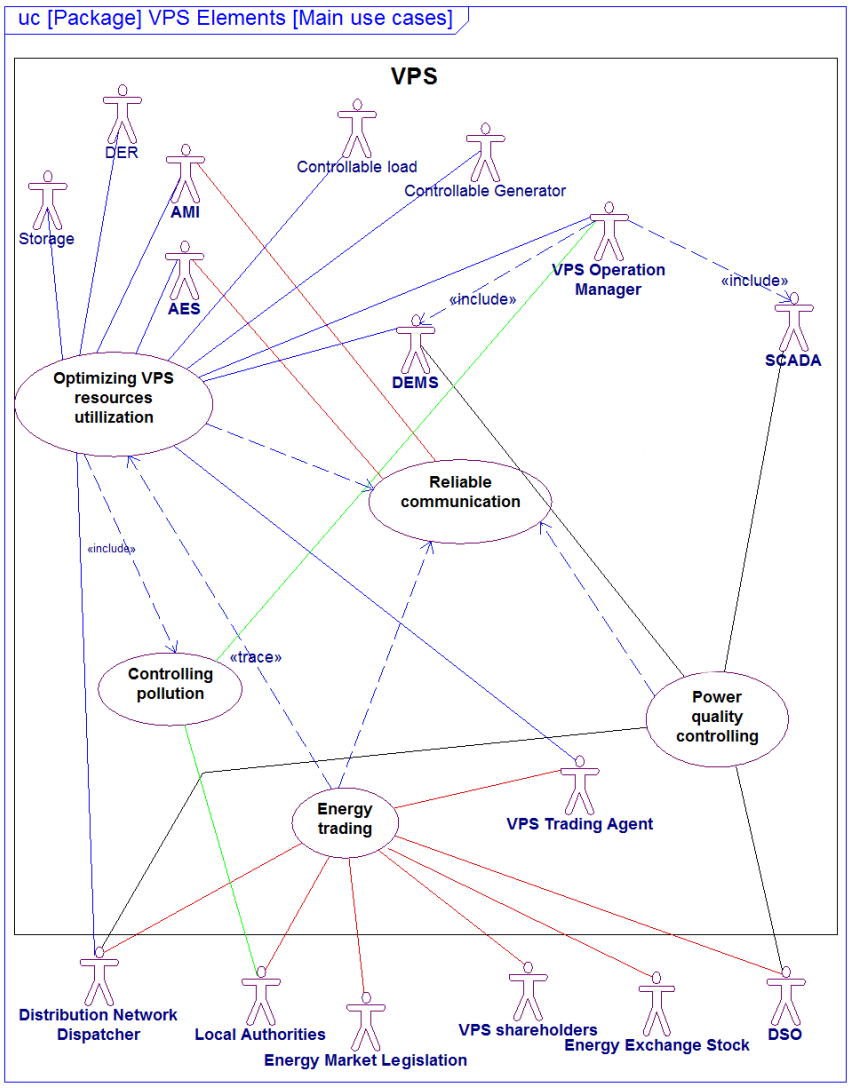


Figure 3 - Major VPS functionalities and related actors

We focus here on a final result and goal of this WP that is identification of VPS structure and communication/data flow between components while briefly describing role of each component. Diagram in Figure 4 - Sequence diagram, shows interaction between system components in order to satisfy use-case “Collecting real time information” that is a part of “Optimize VPS resource” use-case. This and other sequence diagrams are the basis for defining the connections between the VPS components and defining the control and data flow. Each request coming to a component identifies a new component function as well as data flow (if function has parameters). Each ”reply” from the component defines a new type of data that has to be exchange among components.

A full set of VPS components that are identified (with respect to the methodology presented above and system behavioral analysis) is presented on Figure 5 - VPS components. Each system requirement can be traced to one or more components. We focus here on a general overview of components and its relation, while generic internal block diagram will be presented latter.

Particular details (e.g. sensors that AMI includes) are not presented here and can defer depending on particular implementation while general interface presented here should be followed.

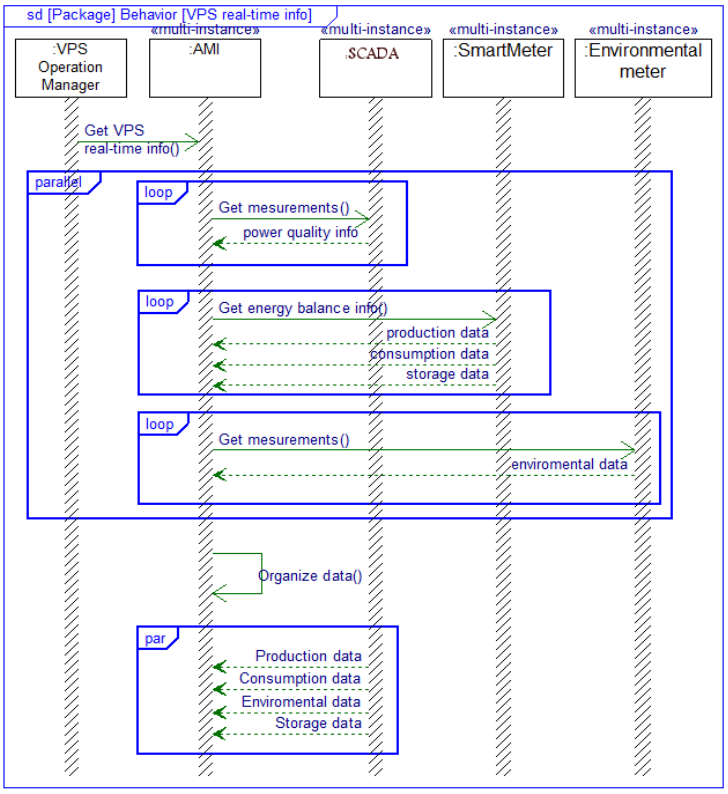


Figure 4 - Sequence diagram

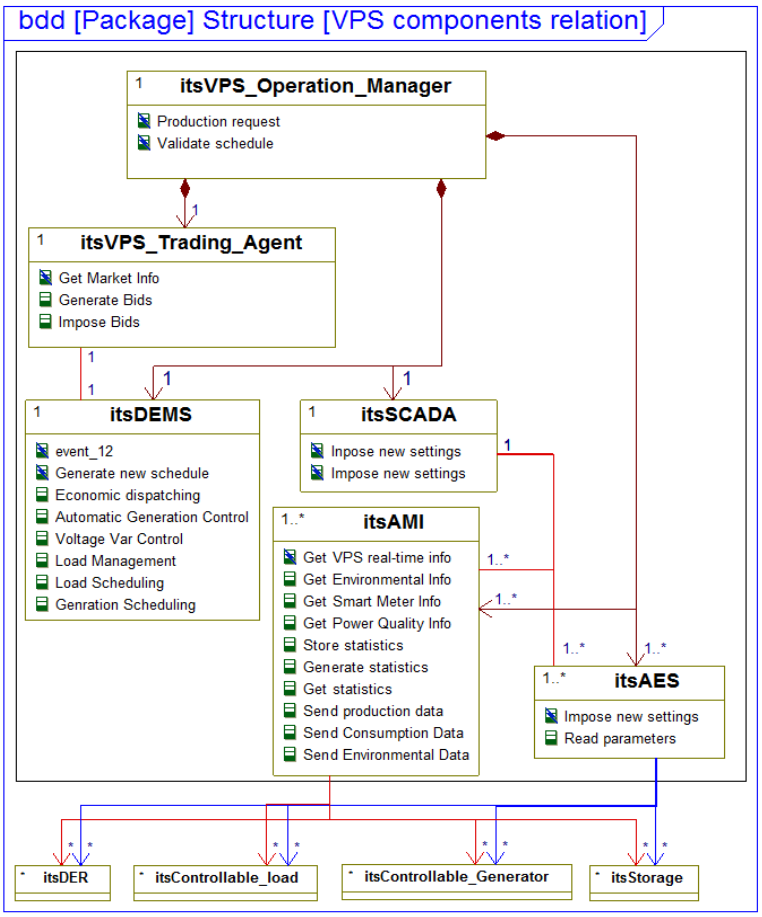


Figure 5 - VPS components

A general role of each component follows:

- SCADA and DEMS are components that already exist in the power system with a main purpose of providing the basic system monitoring and control and assuring the power quality
- Advanced Measuring Infrastructure goes way beyond simple consumption measuring and includes remote measuring of additional parameters needs for proper production planning and consumption scheduling (e.g. temperature, humidity, VaR, etc.) and their proper processing, storing and representation
- Actuating Embedded Systems are extending the SCADA functionalities dealing with particularities of each smart load, DER or storage being included into VPS. They actually drive field devices employed at generation/consuming units
- Trading Agent handles all the commercial issues of the VPS including energy trading, stock state reading, etc.
- VPS operation manager is the brain of the system that schedules production and consumption applying advanced algorithm to be developed, checking the feasibility of production, etc. It is seen as a centralized one at the moment, but could evolve to distributed solution based on agent's technology.

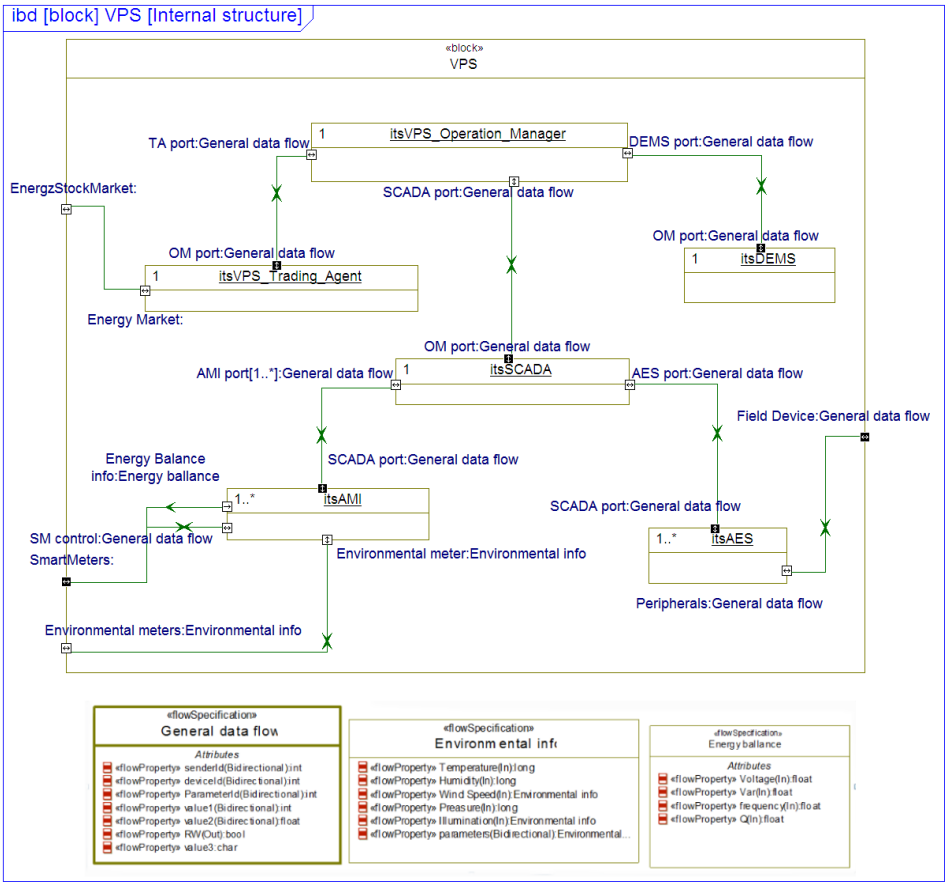


Figure 6 - VPS Internal Block Diagram

Components presented on Figure 5 - VPS components, can be connected in a various ways, depending on the particular implementation. Moreover, communication between them can drastically vary even in case of different implementations in scope of AlPEnergy project. While baring in mind the identified structure of VPS, components roles and behavior we have identified a communication interface combining not only results from AlpEnergy project but several similar projects like [5,6]. Here, we propose just an interface, while not going into details on technology to be used. This heavily depends on field conditions and partners ex-

pertise. Communication interfaces are presented as a part of internal VPS structure (presented in Figure 6 - VPS Internal Block Diagram).

2. Potentials for VPS implementation in Tessin Canton

So far, there are neither VPS installations nor plans for their implementations in Tessin Canton. Nevertheless, our analysis has shown that there is significant potential for deployment of VPS concept. This mostly concerns

In 2020, Switzerland's oldest nuclear power plants will be decommissioned and long-term electricity import agreements with France are due to expire [7]

One way to efficiently cope with a gap in electricity supply that will appear is to decrease consumption and moreover increase energy efficiency. Even thought that there are no current implementations of Virtual Power System (or Virtual Power Plants so far), both concepts could be very powerful means in coping with future problems in Switzerland. With large penetration of hybrid and electrical vehicles that is seen in the future and Swiss plans for increasing renewable production, VPS concept becomes even more interesting for the future.

Table 1 - Most dominant renewable energy sources in Tessin

Renewable energy source	Total Swiss potential	Total Tessin potential (plan till 2030)	Current % of usage
PV (rooftop)	46800	2562	1,3
Photovoltaics, vehicles, open areas and Import	32000	4042	3
Biomass	5450	371	1,6
Wind power (increase)	4000	337	2

As Swiss canton with the largest number of sunny days during the year, it is not surprising that Tessins greatest potential for renewable energy solar one (Table 1 - Most dominant renewable energy sources in T), [8]. Renewable production in Tessin in 2007 has been 2.7 TWh with a plan of reaching 11TWh by 2030. Still, potentials in renewable energy in Tessin are even greater, and ideally could reach even 180 times more electricity production than current consumption. Currently, most of the renewable energy in Tessin is based on solar energy (Roof photovoltaics). Wind energy in the area of Gotthard shows great potential of supplying even 4000 households in the future.

Another important aspect of VPS concept represents utilization of electrical vehicles. According to a study commissioned by Alpiq, 15% market penetration by electric cars would reduce the CO2 emissions of private vehicles in Switzerland by around 10%. With its high vehicle density, Switzerland is an ideal test market for electric cars in Europe [9].
There are a number of programs and initiatives in Tessin Canton which promote utilization of cars with electricity powered engines. The most important ones are:

- For electric and hybrid vehicles already in circulation remain in effect the tax exemption of 100% (electric) and 50% (hybrid), hybrid vehicles not previously registered can also enjoy the bonus[10]
- VEL1,VEL2,VEL3 programs for electrical vehicles utilization support [11]
- Infovel program for sustainable mobility [12]
- RiPartTI program for electical charging stations in Tessin [13]

As shown above even thought there are no VPS implementations in Tessin Canton, there are remarkable potentials for its utilization. The importance of AlpEnergy project in that sense is to provide first of all promotion and awareness of the concept and later on to provide business and technical models for its implementations. Ones results from pilot implementations of AlpEnergy VPS become available we would be able to help development of a visibility study of VPS deployment in Tessin Canton.

3. AlpEnergy Summer School in Lugano

As one of Work Package five tasks USI-ALaRI was asked to organize partners' meeting and Summer School on the topic of technical, communicational and commercial issues of VPS. The event was held in Lugano at USI on July 7-9.
In order to better answer needs of the project consortium we had asked all the partners to provide a report on situation and expectations of each partner regarding VPS. According to the collected inputs an appropriate document has been produced [Appendix A: AlpEnergy - situation and expectations], according to which the program of the school is created.
The participants of the event came from partners' organizations as well as USI-ALaRI students. The discussions have been moderated by Mr. Ludwig Karg a coordinator of the project. The event has been organized in three parts:

- First day has been organized in form of internal partners' meeting in which the open discussion has yielded three groups of issues for open discussion with the experts who have tutored on second day of the event. These issues have been grouped as: Challenges, Questions and Solutions [Appendix B: AlpEnergy – Challenges Problems Solutions]

- Second day of the event has been organized in traditional workshop approach in which three the most important aspects have been covered by invited experts:
    - Technical aspects of the VPS – the invited lecturer was Prof. Filip Kulic from University of Novi Sad
    - Communicational aspects of VPS – the invited lecturer was Prof. Anotio Capone (Politechnico di Milano)
    - Commercial aspects of VPS – the invited lecturer was Prof. Eric Larsen (University of Lugano)

  The open discussion followed sessions. The interested parties discussed with the experts on Challenges/Problems/Solutions for VPS implementation from their aspects.

- The third day of the event was organized as an internal project meeting in which the open discussion on where AlpEnergy goes further has been organized. The wrap-up and closing remarks have been taken [Appendix C: AlpEnergy – Meeting minutes].

In order to provide a relevant feedback for the events to be organized in future we have created an online survey [14] for the participants of the workshop. The results of the survey have been provided in a separate document [Appendix D: Summer School - Survey results]

4. Other activities related to project promotion and dissemination

USI-ALaRI was actively taking part in all partner meetings in 2010 and the our role has been:

- **International conference on SmartGrids and partners meeting (Grenoble 18-19 March)** – Presentation of our activities
- **Summer School and partner's meeting (Lugano 7-9 July) -** Organization of the event and activities presentation

- **Partners meeting in Matua (October 11-12) –** Presentation: VPS modeling

Other activities were mostly related to promotion of the project and dissemination of its results. One of biggest achievements in this sense represents the official acceptance of AlpEnergy as a Sustainable Energy Partner (http://www.sustenergy.org/) on the initiative of USI-ALaRI. On the other hand a publication and presentation at GREEMBED 2010 [1]. Information on AlpEnergy project and our role has been also presented in ARE (http://www.are.admin.ch/) Newsletter October 2010 and local magazine Square [15]

The detailed description of the methodology developed as well as results obtained is provided in publications and appendixes attached to this report attached to this report [1,2,20].

National Collaboration

VPS is a novel concept that requires holistic approach; the consortium intends to find full internal common agreements on conceptual definitions before involving institutions located in the different partners' areas that are not belonging to the AlpEnergy consortium.
AlpEnergy project requires tight collaboration with other partners related to VPS definition, identification of stakeholders and functional requirements determination. In order to perform our role in an efficient way, disseminate results and provide a platform for VPS utilization in Switzerland we have identified potential collaborators and we established contacts with some of them. So far, at a local level we have focused on contacts with DSO from Tessin Agenzia Elettrica Ticinese (AET - www.aet.ch]) research entities active in the field as ISAAC [18], program for electrical cars utilization support RiParTI [13] and technology provided as Solterna [16].

International collaboration

AlpEnergy is an **Interreg IV Alpine Space Programme** funded project. It gathers partners for different countries and fields. **Regional power suppliers and distributors**: *Allgäuer Überlandwerk GmbH* (Germany), *Elektro Gorenjska* (Slovenia), *Elektro Gorenjska, podjetje za distribucijo električne energije* (Slovenia); **Public regional policy makers and counselors**:*Provincia di Mantova*, *Regione Autonoma Valle d'Aosta, Consorzio BIM Piave di Belluno* (Italy), *Allgäu Initiative GbR* (Germany) and Rhônalpénergie-Environnement (France); **Business support centers**: Regionalna razvojna agencija Gorenjske (Slovenia), Rhônalpénergie-Environnement (France), B.A.U.M. Consult GmbH (Germany) closely cooperate with observer *SIR* (*Salzburger Institut für Raumordnung und Wohnen);* **Research partners**: *Fondazione Politecnico di Milano* (Italy), *USI-ALaRI - Advanced Learning and Research Institute all'Università della Svizzera italiana (USI)* (Switzerland), Institut National Polytechnique de Grenoble (France).

In scope of the project USI-ALaRI has been collaborating with all partners and especially closely with *BAUM* and *Fondazione Politecnico di Milano*. ICT structure modeling requires cooperation with experts in power systems so that *USI-ALaRI* established fruitful collaboration with partners outside the consortium i.e. *University of Novi* Sad (Serbia). The very next step consist of collecting data from partners implementing concrete pilot implementations that are in process of realization in Belluno, Allgäue, Val D'Aosta, Gorenjska and Mantova.

USI-ALaRI has become a part of COST IC0806 (http://www.intellicis.eu/) action and the stuff exchange through this program has resulted in mutual publications with COST partners [17]

The evaluation of 2010 and perspectives for 2011

The work carried out during this year has been mostly concentrated in Work Package 5. The system engineering methodology has been developed to optimize requirements collection and based on them develop structural and behavioral models of the system. The information flow has been show using a number of available UML/SysML instruments. The work has resulted in scientific publication [1].

USI-ALaRI performance in the project has been successfully evaluated by other partners which has lead to our involvement in consortia on few other projects: GeoGreen (ERA-Net SmartGrids project scheduled to start on January 1, 2010) and AlpEnergy follow-up project proposal (details undisclosed as projects are still in confidential evaluation phase).

In the following final year of the project USI-ALaRI is getting ready for the tasks foreseen in scope of Work Package 6 related to ICT assessment and final concet evaluation.

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[20] S. Lukovic, I. Kaitovic, ***Adoption of Model-Driven Design for Future Power Grid,*** Publication in the process of the review (Appendix F)

Glossary

SCADA - Supervisory Control and Data Acquisition System

DEMS – Distributed Energy Manager System

DER – Distributed Energy Resources

AES – Actuating Embedded Systems

Apendices: Supplementary documentation

The following documents are attached to the report:

1) Appendix A: AlpEnergy - situation and expectations
2) Appendix B: AlpEnergy – Challenges Problems Solutions
3) Appendix C: Sumer School – Meeting minutes
4) Appendix D: Sumer School – Survey results
5) Appendix E: I. Kaitovic, ***Model-driven system engineering methodology for VPS design***, USI-ALaRI, MSc thesis, 2010
6) Appendix F: S. Lukovic, I. Kaitovic, ***Adoption of Model-Driven Design for Future Power Grid,*** Publication in the process of the review

Annexes

- Publications relevant for this project are copyrighted and moreover some of them are still under the review. For this reason public exposure of these documents is not allowed.