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Swiss2G – Pilot- and Demonstration Project

An innovative concept for the decentralized management of distributed energy generation, storage and consumption and consumer acceptance

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Résumé

The overall aim of the Swiss2Grid project is to investigate a concept of a decentralized and self-regulating load management system. Smart grids are generally considered the answer to the challenges with the new decentralized energy generation, likely to be deployed massively in the coming years according to the national energy strategy 2050. Moreover is it taken for granted that the new energy scenario requires heavy investments in the grids infrastructure and a general smart meter roll-out in Switzerland. The amount of investments, the question where and in which way to invest in grid infrastructure, as well as the benefit of smart meters are still open questions in the ongoing policy debate.

The Swiss2Grid project was designed to investigate and demonstrate an alternative approach to smart grids based on a decentralized load management with no central control and without a sophisticated communication infrastructure. In the first phase of the project the proof of concept to use the local information (voltage drop) on the grid for load shifting with a self-organizing and self-learning algorithm was delivered.

Preliminary results of the highly accurate grid measurements show a significant correlation between the local voltage values at household plugs and electrical loads at low voltage (LV) transformers. The first results of the grid simulation with the S2G algorithm, fed with the local and instantaneous voltage values, are promising, and show an increasing grid stability with the growing diffusion of the S2G algorithm in the local grid. Recent simulations with the grid indicate also beneficial effects on the higher grid levels helping to avoid additional investments in infrastructure.

According to the up-dated project schedule the last components of the project could be installed. In particular the stationary batteries have been installed in four different households. In addition 14 water heaters and heat pumps and three electric car (EV) chargers were equipped for a remote control by the S2G algorithm.

The remaining months of will be used for intensive acquisition and analysis of empirical data from the P&D houses. The Mendrisio platform proved also to be an interesting platform for the development of new research projects and questions linked to the management of smart grids, such as intelligent private and public charging stations, the use of larger batteries for energy storage as well as one of several test sites for the SCCER Grid.

Moreover we applied the Swiss2Grid P&D for an European label GRID+ and introduced the project on the European level in the D-A-CH initiative, the European PV conference in a dedicated session on grid and are supporting the Smart grid ERN-Net plus initiative. The project team is willing to further improve the design of the algorithm and to extend the P&D infrastructure in a new project phase increasing the number and types of households involved in the project.

Buts du projet.

The overall goal of the project is to investigate in a pilot project the technical feasibility of decentralized electric energy production, storage and consumption by combining available and new technologies in an intelligent and self-organizing system. The project intends to analyse the practical use of small energy production units in about 20 smart private households, main loads in a household, plug-ins for storage and environmentally friendly mobility linked to the grid. This is the basic (infra-) structure of the project. This infrastructure allows to define the system parameters and to simulate the behaviour of the users and their impact on the grid on different scales of the technology diffusion.

The basic idea of the project is to optimize the control of the grid by an algorithm based on decentralized decision making with limited knowledge in an environment with selected information in the single nodes and to understand their impact on the grid, simulated by a conventional approach. Unlike the large majority of the projects on smart-grids the present project wants to show, to which extend the need of two-way communication systems capable to manage the smart grids can be reduced and the problems related to the elaboration of huge quantities of information overcome. This represents an innovative approach of the grid management based on intelligent devices with self – optimization capabilities at the level of each node (household). This leads to a decentralization of the decision processes on when to consume, store or produce energy and represents a promising option to the common management approaches for smart grids.

The design of this pilot and demonstration project is a combination of practical feasibility of technical components for the energy production, storage and consumption in real conditions in 20 households and the use of advanced optimization and simulation tools. The project is carried out by an interdisciplinary team of five institutes of SUPSI, Bacher Energy AG, a private consultancy, and the Berner FH, in co-operation with industry partners. The P&D project proves to become an interesting platform to generate new and further research projects (such as the CTI project on Intelligent Home Chargers), which at the same time help to enrich the platform and to render the P&D aspects even more interesting. In the context of the new SCCER Grid network the P&D project could gain an additional function and play a significant role in the development of future grid solutions.

The households are monitored during the whole period, introducing step by step a major involvement of the household. Different household profiles will be defined in order to simulate different patterns of behaviour in the optimization and simulation workpackages. The benefits for households and utilities will be analysed during the whole period.

Travaux effectués et résultats acquis

Installation of HACs and household data gateway

The development and production of the household appliance controller (HAC) required additional work in order to finalize and correct the hardware design. Thanks to this work we could run the production of the final hardware version of the devices in a reliable way and avoid costly and time-intensive modifications of the finished product. In summer 2013 a revision of the firmware has been released, greatly improving the stability and the reliability of the devices.

Detailed description of the installation

In fig. 1 and 2 are displayed the 1-phase and 3-phase HAC ready to be installed.

Figure 1: 1-phase HAC

Figure 2: 3-phase HAC

Installation

In one first phase we have installed GRID and PV 3-phase HAC. Fig. 3 shows a simplified installation schema of the 2 HACs. The PV HAC measures the production of the PV Panel and the GRID HAC measures the consumption of the whole house.

The connection of the PV system is actually in auto consumption, the energy produced by the PV system is used by the household and only the exceeding energy is injected into the grid.

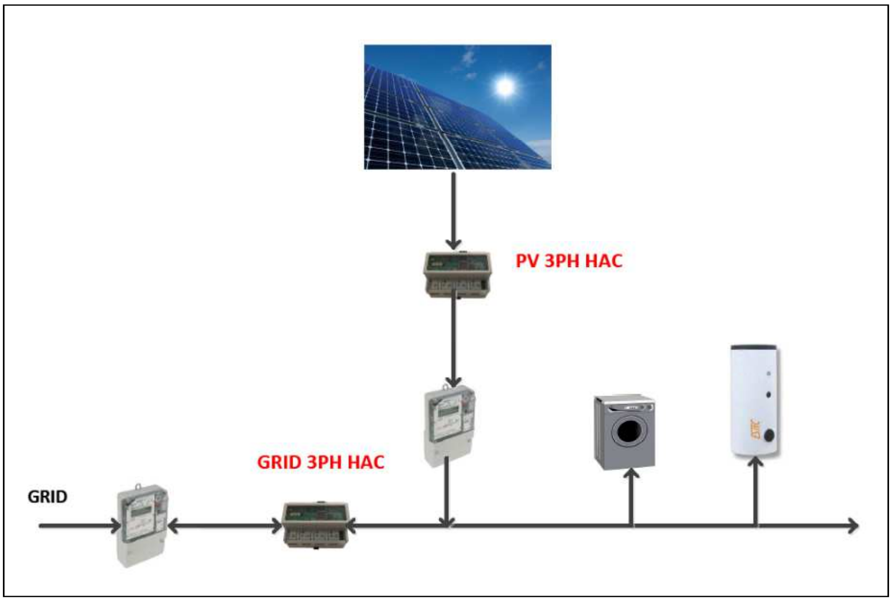

Figure 3: connection of PV HAC and Main HAC

Fig. 3 shows the two 3Phase HAC are connected to the grid to measure PV and main consumption. Fig 4 shows and example of 2 HAC installed in an household.

Figure 4: PV and Grid HAC

More HACs have been installed in all houses to monitor the appliances. Regarding the 3 phase HAC the priority has been given to boilers and heat pumps. In this case a small electrical panel were build that included all the electronics components to control the water heaters or the heat pumps. Also the temperature sensors were forseen. The 1 phase HAC have been connected to washing machines, dryers and dishwasher.

Remote PC Unit

The Remote PC has been installed in every house in a location so that the users can see also information visualized by the user interface developed in task T2.5. In a first step a

Remote PC will monitor the whole system and collect data of every HAC and send it to the remote station at SUPSI-ISAAC. Fig. 5 shows an installed Remote PC unit.

Figure 5: Remote PC unit

Implementation of B2G systems in 4 households

The main goal of this task is to test the storage systems in the households. An intensive test period in collaboration with IDSIA of the B2G prototypes installed in the Trevano were performed in order to validate the system functionality. In the next figure a schema of the designed system is shown.

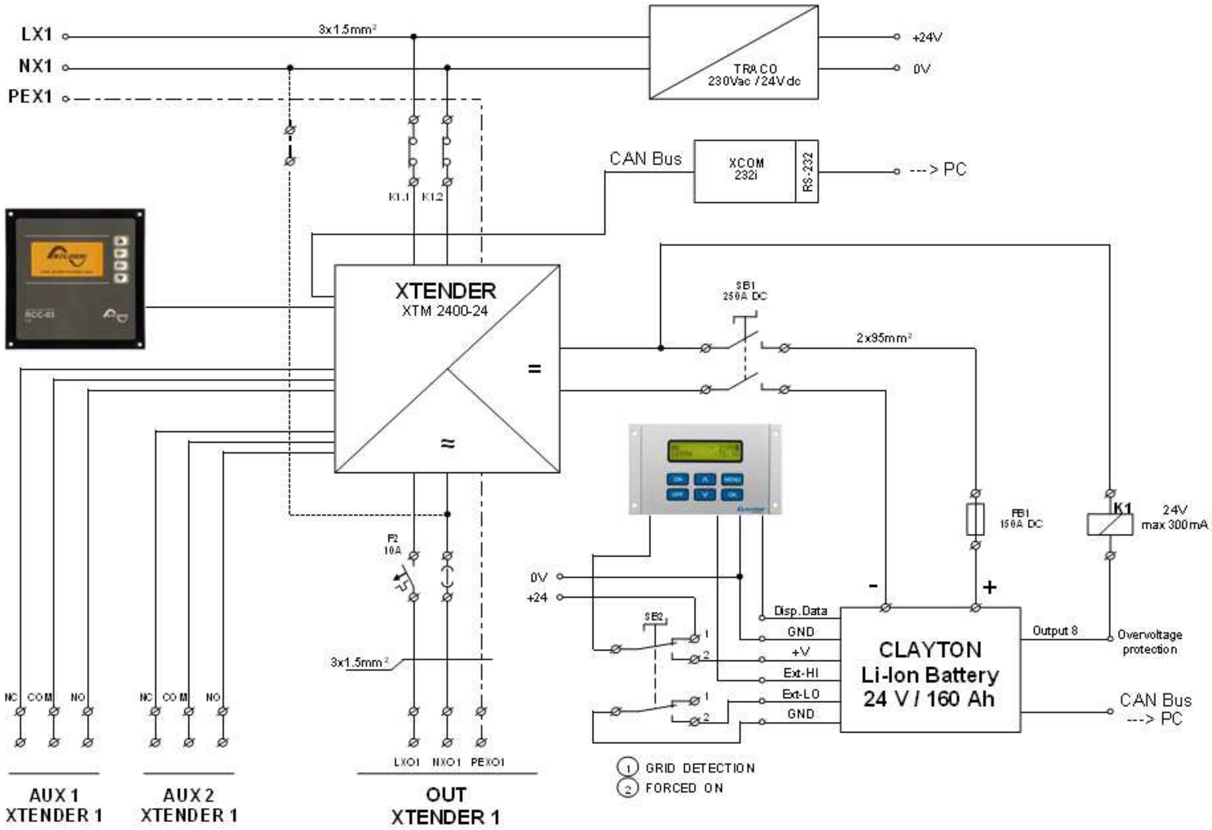

Figure 6: schematics of the B2G system

The battery is connected to multi-functional charger/inverter (Studer XTM 2400-24). This inverter is very flexible and configurable. All the working parameters are externally controllable by a RS232 serial line. The serial port of the household appliance controller will be connected to this serial line in order to control the battery system. The BMS (battery monitoring system) of the Lithium-Ion battery will also be connected to the HAC by a CAN bus line, allowing to monitor the relevant parameters of the battery.

The battery technology has been selected to ensure a safe behavior in a domestic environment. This was especially critical for the Li-Ion battery pack. In this case $LiFePO_4$ chemistry, which is one of the safer options, was chosen. Moreover the battery pack embeds an industrial grade BMS with an electronic safety switch.

After this testing period four households were selected for the installation of a battery to grid system. The priority was given to the Asilo Genestrerio (neighborhood with higher density of participants). This transformer has also the advantage to be monitored by the grid meter from Bacher Energie AG. For this reason we preferred the house connected to the LV lines monitored at the transformer. The selected locations for the B2G installation are:

- HH01: connected to the Campagnola 100 LV line (monitored at the transformer)
- HH05: connected to the Pero 130 LV line (monitored at the transformer)

- HH06:
  - connected to the Campagnola 100 LV line (monitored at the transformer)
  - monitored by Arbiter grid measurements device (voltage local plug)
- HH09:
  - connected to the Pero 130 LV line (monitored at the transformer)monitored by Arbiter grid measurements device (voltage local plug)

The figure 7 shows the installation of the battery-to-grid system inside an household.

Figure 7: Battery-to-grid system installed in the households

Integration of energy thermal buffers

The goal of this task is to control the energy thermal buffers installed in the households. With the help of the local DSO we identified the suitable houses. We chose the houses with night loads over 3kW (activated by the DSO remote control) and the houses equipped with heat pumps.

The DSO gave us the permission to temporarily disable the remote control in order to give total freedom to the algorithm to control the loads.

The HAC are installed nearby the thermal buffers. With electrical water heaters the control are done by a contactor controlled by the HACs which will cut the power supply of the water heater for a limited amount of time. With the heat pumps the HAC his using his relay output to control the “EVU-Sperre” input of the heat pump. The signal disable the heat pumps in a proper and safe way. Temperature sensors are installed in order to monitor the water outlet temperature. This sensor are connected to the digital inputs of the HAC.

The following figure shows an example of the installation.

Figure 8: Heat pump control panel and HAC installation

Installation of dispatchable loads

One-way smart charge of electric vehicle

We have three electric vehicles available to the project:

- Trevano Test facility: Mitsubishi i-MiEV
- HH12: Peugeot iOn
- HH19: Renault Zoe

In order to be able to control the charge in an intelligent way a home charge device (HCD) was provided by Protoscar. We modified this device by installing a HAC unit and connecting the HCD control board to the HAC via a RS232 line. The firmware of this device has been modified in order to enable interaction between the user and the S2G algorithm. By using the HCD interface (LCD + keypad) the user is able to confirm the desired charge due time and enable/disable the algorithm. In the other way the algorithm is able to set the desired charging current. This charging current value is sent by the Mode 3 cable to the charging device of the electric vehicle. This system enable us to start/stop the charging process and change the charging current from 6A to 15A (Mitsubishi MiEV) without any modification of the car.

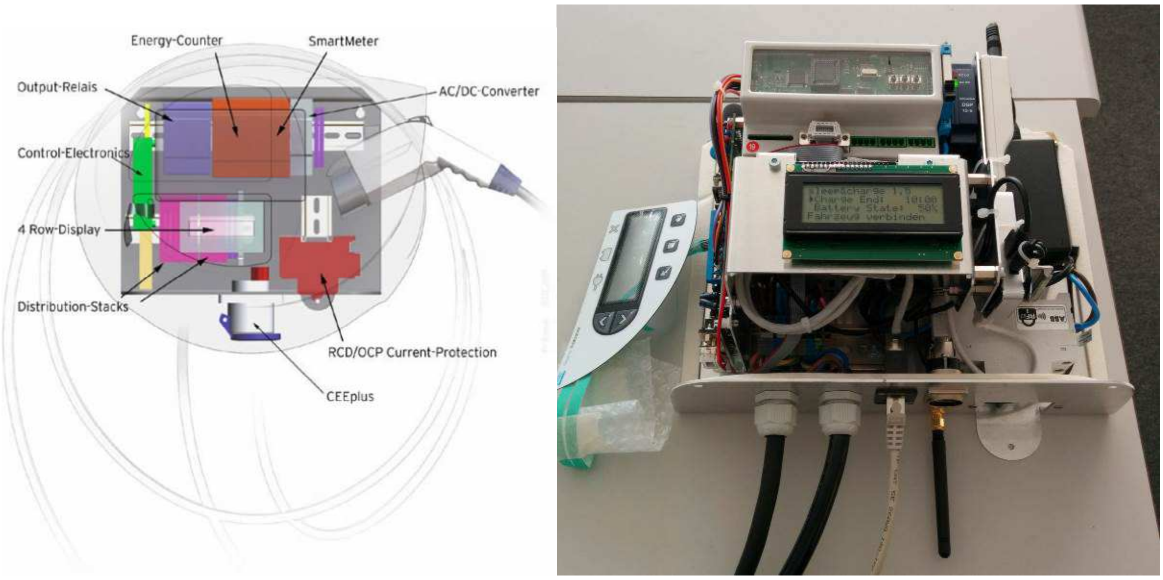

Figure 9: EV Home Charge Device (HCD) with an HAC

This functionality has been realized and tested at the Trevano test facility at the beginning of 2013. We installed the chargers in HH12 and HH19 households. The household HH19 is equipped with a Renault Zoe allowing us to test a 3-phase charger up to 11 kW controlled by the S2G algorithm.

Laundry and washing machine

We also planned to test two washing machines and two laundry drying machines. We evaluated the available devices on the market and we didn't found any appliance with a suitable domotic interface. We also contacted a Swiss manufacturer, which was interested to participated to the project but unfortunately at the moment he had only an hoven with a domotic interface, the washing machine and the laundry driers were planned in 2014 after the end of our project. We also analyzed the energy requirements of the devices current available on the market and we decided that the modern appliances are not interesting for energy shifting because of their increasing energy efficiency: 150 kWh/year for a washing machine and 200-300 kWh/year for a laundry drier (source: topten.ch). This low energy capability is also coupled with a requirement of user behaviour modification which higher the barrier for the algorithm acceptance.

For these reasons we decided not to tests the devices in the households. Anyway we found interesting to perform some hardware tests in our Trevano facility. We developed a programmable active load which can be used to simulate any appliances of the house. This active load can go up to 2.5 kW power with 20W steps. We developed a test software which can be used to reproduce the load profile that we are monitoring in the project households.

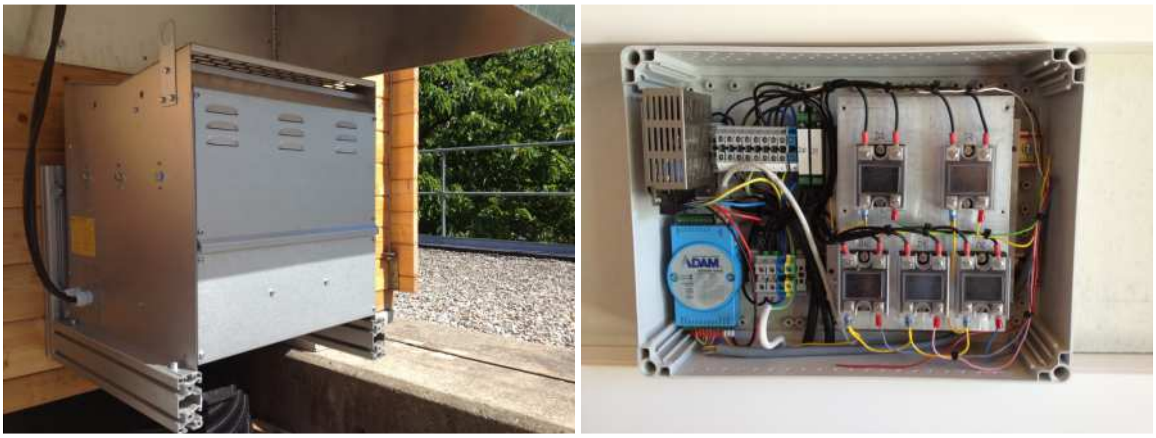

Figure 10: 2.5 kW programmable active load

Integration of S2G algorithm into the household appliance controller

Interface between HAC communication protocol and algorithm via DomoML framework

The DomoML framework is interposed as an interface layer for connecting in a transparent way the software algorithm with the real device, the HAC and the end user. Figure 11 shows its role within the whole system architecture: it let the Algorithm have all the consumption or parameter data of the HACs together with the user tasks, then it passes the scheduled activities to the HAC.

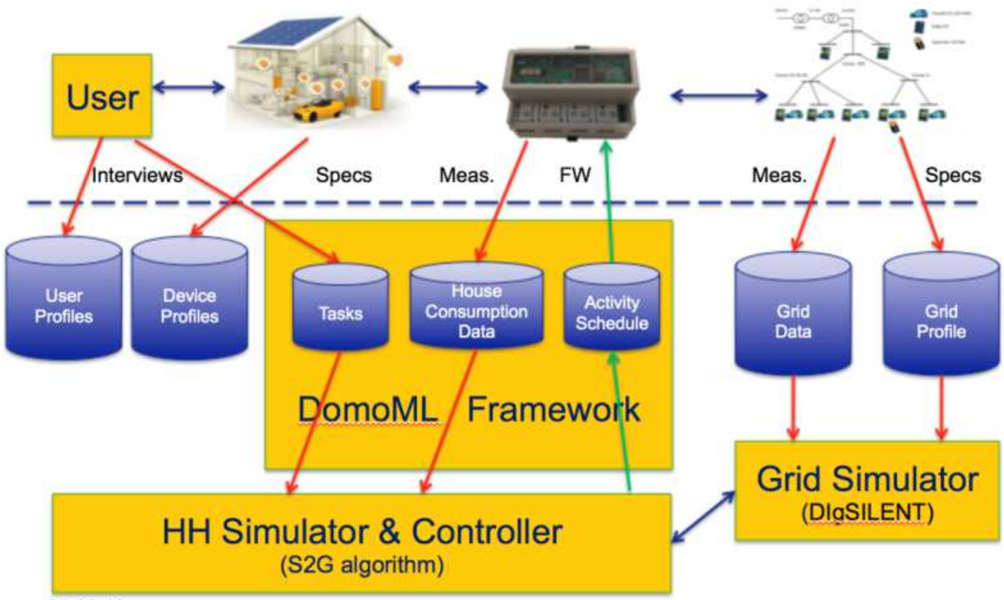

Figure 11: the DomoML framework interfacing User, Algorithm, and HAC within the system architecture

S2GClient

Within the DomoML framework, interfacing the Algorithm with HAC modules has been done by S2GClient. S2GClient is a web application that continuously listens for messages coming from the Algorithm and transforms these messages into commands for the DomoML framework.

S2GClient supports HAC devices that expose a "relay=on/off" command. In the future, other commands will be supported.

Each HAC device has a field, named "label", in the DomoML framework. This field is important because DomoML relies on it to identify the different HAC device types and to build the corresponding tasks required by the Algorithm.

Beside timers and rules, S2GClient web application creates other objects, named Task, that are associated with HAC devices and are added to DomoML framework as virtual devices.

DomoML is also useful for the installation phase. When a HAC device is physically connected to the LON network for the first time, the lonbridge server usually auto-detects it and notifies it to DomoML.

Data storage implementation

Local and remote data persistence has been supported by means of a data logger module.

DataLogger is a web application developed for full data storage purpose within the DomoML framework. The energy data are immediately stored as soon as they arrive from HAC devices, they are zipped and sent to a remote server every 10 minutes. This mechanism of storing is currently running in 20 S2G installed households.

Long term aggregated data set has been also developed; the average of HAC measurement samples is stored every hour. This implementation will be installed after testing in all the households.

Current status

In the last month the staibility of the system has been improved following the extensive test done in the S2G test facility and on site. New parameters have been added and additional logging of information has been implemented. This work is considered complete.

Interface and interaction design

After a preliminary user need analysis, some basic requirements have been defined, and will be refined according to real user needs during the tests in the households.

A interface has been developed in the form of an HTML5-CCS3 page targeted to run on different devices, such as tablets or touch panel PCs. This user interface has been implemented as a standard web technologies complaint web page, exploiting some graphic libraries for graph data display (HighStocks, www.highcharts.com).

The user interface is organized in a main view - home page, which can give access to all the other existing devices where the corresponding detailed view is presented. In addition, the user can access also some historical data and see some comparison between the mea

Main view

This is the home page for the end user interface, which is provided to each apartment owner on a tablet (mini iPad are foreseen to be used).

Each HAC device existing in the house is represented as a hexagon with a descriptive icon and its name. Selecting one of this, the user can enter the detailed view.

Figure 12: main view - home page of the end user interface

Detailed view for each device

This page displays the data of the specific device. The information is divided into sections that can be selected with the right menu where the items are depending on the type of device. The user can visualized detailed information about the current and historical status of the device and can also temporarely disable the algorithm if needed.

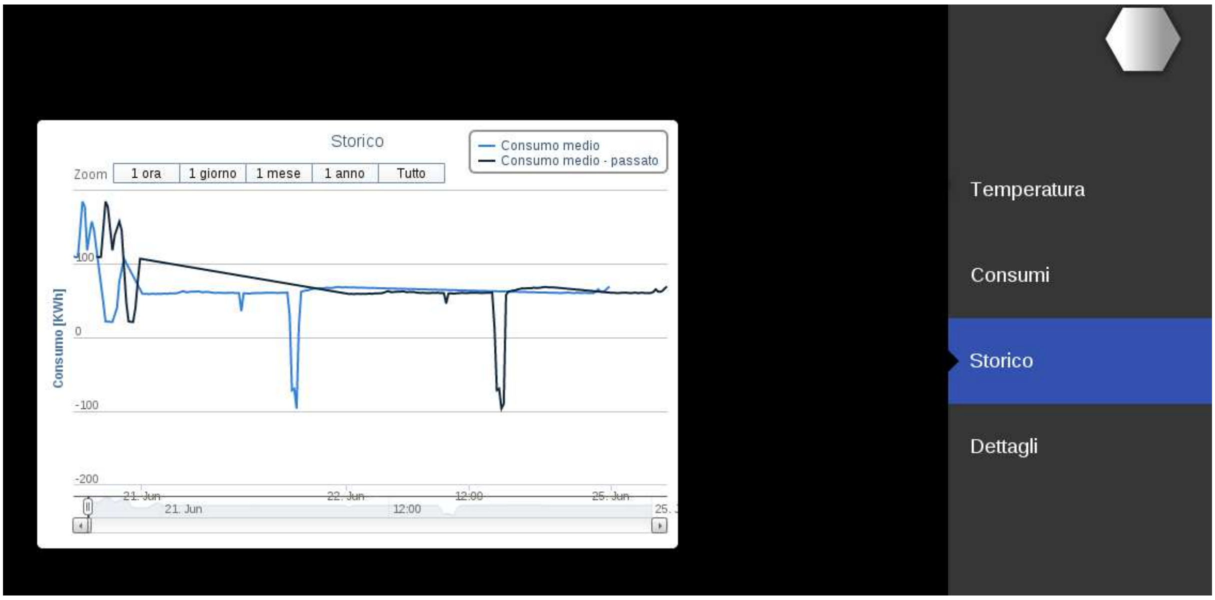

Figure 13: HAC boiler detailed view page – Historical data

Current status

After preliminary tests and impovement we are currently installing the user interface in the households. The user interface performance has been significantly improved in order to support tablet devices like iPads and Android systems.

Tariff/pricing scenarios

Introduction

The optimization or decision making behavior of the algorithm developed within the S2G project also depends on the tariff structure/price level that will be charged to end-users (mainly including energy services and network activities) and, in a wider perspective, on the development of an innovative and appropriate business model for the utilities (typically DSOs) involved.

Workpackage goals

The overall goal of the workpackage is to provide an optimal set of tariff/pricing scenarios useful to test many aspects of the optimization and simulation process, reflecting players' expectations about the future development of the electricity market in Ticino.

From a practical point of view, we'll conduct a qualitative analysis based on the expectations of the main players involved (AET, AIM Mendrisio, other DSOs, households/consumers) throughout which we'll select a set of scenarios that will be integrated as an algorithm parameter.

Activities done/current activities

1. Analysis of the literature and major field experiences

The first step of this task has been the analysis of the existing literature and major field experiences about electricity tariff schemes in order to understand the economic rationale and the technical/administrative problems behind a given tariff/pricing strategy. This phase has been completed, and main results could be summarized as follows:

Economic literature:

- For liberalized/competitive activities (upstream and downstream), according to the theory of efficient pricing consumers should face prices equal to marginal cost. Otherwise, for natural monopolies (typically transmission and distribution), due to substantial fixed costs, prices should be defined equal to the average cost[1];
- The presence of externalities, mainly related to the fall outs on the environment of generation activities. This implies that social costs usually differ (are higher) that private costs;
- The development of a spot market – where prices are defined consistent with short run marginal cost – could help in the definition of tariff schemes oriented to the maximization of economic efficiency;
- There is a wide spectrum of possible tariff schemes; with respect to time, the two main categories are time constant and time-varying ones. The latter could be more or less close to short run marginal cost and could also affect the behavior of consumers;
- The peak load matters. The load duration curve for most utilities is usually very peaky; the result is that, according to marginal cost pricing rule, the higher is the demand during the peak, the higher is the cost – and so the final price – for the service. Therefore, is pretty clear that the peak shaving could has an important economic impact, and costs related to this reduction could be partially/totally overweighed by benefits. This means that, from a theoretical point of view, the optimal way for pricing electricity would be for regulators to institute time-varying rates.

Field experiences

- The main focus of the experiences analysed is in nearly all cases the peak reduction;

[1] In any case, also for network activities it could be applied the marginal cos pricing rule, but the presence of natural monopolies characteristics implies the presence of subsidies.

- Most popular tariffs are schemes adopted are time-varying ones, in particular those oriented to the punishment/penalization of peaky energy consumption (critical peak pricing, peak time rebate, real-time pricing);
- Consumers similarly understand and respond to critical-peak pricing programs;
- The key point for the success of the project is represented by the peak to off peak price ratio. The more is higher, the more the peak reduction is significant. Nevertheless, for ratios higher than 10 the load shifting increases but at a decreasing rate;
- The presence of enabling technologies such as smart meters have been shown to incrementally boost price response;
- Low-income customers are price responsive_although not always as responsive as the average residential customer;
- Opt in or default (opt out) solution? If dynamic pricing become the default tariff substantial benefits can accrue to customers. If it's offered only as an optional tariff, benefits would be lower. Actually, it is most likely that dynamic pricing programs will evolve slowly, and that most utilities will begin by allowing volunteers to opt on to alternatives tariffs while leaving flat-rate pricing the default option.

The degree to which customers shift load in response to time-varying rates appeared to be strongly affected by several factors.

Focus – Against dynamic prices

- ❑ "Dynamic peak time": with the increasing adoption of solar and wind energy on the supply side, and EV on the demand side, electric utilities will face new challenges in determining the new peak time compared to their historical norms; the discussion should shift from "dynamic pricing" to "dynamic peak time".
- ❑ Usually consumers prefer a simple tariff structure (such as a flat rate) instead of an "unpredictable" price scheme (dynamic prices). Furthermore, the deployment of dynamic princes could increase the price volatility (the price of electricity to end-users would vary, unpredictably, according to its wholesale price).
- ❑ The monitoring function of the smart grid truly affect demand only if prices are simple enough for the consumer to understand. Very often dynamic prices are sophisticated and complicated to understand.
- ❑ Results in terms of money and energy savings are frequently estimated using pilot projects data, but the latter involve "opt-in" consumers, in other words consumers that have voluntary chosen to be included in the simulation. There has been some kind of self-selection so consumers analysed are probably already prepared to change their behaviour ad a response to price variations.
- ❑ Lawrence Makovich, a Vice President at Cambridge Energy Research Associates (CERA), now called IHS CERA, "Dynamic pricing is not a new idea"

2. The S2G project

In addition to the above mentioned variables, the selection of tariff pricing schemes – and, more generally, of the business model - must consider also those more country-specific topics:

- ❑ National energy strategy to 2050
- ❑ Local energy strategy (PEC)
- ❑ National/local electricity market organization
- ❑ Evolution of national/local electricity market
    - ❖ national/international crisis/growth
    - ❖ degree of liberalization
    - ❖ cost of electricity
    - ❖ role of RES (in particular PV/battery storage)
    - ❖ relevance of peak load matter
    - ❖ Weight of electricity bill on total monthly utilities expenditure

- ❑ Contractual arrangement between DSO and generators/traders
    - ❖ Variable price
    - ❖ Fixed price
- ❑ Installed generation capacity (spare capacity for peak)

2.1 The selected tariff pricing schemes

Based on socio-economic characteristics of our sample, other than the current ToU rates, we could test five different tariff pricing schemes:

- Time of Use (control group)

a. Time of use and Dynamic Rates (Peak Time Rebate)
b. Flat Rate
c. Flat Rate and Dynamic Rates (Peak Time Rebate)
d. Flat Rate with Inclining Block Tariffs
e. Real Time Prices

a) Time of Use and Dynamic Rates (Peak Time Rebate)

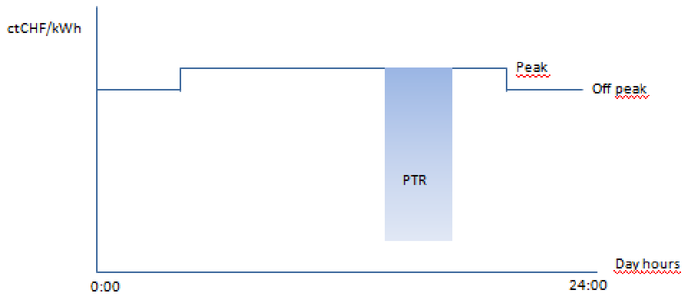

Figure 14: Time of Use and Dynamic Rates (Peak Time Rebate)

If consumers will accept to not consume during the peak or shift the use of some commodities later (or before) they'll have the possibility to benefit of a credit/reduction.

Other than the advantages related to the load reduction in critical periods, utilities could use the electricity saved during the peak to participate to the balancing/regulation market.

This tariff pricing scheme could be roll out as the default option (opt out). If customers do not wish to participate, they simply buy through at the existing.

b) Flat rate

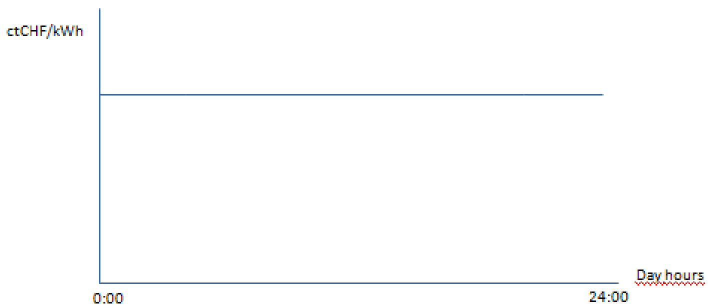

Figure 15: Flat rate tariffs

Is the simplest type of tariff; each customer pays a fixed price per kWh no matter how much it costs the utility to deliver it.

A slightly advanced version of this tariff utilizes different price levels based on the season that it is applied.

The crucial point is represented by the definition of the price level.

The presence of a generalized undifferentiated tariff could help in shifting the load. In our specific case, the algorithm could be “free” to shift the peak load.

c) Flat rate and Dynamic Rates (PTR)

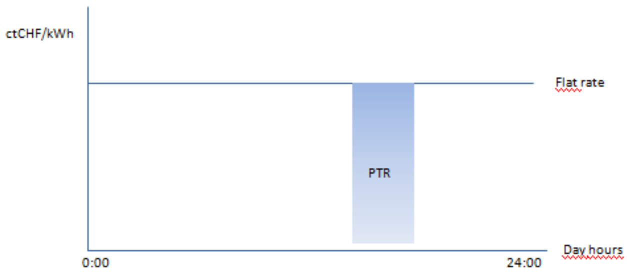

Figure 16: Flat rate and Dynamic Rates (PTR)

Also in this case, as well as in a), instead of charging a higher rate during critical events, participants are paid for load reductions (estimated relative to a forecast of what the customer otherwise would have consumed).

The difference with the first model is the general price level (flat price instead of ToU price).

d) Flat rates – Pure Inclining Block rates (IBR)

A variation of the “classic” flat rate is the increasing-block tariff, a ladder-like pricing mechanism where customers pay a low, fixed price until a consumption threshold is reached after which they pay higher amount. There could also be more than one thresholds (tiers) included in this tariff.

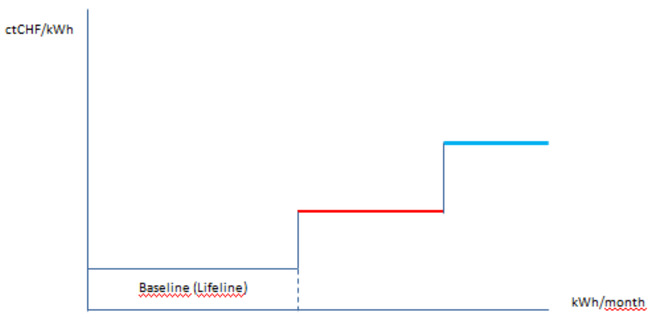

Figure 17: Flat rates – Pure Inclining Block rates (IBR)

In designing an IBR difficulties are related to:

- Aligning prices with system costs;
- Establishing the number of tires;
- Determining cutoff points;
- Encouraging more efficient energy consumption;
- Promoting social objectives (e.g., income re-distribution)

- Ensuring bill stability or rate continuity

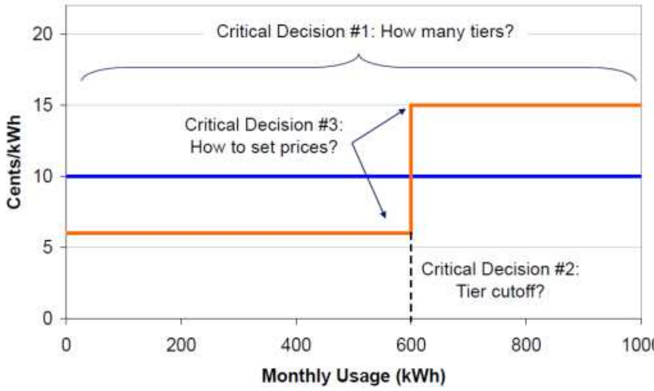

Figure 18: IBR design, critical decisions are needed

A Smart rate design could be obtained combining Inclining block rates for energy efficiency and dynamic pricing rates for peak load management.

An idea could be to mix IBR and some kind of credit/award if the user accept to shift consumption or to not consume in a certain time period (for example, a CHF credit or a kWh surplus).

Future developments could be tailored offers and profit sharing.

e) Real time prices

Participants in RTP programs pay for energy at a rate that is linked to the hourly market price for electricity .

Prices most accurately reflect the cost of producing electricity during each hour of the day, and thus provide the best price signals to customers, giving them the incentive to reduce consumption at the most expensive times.

Against: from “dynamic pricing” to “dynamic peak time”; complexity; price risk/volatility

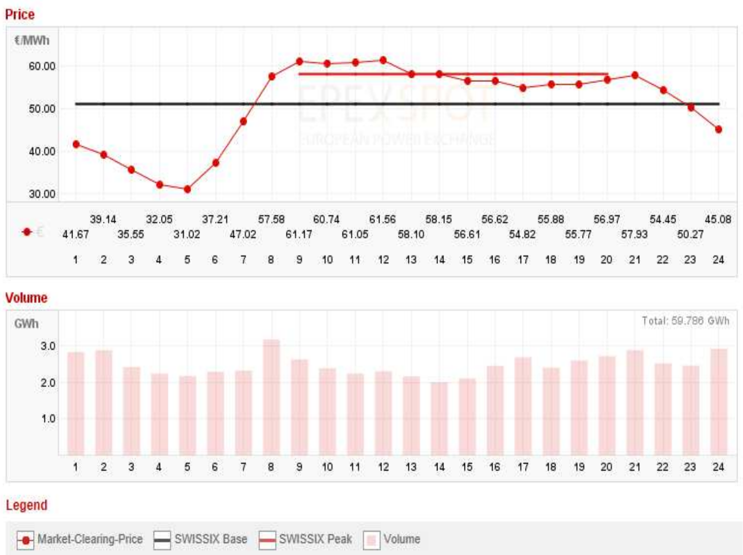

Figure 19: Real time prices

3. Re-thinking the Electric Utilities' Business Model: a first sketch

The selection and the adoption of the most appropriate tariff schemes are strictly related to the wider topic of the new business model for electric utilities.

We have to keep in mind that the profitability (intended in terms of marginality/earnings) of "classic" electricity commodity supply is declining, due to an higher level of competition (among large national/international companies and bigger and smaller ones) and to the maturity of the industry.

Other than smart grids and AMI, the new drivers that seem to address the utilities' activities in the very next future could be:

- ❑ Energy efficiency

As more aggressive energy-efficiency measures are deployed, utilities' generation volumes and revenues are likely to decline.

Utilities can act as aggregators. Utilities seeking the broadest opportunity can become aggregators, coordinating the full range of activities for customers across a spectrum of product and service providers. The utility may deliver services itself when it has the capabilities, or it may engage other entities to provide them when it does not. Utilities can act as a single point of contractor for customers, enabling them to access anything from financing to maintenance through one source

- ❑ Challenges due to Distributed Generation/renewables grid integration

Also the increasing weight of DG will determine a generalized reduction in volumes supplied. The other side of the coin is the rise in network charges, with a cross subsidization between DG owners and other customers. Futures regulatory/energy policies scenarios must be take into account this evolution, maybe with the definition of a more considerable network tariff for the connection to the grid of DG. In any case, the level of the above mentioned tariff should be fair and not excessive because otherwise generators will find more advantageous to be off-grid.

- ❑ New RES economic incentives

The deployment of DG is still mainly associated to the presence of some kind of RES subsidies such as investment-based incentives or production-based incentives (feed-in tariff, quota system). The current proposal of review of the present Swiss system (see "*Sistema di rimunerazione per l'immissione di elettricità con commercializzazione diretta per le nuove energie rinnovabili*", UFE), more oriented to the market, is aimed to the optimization through the commercialization by generators.

- ❑ RES overgeneration

There will be – and in some cases there have already been – situation of overgeneration, when more electricity is supplied than is needed to satisfy real-time electricity requirements. This will require more flexibility at grid level.

- ❑ Market for regulation

The Energy market for regulation will become more and more attractive, also due to its high profit margins. In particular, experts agree about the increasing importance of the infra-day market. Utilities that will be able to active part of this market, also thanks to more interaction/control of consumer behavior, will certainly will be better positioned from an economic point of view.

- The role of storage facilities

There will be room Limited energy Storage Resources (LESRs). They are generators with extremely fast response time; they can act as a load (charging) or as a generator (discharging). LESRs include:

- Flywheels
- Batteries
- Compressed air energy storage
- Plug-in electric vehicles

Disruption and rebuilding of Utilities business models

The drivers above mentioned will determine the disruption and the necessity to rebuild the utilities's business model.

A new source of value could be linked to the deployment of new services, so utilities should determine where they want to fit along the continuum from pure "commodity" electrons to value-added services.

The possible path

The general impression is that there is a shift from current models to those that rely on more:

- customer interaction
- commercial and energy services
- information management

- Utilities should consider establishing partnership with financial institutions to help customers finance investment in energy-efficient products and services. A utility could simply act as a sales channel for an existing financial institution, or it could establish an internal division that originates, processes and distributes loans.
- Utilities should train their field forces to act as advisers, consultants and relationship managers, able to engage consumers at moments when they are likely to make decisions that could affect they energy footprint.
- Utilities should build on the brand attributes that they have already established with customers to persuade sceptics that they are reliable providers of energy-efficient products and services.
- Cost-sharing arrangement between distributed generators

- First phase: experimentation in business model

Expansion into energy services and behind-the-meter assets, either on their own or with third-party partners. Customers increasingly want value-added energy services such as consumption information, consumption controls (load shifting), green energy, demand response, higher reliability, and "energy bundles" -- electricity combined with other products and services (rooftop solar owned by the utility, free air conditioner maintenance if enrolled in demand response, a special rate for electric vehicle owners, and so on).

- Second phase: Consolidation.

The experimentation of the first phase will gradually create winners and losers.

- Third phase: expansion.

In the third phase, the industry is likely to move away from failed experiments and expand into those new models that have proven successful

It could be useful to seek partnership with companies from other sectors (telecom, technology, media, finance companies and home building) or deploy portfolios of products and services from basic insulation to systems that automatically adjust energy consumption to the needs of people in their homes

Utilities could move from energy provider to Network provider up to Content provider. The main risk is the distortion of the Utilities nature.

Acquisition and analysis of grid measurement data

The project team has been measuring the relevant “plug-quantities” in masses since approx. August 2012. The data is captured and stored in a database at SUPSI. The data is accessible via internet and can be downloaded. In the following, we report – as an example - on a very small subset of filtered data sets taken from this database. We show results from the following locations in Mendrisio:

- Transformer Asilo – direction Campagnola
- Transformer Asilo – direction Pero
- HH06 (Household # 6 in Campagnola part of 400V grid)

Main Question: Is it possible to use a real-time plug based real-time voltage signal measurement at the 400V plug to control Electric cars and other households with the optimal grid security / minimum cost / minimum losses / minimum sufficiency as multi-objective? For that, we need to know if the voltage at the plug includes “sensitivities” related to state of the grid (critical grid state values have been mentioned in the sections before).

What does the measured data show so far? Example of one single day (of hundred measured days) measured sample data captured at “400 V plug”:

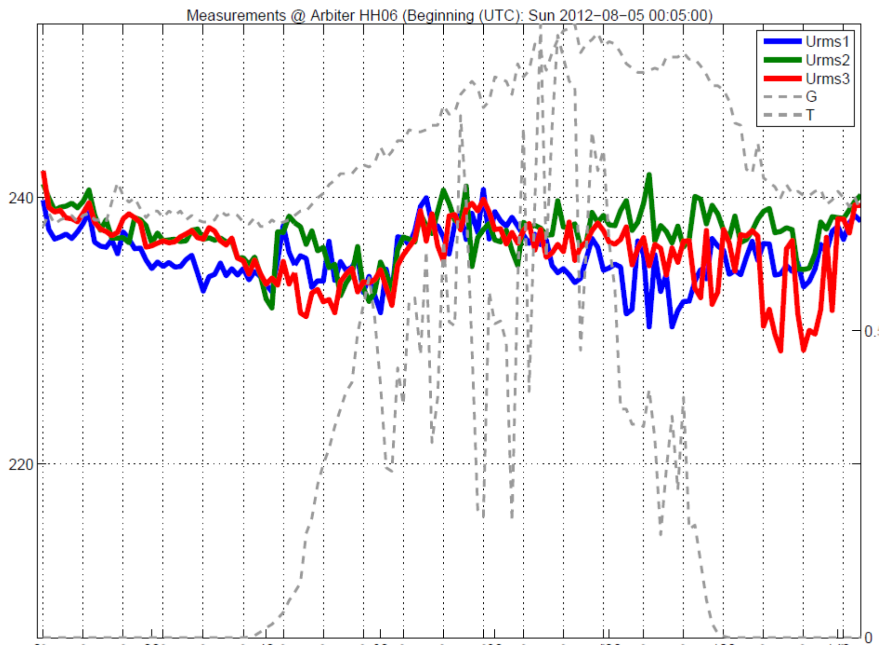

Figure 20: x-Axis: Example of measurements at HH06 in 10-minute intervals of a single day (Sun 2012−08−05, beginning at midnight); y-axis (left side: voltage magnitudes [V] of the three phases (red, blue, green); right side: Temperature (normalized T, upper dashed line) and sun shine (normalized G, lower dashed line)

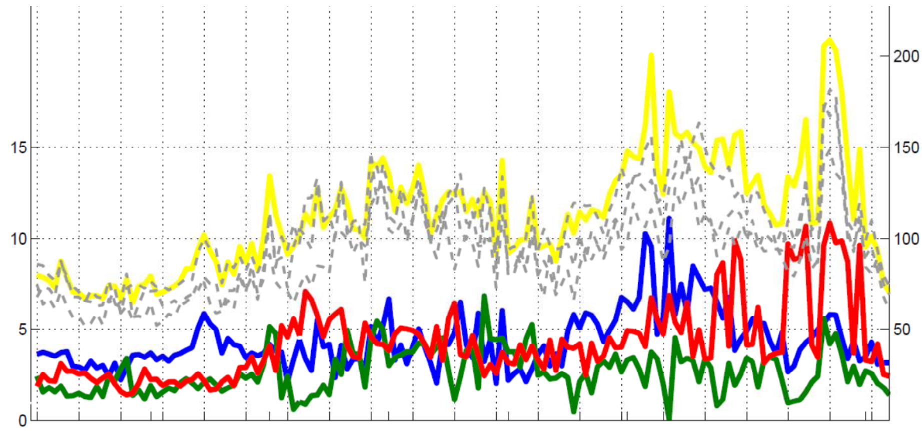

Figure 21: x-Axis: Example of (left side y-axis) voltage phase differences of HH06 plug to Asilo transformer plug in 10-minute values of a single day (Sun 2012−08−05, beginning at midnight) and the (right side y-axis) currents at the transformer low voltage side. y-axis (left side: voltage differences of the three phases (red, blue, green); right side: currents measured at transformer).

In Fig. 25, we show the phase currents at the Asilo transformer with direction towards HH06 (y-axis) and the phase voltage at the HH06 (all three phases shown) in 10-minute intervals of all measured days of the month of December .

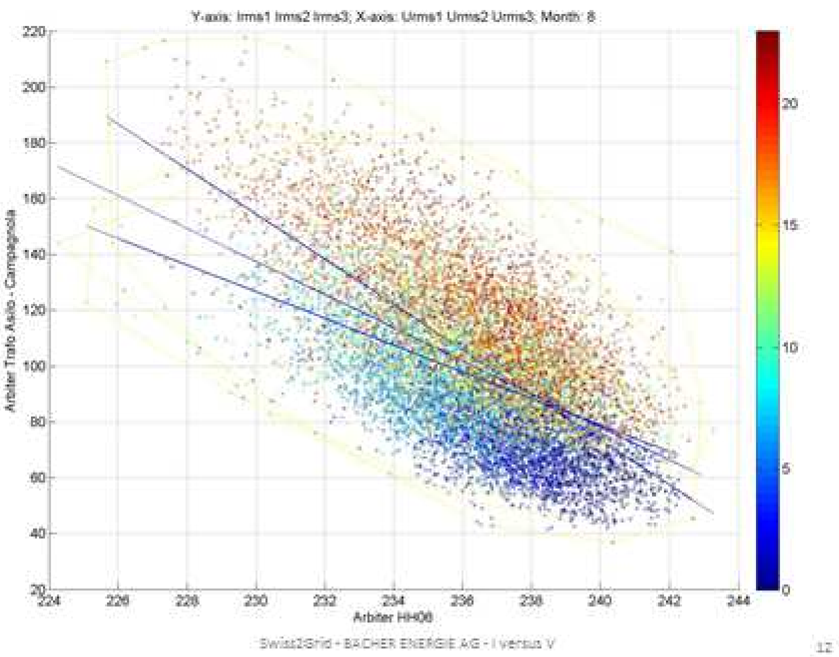

Figure 22: Phase currents at the Asilo transformer with direction towards HH06 (y-axis) and the phase voltage at the HH06 (x-axis) (all three phases shown) in 10-minute intervals of all measured days of the month of August. The colors indicate the (UTC) time of day when the point was measured.

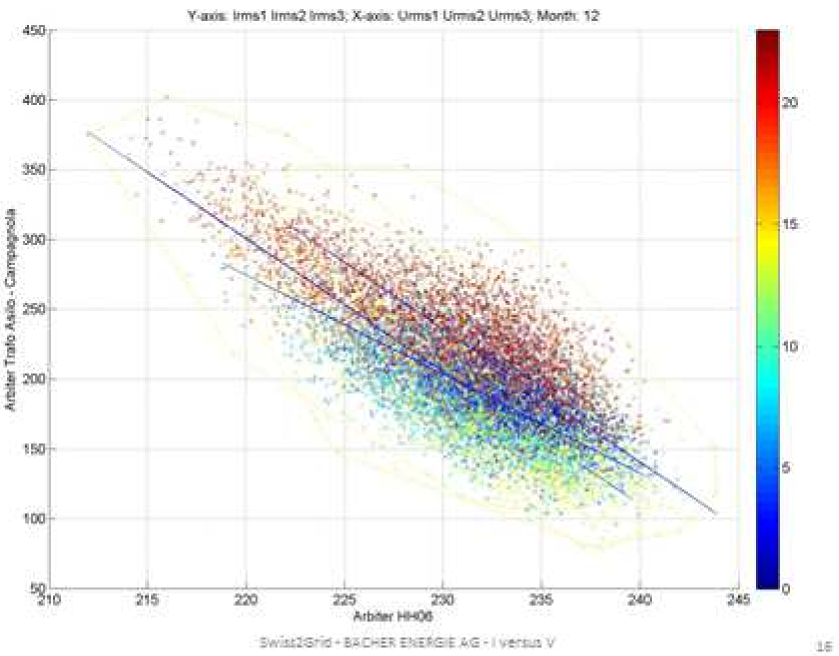

Figure 23: Phase currents at the Asilo transformer with direction towards HH06 (y-axis) and the phase voltage at the HH06 (x-axis) (all three phases shown) in 10-minute intervals of all measured days of the month of December. The colors indicate the (UTC) time of day when the point was measured.

In Figs 27 and 28, we show the phase currents at the Asilo transformer with direction towards HH06 (y-axis) and the phase voltage difference between HH06 and the Asilo transformer voltage (all three phases shown) in 10-minute intervals of all measured days of the month of August (Fig. 27) and December (Fig. 28).

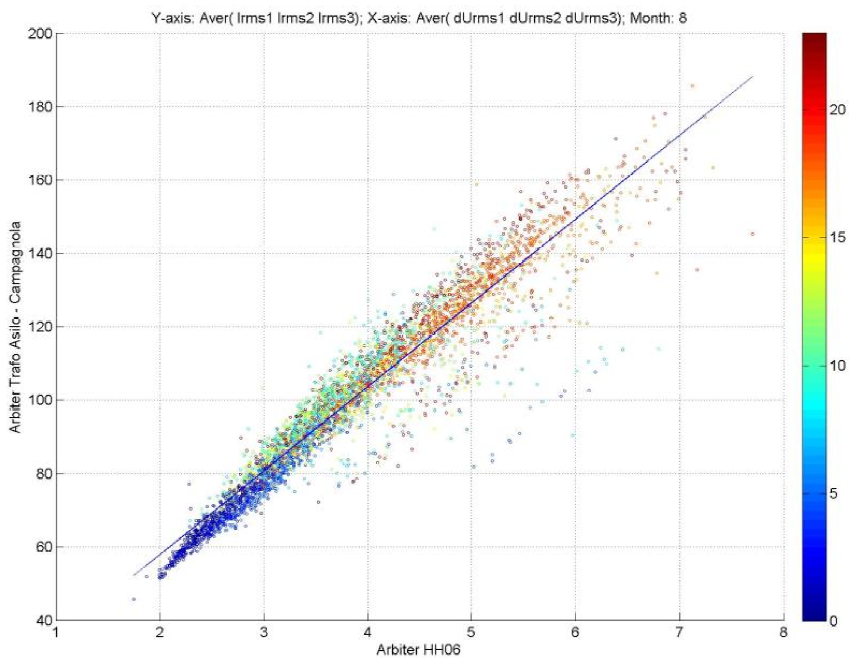

Figure 24: Phase currents at the Asilo transformer with direction towards HH06 (y-axis) and the phase voltage difference between HH06 and the Asilo transformer voltages (x-axis) (all three phases shown) in 10-minute intervals of all measured days

of the month of August. The colors indicate the (UTC) time of day when the point was measured.

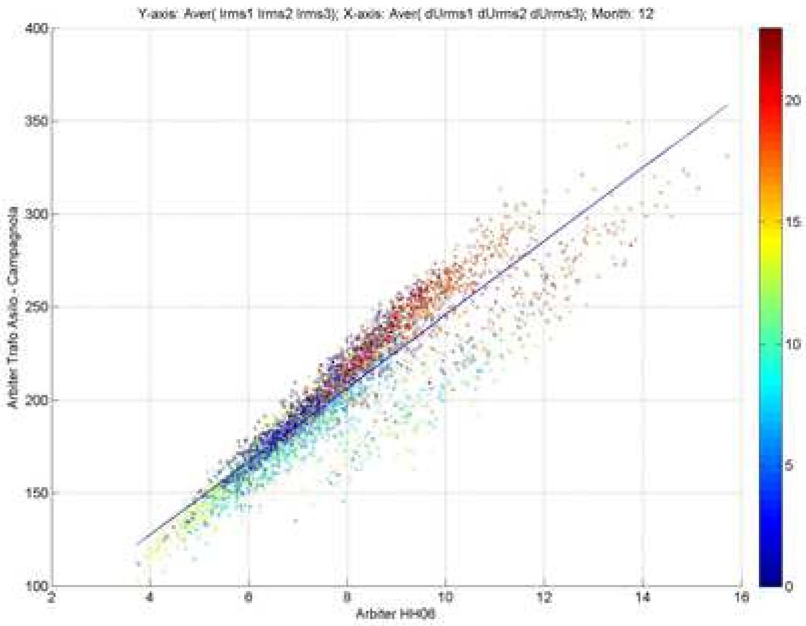

Figure 25: Phase currents at the Asilo transformer with direction towards HH06 (y-axis) and the phase voltage difference between HH06 and the Asilo transformer voltages (x-axis) (all three phases shown) in 10-minute intervals of all measured days of the month of December. The colors indicate the (UTC) time of day when the point was measured.

Assessment of the intermediate results

- The monitored voltage level itself at the plug is very relevant for a healthy state of the future distribution grid. It must remain within given bounds. This is immediately given by the voltage measurement. A monitored voltage value approaching or beyond 110% and below 90% nominal voltage (i.e. below 207V and above 253 V for a nominal phase-neutral voltage of 230V) must trigger local action at relevant plugs (usually: too high voltages are relieved by switching off generation or switching in consumers near the plug-location).
- Both Figures 22 and 23 (and those for other months) indicate that there is some correlation between «Voltage Amplitude at plug» (here HH06) and «Current in line between plug and 11kV/400V transformer» (here: Asilo campagnola): Higher currents indicate a lower voltage, lower currents indicate a higher voltage at HH06. A similar, but more varying information has been seen at the other path from the transformer towards HH09.
- Figures 24 and 25 show a clear trend: There is a correlation between voltage (magnitude) difference of a node (here HH06) and the transformer (here Asilo) and the current flowing in the same transformer towards the node. It seems evident that this correlation represents the impedance of the connection between the two nodes.
- Statistics of other nodes show that the more distant the node (and its measured voltage) is from the next higher voltage level, the higher is the chance to find a correlation between voltage level and currents at the transformer higher up.

  Main reasons (fully explained by simulation module within S2G, BFH):

  - The relative voltage change of higher-up grid levels is in general lower than the voltage change at lower voltage levels. As a consequence, the voltage variations are smaller, the higher-up in terms of voltage levels one goes. When looking at the voltage from a distribution grid node, the upper levels

appear like a voltage source with relatively low variation as compared to the own voltage.
- The longer the cable is towards a node at a lower voltage level, the higher is the impedance to this (upper-level) voltage source. Since cables at the lower end of 400V grids tend to become thinner (lower cupper diameter, the specific impedances (Ohm/km) of these ending cables – also within the end-consumer premises – can increase strongly. As a consequence, the voltage drops caused by these ending cables are higher even with smaller currents towards the ends of radial street lines.
- The voltage amplitude at plug [i] towards the ends of street lines seems to be more sensitive to changes by local consumers (and generators).
- For nodes nearer to the transformers the voltage amplitude at plug[i] is influenced more by the grid users of lines plugged in «parallel» 400V street cables (i.e. other tree grid parts below transformer grid levels 4 and 6)
- In addition, voltage amplitude levels of whole trees below transformers at grid levels 4 and 6 are (automatically, manually) partially controlled by voltage control mechanisms in upper voltage levels without sensitivity towards individual local 400V grid loading.
- Grid characteristics (impedances) and possibly load / generation characteristics of higher-up grids prevent a strong correlation of current magnitude in the grid parts nearer to the transformers and voltages measured there.
- There seems to be a good correlation between voltage difference at a plug at or near the transformer and the one of a household plug AND the flow (i.e. aggregated net load) measurement along the cables / lines between these two plugs
- Two plugs:
  - Plug 1 is 400V e.g. at home;
  - Plug 2 is 400V plug „higher up“ (nearer to transformer)
- Voltage amplitude difference shows (very) good correlation with aggregated load (current) on the cables between the two nodes

Development of the S2G algorithm

Development of algorithm scenarios with varying levels of communication

The aim of the task is to study different version of the S2G algorithm under different inter and intra-agent communication scenarios.

When a bidirectional communication infrastructure is in place, we define the concept of *neighborhood* as the set of households able to communicate among each other. We define the *full neighborhood* case as the scenario in which all households connected to the same MV-LV transformer can communicate among them. We also study the scenario in which the households under a transformer are partitioned in a set of smaller, distinct neighborhoods, composed by as few as two households.

Every household computes its own forecast load for the next 24 hours, and broadcasts this information to its neighbors. The forecast load is computed by the household accounting for the contribution of both for its controllable and non-controllable appliances.

Future loads of non-controllable appliances are predicted by considering the average load of such appliances as measured during the previous 3 months for the same time of the day and day of week.

Each controller repeatedly solves the S2G algorithm in a non-synchronized fashion. In our experiments, optimizations are triggered on average *52.4* times per day per household. It is important to remark that for a 24 hours horizon, using a common PC, the solution of the household optimization problem takes less than 1s, such that computational aspects are not really an issue.

Communication infrastructure, requirements and protocol

Since communication occurs exclusively among HAC controllers in the same neighborhood, no strict technological requirements need to be imposed on the characteristics of the communication infrastructure. Communication losses among controllers would result in a smooth degradation of system's load flattening performance: in the worst case, if all controllers lost communication abilities, the system would behave like in the baseline case. Remarkably, thanks to the fully decentralized model, the choice of communication infrastructure is flexible and can potentially be different for different neighborhoods.

The communication protocol uses a single message type, wherein a controller broadcasts its ID (assumed to be unique within the communication neighborhood), and its expected load for each *15*-minute timeslot in the next 24 hours.

In terms of bandwidth, when encoding the controller ID with 4 bytes and the expected load at each timeslot with 2 bytes, the size *L* of each message amounts to 4 + 2 x 24 x 4 bytes.

Additional payload might result from the characteristics of the technologies used to implement reliable local data communication in the network.

On average, each controller broadcasts a message twice per hour (i.e., after each rescheduling). Then, the total expected payload generated by a single controller amounts to about 10kBytes per day, i.e. roughly 1 bit per second (bps).

Up to relatively large values of number of households this amount of traffic can be reasonably handled by available Powerline communication (PLC) or wireless technologies. For example, the set of narrow-band PLC standards promoted by the PRIME Alliance for metering provides a minimum throughput of *21.4* kbps http://www.prime-alliance.org/, whereas the G3-PLC specification http://www.g3-plc.com/, backed by several companies providing inexpensive, interoperable implementations, yields a *33.4* kbps data rate; similar performance can be expected from the P1901.2 standard being developed by the IEEE http://dx.doi.org/10.1109%2FMCOM.2008.4557044

Note that communication requirements only depend on the amount of households in each communication neighborhood, and are not affected by the total amount of neighborhoods. Therefore, the system is inherently scalable to huge deployments, provided that the size of each neighborhood does not exceed the specified limits.

Assessment of the results

We have performed several simulation experiments have been performed on a set 120 households. All households are downstream a single MV-LV transformer.

- *Communication-free scenarios*
- *Baseline*: No demand side management.
- *Baseline-random*: Appliances are managed by a controller that randomizes their behavior, still meeting their operational constraints.
- *Cost*: Controllers only implement the single-objective optimization of end used energy costs.
- *Cost-random*: Controllers implement single-objective optimization of energy cost and randomization.

Communication scenarios

C-n: 120 households are divided in 120/n neighborhoods we analyze each scenario with n={2,3,4,5,6,8,10,20,60,120}. E.g scenario *C-2* implies that each pair of households are communicating among them, while *C-120* implies full communication between all simulated households.

Stability-120: stability is optimized with full communication.

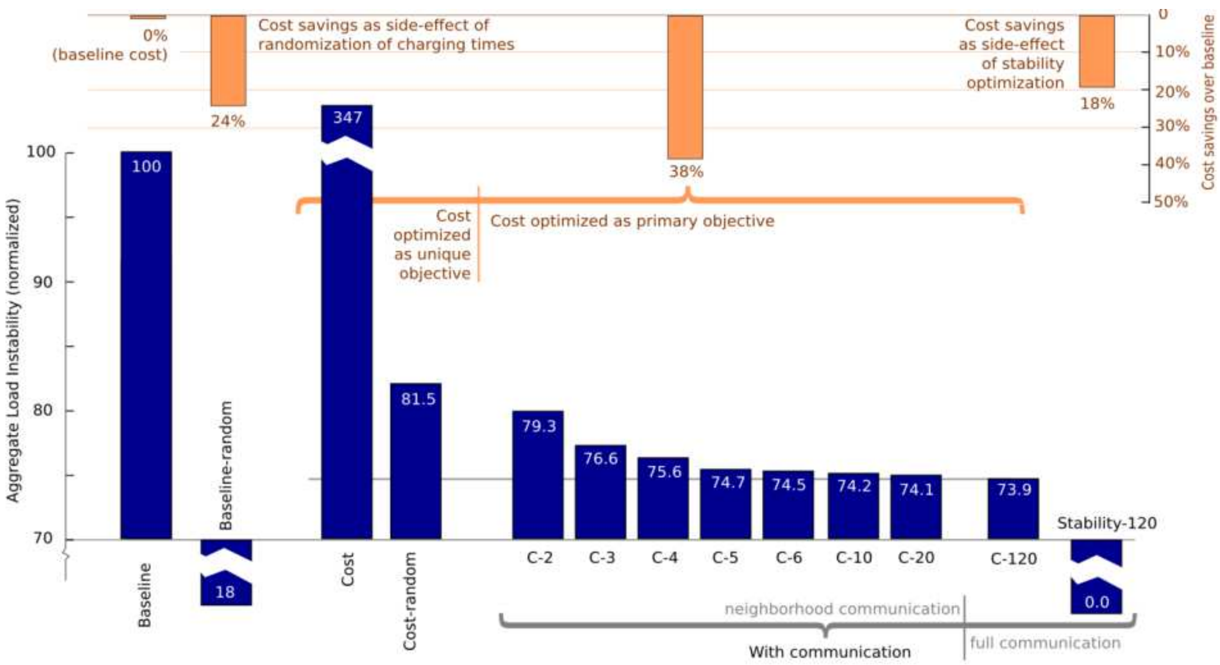

Figure 26: summary of results for decentralized communication. Baseline case is normalized so that its costs represent 0% and stability performance amounts at 100%. Randomization helps in both reducing the costs and stabilizing the network. When cost is optimized at its maximum (38%), network stability is severely deteriorated. When we enable network stabilization via communication we can still obtain optimal cost savings (38%) while stabilizing the network with a performance lower than the 80%. We observe that pervasive communication does not help to improve more than 73.9%

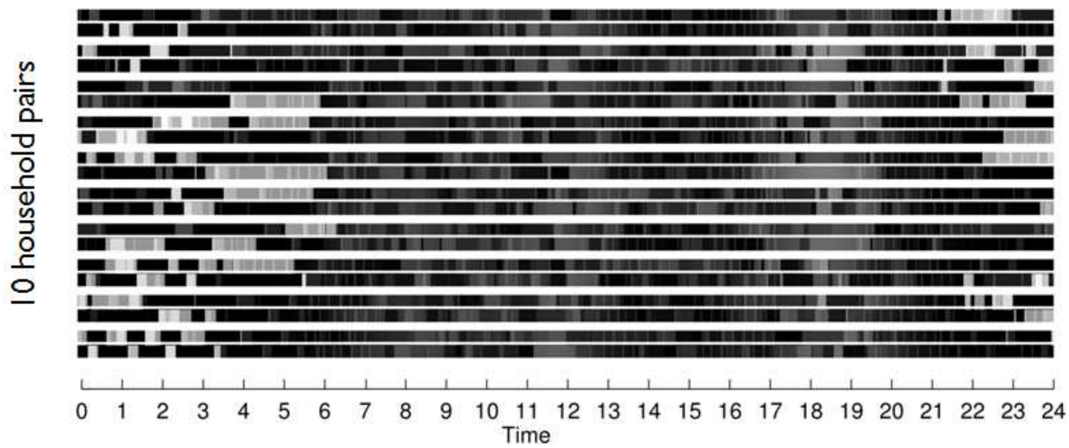

Figure 27: a detailed representation of a C-2 scenario. Pair of households are enabled to communicate among them. Bright timeslots represent moments in which an high power is drawn from the network.

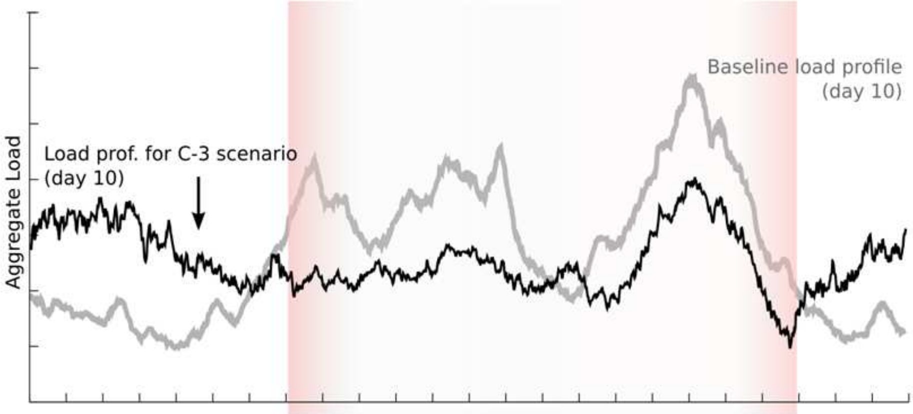

Figure 28: detailed results for the Baseline and C-3 case. The overall network load at the MV-LV transformer is reported for day 10. The overall load is substantially flattened with a remarkable load shift towards periods with low price of energy.

Development of algorithm for grid constraints forecasting

According to results obtained in the monitoring I work package of phase A in the grid of Mendrisio, a significant dependence is present at the MV-LV transformer between voltage and grid loading in given situations. During field tests we have monitored voltage drops induced by the choices of the algorithm and therefore enhanced voltage forecast algorithms.

Theoretically, voltage drops depend on the load and the impedance of the network.

Assessment of the results

In field tests we intended to measure the voltage drops induced by the algorithm in different scenarios. Therefore, we have implemented different load scenarios and measured voltage drops. We have observed an average of 2 Volts drop per absorbed kW. We used these results to adjust the voltage forecast algorithms.

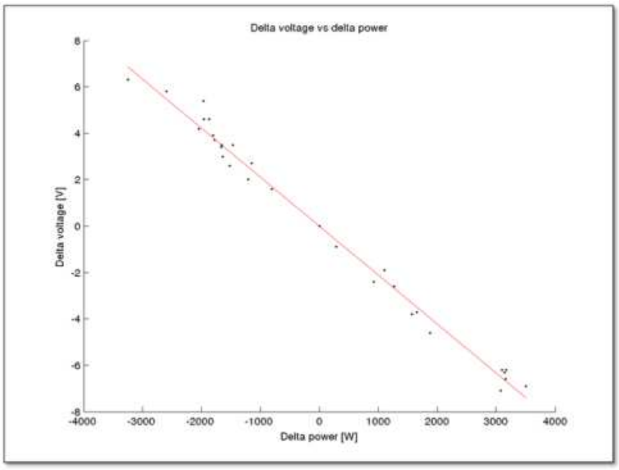

Figure 29: voltage drops depending on differences in absorbed power. Voltage drops exhibit a quite neat linear relationship of about 2 Volts per kW.

Update of and tests with algorithm

IDSIA analyzed results coming from large-scale simulations and deployments of the algorithm on real hardware.

Large-scale simulations with up to 220 smart households have shown generally positive behaviors with reduction of peak loads and stabilization of voltages within the distribution network. Example simulation results showing how algorithms can reduce the voltage oscillations observed in different parts of the distribution network are reported below.

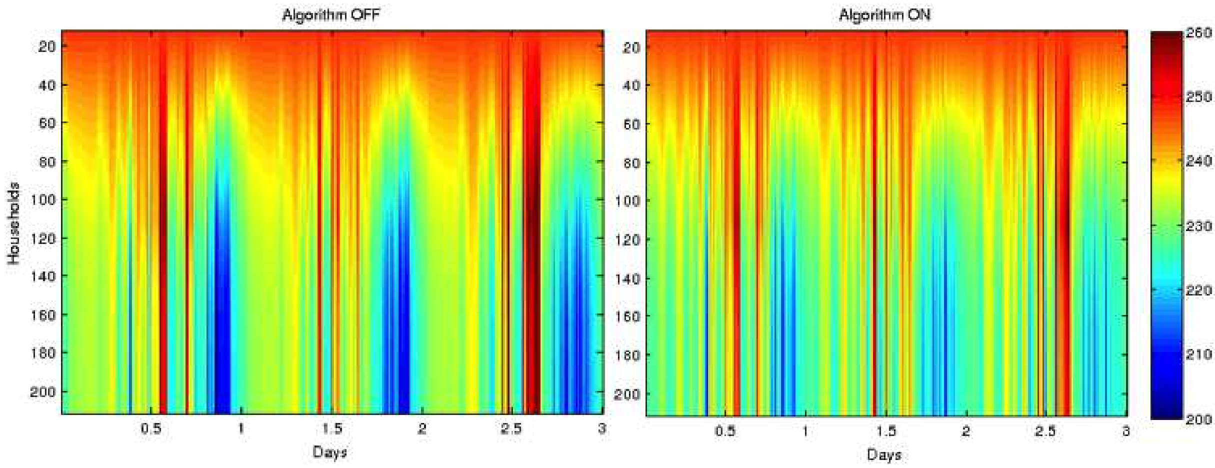

Figure 30: 220-households simulation: representation of voltages (colors: blue: low, red: high) according to the position of the household along the distribution network (y axis) and time (x axis). Left plot shows behavior when the algorithm is switched off, compared with the behavior when the algorithm is on (right plot). Note that the algorithm reduces extreme voltages.

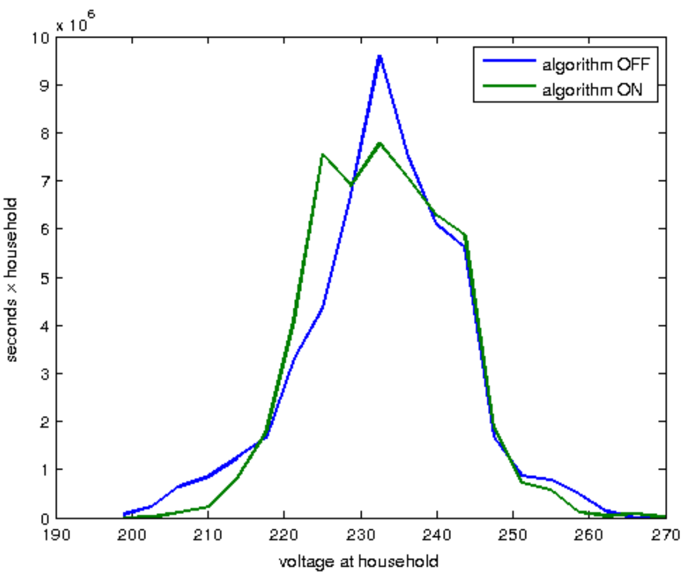

Figure 31: the plot reports the amount of time (y axis) that a given voltage (x axis) was measured during the simulation reported in Figure 11. Blue plot reports results when algorithms were turned off, whereas green plot reports results with active algorithms.

However, when algorithms are active, the state of the controlled appliances is switched more frequently than when algorithms are inactive. Anticipating that this may lead to concerns, we introduced two modifications to the algorithm:

- we added constraints enforcing that the load profile scheduled by the algorithm is as smooth as possible (i.e. it avoids frequent changes in the state of controlled appliances, or schedules such changes in order to cancel each other). Preliminary tests have shown improved smoothness characteristics of aggregate load profiles when algorithm implements these techniques.
- we added a safety “knob”, in form of a randomization parameter (whose effects are illustrated in the figure below) which can be easily tuned by the end-user or utility. When set to 0, the algorithm behaves as normal. When set to larger values, algorithms disregard small changes in voltages. In the extreme case the parameter is set to 1 and the algorithm’s behavior is completely randomized by ignoring voltage profiles. This ensures that unstable behavior can never occur.

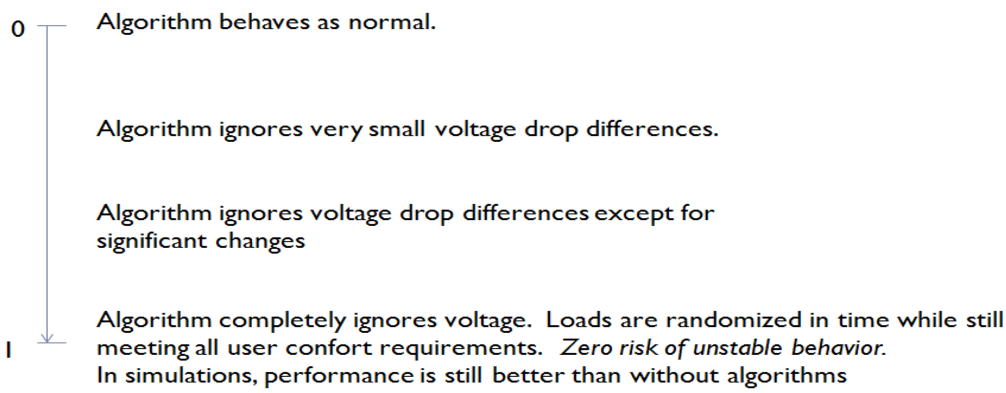

Figure 32: effects of the randomization parameter.

Assessment of the results

The implemented modifications improve the behavior of large groups of algorithms

Modeling, Simulations and Investigations

For identification the limitations of the power grid measurement, modeling and simulation of the power grids at all voltages levels is essential, because many effects can only been shown by interconnecting the distribution grid to an aggregated transmission grid.

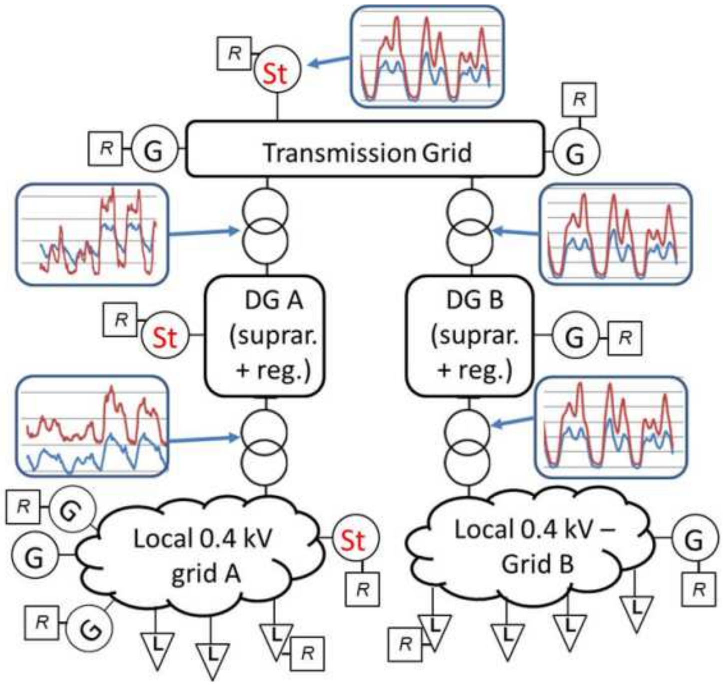

Figure 33: representation of the Future Grid

A simple example is the voltage drop and angle change caused of active and reactive power in all grid levels. In each grid level a line was chosen and charged at about 55 %, once with only active power and once with only reactive power. In both cases the same power was set (if in the first case the simulation was made with 100 kW in the second case the simulation was made with 100 kVA). The voltage drop respectively the angle change over the line in the reactive power case was set as reference to 100 %. The context of the active power case to the reactive power case was then calculated.

The results are displayed in figure 34. LV lines are mostly resistive. But in high voltage line the capacity is the most important part. That means: active power in LV grids is creating almost only voltage drop (9 times more than the same amount of reactive power) and almost don’t affect the voltage angels (only 12 % of the angle change with the same amount of reactive power). But reactive power in LV grid almost slightly affects the voltage drop, but creates almost only an angle change.

In MV grids the voltage drop as well as the angel change are both almost similar affected by active power and by reactive power. But in HV grids this situation changes due to the big capacity of the lines. Active power almost only creates an angle change and a negligible voltage drop while reactive power creates big voltage drop but negligible angle changes.

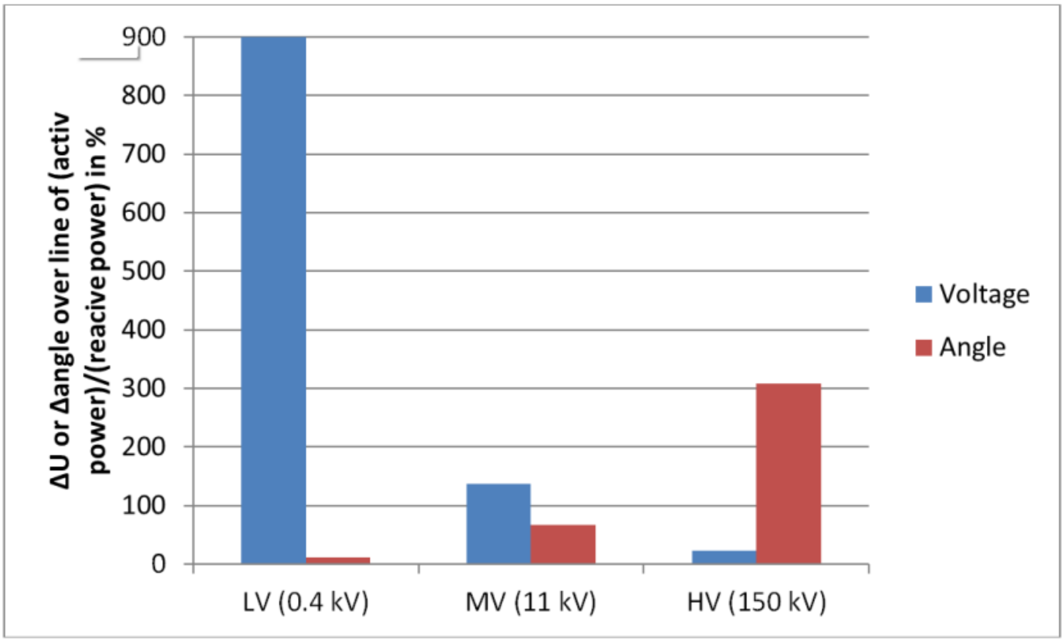

Figure 34: effect of power in different grid levels

Grids with a big amount of decentralized production and storage systems has active power and voltage regulation at many points of common coupling. The algorithm on which the regulation will act might have a big influence on the system behavior. The influence of voltage regulators will be local or regional but the active power regulators can influence the global frequency regulation. The biggest task in modeling of future grids will be to find the right compromise between exactness and high functionality and high aggregation.

The implementation of an amount of several (ten) GW of decentralized production in distribution grids is a question with a high complexity. By modeling of grids, focused on those with decentralized generation, poor architecture or weak connection to higher level grids measured effects could be extrapolated to more severe situations. These identified grid models deliver a good base for testing and developing decentralized control algorithms. The overall and important question of the stable behavior of the grids in relation to architecture, penetration rate and control algorithm will be answered.

Maintenance and update grid model Mendrisio with measurements phase B

To be sure that the simulation in the low voltage grid is near to the reality a measurement campaign of BFH was made in the low voltage grid Mendrisio. There were already installed measurement devices at the transformer (Arbiter) and at the households (HAC's). But for verification there are also needed measurements in between. To get this data BFH installed several measurement devices during the first three weeks of April 2013. A high load and a low load flow was then simulated in DIgSILENT PF and compared with the measurements. The results are displayed in Figure 35. It's visible that simulation and measurements gives almost the same result. The small difference on the household 2 of the low load curve is due to different measurement methods: While the BFH measurement devices on "Trafo" at "Camp 320" are calculating the mean value over 10 minutes the HAC device at "HH" is just displaying a single 1 sec value every 15 min.

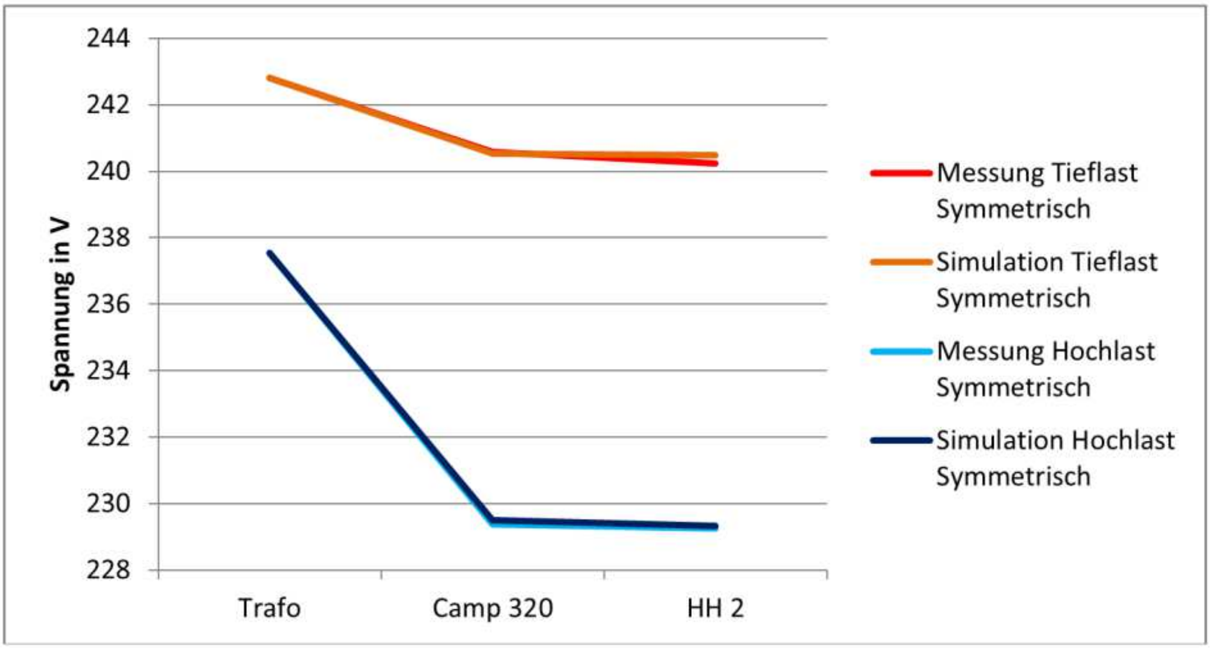

Figure 35: comparison of measurement and simulation

The deviation between modeling and reality for the symmetric grid model is absolutely low. The grid model is validated. The representation for asymmetric use of the grid is very close to the reality. The validation of the so-called zero system of the grid has its limitations because of lack of exact information about earthing impedances.

Development of aggregate model for smart households

The algorithm is implemented by an interface called “Engine Mode”. This DIgSILENT PF interface allows the java program (containing S2G algorithm) developed by SUPSI to execute some basic commands and DPL scripts in DIgSILENT PF. All parameters for a simulation (like a list of dump and smart Households and EV and some other configuration parameters) can be specified in a text file. The algorithm reads this text files and creates a file with household loads. By an engine mode command a DPL script is executed which reads the loads, sets them into DIgSILENT PF and executes a load flow. Another Engine mode command executes a DGS export which is already preconfigured in DIgSILENT PF. The resulted voltage is written in a text file by DGS export and then read by the java script to calculate the load situation for the next time step. Then the process is starting at the beginning.

To be sure that the real load profile is similar as the simulated load profile the simulation results are compared with the measurement results. The number of households in each measured string is defined so that the maximal power of the simulation and the maximal power of the measurements are similar. The transformer voltage is set so that the mean simulated voltage is about the mean measured voltage. The results are displayed in Figure 36 and Figure 37.

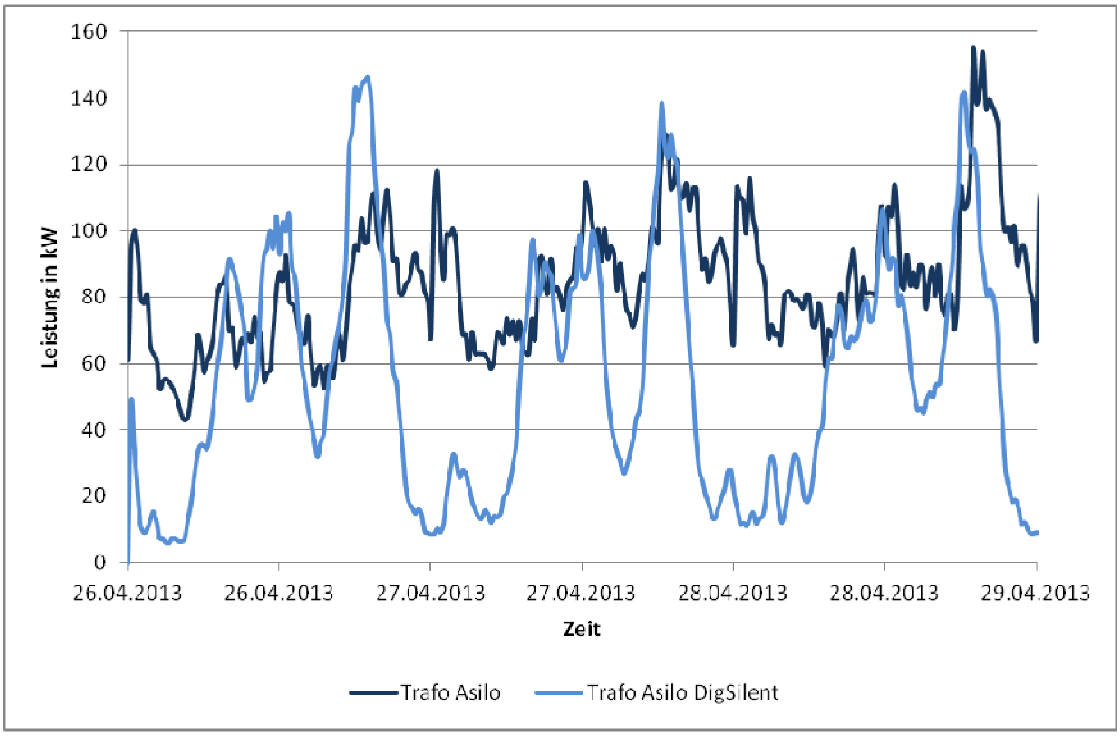

Figure 36: comparison of power between simulated and measured string

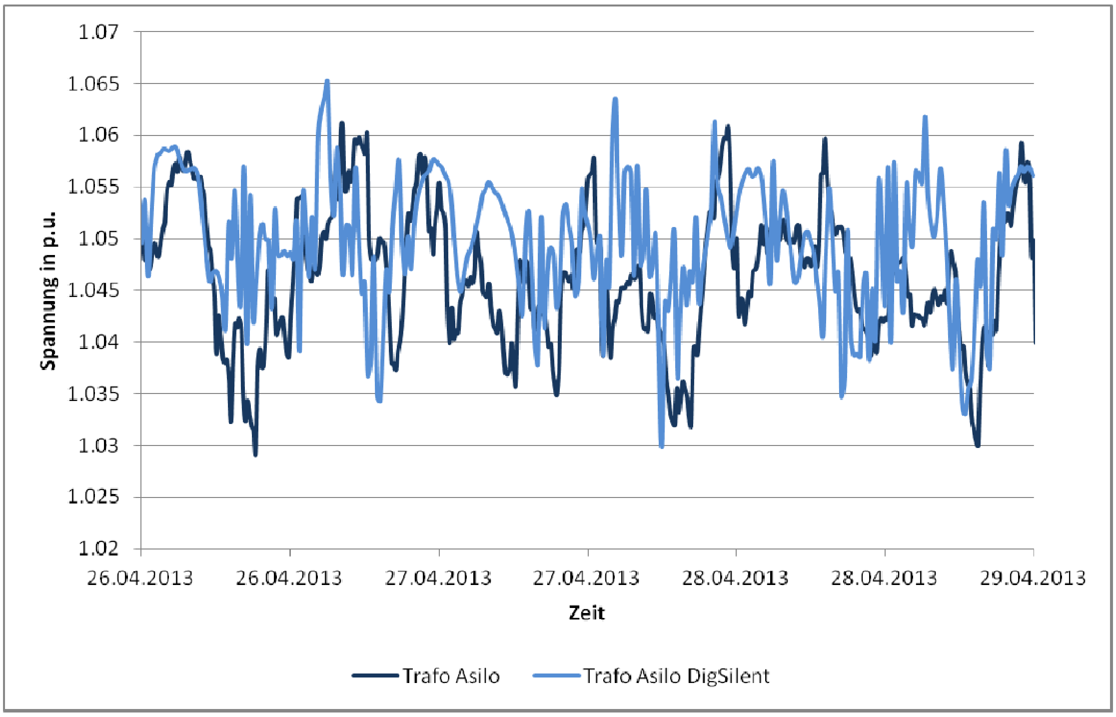

Figure 37: comparison of voltage between simulated and measured string

While during the day the profiles are nearly identically, there is a big difference during the night. This difference is most probably due to electric heating systems installed in real households, which are switching on by a ripple control signal. The household simulator doesn't simulate electrical heating systems, but air acclimatization which is quite similar to an electric heating system. But the simulator can't simulate some ripple control signals, so that the air acclimatization is switched on and off during the whole day. But this difference is not so important, because to investigate the benefits and problems of the algorithm in general it's not essential to have the real load curve.

IDSIA started work on an aggregate model of smart households within a branch of a distribution network. In particular, a fast, simplified simulation of voltage within said branch was developed in order to determine the aggregate behavior of such households also accounting for the interplay between each other.

In addition, due to technical reasons the timesteps for simulating households and algorithms (10 seconds) were decoupled from the timesteps used to simulate the large-scale grid (15 minutes). This leads to a number of issues in the resulting simulations. In order to overcome these issues, a simplified simulation of different LV grids have been directly integrated in the algorithm simulator, so that he can calculate the behaviour of the different grid (only active power) by himself.

This new approach enable to use in a very efficient way the coupling between the simulator and DIgSILENT. DIgSILENT simulate the behaviour of MV and HV grid and feed the simulator with the LV trasformer electric values.

Investigation of the effect of the S2G algorithm to higher grid levels

The HV grid was simplified as shown in Figure 38. This was made by a network reduction. The red area is simulated explicitly; the rest replaced by equivalent impedances and voltage sources.

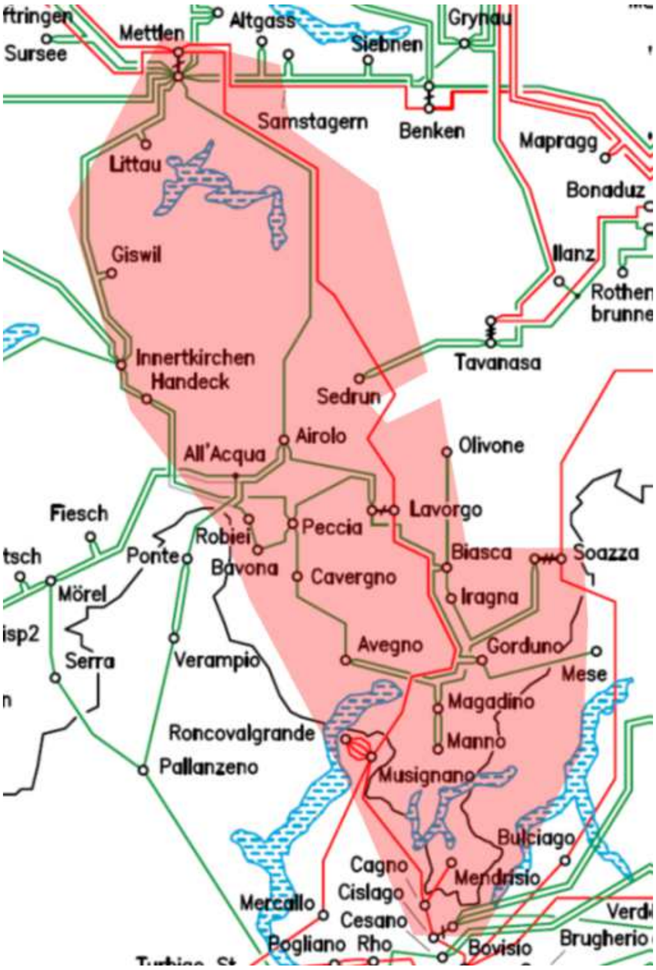

Figure 38: simplified HV grid (red area)

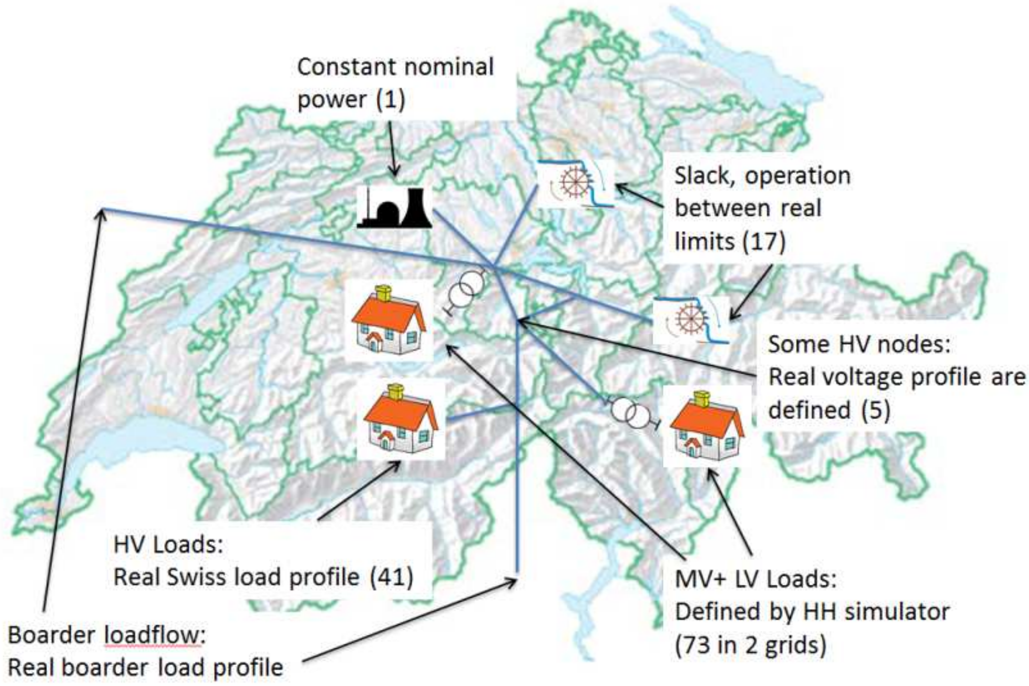

Figure 39: Loads and production in the different grid levels

For all simulations the reference period are the working days between the 26.7.2011 and the 8.8.2011, because they are the closest to the simulated household profiles of the java household profile simulator developed by SUPSI (summer, working day…). All high voltage loads are defined based on the gross load profile of Switzerland for this period. The other loads are directly defined by the household profile simulator of SUPSI. Energy is produced manly by nuclear- and hydro power stations. Nuclear power stations operates on their normal operating point and hydro power stations depending on the needed energy inside their real maximal and minimal power limits.

Complementary simulations with other grid models

To test the algorithm in all grid levels, the LV and MV grids of Meiringen and Mendrisio have been connected by a simplified version of the European HV grid by DIgSILENT PF. In Figure 40 a simple overview is shown:

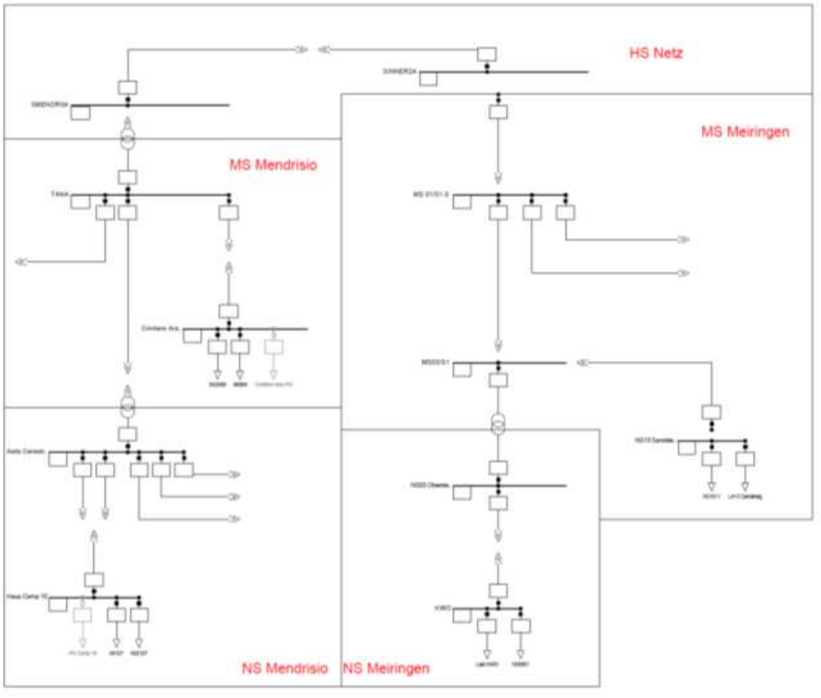

Figure 40: overview over DIgSILENT PF grid model

Some first simulations have been made to test the algorithm. In Figure 41 and Figure 42 there are only 5 smart households on the end of the LV grid. In this case, the potential of the S2G algorithm is very low, maximal and minimal voltage are not significantly reduced, because some single households can't change much the load flow in a whole LV grid. The influence might slightly increase when electric vehicles (EV) are used.

But with the actual version of the algorithm this leads to some problems (see arrows): The households with storage possibilities charge too much energy at the same time of day. The voltage drops down and the batteries are charged quickly. Afterwards the voltage goes back to a high value, so that peak voltage is not really reduced. In fact it's not a general problem of the algorithm but of coupling between DIgSILENT PF and the algorithm. The algorithm is calculating new values every 10s and grid simulation tool simulates the voltage every 15 min due to long simulation time with too small time steps.

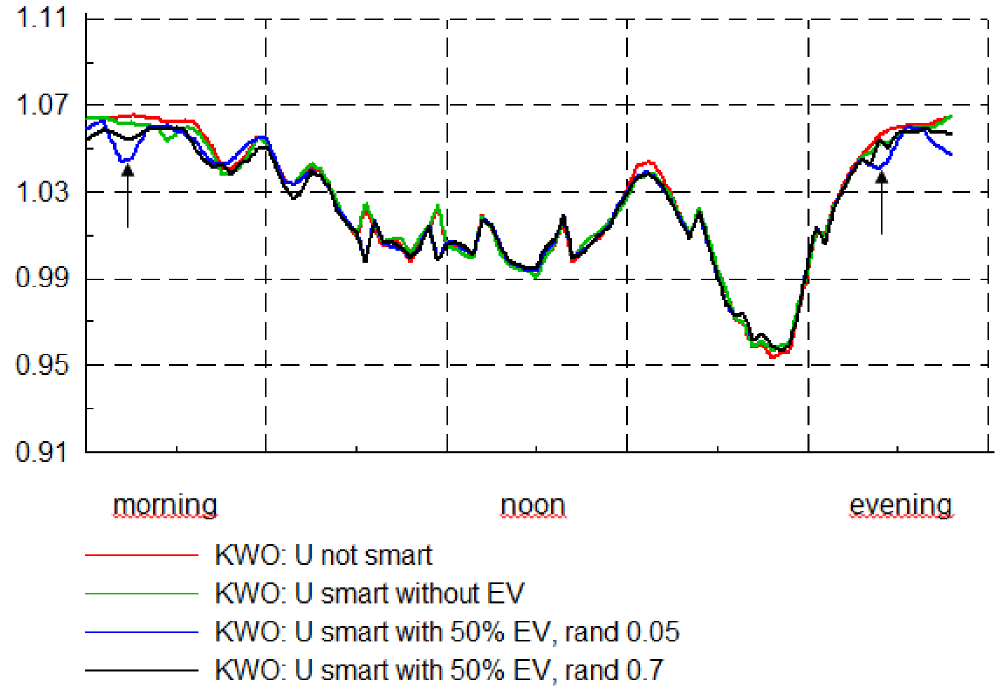

Figure 41: run of the voltage [p.u.] at the end of a low voltage sting when implementing only one smart load (equal to 5 HH) and by varying EV use and randomisation factor at the end of the string

For the moment to avoid this big power peaks a "randomization factor", that lowers the load reaction, has been implemented in the actual version. It's obvious that with a big randomization factor the algorithm works much better. While the real load behavior is different, for the final implementation another solution will be implemented.

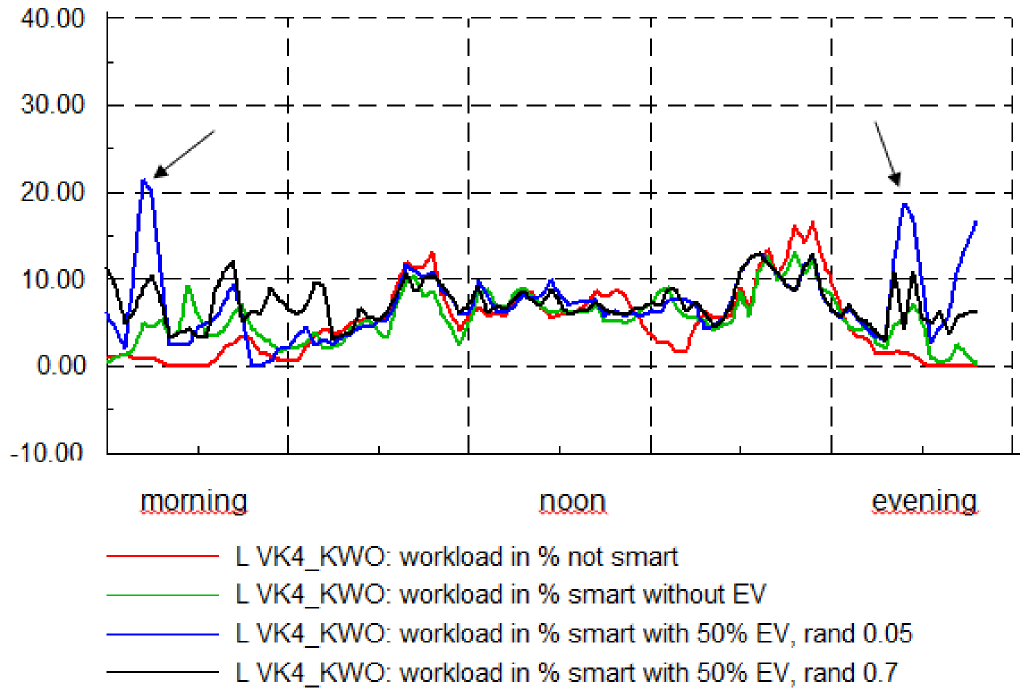

Figure 42: run of the active power [kW] on a low voltage line when implementing only one smart load (equal to 5 HH) and by varying EV use and randomisation factor at the end of the string

In Figure 43 and Figure 44 all households in the LV and MV grid are “smart”. Again it’s obvious that a big randomization factor is needed to avoid big peaks. But then the maximum and minimum voltage can be reduced significantly and in the MV grid voltage can be almost flattened. In the next version this should also be possible without randomization factor.

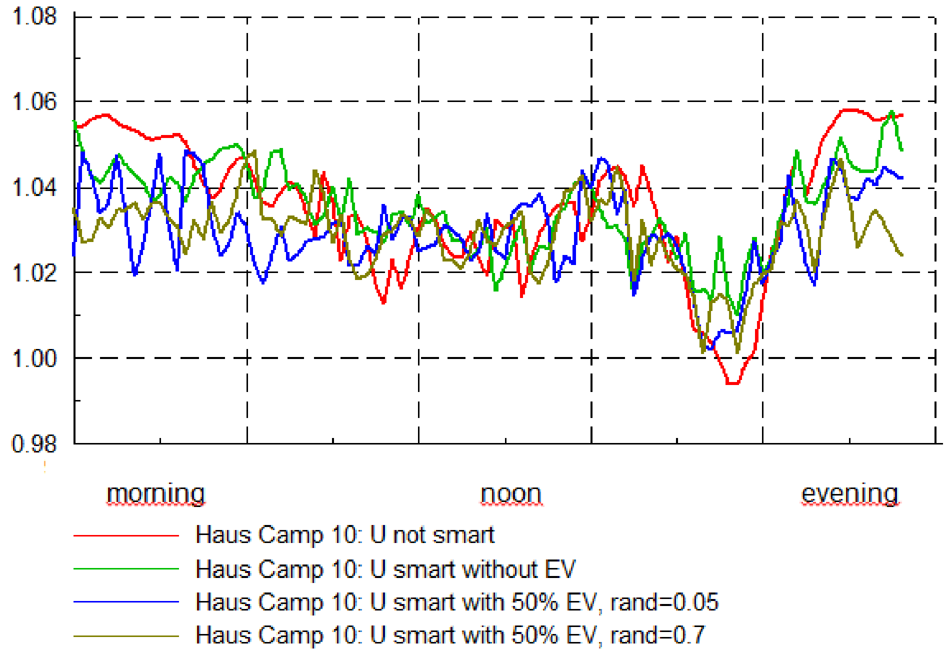

Figure 43: run of the voltage [p.u.] at end of a low voltage string in Meiringen with maximal penetration of smart HH and by varying EV use and randomisation factor

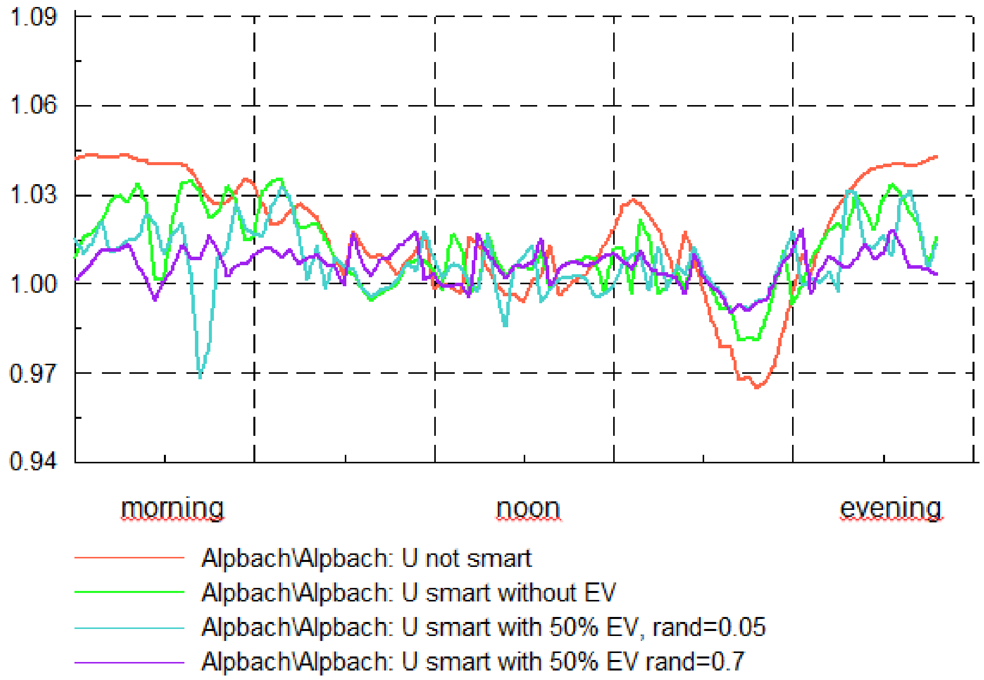

Figure 44: run of the voltage [p.u.] at a medium voltage busbar in Meiringen with maximal penetration of smart HH and by varying EV use and randomisation factor

Figure 45 shows the simulation applied to the Mendrisio case. The load profile in MV is clearly flattened and the grid stabilized. The usage of EV don’t increase the peaks at noon.

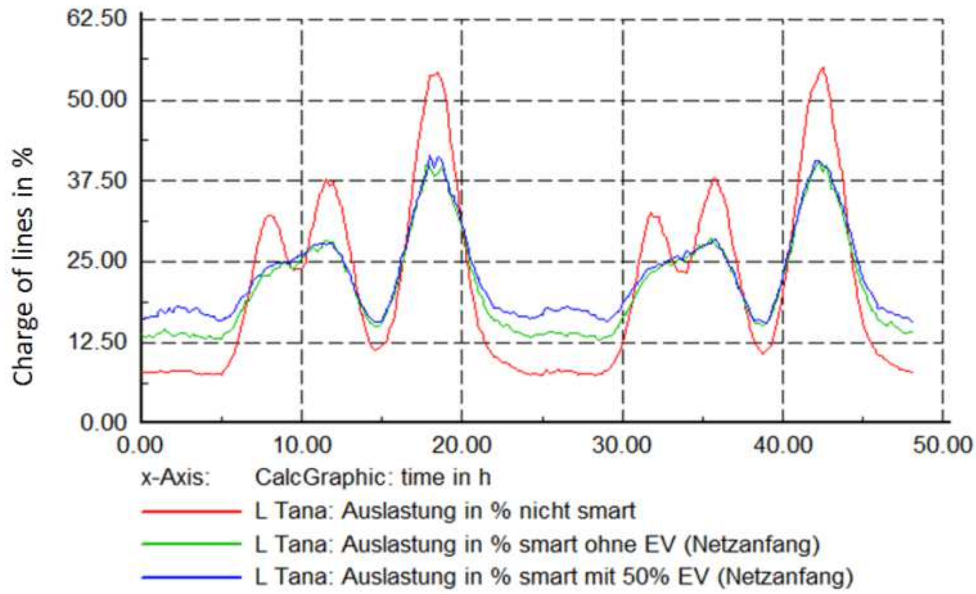

Figure 45: run of the active power [kW] on a medium voltage line in Mendrisio when implementing smart households with and without EV

Figure 46 shows the voltage simulation for Mendrisio. The voltage at the top of MV grid is almost not impacted by S2G because the voltage in HV grid is fixed and active power almost doesn't affect voltage in HV. The pap changes of transformer are clearly visible, the S2G algorithm reduces the frequency of tab changes

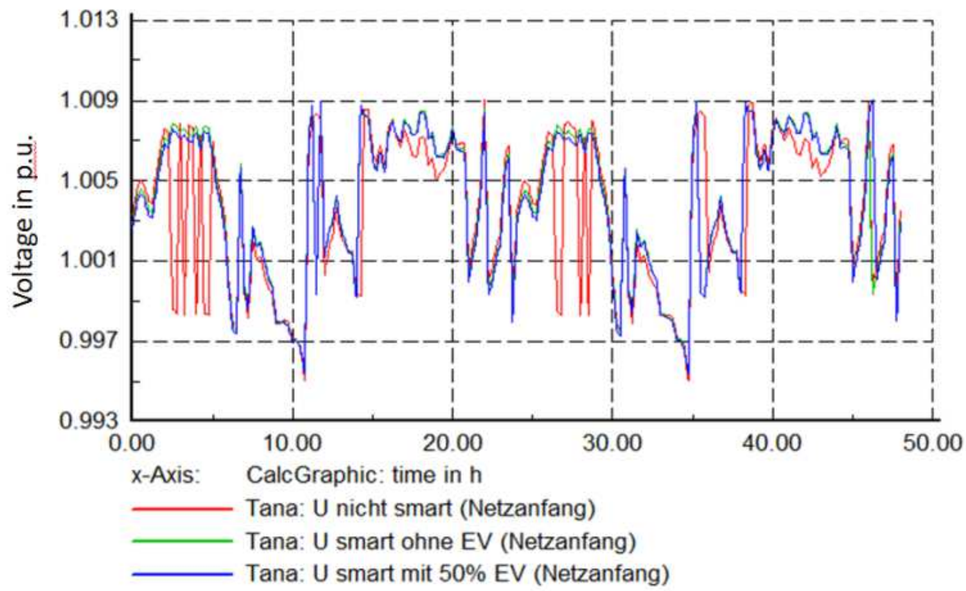

Figure 46: run of the voltage [p.u.] at the MV/LV transformer in Mendrisio when implementing smart households with and without EV with automatic transformer taps

Summary of the work done:

- Grid model: It has been built up a complete simulation platform,I ntegrating the LV grid of Meiringen and Mendrisio, their regional MV-grids and the relevant part of the Swiss HV grid.

- The inputs in the grid model are measured voltages and currents at important grid points and synthetic load data. All data are daily curves with 1/4 h timesteps.

- The Digsilent model runs in parallel with the HH-simulator, while a free number of households or LV grids can be defined as smart. There is a mass of simulation results which lead to important conclusions (transformer taps gives problems, stochastic loads and generation disturb the optimisation.

- The limits of this parallel mode are very stick so that the results cannot be judged as “real” or “reliable”. The algorithm in the simulation does not react upon voltage variations and is not able to learn. These severe problems occur because the interface between both is to slow so that the chosen timesteps cannot be chosen as small (10s) as necessary.

Outlook:

- Recently it has been decided to stop working on the interface or the adaption of the HH simulator for Digsilent.
- Different LV grids will be integrated in the simulator, so that he can calculate the behaviour of the different grid (only active power) by himself.
- The simulator will be feed with an overall voltage at the transformer and with stochastic generation where it is.
- The results of the different types of LV grids are implemented in DIgSILENT to analyse the influence on the higher level grid.
- This work plan gives exact results for the LV grids and estimated effects on the MV and HV grid.

Collaboration nationale

The project is collaborating in the national competence center for energy, the SCCER – Grid.

A joint project proposal on massive integration of PV and it’s impact on the grid (ISAAC, BFH, FFHS, ZHAW) has been proposed for the PNR – 70 project call.

Collaboration internationale

International collaboration with similar projects is being developed. SUPSI recently acquired an EU project (FP7-ENERGY-2012-1-2Stage / ENERGY.2012.2.1.1, Reliable, cost-effective, highly performing PV systems). This project focus on PV systems but it includes energy management and storage control. This will allow a benchmark between S2G algorithm and the EU project control approaches.

One member of the project team is also strongly involved in the topic of grid management on the international level, serving as a potential door opener for additional international projects.

In this context the D-A-CH initiative has to be seriously take into account. In a meeting in January with all project teams we will define a common strategy in this regard.

Évaluation de l'année 2013 et perspectives pour 2014

On the background of this detailed progress report we can draw some very short concluding remarks stressing the following aspects:

- Based on the first project phase different lessons could be learnt and implemented in the second phase. These lessons and insights prove to be very helpful in the ongoing progress of the project, regarding the redefinition and refocusing of the goals, the difficulties and modalities to be overcome as well as all the project management aspects.

- Despite different HW and SW problems in the installation of the HACs, which could be overcome with some delay, the overall progress of the project is in line with the schedule and the overall goals. There are no major risks to be identified for the next steps and project period.

- The project, integrating different disciplines and approaches to the topic of smart grids, proves to be quite fruitful and is, by itself, an interesting learning process in a complex and rapidly changing environment.

- The project is generating unexpected interest in the energy sector and we have proposals for collaborations by different utilities in Ticino and an informal declaration of interest by a major utility. The mentioned CTI – project is a further indication, that different actors are interested to use and implement our decentralized and algorithm based approach to load management.

- In the near future (after the acceptance of this intermediate report) the project team will elaborate a strategy to keep using and developing the P&D platform in Mendrisio considering different research opportunities (SCCER, NFP 70/71, FP7, Horizon 2020, CTI – Energy projects).

- The project team is also willing to increase the activities of dissemination, publication and demonstration of the platform.

Références

Pubblications:

A. Giusti, M. Salani, G. Di Caro, A. Rizzoli, L. Gambardella: "Restricted Neighborhood Communication Improves Decentralized Demand-Side Load Management". 2012. Accepted on IEEE Transactions on Smart Grid.

M. Höckel, T. Häni, S. Eberhart: "Elektromobilität in Verteilnetzen", Messung, Modellierung und Simulation von Netzen mit dezentralen Erzeugungsanlagen, Speichern und Elektroautos, VSE Bulletin, 9/2012

D. Rivola, A. Giusti, M. Salani, A. Rizzoli, R. Rudel and L. Gambardella, "A decentralized approach to demand side load management: the Swiss2Grid project", 2013, Submitted to Energieinformatik 2013, IEEE IECON13

D. Rivola, M. Marzoli, Matteo, D. Chianese and R. Rudel, "High Penetration of Photovoltaic Systems in Residential District: an Innovative Project for the Decentralized Management of the Distributed Generation", 2013, 28th European PV Solar Energy Conference.

Conferences and meetings:

- 28th European Photovoltaic Solar Energy Conference – September 2013 – Paris
- Swiss Grid Day - October 2013
- Energieinformatiktagung - November 2013 – Vienna
- ERA-Net plus Tagung - Oktober 2013 - Vienna