Hybrid-VPP4DSO

Deliverable 1

Work Package 1

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Critical Network Areas and Business Models for hybrid-VPP-Services:

Critical Network Areas; Suitable DR- and DG-Resources, DR-Audits in Enterprises; Data Base for DR- and DG-Resources; Business Models: Evaluation Criteria, Stakeholders and Pre-selection

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1 Abstract

The aim of the project *hybrid*-VPP4DSO is the design, evaluation and validation of a hybrid virtual power plant concept including electricity generation from renewable resources as well as consumer-related measures (provision of negawatts) to optimize the power system. Network and market driven approaches will be combined, especially to provide services for the requirements of distribution grid operators. The simulation-based development of the hybrid-VPP-concept will be performed with real company data. After successful validation a proof of concept in two specific network areas in Slovenia and in Austria is planned. Furthermore, the possibilities for business models, technical and not-technical barriers of the VPP market will be evaluated.

2 Introduction

In different European research projects and activities first applications for virtual power plants (VPP) which focus on trading on selected power markets have been developed. These VPPs use ‘flexibilities’ like curtailment of aggregated loads, generation and “unused” capacities like emergency power supplies as “resource”, which can be delivered to different customers like transmission system operators (TSOs) or power traders. On the other hand there are technically oriented VPPs which try to manage loads and generation in distribution grids in order to keep the power quality parameters within tolerable limits. These VPPs are part of the smart grid idea, nevertheless there are no suitable business models fitting into the regulatory framework in most European countries.

According to the above mentioned background of VPPs in the European markets the main objectives of the project *hybrid*-VPP4DSO are the following: Stepwise simulation-based development, evaluation and validation of a hybrid VPP concept and an implementation process of two hybrid VPP research systems to manage distribution grid issues and “normal” demand response (DR) resource aggregator business with one VPP system including:

- Simulation-based validation of hybrid VPP operation concerning grid impacts (power flow simulation), technical-economic simulation of DR resource aggregation and simulation of suitable business models.
- Technical proof of concept will be first realized at laboratory level followed by test switching of real customer loads in two distribution grid sections in Slovenia and Styria, including a security analysis of such a concept.

The project is performed following a 4 step approach: i.) Preparing of the simulation environment including the definition and selection of the system boundaries (technical, economical and legal) and models of specific distribution network areas including a customer VPP data base (customers and generators), as well as the preselection of business models; ii.) Developing and modelling of future scenarios for generation and loads in the network areas and modelling of future scenarios including a cost benefit analysis for different market models; iii) Design and validation of a hybrid VPP aggregation concept via dynamic load flow simulations including the previous mentioned models; iv.) if the simulation-based validation of the developed hybrid VPP concept leads to promising results for a future implementation, the concept will be verified in a proof of concept in real networks.

The final result will be a validated hybrid virtual power plant concept to provide services especially for the requirements of distribution grid operators by combining network driven and market driven approaches in one concept including a proof of concept in selected distribution network areas in Austria and Slovenia. Additionally, the most promising business case will be further evaluated regarding non-technical aspects (e.g. legal and regulatory) resulting in recommendations for possible adjustments of market rules to better enable hybrid VPPs in Austria and Slovenia.

This is the work package 1, deliverable 1 intermediary report of the *hybrid*-VPP4DSO project. It covers the findings of the following subtasks and its main goals:

1.1a Analyses and selection of critical network areas, nodes, branches in Styria (cf. section 3, Dr. Taljan, Energienetze Steiermark)
=> *Main goal*: Selection of critical network areas for further analyses

1.1b Analyses and selection of critical network areas, nodes, branches in Slovenia (cf. section 4, Krisper, Elektro Ljubljana)
=> *Main goal*: Selection of critical network areas for further analyses

1.2a DG resources in Styria (cf. section 5, Meißner, Grazer Energie Agentur)
=> *Main goal*: Inputs for DG VPP data base (focus on critical areas)

1.2b DG resources Slovenia (cf. section 6, Krisper, Elektro Ljubljana)
=> *Main goal*: Inputs for DG VPP data base (focus on critical areas)

1.3a DR clients in Styria (cf. section 5, Meißner, Grazer Energie Agentur)
=> *Main goal*: DR data for VPP data base (focus on critical areas)

1.3b DR clients in Slovenia (cf. section 6, Krisper, Elektro Ljubljana)
=> *Main goal*: DR data for VPP data base (focus on critical areas)

1.4 DR resources data base for VPP simulation (cf. section 7, Zach, cyberGRID)
=> *Main goal*: Preliminary VPP data base ready for simulations

1.5 Pre-selection of business models for VPP DSO services and evaluation criteria (cf. section 8, Bleyl, Energetic Solutions in close cooperation with AIT, EEG and cyberGRID authors (cf. title page)
=> *Main goals*: Evaluation matrix and pre-selection of business models

The respective reporting sections and responsible subtask leaders are named in parentheses.

3 Selected Critical Network Areas in Styria

The criteria for critical grid section were defined to achieve the greatest economic potential for the improvements in the supply reliability (outages, brownouts, blackouts) and in the capacity (thermal capacity, voltage profile related capacity) of the grid to accommodate new loads and generators. The potential to attract the DR and DG customers in the chosen grid area was also considered. The chosen criteria include the following parameters:

- The severity of the current voltage profile in both directions, i.e. voltage rise due to infeed as well as voltage drop due to loads.
- Potential for requests for connection of further loads (DR) and generators (DG).
- Topology of the grid, e.g. line capacities, mashed grid vs. stub lines, etc.
- Geography of the grid, i.e. outage probability due to difficult terrain, wooden areas, adverse weather conditions, etc.

According to these criteria multiple discussions with the responsible heads of regional offices were carried out considering also past experiences with the evaluation of grid connection requests. Two critical grid sections in the medium voltage have been identified as best suited for the project. Both grid sections are presented in the Figure 1, are interlinked but operated disconnectedly with the disconnection point between the two grids in the switching station SWST3.

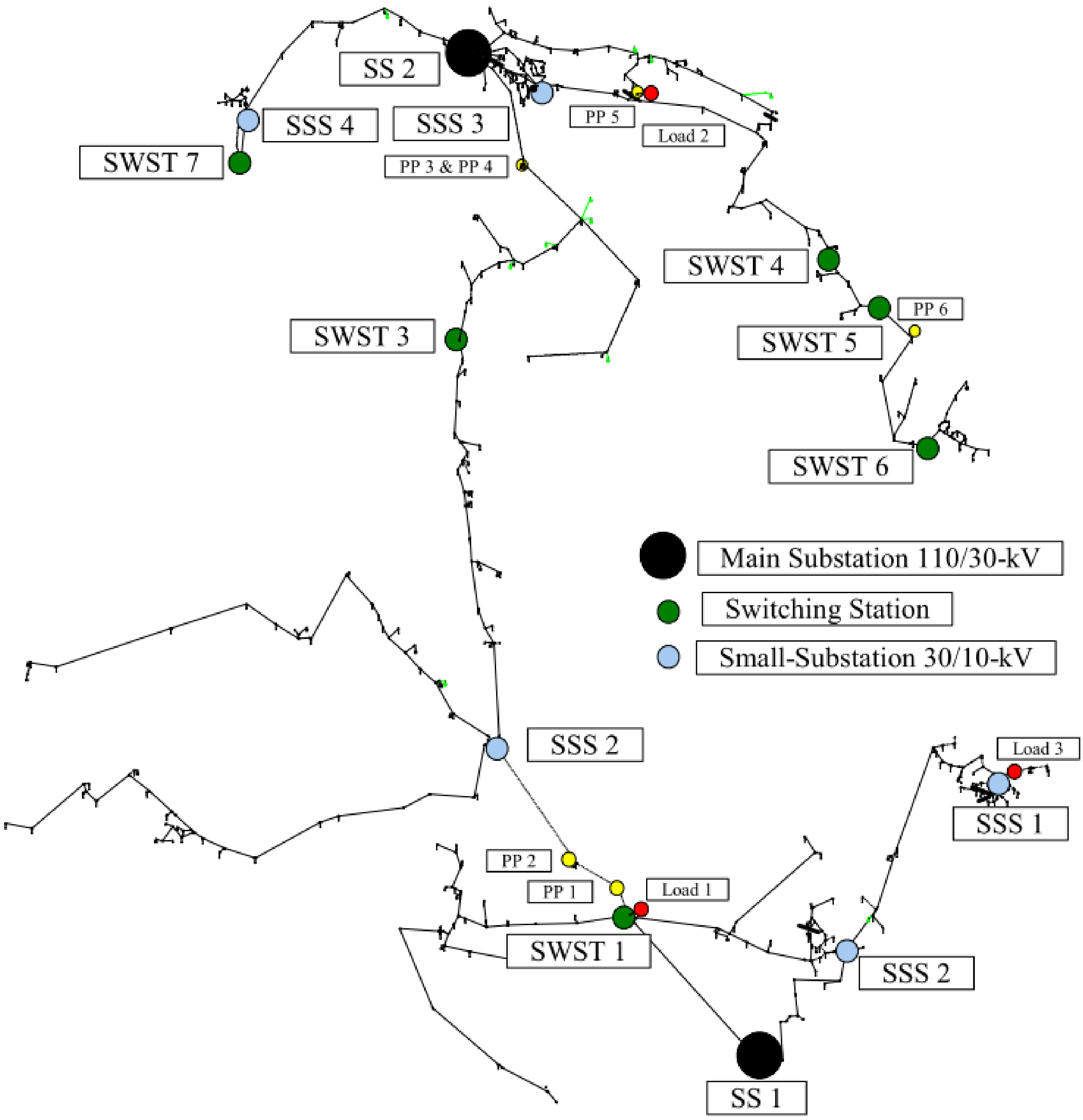


Figure 1: The selected grid sections.

The two chosen grids are composed of 240 transformer stations, 46 generators and a total system length of 255.8 km. The Real Power Measurements of the SS1 are presented in Figure 2 and those of the SS2 in the Figure 3. Both 30-kV grids have seen a constant expansion in the generating capacity in the past couple of decades and are, thus, facing severe capacity shortages due to the voltage rise. Furthermore, the grid outages are critical due to geographical situation and adverse weather impacts in the area.

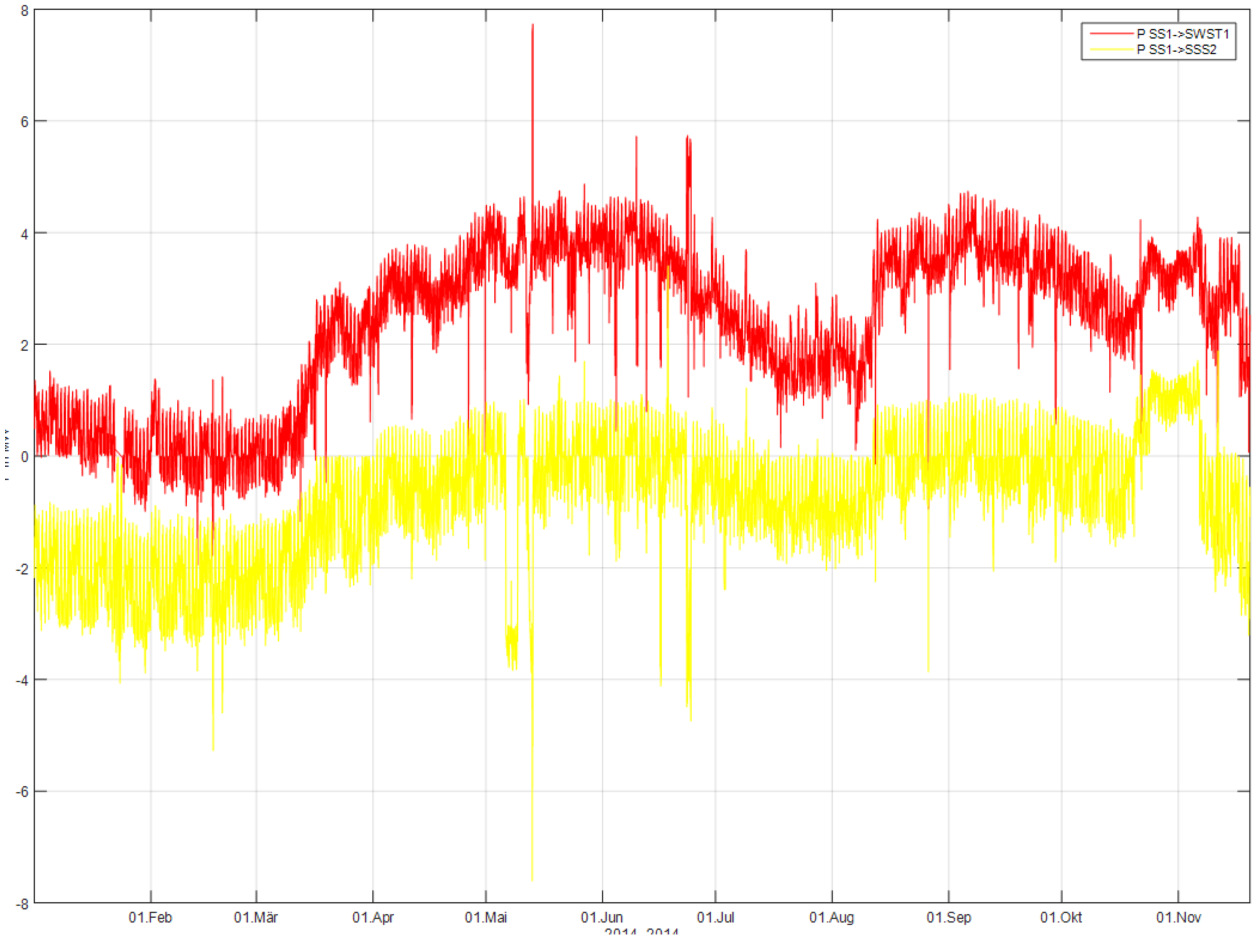


Figure 2: The Real Power Measurements at the SS1.

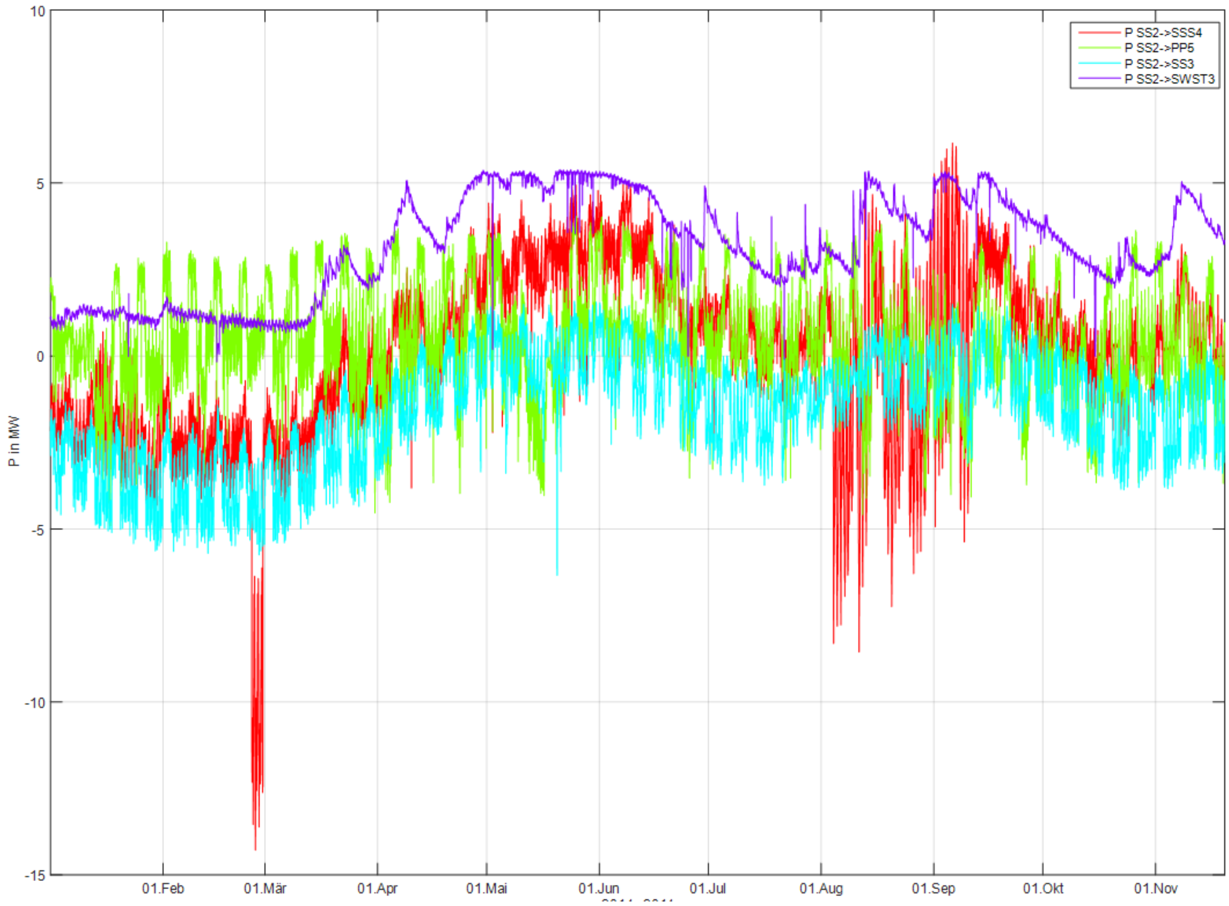


Figure 3: The Real Power Measurements at the SS2

The geography of both grids is mainly mountainous with the two grids being connected with only one overhead line with a minimal capacity running over a high mountain pass. Thus, the seasonal rain and snow storms frequently result in power outages in the grid; e.g. in 2012 a cable was torn open for multiple months due to a landslide and only limited amount of generated power could be fed into the grid at that time. Several larger HPP units were offline for the entire outage time.

The grid topology can be described with very long (over 35 km) overhead lines, which normally end in narrow rift mountain valleys with lots of generation but almost no load. This typically results in very high voltage rise especially in spring and early summer where the water influx is at its peak.

In the same area a smart grid project has been implemented to boost the grid capacity for further HPPs as the grid already reached its capacity limits. According to the project concept, all larger existing HPPs have been integrated into a centrally controlled voltage management scheme with power factor control and control of the set point of the main 110-kV/30-kV transformer. However, further development of generation and further requests for connection to the grid that have been submitted in the last years, brought the grid to a new capacity limit where the voltage control through reactive power control of generators alone is not going to suffice for the new connection requests.

A solution for a further expansion of connection capacity for renewables is expected to be found in the hybrid-VPP4DSO project by adding the real power control to the existing voltage control scheme. This concept should not only help stabilising the grid in problematic voltage rise affected times but also in times with major outages, e.g. in extreme weather conditions. The goal of this second use case is to supply as many consumers as possible and to increase the infeed of the generators to the maximal possible level in constrained grid conditions to minimise the financial losses due to curtailment of generation or consumption.

Further two 20-kV grid sections have been identified as reserve grid sections for the case that the response of the customers would not be sufficient or if it is shown during the network calculation process that the main grid sections are not as critical as firstly assumed.

According to the tasks T1.2 und T1.3, suitable demand response and distributed generation resources have been selected in the critical grid sections in the next step in the project. In these selected 30-kV sections, possible DG and DSM customers were identified with the most important criteria being the potential impact on the voltage profile and on the prevention of the grid bottlenecks. The most important parameters of this criterion are the installed capacity and the location in the grid. Customers with high capacity and location far away from the SS would have a potentially greater impact on the grid operation compared to smaller customers in the vicinity of the SS. The grid connection points of the DG und DR customers are presented in the Figure 1.

On the **generation** side, the gens 1 and 2 are of 1.65 MW and 1.15 MW installed power, respectively, and are connected directly to the 30-kV grid of the SS1. The Gens 3 and 4 have the generating capacity of 1.35 MW and 1.75 MW, respectively, and are connected to the 30-kV grid of the SS2. The PP 5 is also connected to the grid of SS2 and can maximally produce 5 MW of real power. The PP6 is a smaller HPP with the capacity of 670 kW but is connected almost at the end of a longer 30-kV line going out of the SS2. All the mentioned generators are on the same time also prospective providers of inductive as well as capacitive reactive power and some of them are already integrated into the voltage control scheme of the Energienetze Steiermark GmbH with the power factor control.

On the **consumption** side, the Load 1 is a larger customer with the maximal load of 25 MW and is connected directly to the 110-kV Grid with its own generation, which makes him a prosumer. However, this customer has also a 30-kV connection with limited capacity for emergency purposes, which could be used, if needed, for voltage control in the 30-kV grid under the condition that the grid tariff would not change due to this voltage level switching; the grid tariff in the medium voltage is namely higher than the one in the high voltage. Furthermore, this customer could also support the grid with its internal generation acting as a generator in critical grid states. The Load 2 is a larger wood processing factory with the maximal load power of 3,5 MW and the load 3 is actually a potential prosumer with a maximal load power of about 2 MW and a couple of backup generator sets. All the generators and loads are going to be presented in detail in the following chapters with the data being gathered in the Customer Database.

4 Selected Critical Network Areas in Slovenia

The first selection of the critical network areas has been prepared by the Elektro Ljubljana's experts whose work is focused on the Distribution Grid Management and Operation. Two areas were chosen. One area has been chosen geographically in the country, agricultural area, with lower density of population, the other one in the city.

The first area, the country side located grid, might be interesting to observe with the aspect to solve the problem of infrequent increase of the voltage level. The reason for voltage drift/minor change is caused by the solar power units. At this location, during recent three years a larger number of small production units have been build, the majority at the roofs of farmer's buildings. So this part of the observed grid supplies mainly non industrial customers, just a majority of connected consumers can represent commercials. The second reason is non-optimistic economic situation. The negative influence of economic crises caused the abolition of either poor industry or commercial sector. The result was, that in particular moments, during the summer holidays, when the production from solar plans was the highest, but the consumption the lowest, a minor increase of the voltage appeared. As additional information, the reason for high number installed solar power plants lied in subsidiary scheme. The consequence of this situation is that the grid voltage balance operation suddenly did not suit any more. At the low voltage level voltage balancing is done by transformer step change. The solution suits and no special measures have been taken, because all later prepared analyses showed that the grid is built up strong enough and it is also stable enough. Just transformers steps have to be adopted.

Beside all the facts, consumers of some production units are also connected to both selected parts of the grid. Additionally, we show the topology of both selected grids in Figure 5 and Figure 8, and a brief description of installed energy sources. Both grids are positioned in the basins, no significant influence of the geography might be taken into account. Both grids consist of mixture of underground cables and air lines.

Grid 1: RTP 110/20 kV Črnomelj,

Distributed Generators:

SPTE/CHP units:

TP/ Transformerstation Žaga Zora: 240 kW,

TP/ Transformerstation Leso: 999 kW,

TP/ Transformerstation Bioplin Lokve: 999 kW,

MFE/ Micro and Small Hydro Power Plant:

TP/Transformerstation OKP Črnomelj : 64 kW,

TP/ Transformerstation Elektro Črnomelj: 22 kW, TP/ Transformerstation Majer 1: 32,5 kW,

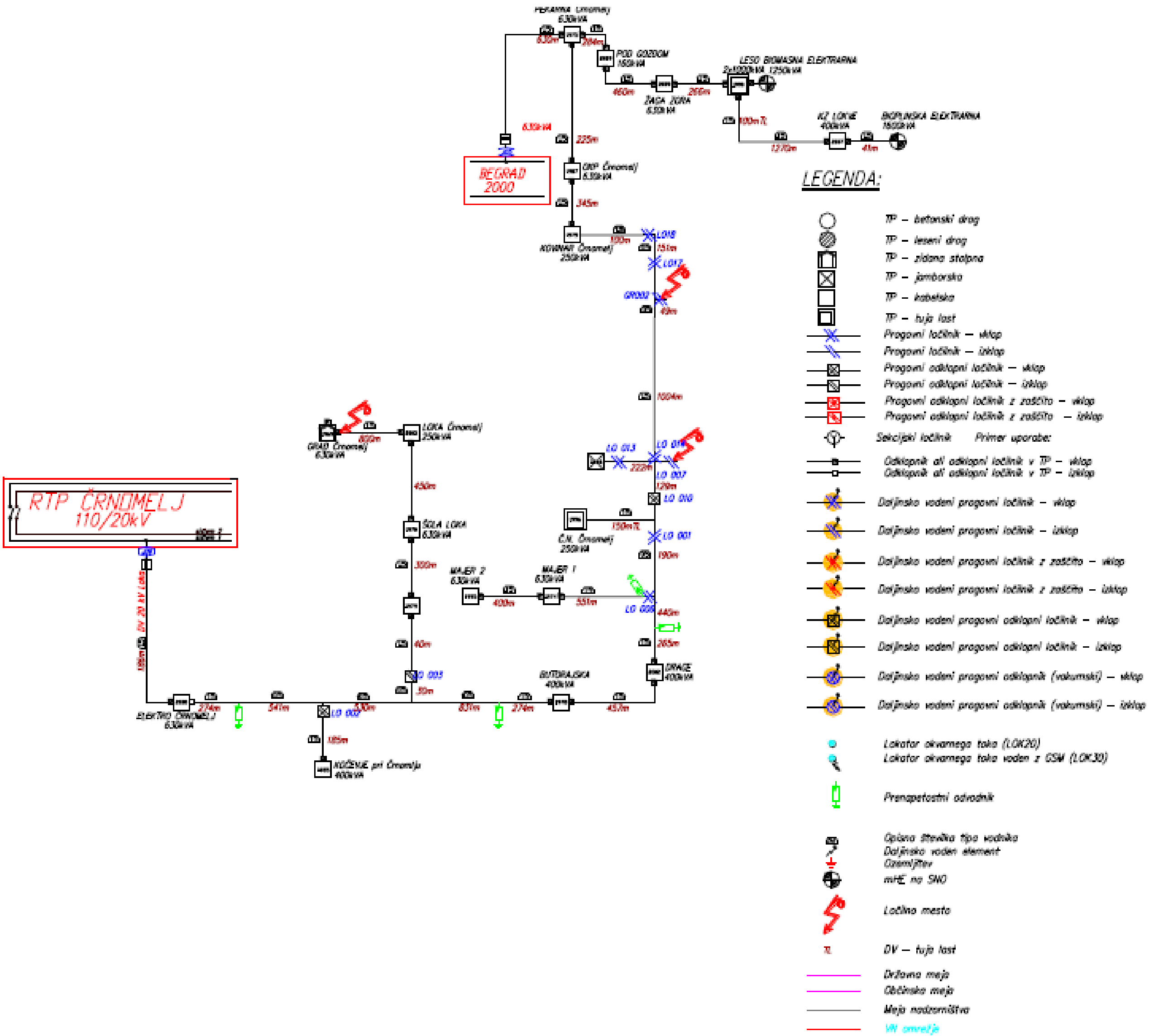


Figure 4: MV grid, south east area in Slovenia, electric scheme

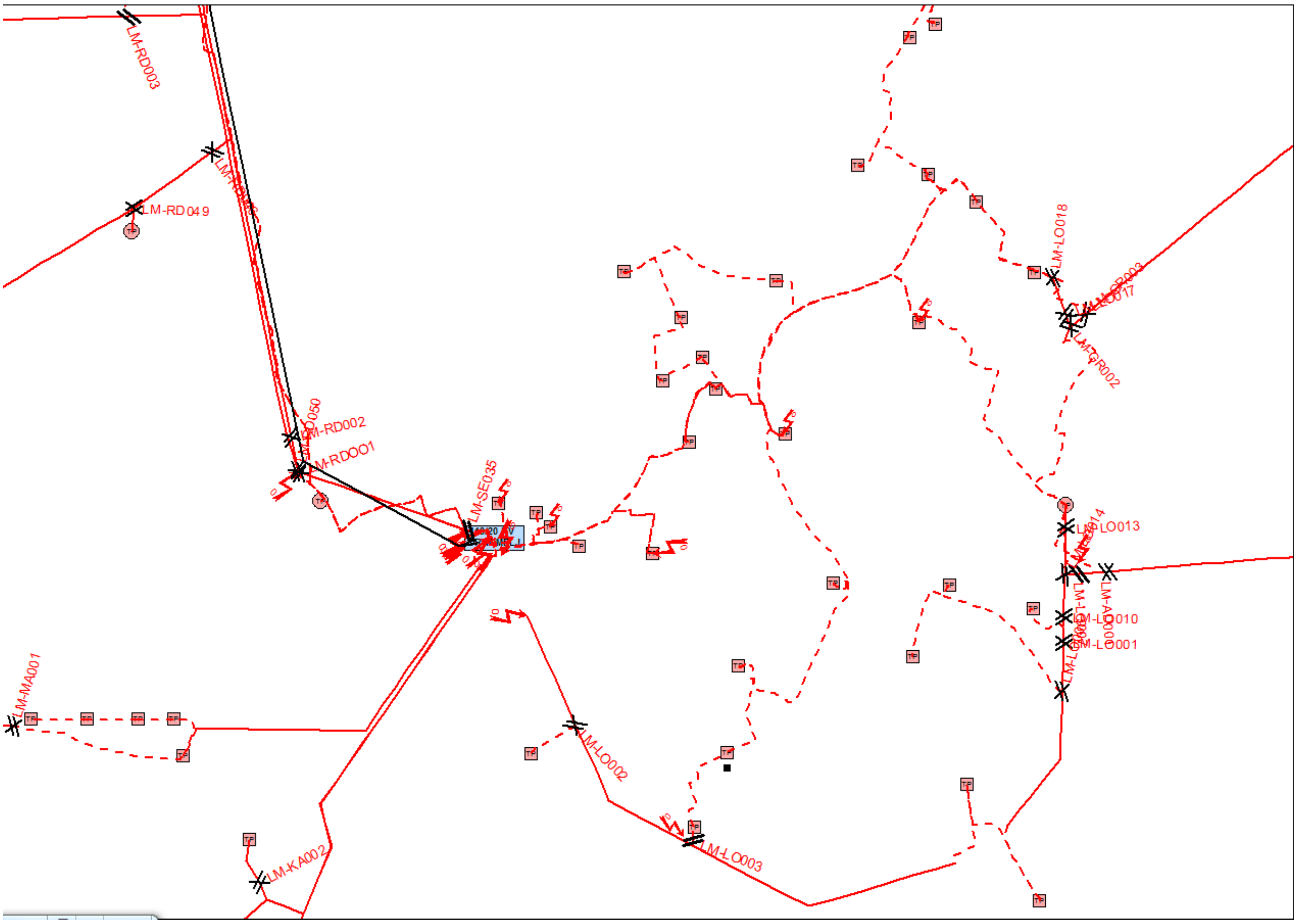


Figure 5: MV grid, south east area in Slovenia, geographical representation of the grid

If a detailed observation is made at some substations, only one larger consumer is connected who possesses his own station. n t At other stations, however, a mix of domestic and commercial consumers is connected.

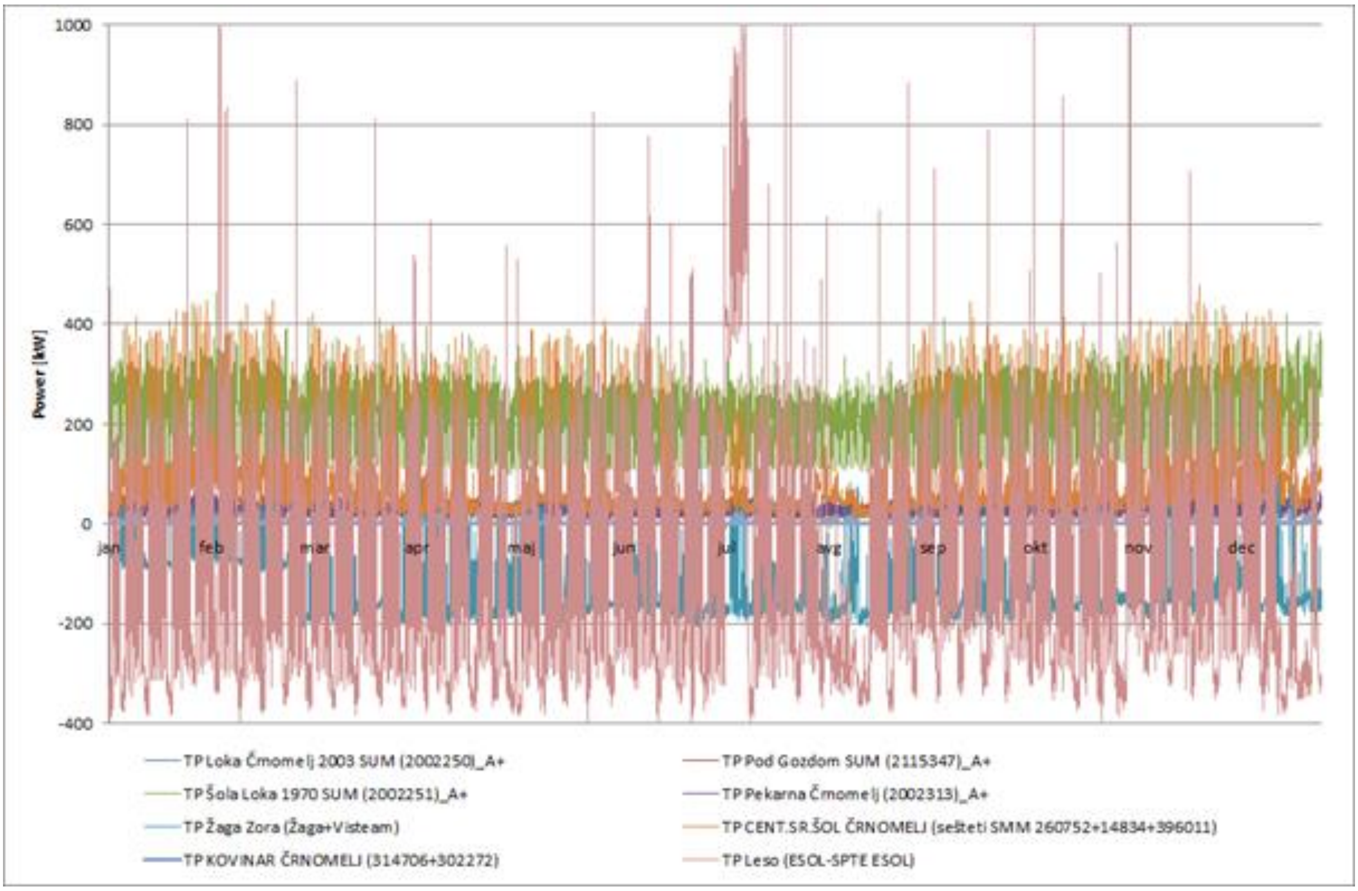


Figure 6: Grid 1 - The Real Power Measurements at eight substations for the whole year 2014

The second chosen grid is located in the capital of Slovenia, Ljubljana. The reason to choose this part lies in the existence of CHP units and in the higher potential to find consumers, which might be prepared to follow the demand management measures actand participate at the demand response actions. The grid selection has been also made on the criterion of voltage profile, but again because of the strong grid, it was harder to find any part with voltage drops or drifts, regarding urban environment.

Grid 2/ Stromnetz 2: RTP 110/10 kV Šiška, k42 KB 10 kV Asfaltna baza

Distributed Generators:

SPTE/CHP units

TP/ Transformerstation Bokalci : 100 kW,

TP/ Transformerstation Hotel Mons, Pot za Brdom 55: 152 kW,

MFE/ Micro and Small Hydro Power Plant:

TP/ Transformerstation Bokalci: 14,94 kW,

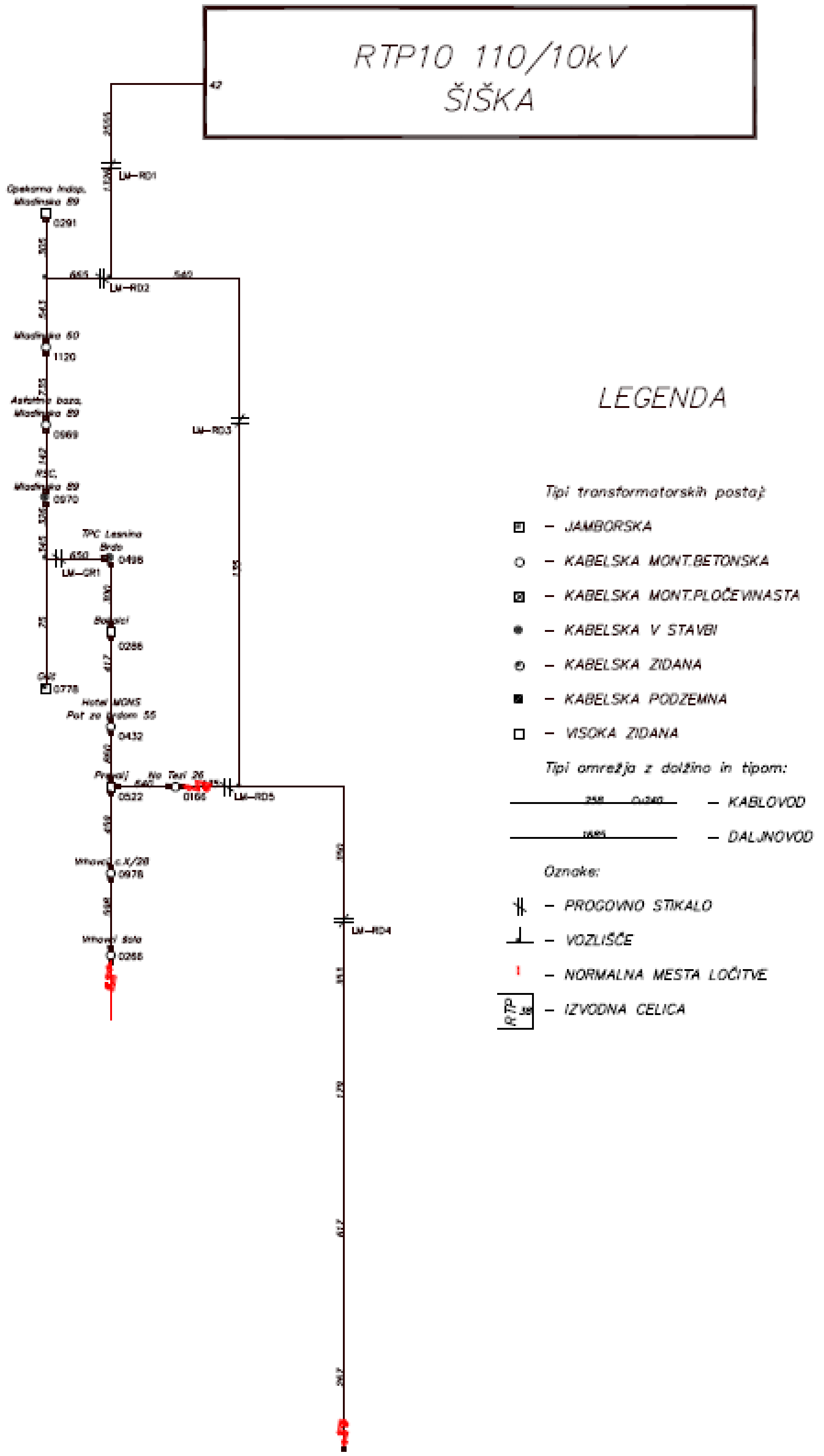


Figure 7: MV grid, city, electric scheme

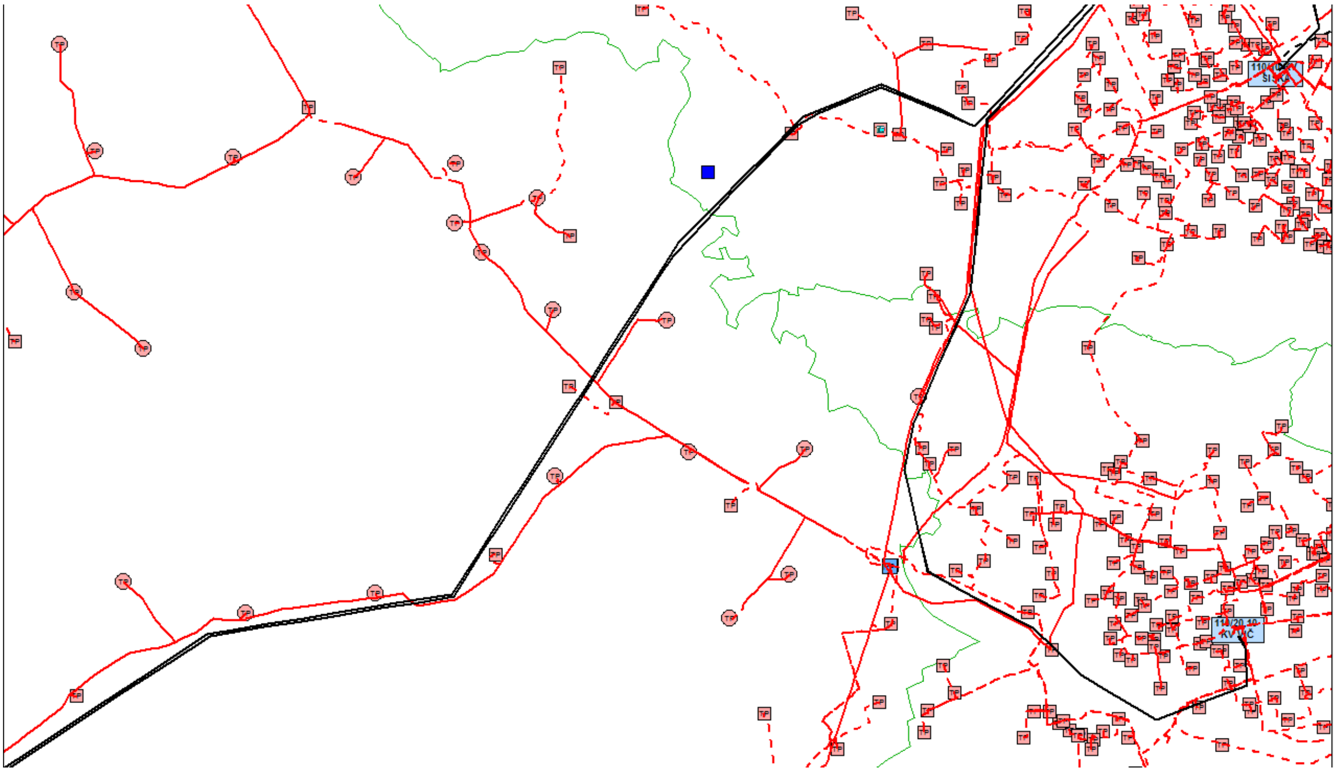


Figure 8: MV grid, city, geographical installation of the grid

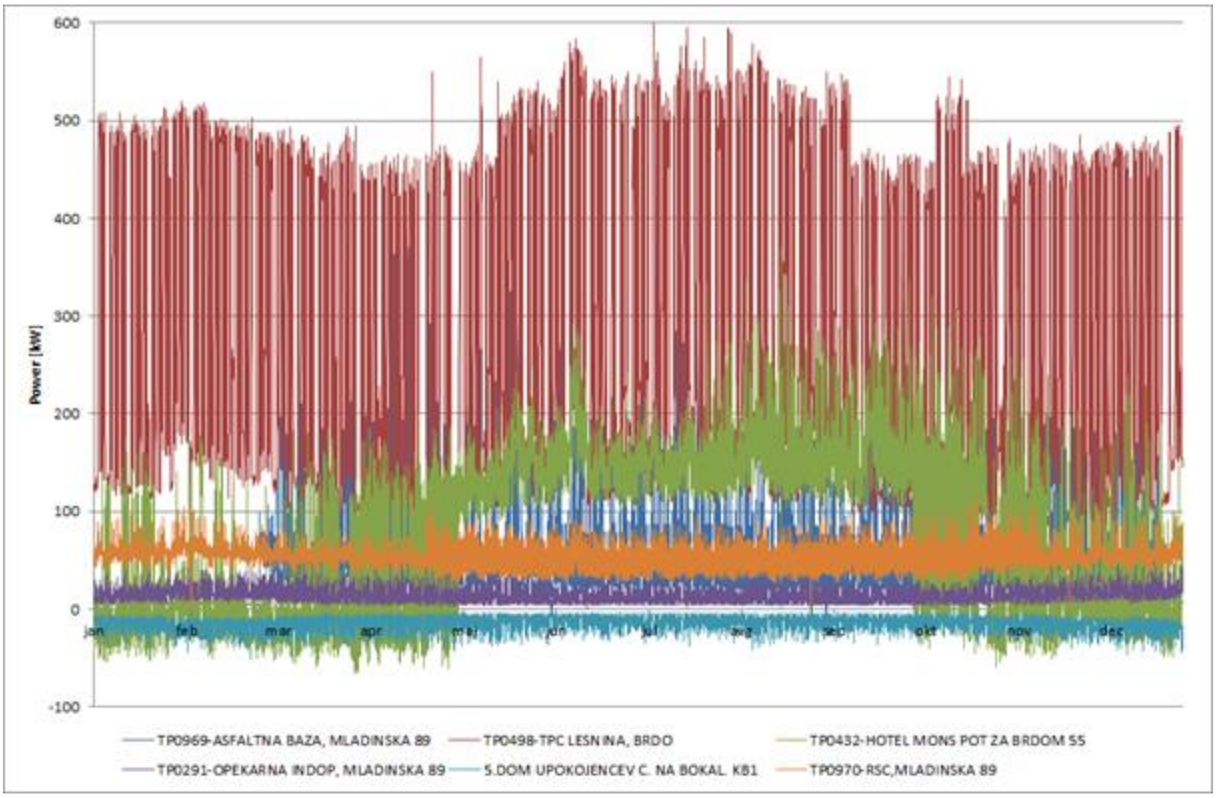


Figure 9: Grid 2- The Real Power Measurements at eight substations for the whole year 2014

As shown in Figure 9 the commercial consumer shows the largest load, connected at the observed part of the grid.

5 DR-Audits in Enterprises in Styria

The DR-Audits in Styria were organised in cooperation with the local Energy supplier “Energie Steiermark Kunden GmbH” and the local grid operator “Energienetze Steiermark GmbH”. The target was: 20 to 30 companies for the DR-Audits in Styria.

For the evaluation of the potential demand response customers the following criteria were defined:

- About 50% in the “critical grid sections” (about 15 companies)
- Remaining 50% as representatives of “typical customer-groups” (about 15 companies)
- Range of varying power consumption/production > 100 kW (interruptible load)
- Focus on companies in Styria, but also customers of the “Energie Steiermark Kunden GmbH” outside Styria possible

In total 35 companies were contacted. In the first telephone-conference a rough estimation of the potential of interruptible loads in the company and the interest of the decision makers in the companies for the hybrid-VPP4DSO-project was evaluated.

The following figure shows the diversity of the scope of activities of the contacted companies:

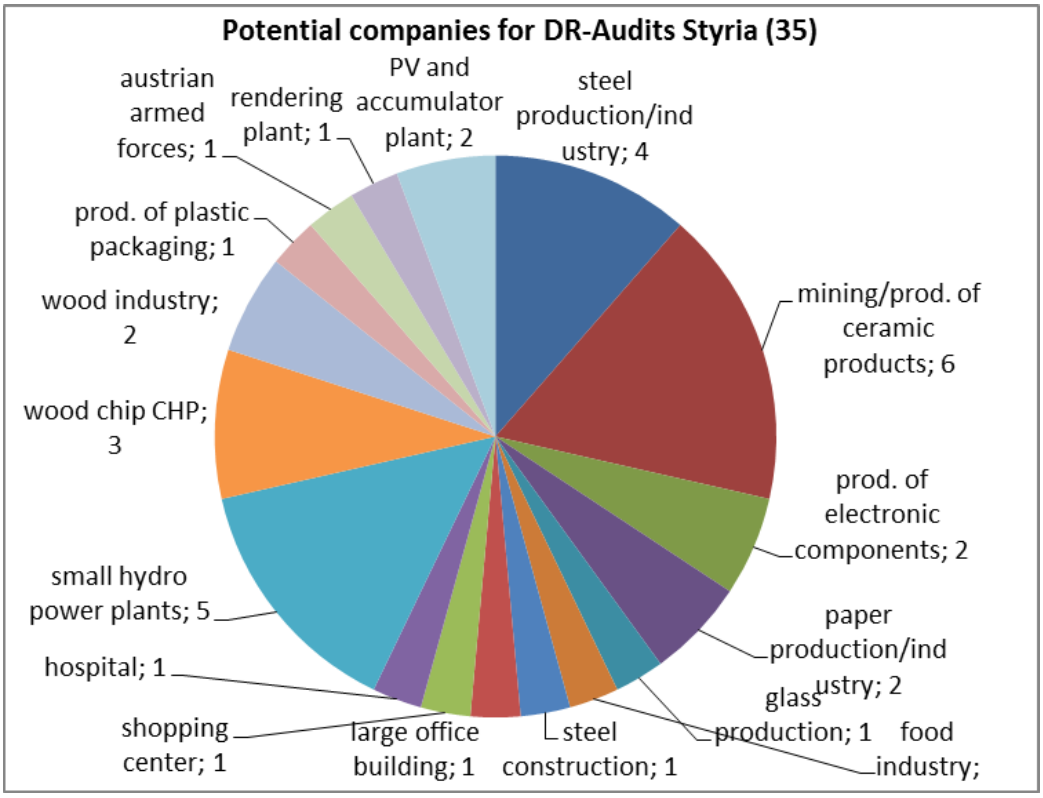


Figure 10: Potential companies for DR-Audits in Styria according their scope of activities

After this first evaluation 24 companies turned out to be "very interesting" for the *hybrid*-VPP4DSO-project. The detailed DR-audits started in August 2014 and till mid of January 2015 20 DR-audits were carried out. With the remaining companies either the dates for the audits are already scheduled or the scheduling is ongoing. The finalisation of the DR-Audits in Styria is planned for end of February 2015.

The contact persons for the first contact with the potential companies were identified by the key account management of Energie Steiermark Kunden GmbH and Energienetze Steiermark GmbH. These contact persons were mainly from the management board in the companies, persons from the energy/facility management or buying department. The process took longer than estimated in the proposal because beside the presentation of the project for the decision makers in the companies (management) the clarification of the technical details with the technical department was necessary. So in many cases at least 2 meetings were needed for the DR-Audits.

The DR-audits were carried out at least by one representative of Energie Steiermark Kunden GmbH or Energienetze Steiermark GmbH, one representative of GEA and in most cases also one representative of Cybergrid. In many of the DR-audits also a second representative of Energie Steiermark Kunden GmbH or Energienetze Steiermark GmbH was also in the audit-team (team leader or the head of the department).

The following figure shows the finally evaluated companies with their scope of activities.

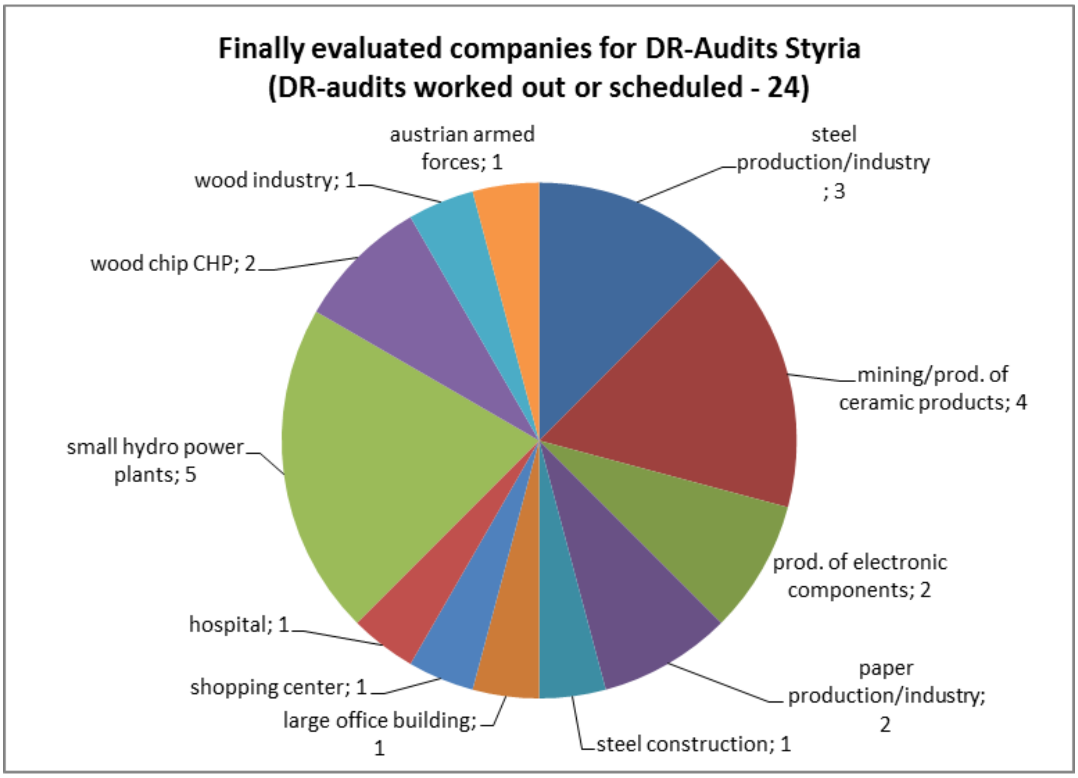


Figure 11: Finally evaluated companies for DR-Audits in Styria according their scope of activities

The following figure shows the summarised results of the interruptible load/production after 20 DR-Audits in Styria. The results are summarised in 3 categories:

- Production (small hydro power plants, wood chip CHP, diesel-emergency generator, gas turbine, etc.): increase of production / reduction of production
- Consumption for process (furnace, laser cutting machine, shredders, grinders, mills, chillers, etc.): increase of consumption / reduction of consumption
- Consumption for non-process (ventilation, air conditioning, steam humidifier, electric water heaters, etc.): increase of consumption / reduction of consumption

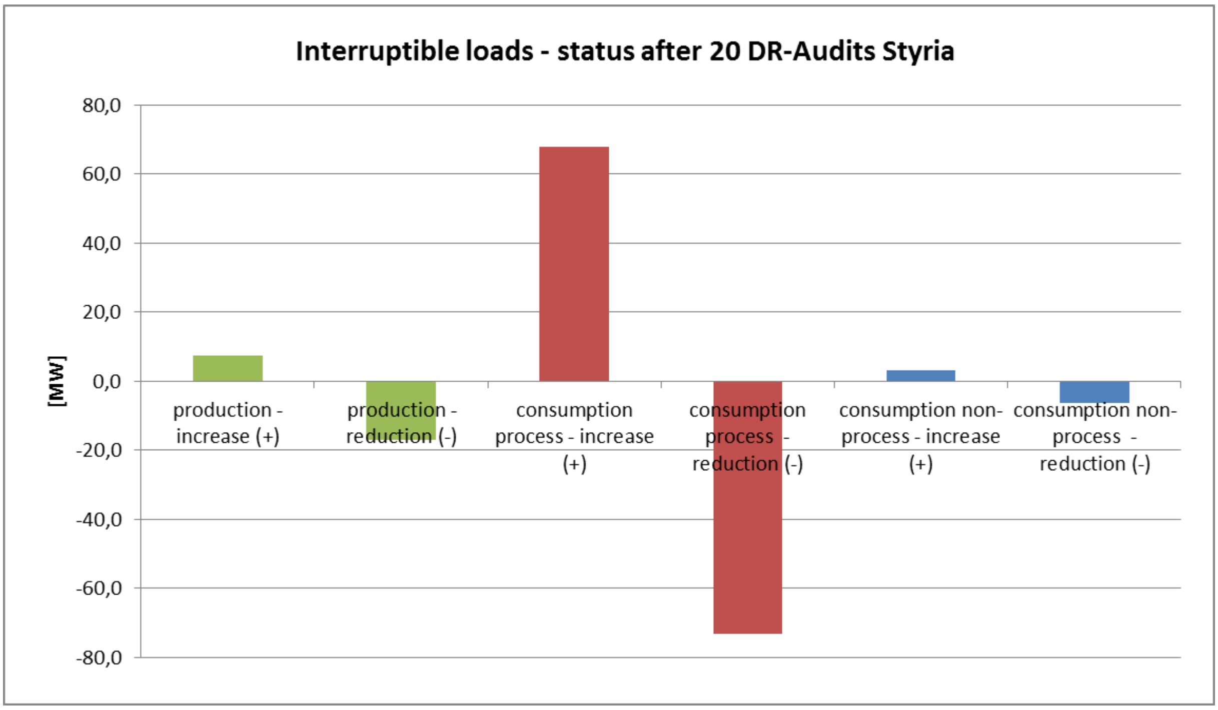


Figure 12: Interruptible loads – Status after 20 DR-Audits in Styria

The interruptible single-loads in the category "consumption process" and "consumption non-process" are in the above mentioned companies between 150 kW and 8.000 kW. In the category "production" the increase or reduction of single loads between 140 kW and 5.000 kW is possible.

The shifting time for the single consumers/producers varies between a few minutes and several hours/days.

About 50% of the above mentioned interruptible load in the category "process" comes from one company and it is a group of machines for the production of ceramic products (mills etc.). The maximum switching time for this consumer group is about 30 minutes. The second largest interruptible load in the category "process" (35%) would be possible with a change of the shift-work model. This results in quite long switching times (normally 8 hours) but it is necessary to adapt the whole shift-work model which means lead times for at least one week and ideally the switching time should be 8 hours.

The following figures show the characteristic between the interruptible load (in MW) and the maximum switching time (in hours) for the categories “production” and “consumption”.

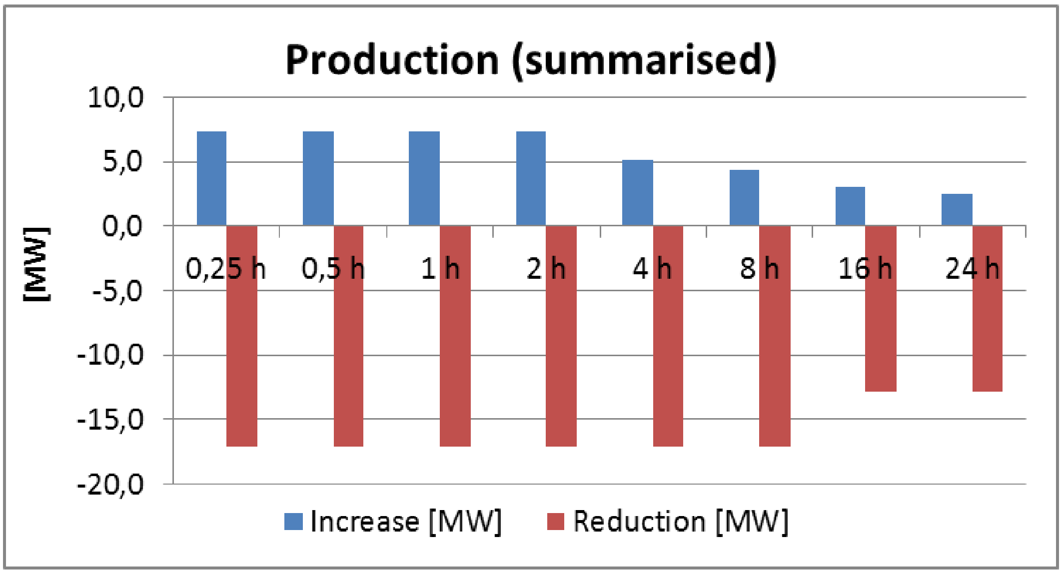


Figure 13: Interruptible loads for the category “production” – Status after 20 DR-Audits in Styria

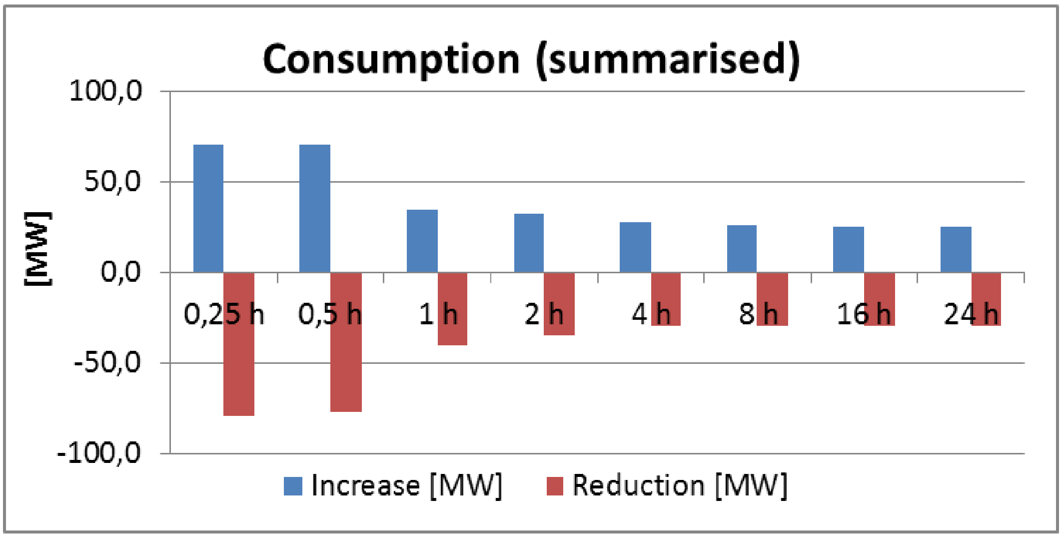


Figure 14: Interruptible loads for the category “consumption” – Status after 20 DR-Audits in Styria

A very often discussed potential for load shifting in the category “consumption process” is the shift from the main working time (Monday -Friday 6:00 - 22:00) to night or weekend. If the (production-) processes are highly automated, this shift shouldn't be a big problem when the process isn't used up to now for 24h/day and on weekends. The higher the percentage of manpower for the production process the more difficult is such a load shift process because of the higher percentage of extra payments for night or weekend compensation.

It has to be mentioned that although the pre-check of the companies figured out relevant interruptible loads, during the detailed DR-Audit this potential couldn't be confirmed in some of the companies. The main reasons were:

- Some emergency generators cannot be used as either a main parallel operation mode is not possible or it is according to the national regulations (disaster protection plan) not allowed to use them for other purposes than for disaster protection.
- Some processes cannot be interrupted as either the quality of the produced goods may be degraded or the machines may operate in a less optimal way or even may be damaged (higher production costs and/or reduction of life time of machines).
- In some companies a change of the shift-work model is not possible

In the following list the main results of the DR-audits in Styria for the different types of companies (according their scope of activities) is summarised:

- Mining/production of ceramic goods: quite high potential in some companies for reduction/increase of loads; mainly depending on level of automation, storage capacity and actual degree of their capacity utilisation; shifting times between 0,5 and 8 hours
- Steel production: potential for load-reduction with electric arc furnace for raw materials but the higher the requirement for the good the less the chance for load shifts; nearly no chance for load shifts in thermal treatment processes; shifting times between 0,25 and 24 hours
- Paper industry/wood industry: small/medium potential for load shift mainly depending on storage capacity before/after shredders, grinding machines, mills etc.; shifting times between 0,5 and 24 hours
- Shopping centre/office building: small potential for load shift for ventilation, air conditioning, etc. - mainly short time (max. 30 minutes); shifting times between 0,25 and 1 hour
- Hospital: most of the installed emergency generators cannot be used as it is not allowed to use them for other purposes than for disaster protection (according disaster protection plan); Small/medium potential for load shift with ventilation, air conditioning, steam humidifiers, etc.; shifting times between 0,25 and 2 hours
- Small hydro power plants: in general reduction of production capacity possible – actual capacity level of run-of-river plants without reservoir depending on flow rate of river (April to June 100%,

rest of the year reduced); feeding-in tariff regulation for renewable energies has to be considered; shifting times up to 24 hours possible

- Wood chip CHP: in general reduction of production capacity (electricity) possible if bypass for heat production is foreseen; feeding-in tariff regulation for renewable energies has to be considered; shifting times up to 12 hours possible

In the DR-audits the decision makers in the companies were also asked about their experiences about DR, their concerns, their minimum requirements to be a partner in the hybrid-VPP4DSO project, etc.

The main results are:

Interest in the *hybrid*-VPP4DSO project:

In general companies are very interested in the project hybridVPP4DSO because:

- they want to be up to date (legislation, situation on the market)
- they are interested in economic benefits (or for example even the chance to have more in-house production instead of outsourcing)
- Some of them are interested in a “green image” for the company

Experience with DR:

Some of the evaluated companies have already experience with DR, mainly from peak load management

- Acceptance of users/workers is sometimes limited because it is a change in the well-known process (shift-work model, etc.)
- The financial benefit with peak load management is not as attractive as in the past
- Some (especially old) peak load management systems caused problems with electric consumers (consumers not applicable for on/off regime, no preliminary lead times and follow-up times considered, etc.)

Concerns:

- Mustn’t result in an economic disadvantage for the company
- Increase of technical problems with production line (higher effort and costs for maintenance etc.)
- Reduction of comfort parameters for employees (HVAC system etc.)
- Reduction of the quality of the products
- Technical capability of the existing system (part load behaviour turbine/generator, etc.)
- Disadvantage with energy tax reimbursements
- Disadvantage with feeding-in tariff regulation for renewable energies

- Conformity with disaster protection plan
- Data security

Chances:

- Economic profit for the company
- Less outsourcing due to the chance of economic production during weekend (lower energy costs compensate extra payments for night or weekend compensation)
- Increasing the green image of the company
- Chance for economic attractive operation mode of renewable electricity production (biomass-/ biogas CHP, etc.) after the end of the feeding-in tariff model for green electricity
- Consideration of the actions within the new energy efficiency law

Importance of green image for the company:

The statements of the companies are varying between 3 and 5 (1=not important, 5=very important)

Percentage of the electricity costs of the whole production costs:

In average the percentage is between 1 and 5% but as these data are very confidential only a small number of companies answered this question.

Which person in the company will make the decisions pro/contra implementation of DR-system?

The main decision-maker in nearly all companies are from the management level but the heads of the department's production planning, facility management and electrical department will always be involved in the decision-process.

Which additional effort would be necessary in the company to implement a DR-system?

In most companies the already existing production planning system can be adapted. The technical capability of the existing systems has to be considered, sometimes technical adaptations will be necessary (separate cabling of consumers and integration in process control, mains parallel mode of generator, etc.).

What would be a knock-out criteria for a participation in a DR-project?

In most cases the main knock-out criteria would be the economic disadvantage for the company. But also the risk of a lower quality of the produced goods or higher maintenance costs and data security was mentioned in the DR-audits.

What would be the main arguments for a participation in a DR-project?

The economic benefit is in most cases the main argument. Some companies are interested to use the flexibility in their production process (not 100% operating grade, storage capacity, etc.) to shift the process to times with lower electricity costs. Other companies are interested to show their green image (help renewables to increase their share in the electricity mix).

6 DR-Audits in Enterprises in Slovenia

During the summer 2014, for the needs of this project, both Slovenian partners have started to search industrial and business customers, who might have the possibility by decreasing or increasing their power to take a part in this project. This was the first criterion. The second important criterion was the potential impact on the voltage profile. No significant influence on the voltage level could be found, so the decision of grids selection remained unchanged, the first one in the city; the second in the country.

When collecting the potential participants it was not exclusively decisively, whether the customers are connected at the critical parts of the grid. It was important that they were prepared to answer the questions and to give the necessary information. The reason for not being focused to the critical parts of the grid is that in the very first step potential customers have to be found. If we want to have at least the planned number of customers, larger number of them have to be asked and this regardless of their position. It is also necessary to be mentioned, that in Slovenia, because of smallness and not to rich industrial development, not so many customers could be found. Long time Elektro Ljubljana's experiences confirm these. This statement can be proved by surveys during previous years, when Elektro Ljubljana d.d. just even started with thinking about the demand response and demand side management.

Survey's abstract:

> During the first trial of collecting customer information (finished in August 2014), we have asked 15 customers for return the questionnaire and finally received 5 of them. This result shows that at least one more time the whole procedure of collecting information has to be done.
>
> General results of the survey:

1. Four industrial customers and one commercial customer returned the fulfilled questionnaires.
2. One of the companies has three power grid connecting points (measurement places), one company has six, and the rest of the customers each of them has one measurement place. Altogether we can count on twelve geographically different grid connecting points and measurement places respectively.
3. Two companies have DSM and Demand Response experiences, but both are concerned about receiving a short term call to decrease demand at an unfavourable time point.
4. Refusing to take part in demand response is generally based on their priorities following their production plans and, as a second reason, on the fact that they do not see DR as much important.
5. Another important barrier of not being prepared for the demand decreasing cooperation is not clear defined possible additional costs (in some cases also technical upgrades necessary).

General electricity consumption data:

1. Max. available grid connection active power is between 0,2 kW (the commercial customer) per connection and up to 702 kW.
2. Yearly consumption: up to 120.000 kWh.
3. Almost all customers collect electricity consumption data daily.
4. Most customers are able to forecast the needed electricity at least one day in advance
5. The percentage of electricity costs in the material and sold products costs is from 2 to 10 % (industrial) and less than 1% (commercial) for each company.
6. Electricity data collection is done via bills or SCADA Systems (daily or one minute level).
7. One industrial and one commercial company have their own energy sources, but these are not in use regularly.
8. Almost all companies, during the hours of their highest production, exceed their maximum available power.
9. Night shifts: two companies. Four companies work more than one shift.

General Power Grid Connection Information/Grid Acess:

1. All customers are connected to MV or LV Power Grid.
2. All but one of the industrial customers have installed dynamic reactive power compensation devices. The nominal Power of the Compensation devices is in range between 200 to 810 kVAr.
3. Synchronous Energy production Capacities, actually electricity power generators are installed only at one customer. Two customers have generators, but cannot operate synchronously to the grid.

Besides general information as described above the questionnaire contains two additional sheets, where some detailed information about the loads are demanded.

Detailed information about the production process and process independent loads:

1. In the facilities some process independent loads (auxiliary units) and generation units are installed. Its estimated power is between 2 to 200 kW. If we express and calculate this power in the share of the summarized installed power, the percentage is between 0,02 and 50%.
2. In addition, some leading or process main loads are also installed. Estimated power is between 30 and up to 30.000 kW. At these devices the available power reduction or rise (production) is from 2,8 % to 100%. 100% means that the whole process is stopped, when putting such a load off.

3. Time needed to come in normal operation when a load is switched off and later on is estimated at minimum 10 minutes and maximum 1 hour.
4. Process loads which can be taken for the available power operate non-stop during the production.
5. For the energy management just some of process loads can be switched off for different periods of time; minimum time begins at 3 hours and maximum time at 8 hours.
6. For available power activation it is asked, if the possibility exists to be informed one day in advance.
7. The maximum possible number of switching the loads on and off is different per company.
8. Switching off the load shall effect on consumption drop.

Detailed information about the switchable process loads:

1. When switching off the process loads and consequently to reach the desired level of power decrease, at least 5 minutes and maximum 1 hour are needed.
2. The longest time of being switched off is 8 hours.
3. For available power activation it is desired to be informed one day in advance.
4. It depends from each load separately what is the maximum of being switched off, meaning per month or per whole year.
5. Switchable loads which are the part of production process substantially affect electricity demand.
6. Process loads might to be switched off no longer than 30 minutes or more.

Second information collecting was done in autumn 2014. The results about the fulfilled surveys were more optimistic. We have got additional 8 completed questionnaires back. The most important fact is, that most of these customers are involved in established and operating VPPs. If we made a sort by their activities we were in contact with 3 paper mills, one but the largest iron works, one pharmaceutics industry, one cement production, one producer of newsprint and coated graphic papers, one commerce, one automobile factory, one brewery and one production and processing of silica sands and the production of auxiliary casting material for foundries and ironworks. There is only one concern; this selection of customers involves participants which are wide spread all over Slovenia. It might be also a minor disadvantage; these customers are not connected to our critical parts of the grid, which shall be analysed in the project.

Customers collected at project's focused part of the power grid:

Detailed analyse of possible suitable customers has been done. Table 1 and Table 2 show the selected customers in the area of Ljubljana city and the area of South East Slovenia, Bela Krajina.

Table 1: Selected customers in Ljubljana and South East Slovenia, Bela Krajina

No.:	No. Of the mesuremnt Place	Ljubljana Area
1	3004298	Police station
2	3004293	Industry
3	3308009	Furniture store
4	3325599	Hotel
5	3423633	Hotel
6	3334323	
7	3407335	CHP
8	3004296	Industry
9	3003380	Primary school
10	3003381	Primary school
11	3003384	Rest Home
12	3003356	Rest Home
13	3408251	CHP
14	3344366	Telekom
15	3001195	Telekom
16	3344366	Telekom
17	3310824	Shopping Mal
18	3004204	Gasoline station
19	3337458	Shopping Mal
20	3337457	Shopping Mal
21	3337649	Shopping Mal
22	3337456	Shopping Mal
23	3003622	Pharmaceuticals industry

Table 2: Selected customers in South East Slovenia (Bela Krajina)

No.:	No. Of the mesuremnt Place	South East Area
1	3418157	CHP
2	3292345	Industry
3	3292346	Wood factory
4	3014804	Shopping Mal
5	3014833	Kindergarden
6	3014727	Industry
7	3292344	Industry
8	3402527	CHP
9	3302272	Industry
10	3314706	Industry
11	3260752	Industry
12	3396011	Teniss Hall
13	3014834	Secondary School
14	3380739	Industry

Yellow marked customers are those who necessarily have to be asked and surveyed because they belong to our focus group from the observed parts of the grid. Other customers, not marked, represent the additionally selected customers, who might be asked for the will to cooperate at the survey, with the aim to gather as much possible data and information.

The results of answered questionnaires were not so optimistic, only 3 customers gave us the fulfilled surveys; others were not prepared even to talk. In many cases the reason of not being prepared to answer the questionnaire was its length and too technical content.

7 Data Base for DR- and Controllable DG- Resources

The database for DR- and controllable DR-resources was implemented by cyberGRID in Microsoft Access. The data base' structure is depicted in Figure 15.

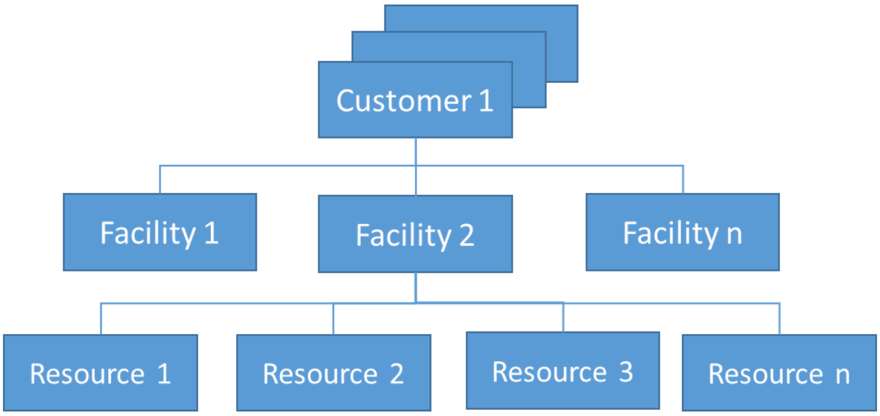
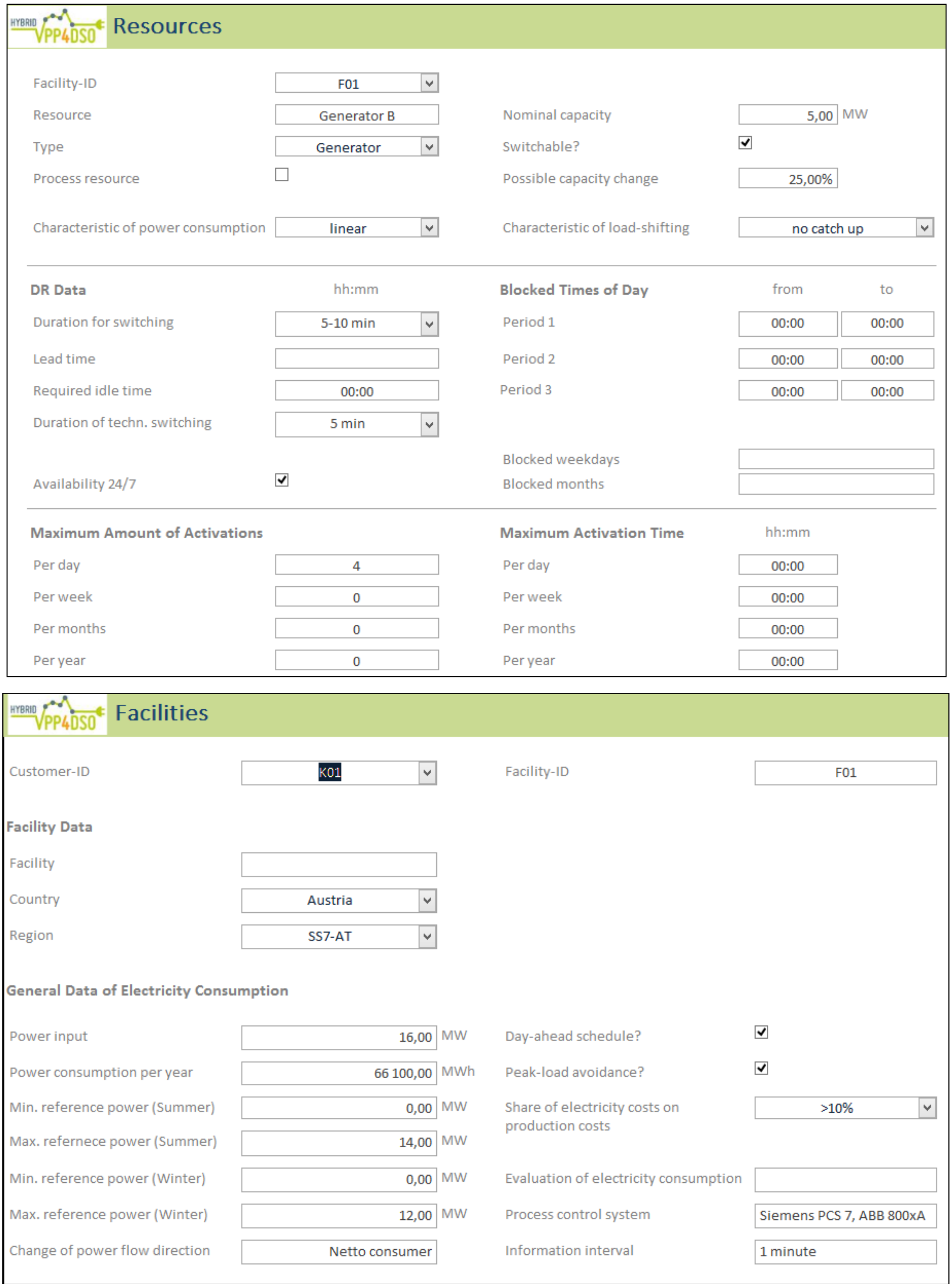


Figure 15: Structure of the data base

The database structure allows every customer/company to have multiple facilities comprising of multiple DR-/DG-resources. In general, the data base incorporates all gathered information from the DR-audits (see chapters 4 and 5) including answers to the topics/questions of the customer questionnaire. However, due to sensitive customer data all entries in the database were anonymised. Instead of company names, addresses, contact persons, etc. customer and facility ID codes are used to clearly identify and distinguish the entries. To allocate the DR-/DG-resources to the analysed grid sections in Styria and Slovenia, region codes (e.g. SS1, SS2, etc.) are added to the facility entries.

Figure 16 exemplarily shows (parts of) two of the implemented data base forms – for facilities and for resources – in MS Access.



Resources

Facility-ID	F01		
Resource	Generator B	Nominal capacity	5,00 MW
Type	Generator	Switchable?	☑
Process resource	☐	Possible capacity change	25,00%
Characteristic of power consumption	linear	Characteristic of load-shifting	no catch up

DR Data	hh:mm	Blocked Times of Day	from	to
Duration for switching	5-10 min	Period 1	00:00	00:00
Lead time		Period 2	00:00	00:00
Required idle time	00:00	Period 3	00:00	00:00
Duration of techn. switching	5 min			
		Blocked weekdays		
Availability 24/7	☑	Blocked months		

Maximum Amount of Activations		Maximum Activation Time	hh:mm
Per day	4	Per day	00:00
Per week	0	Per week	00:00
Per months	0	Per months	00:00
Per year	0	Per year	00:00

Facilities

Customer-ID	K01	Facility-ID	F01

Facility Data

Facility	
Country	Austria
Region	SS7-AT

General Data of Electricity Consumption

Power input	16,00 MW	Day-ahead schedule?	☑
Power consumption per year	66 100,00 MWh	Peak-load avoidance?	☑
Min. reference power (Summer)	0,00 MW	Share of electricity costs on production costs	>10%
Max. refernece power (Summer)	14,00 MW		
Min. reference power (Winter)	0,00 MW	Evaluation of electricity consumption	
Max. reference power (Winter)	12,00 MW	Process control system	Siemens PCS 7, ABB 800xA
Change of power flow direction	Netto consumer	Information interval	1 minute

Figure 16: Data base forms in MS Access

8 Business Models for Hybrid-VPPs

8.1 Introduction

The goal of this chapter is to pre-select suitable hybrid business models for VPP for the DSO as well as for market participation based on the literature and interviews with experts. This pre-selection involves, for each business model, the creation of an evaluation matrix, containing the involved stakeholders and evaluation parameters, which cover the most important aspects of the business model. Furthermore, evaluation criteria (or catalogue) to characterize and compare different business models are determined. These evaluation criteria shall be applied throughout the entire *hybrid*-VPP4DSO project in order to use a coherent methodology.

8.2 Business model, use and business case definitions

With `**business model**', we refer to "the rationale of how an organization creates, delivers, and captures value (economic, social, or other forms of value)" (Kaplan, 2012). Even though there is no commonly agreed definition in academia or practice on 'What is a business model?' the former definition is widely used (C. Zott, 2011).

According to (Stähler, 2002), a business models' four key components should describe the

1. Value proposition to the customer (or strategic partner),
2. Product or service, through which the client delivers the value proposition
3. Architecture of the value added and where and how the products or services are marketed
4. Earnings model, to answer how and where the business earns profits, which should be structured into a revenue and a cost model

Originally, the "rise of the term is closely related to the emergence and diffusion of commercial activities on the internet", but is now applied in other commercial and also non-commercial sectors alike.

(Osterwalder & Pigneur, 2010) view the value proposition to the customer in the centre of a business model. They propose to further differentiate between i) Market perspective (broken down into customer relationships, communication and distribution channels, targeted customer segments and revenue sources) and ii) Company perspective (broken down into key resources, activities, partners and cost structure).

From an operations management perspective, a business model would be "the operating model of a company or the product/ service delivery system". All of the aforementioned definitions are „intimately related to the way the organization produces and delivers value to customers. (Girotra, 2013)

Within a business model different **use** and **business cases** can be distinguished. Sometimes there are overlaps between the terms and a clear distinction may be difficult. However, we view the business model as the more generic and comprehensive concept, structure and strategy of an organization (in the sense of the aforementioned definitions), which in practice may be applied to different goals, applications and projects (labelled as use and business cases in the absence of a better term).

8.3 The "*hybrid*-VPP" and its application

VPPs can be applied in different ways in a given business model. These applications can include services to the grid where it is connected to (operated) by the DSO and/or the participation in electricity markets. Four applications of VPPs were therefore identified, depending on if they are more grid- or market-oriented, as depicted in Figure 17.

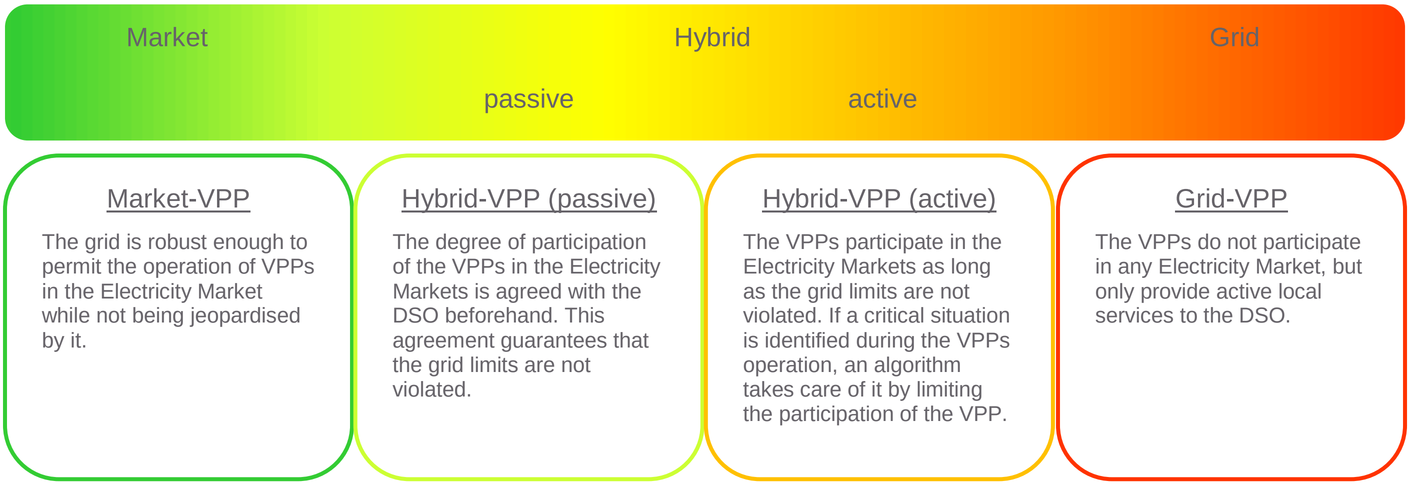


Figure 17: VPP applications (Market X Grid)

The first application is 100% market-oriented, while the fourth is 100% grid-oriented. Since the project *hybrid*-VPP4DSO considers hybrid VPPs, these will not be directly considered and are merely interesting as a reference. Despite that the first application will be considered as a mean of comparison (see 'Means of Comparison' below) for the economic analysis.

The second application considers a pre-agreement between the DSO and the VPP operator. As soon as this agreement is valid no network problems will occur – this fact makes this application identical to the first one.

A true hybrid behaviour is depicted by third application, where VPPs participate on electricity markets without pre-defined limitations, however, if specific critical situations occur, measurements need to be taken to limit this participation in order not to endanger the network. The third application will, therefore, be the one considered in the project. A further explanation of the behaviour of the active hybrid-VPP application, with its related decision making logic will be provided in the Deliverable 3 of this project.

8.4 Pre-selection of business models – the affiliation of VPPs

Based on the aforementioned business model definitions and the "Guidelines for business models between energy and ICT sectors" (Navodnik, Kern, Sernec, Krisper, & Turha, 2013), 4 business models are differentiated based on the affiliation of the VPP (which is in this text called "VPP-operator"). Depending on which party is operating the VPP for a certain purpose, a different business model applies. Four different business models are considered in this project, based on the affiliation of VPPs, as follows:

8.4.1 DSO

The distribution system operator is especially interested in the business cases seen from the grid-view. In the hybrid approach, the DSO has – as the only actor – all the relevant information of the network in real time. Furthermore, the concept has the advantage that smart-meter data remain with the DSO and must not be passed on to any other market participants. Therefore, the DSO is suitable best at least for the coordination of a pure technical VPP. In addition, the DSO would need further information about the customers and their flexibility potentials. It should be clarified whether and in what form the collection of flexibility potentials from a regulatory perspective belongs to the jurisdiction of the DSO. One of the biggest limitations, for assigning the hybrid VPP to the DSO, is the unbundling conformity in electricity markets. One assumption for further analyses of this business model could be that the DSO only participates in ancillary services, like balancing market.

8.4.2 Energy Retailer

The energy retailer is a provider of electricity to at least one end consumer. The power company is an established player in the energy market with market know-how. Moreover, it can participate in the energy markets according to the regulatory framework in contrast to the DSO. If it is assumed that the energy retailer has its own balance group, the VPP can also help to minimize energy balancing costs. In addition, they have the advantage that they can access a broad customer base; which makes it easier for them to take advantage of different business cases.

8.4.3 Independent Aggregator

Aggregators are new market players who try to acquire new customers with innovative business models like using flexibility potential to generate revenues. Aggregators are usually independent from conventional energy market processes and can have different backgrounds like software and ICT technology. By using their competencies for aggregating DG and DR they could have an advantage compared to other actors in the energy sector.

8.4.4 Customer VPP

The advantage of operating a VPP for the customer is that consumers know their energy resources and their potential itself very well. It strongly depends on the size of the consumers, whether they have the know-how for energy trading and whether it would be profitable to acquire knowledge for the operation of an own VPP. Economies of scale could be used when these consumers merge with other consumers to a larger entity.

We do not consider technology providers and traditional integrated utility models. As a basic requirement, all business models must comply with the hybrid target function as described above.

8.5 Stakeholders

Affiliation of the VPP refers to the different possible operators of a VPP. Stakeholders though, are other existing entities in the energy sector. Regardless who is operating the VPP, the influence on the different stakeholders is analysed.

8.5.1 DSO

"A natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution network in a given area and, where applicable, its interconnections with other networks and for ensuring the long–term ability of the network to meet reasonable demands for the distribution of electricity." (https://emr.entsoe.eu/glossary/bin/view/GlossaryCode/GlossaryIndex) In case the DSO is responsible for the business model the stakeholder DSO represents other DSOs, e.g. DSOs in the neighbourhood of the DSO with the VPP.

8.5.2 Energy Retailer

Here energy retailer means a competitor of the currently analyzed VPP-operator without an own VPP. In general an energy retailer has its own power plants, but also pure purchasers with their own customers fall in here. In case the VPP is owned by the energy retailer, the stakeholder "energy retailer" represents the competition without an own VPP.

8.5.3 Aggregator

"Aggregator means a legal entity which is responsible for the operation of a number of demand facilities by means of demand aggregation." https://emr.entsoe.eu/glossary/bin/view/GlossaryCode/GlossaryIndex)

In case the VPP is owned by the aggregator, the stakeholder "aggregator" represents the competition with VPP.

The above mentioned definition is extended in this work. Here it means an aggregator of flexible loads and generators. An aggregator as a stakeholder is a competitor of the analysed VPP-operator with an own VPP.

8.5.4 Participant in considered VPP: Flexible Load/Generation

Flexible load/generation refers to an energy resource participating in the considered VPP. In case the VPP is owned by the flexible loads themselves (customer VPP), the stakeholder and the owner of the VPP are identical.

8.5.5 Other non-flexible Customers/Generation

This stakeholder resembles other customers (load/generation). Costs that can be reduced by a VPP are perceived as positive, like reduced grid costs or general benefits (political framework), like a higher RES share or higher energy-efficiency.

8.6 Evaluation criteria for business models

In order to make qualitative statements about the suitability of the respective business models, the following criteria have been evaluated:

- Technical requirements
- Organisational requirements
- Regulatory framework
- Political Framework
- Monetary aspects
- Other benefits

Each of these criteria is divided in one or more specific parameters, which will be used to compare and evaluate the different business models of hybrid VPPs for the various design options for the market and grid operation participation. The considered parameters are then displayed in a table (matrix), where for each of them both the VPP-owner and other stakeholders are marked as positive (5/4), neutral (3) or negative (2/1), depending on different reasons, which are explained below in the section Evaluation – existing for each parameter.

8.6.1 Evaluation Matrix

As stated above an evaluation matrix is to be created for each of the four analysed Business Models. Table 3 shows an example of this matrix. It contains an indication of the application of VPPs ("active-hybrid – refer to 8.3). The columns of the matrix represent the considered VPP-owner (8.4) and the other stakeholders (8.5), while the lines are the evaluation parameters. It is important to highlight that the actual qualitative evaluation of the different Business Models is not goal of Task 1.5, but is included in the Deliverable 2 (WP2). The total (Σ) values will be used for summing the evaluations over one parameter or/and one stakeholder.

Table 3: Evaluation Matrix

	active hybrid-VPP	VPP-owner: Affiliation of VPP (DSO/Retailer/Aggregator/Customer)	Stakeholders: DSO	Energy Retailer (comp. without VPP)	Aggregator (comp. with VPP)	VPP-participant (flex. load/gen)	Other Customers	total: Σ
Technical	Solution of grid problems							
	Data safety and security							
	Geographical limitation / limitation in participating units							
	> geographical limitaion							
	> limitation in participating units							
Organisational	High system complexity							
	Existing information / know-how							
	> information about own facilities							
	> know-how about trading / energy markets							
	Existing customer pool							
Regulatory	Compliance with regulatory framework							
Political	Fullfilment of political framework conditions e.g. climate targets							
	> share of RES							
	> energy efficiency							
Monetary	Possibility to get revenues by business cases - market view							
	> energy only market							
	> balancing market							
	> capacity market							
	> minimizing imbalance costs							
	Possibility to get revenues by business cases - grid view							
	> minimizing connection costs for customer							
	> minimizing grid investments for the DSO							
	> energy provision during failures							
	> Minimizing grid tariffs charged by DSO / TSO							
	Low investment costs: ICT, infrastructure, etc.							
	Avoided grid enhancement							
Other	Green image							
	New tariff structures / products							
Σ	total							

8.6.2 Technical Requirements

8.6.2.1 Solution of grid problems

Distribution grids in rural areas often consist of long lines with relative few network nodes. This can be challenging especially regarding the compliance with certain voltage limits. In urban areas, however, overloading of network components such as lines and transformer stations are more likely. The flexibility of a VPP can be used to contribute to the solution of these network problems and therefore support network operation.

Evaluation: It is evaluated whether it has a positive or negative impact on the stakeholders and if someone can profit from the solution of grid problems. Regarding the VPP-operator it is estimated how suitable the business model is for solving network problems.

8.6.2.2 Data safety and security

To evaluate the security aspects that are relevant for the individual business models, a clear picture of the underlying ICT architecture is required. The different actors and components need to be identified, and the scope and content of the communication occurring between them must be defined. High security issues arise if the data exchanged contains:

- personally identifiable information;
- information that requires specific protection in terms of integrity, authenticity and confidentiality;
- time critical information.

Evaluation: Business models that do not involve the exchange of confidential data are rather positive. This parameter might affect both VPP-operators and stakeholders.

8.6.2.3 Geographical limitation / limitation in participating units

In general a higher availability of potential flexible loads/generators has a positive effect on the VPP performance. To be able to choose from a wide range of different units is very important because picking suitable units can help to achieve desired portfolio-effects like:

- compensation of volatility in specific load/generation;
- higher ramping rates for upwards or downwards regulation;
- better composition of short or long running units;
- faster response time.

Depending on the response time the VPP can be used to provide different ancillary services to the grid and balancing markets. The response time of the VPP results from the total time required for gathering measurements, data processing, sending signals-to-action to the VPP and the reaction time of the installation(s). With shorter response times, the VPP can be used for more diverse grid support services and balancing markets. If a VPP participates in regulating energy markets, it has to be guaranteed that special market requirements are fulfilled. The tertiary control power, for example, has to be available within 10 minutes after a request. The response time of the VPP is therefore an important parameter. Another positive effect is that with a higher variety of units it is possible to control more units in the critical grid and those units that are especially suited to solve grid problems on a local or central control level.

The parameter is takes two separate aspects into consideration:

- the geographical limitation of a VPP-operator as for example the DSO, who is more or less restricted by its own distribution grid
- the limitation of participating units as for example the customer-VPP is limited to its own units and hence, has e.g. only hydro power in the portfolio

Evaluation:

When a VPP-operator is either geographically limited or restricted in the availability of flexible loads/generators that can participate in the VPP, this parameter is surveyed negatively; otherwise positively.

8.6.3 Organisational Requirements

8.6.3.1 High system complexity

The aggregation of a number of decentralized energy resources to a VPP can potentially lead to significant organizational requirements. The complexity of the system increases with the number of participating actors. This is especially crucial when the VPP consists of many small distributed energy resources. A continuous flow of information across all components / VPP participants must be ensured. This has to be considered in the ICT-architecture of the VPP.

Evaluation: Depending on who operates the VPP the system can vary in complexity. High system complexity is rather negative. More involved players result in a higher system complexity. It is mainly important for the VPP-operator but could also affect other stakeholders. If other stakeholders have a disadvantage, the parameter is evaluated negatively.

8.6.3.2 Existing information/know-how

Depending on the affiliation of the VPP, the respective actors have different expertise in trading on the energy market or in network operation. Additionally some of the VPP-operators have good knowledge about the current status of their facilities, others not. For example, a DSO or retailer has already a lot of information about their customers.

- *Information about aggregated/pool facilities*
  Evaluation according to the following criteria:
  Positive: information required and existing information
  Negative information required but no existing information
  Neutral: no information required

- *Know-how about trading/energy markets*
  Evaluation:
  Positive: know-how required and existing know-how
  Negative: know-how required but no existing know-how
  Neutral: no know-how required

8.6.3.3 Existing costumer pool

In order to form a VPP, interactions between different actors are necessary. The effort to acquire customers for the VPP can be avoided if there is an existing customer pool that can be used.

Evaluation: A VPP-operator with existing customers has an advantage in forming a VPP; therefore, it is evaluated as positive. Other involved stakeholders might profit if this results in less effort for them; otherwise it is neutral for them.

8.6.4 Regulatory Framework: Compliance with regulatory framework

Various regulatory conditions must be considered when operating a VPP. Since the liberalization of the energy sector, the principle of unbundling exists. That means a clear separation between network and market. In the network area, there is a state-controlled monopoly consisting of the distribution system operator (DSO) and transmission system operator (TSO) ensuring security of supply. On the market side (production and sale), however, there is free competition, offering all stakeholders non-discriminatory market access. Network operators, however, are under the current system, not being allowed to participate in energy markets and to have their own generating capacity. If a VPP participates both in market and network services, it must be ensured that this happens unbundling-conform. In this work long-term scenarios in which a DSO itself can operate a VPP to relieve the distribution, will also be examined. Currently this is not compatible with unbundling and could only be implemented by changing the regulatory framework.

Evaluation: If operating a VPP under the specific affiliation is in accordance with current regulatory framework it is reckoned as positive otherwise as negative. This criterion relates only to the VPP-operator and is neutral for other stakeholders.

8.6.5 Political Framework: Fulfilment of political framework conditions e.g. climate targets

The energy sector is highly influenced by political decisions on European and national level, such as 20-20-20 objectives of the EU Directive 2009/29/EC, EU energy policy 2050 goals or the *Ökostromgesetz*. The measures include requirements for energy savings, the share of renewable energies in power generation as well as the reduction of emissions. Here two key objectives are considered: Share of RES and Energy efficiency.

Evaluation: A higher contribution to political frameworks, like climate targets or higher energy efficiency from a specific VPP-operator is weighted as positive. The stakeholders who profit from this criterion are also evaluated positively.

8.6.6 Monetary Aspects

8.6.6.1 Possibility to get revenues by business cases - market view

- *Energy only market*

Especially the day-ahead and intraday markets are relevant for VPPs. The futures market is not further considered, because here long-term planning would be required. The focus however, lies more on using the VPP's short-term market flexibility. The flexibility of the VPP offers the possibility to take advantage of price spreads on both the day-ahead spot and the intraday spot between peak and off-peak hours or quarter hours. For directly-controlled generators, an optimal schedule can be created. By pooling the assets in a VPP, the volatility of renewables can be reduced. Switchable consumers can shift their consumption pattern from peak to off-peak periods, where technically and economically feasible.

➢ *Balancing market*

On the balancing markets, participants are paid for the provided power and depending on the balancing market, also separately for the requested energy. In general, separate products are Primary, secondary and tertiary control power markets have different technical prequalification and differ in their probability and frequency of the requests for balancing energy. The tertiary control reserve has the lowest probability of request. In 2012 the control reserve featured a probability of request of 2.48% per hour for positive calls and of 8.19% per hour for negative ones.

➢ *Capacity market*

The capacity mechanisms mainly deal with providing guaranteed production capacities in the future, this market is rather less interesting for a VPP because of its special design for long-term planning. Decentralized capacity mechanisms would be more interesting for a VPP, since on balance-group level or at the consumer level, the capacity must be ensured also in critical times. Nevertheless, capacity mechanisms are long term market products. In general, it will be difficult for VPPs to generate revenues in such market places; hence, this parameter is not included in the evaluation matrix.

➢ *Minimizing imbalance costs*

Each market participant has to join a balance group. In case a balance group deviates from its schedule it is charged for this deviation (imbalance volume) with the imbalance price. The imbalance price depends amongst others on the control area, so on the direction of all other balance groups. The deviations of the balance group and by this, the resulting costs can be reduced with the flexibility of a VPP.

8.6.6.2 Possibility to get revenues by business cases - grid view

➢ *Minimizing connection costs for customer*

The integration of new customers (consumers, producers or prosumer) could result in new investments into the electricity grid, in case available free network capacities are not sufficient. Costs incurred thereby have to be covered by the customer in accordance with current regulations. This may be an interesting opportunity for a VPP. The feed-in or load of a customer can be temporarily restricted at the request of the DSO. In exchange, no or reduced grid connection costs for the customer occur. This guarantees that a certain level of network utilization is not exceeded (in terms of thermal overload or compliance with predetermined voltage bands). In consequence damages to the power components (lines, transformers, etc.) can be avoided. Such high load situations, that require a power adaptation by the DSO, usually happen very rarely, so this poses only a very small restriction to customers while saving high network connection costs. The benefit is easy to measure and can be directly assigned to the customer.

- *Minimizing grid investments for the DSO*

General network expansion projects, within the scope of the DSO, due to an increasing number of consumers and producers in the network, can also be prevented or delayed by flexible concepts. However, an adaption of the tariff-system seems necessary because under the current framework there are no incentives for the customer, to change their behavior regarding to the current network situation. The temporary adjustment of the load or feed-in must be adequately reimbursed to the customer, this could be done either on an ad hoc basis (payment on demand) or special network tariffs for flexible customers can be offered. Such measures could be necessary only for a certain period. This should be considered in the tariff structures to be implemented.

- *Energy provision during failures*

The ability to temporarily control the behavior of customers can also be used specifically for grid faults and congestion of network infrastructure. Taljan et al. (2014) presents an approach to integrate this concept into a network control system, a possible remote control topology and an automatic remote control. Furthermore, first results are shown for the medium voltage network demo-site.

- *Minimizing grid tariffs charged by DSO / TSO*

If the VPP is used to limit maximum reference power from the upstream network, a reduction in procurement costs from the upstream network can be achieved. Although there is no direct monetary benefit for the DSO according to the current framework, overall resulting network charges can be reduced. In addition, this is also a benefit for the transmission system operator (TSO).

Evaluation: If the VPP-operator can participate in a certain business model from market or grid view, it is in general rather positive. It could also affect other stakeholders, e. g. more participants in a market can have negative effects on competitors. However it might be positive for other customers because a higher competition could be beneficial from system-view. The stakeholder that profits from a business model, because costs are reduced etc., is also evaluated positively. In case these aspects have no effect it is evaluated neutrally.

8.6.6.3 Low investment costs: ICT, infrastructure, etc.

To integrate generation plants and consumers in a VPP, investments in ICT and smart meters are necessary. It is assumed that the VPP-operator has to pay for these costs. If existing smart grid components and structures exist, investment costs can be saved. This should be considered for the different business models.

Evaluation: The availability of existing infrastructure respectively know-how of e.g. a technology provider of IKT is positive for the VPP-operator because investment costs can be saved. This might also be a benefit for involved stakeholders because no adaption of their system is necessary. Not involved stakeholders are not affected (neutral).

8.6.6.4 Avoided grid enhancement

This aspect considers general expenses for grid enhancements that can possibly be prevented or postponed by a VPP. These costs are usually allocated to final consumers.

Evaluation: This aspect is measured positively if a specific VPP-operator can contribute to avoid grid enhancements. This is also beneficial for the concerned stakeholders that have to pay for the respective costs.

8.6.7 Others (co-)benefits

8.6.7.1 Green image

Evaluation: In general, a VPP-operator profits from a green image. But for some VPP-operators it could have a higher impact on their core-business. The other stakeholders are not really affected by this parameter.

8.6.7.2 New tariff structures / products

Evaluation: Some VPP-operators might profit more from this aspect than others. There might also be an advantage for other stakeholders if new tariff structures are implemented.

Excluded criteria are gender aspects, because they are not considered relevant for business model development.

Way forward*:* According to the project proposal, the above evaluation criteria shall be applied throughout the project in all consecutive work packages (e.g. in order to structure recommendations and other results).

The definition of concrete, real world use and business cases from DSO, retailer, aggregator, client VPP and BRP perspectives and formulation of related research questions (c.f paper Taljan 14.11.14) will be elaborated and answered in consecutive work packages.

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