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Vision of Future Energy Networks (VoFEN)

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Zusammenfassung

Das Projekt "Vision of Future Energy Networks (VoFEN)" beschäftigt sich mit dem Entwurf, der Modellierung und der Analyse zukünftiger Infrastrukturen zur Energieübertragung und -verteilung. Ursprünglich 2002 mit vier verschiedenen Themenschwerpunkten bzw. Arbeitspaketen initiiert, umfasst das Projekt momentan sechs Arbeitspakte. Bearbeitet werden Fragen hinsichtlich Risikomanagement und Investitionsstrategien für nachhaltige Energiesysteme, dezentraler Regelung in Verteilnetzen, optimalem Netzdesign als auch der Netzintegration von Plug-In Hybriden Fahrzeugen. Ziel ist es, ein umfassendes Verständnis möglicher zukünftiger Energienetze zu erarbeiten, wobei der Fokus nicht nur auf der Elektrizität liegt. Das Projekt verfolgt einen sogenannten Multi-Energieträgeransatz, d.h. die kombinierte Betrachtung von diversen leitungsgebundenen Energieträgern wie z.B. Elektrizität, Gas, Fernwärme, Kälte etc. Zentral für das Projekt sind dabei auch die zwei Fallstudien zur praktischen Verifizierung der theoretischen Ansätze in Anwendung auf die Energienetze in Baden-Dättwil und Bern. Im Jahr 2009 sind Forschungsbeiträge aus dem Projekt auf wichtigen internationalen Konferenzen präsentiert worden (z.B. 2009 IEEE Power & Energy Society General Meeting, Calgary, Canada / 2009 Powertech, Bucharest, Romania). Mitglieder des VoFEN-Projekts sind darüber hinaus auch in CIGRE Arbeitsgruppen vertreten, um die Forschungsresultate direkt in aktuelle wissenschaftliche Diskussionen einfliessen zu lassen. Das Projekt VoFEN stellt zudem eine wichtige Basis für thematisch verwandte Forschung am Institut dar, wie z.B. das von der Europäischen Union finanzierte Projekt "Infrastructure Roadmap for Energy Networks in Europe (IRENE-40)". 2010 werden drei Arbeitspakete (Dissertationen) abgeschlossen. Es ist geplant, in Zusammenarbeit mit den Hauptprojektträgern BFE, AREVA, ABB, Siemens und Swisspower weiterführende Forschungsziele zu definieren.

Abstract

Bulk electricity generation and transmission technologies often exhibit large economies of scale. Driven by these scale effects, power systems historically evolved into large, interconnected structures, where electricity is mostly produced in “centralized”' power plants with ratings ranging from several hundreds to thousands of Megawatts. On the contrary, climate change, fossil resource depletion, policy incentives as well as higher public awareness in term of sustainability have promoted the deployment of small decentralized and renewable generation technologies, typically including photovoltaics, microturbines, combined heat and power (CHP), waste and wood incineration plants etc. Nonetheless, the size of distributed generation facilities is not the only aspect influencing the currently prevailing power system structure. A number of these technologies also provide the possibility for so-called co- or tri-generation. Using e.g. CHPs or microturbines it is possible to produce electricity and heat out of natural or bio gas, biomass etc. Together with the deployment of distributed storage technologies or the prospective integration of Plug-In Hybrid Electric Vehicles (PHEVs) complex interactions between the different energy carries and systems arise. The traditional “setup” of the power system with the typical power flow from higher to lower voltage levels may be altered. Infeeds from lower voltage levels are becoming increasingly common. Additionally, new building standards promote energy efficiency benefiting from advanced information and communication technologies to “exploit”' the intensified couplings between both: production, transmission and consumption as well as the different energy carriers. Such an operational and topological flexibility calls for a generic framework to describe the effects on economic, ecological and technical indicators related to energy systems.

Since 2002 the project “Vision of Future Energy Networks” addresses the above questions. Currently, six work packages are running dedicated to research ranging from risk assessment and investment considerations, control strategies and Plug-In Hybrid Vehicle (PHEV) integration to exemplary case studies. The results within the individual work packages as well as an outlook for the year 2010 are presented in the sections below.

1. Introduction

Problem Description

Bulk electricity generation and transmission technologies often exhibit large economies of scale. Driven by these scale effects, power systems historically evolved into large, interconnected structures, where electricity is mostly produced in "centralized"' power plants with ratings ranging from several hundreds to thousands of Megawatts. On the contrary, climate change, fossil resource depletion, policy incentives as well as higher public awareness in term of sustainability have promoted the deployment of small decentralized and renewable generation technologies, typically including photovoltaics, microturbines, combined heat and power (CHP), waste and wood incineration plants etc. Nonetheless, the size of distributed generation facilities is not the only aspect influencing the currently prevailing power system structure. A number of these technologies also provide the possibility for so-called co- or tri-generation. Using e.g. CHPs or microturbines it is possible to produce electricity and heat out of natural or bio gas, biomass etc. Together with the deployment of distributed storage technologies or the prospective integration of Plug-In Hybrid Electric Vehicles (PHEVs) complex interactions between the different energy carries and systems arise. The traditional "setup" of the power system with the typical power flow from higher to lower voltage levels may be altered. Infeeds from lower voltage levels are becoming increasingly common. Additionally, new building standards promote energy efficiency benefiting from advanced information and communication technologies to "exploit"' the intensified couplings between both: production, transmission and consumption as well as the different energy carriers. Such an operational and topological flexibility calls for a generic framework to describe the effects on economic, ecological and technical indicators related to energy systems.

Since 2002 the VoFEN project aims at developing such a generic modeling and analysis framework, where the approach is in more detail outlined in the next section.

Proposed Course of Research

Since the start of the project in 2002, VoFEN was focused on a so-called Greenfield approach, targeting the question on how future transmission and distribution systems for energy should look like for the improvement of technical, economic and ecological performance. The concept of choice is to build a fictitious optimum system from scratch neglecting the current system structure and then to identify the differences between the present situation and the desirable system. Main drivers of the research work were the increasing share of decentralized and renewable generation sources as well as an integrated look on energy systems, i.e. the incorporation of a multi-energy perspective, studying the dependency of major grid-bound and non-grid-bound energy carriers, such as electricity, heat, gas, biomass etc. This integrated view on energy systems provides the opportunity to study the dependencies and synergies among different energy carriers in order to, i.e. minimize primary energy use by optimizing overall energy efficiency. It also allows developing innovative operational and control strategies for multi-carrier energy networks, as found for instance in urban areas where water, gas and electricity networks are closely linked. In that, the VoFEN project aims to identify future structures for transmission and distributions networks and to show strategies how to move from the current system setup to a hopefully more efficient and sustainable system incorporating the various needs of network participants, such as households, industrial customers, large-scale and small-scale generation and transmission and distribution system operators themselves.

In previous years the so-called "energy hub" was developed and identified as major modeling and analysis tool. An energy hub is an integrated system of units that allows the conversion, conditioning and storage of multiple energy carriers. It represents an interface between different energy infrastructures and/or loads. Energy hubs consume power at their input ports connected to e.g. electricity and natural gas infrastructures, and provide certain required energy services such as electricity, heating, cooling, compressed air, etc. at the output ports. Within the hub, energy is converted and conditioned using e.g. combined heat and power technology, transformers, power-electronic devices, compressors, heat exchangers, and other equipment. Existing facilities that can be considered as energy hubs are for example industrial plants (steel works, paper mills), big buildings (airports, hospitals, shopping malls), rural and urban districts, and island energy systems (trains, ships, aircrafts).

The energy hub is the major modeling concept of the VoFEN project, i.e. the underlying theory serves as basis for the currently running working packages described in the respective sections.

2. Objective of the Research Project

Using the energy hub approach, and thus, relying on a multi-energy carrier perspective the following objectives of the VoFEN project could be identified:

- Contributions to identifying future network topologies facilitating the grid integration of small, renewable generation facilities.
- The development of innovative control strategies for decentralized generation units (e.g. in distribution grids) as well as analyzing the prospective economic benefits of certain generation portfolios by means of risk and portfolio management tools.
- Verification of the theoretical concepts by means of case studies in close cooperation with Swiss municipalities (Baden-Dättwil and Bern)

3. Results

The following section summarizes the six currently running work packages of VoFEN.

I) RISK ASSESSMENT AND INVESTMENT STRATEGIES FOR MULTI-CARRIER ENERGY SYSTEMS (Florian Kienzle)

The first part of the work in 2009 dealt with developing a model for the design of future multi-energy portfolios including electricity. In this context a greenfield approach is applied, i.e. in a first step efficient portfolios for the supply of multiple energy carriers (e.g. electrical energy, heat, and chemical energy carriers) are calculated for a certain target year. In a second step, an optimal transition path from a portfolio given today to the desired optimal portfolio in the future is determined. The method is based on a previously developed single-period mean-variance portfolio model, which is adapted to be used for portfolios providing multiple energy carriers. Optimal transition paths are calculated applying a dynamic programming method that maximizes utility along the transition path. The proposed method is described in [1]. There, an exemplary application to a combined heat and power portfolio consisting of a set of small-scale generation technologies is described.

A second focus area in 2009 was the elaboration of a valuation method for Energy Hubs. The economic value of an Energy Hub including the value of its operational flexibility is calculated by means of a Monte Carlo simulation method that uses a large amount of simulated possible price paths for the input and output energy carriers of the respective hub configuration. An exemplary distribution of a hub value is shown in Fig. 1. The proposed Energy Hub real options model can be used to identify prospective hub configurations for future energy systems given the uncertainty concerning the future development of energy prices. The method is explained in detail in [2].

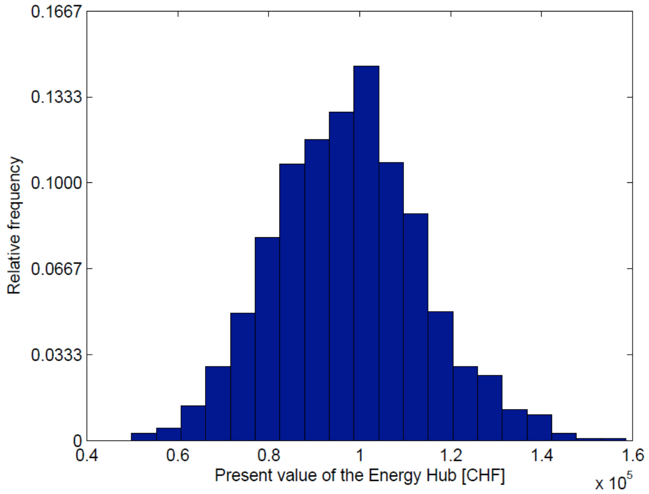

Figure 1: Distribution of the simulated present values of a basic Energy Hub configuration with CHP unit.

Evaluation of 2009

Goals:

- Development of a multi-period optimization method in order to use the multi-energy portfolio model within a greenfield approach (forecast and backcast)
- Development of an Energy Hub real option model that can be used for the determination of the economic value of a hub

Evaluation:

The first goal was achieved and is documented in [2]. Regarding the second goal a basic form of the Energy Hub real option model has been completed and described in [3]. This model will be extended with several features which are outlined in the outlook for 2010.

Outlook 2010

During 2010 the research within the WP "Risk Assessment and Investment Strategies" will focus on extending the Energy Hub real options model developed in 2009. The current model shall be improved with respect to two dimensions. First of all, the influence of the network characteristics (losses, capacity limits of lines, etc.) as well as the location of the Energy Hub shall be considered in the model. For that, the locational prices resulting from an optimal power flow calculation are used as input for the price processes in the real options valuation model. In doing so, a location-dependent value of an Energy Hub can be determined. Secondly, the possibility of valuing storage devices by means of the developed Energy Hub real option model will be evaluated. It will be analyzed if such a valuation is feasible from a conceptional as well as from a computational point of view. Finally, the models, insights and results obtained in the course of this WP will be put down on paper within a dissertation. The final presentation of the dissertation is expected to take place in the second half of 2010.

Schedule 2010 (in quarters)

I/2010: Complete the combination of the Energy Hub real options model with multi-energy network model; evaluate the feasibility of valuing storage devices by means of the existing model
II/2010: Write dissertation
III/2010: End of this WP and final presentation of dissertation

II) DISTRIBUTED CONTROL (Michèle Arnold)

Distributed generation plays an important role in today's energy infrastructure systems. Therefore, different energy systems, such as electricity, hydrogen, natural gas and local district heating systems are not anymore operated independently of each other, but investigated and optimized as combined system. Such combined systems are modeled by means of energy hubs which describe the conversion and storage of the various energy carriers [4].

For determining the optimal operation of the system an optimization problem is solved which determines the optimal operational set-points of the system, i.e. of the energy generation units, converters and storage devices. A predictive scheme (MPC: Model Predictive Control) is implemented taking into account the expected future behavior of the system. For this, future price and load forecasts are needed.

The MPC can be used in the form of a centralized, supervisory controller that can measure all variables in the network and that determines actions for all actuators [6]. Due to practical and computational issues implementing such a centralized controller may not be feasible. Individual hubs may not want to give access to their sensors and actuators to a centralized authority and even if they would allow a centralized authority to take over control of their hubs, this centralized authority could have computational problems with respect to required time when solving the resulting centralized control problem. Therefore, a distributed MPC scheme, in which the control is spread over the individual hubs is implemented. Each controller solves its own local MPC problem using the local model of its hub. However, this local MPC problem depends on the MPC problems of the other controllers, since the electricity and gas networks interconnect the hubs. Therefore, the MPC optimization problems of the controllers have to be solved in a cooperative way [5],[7]. Figure 2 shows a three-hub system with three communicating agents.

In future research, model extensions are planned in terms of incorporating network operators and more hubs. Possible system extensions may include larger electricity networks, where hubs are only attached at the border buses. Furthermore, instead of assuming perfect forecasts, the incorporation forecast errors in the scheme will be addressed. Finally, the developed matlab files will be applied to a case study, representing a realistic network. Thereby, forecasts for actual energy prices and load profiles as well as system limitations have to be incorporated.

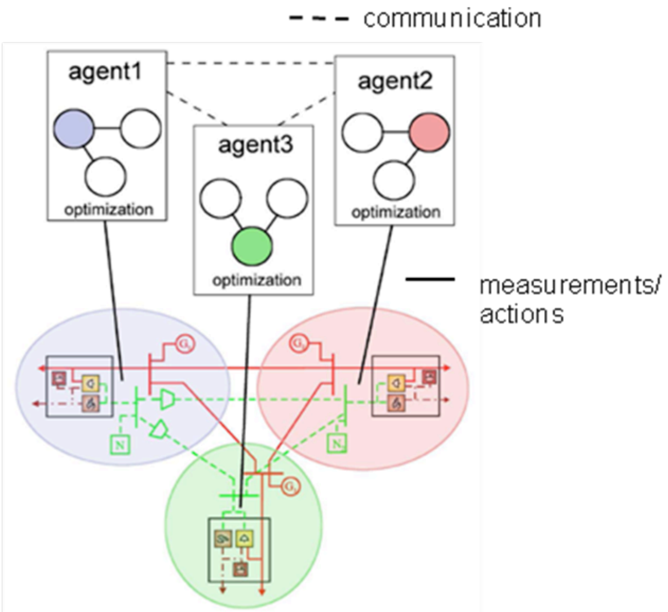

Figure 2: Three-hub system, interconnected by electricity (solid red) and natural gas (dashed green) system. Three control agents exchange information for coordination.

Evaluation 2009 and Outlook 2010

In 2009 the following research has been covered:

- Implementation of a control strategy based on Model Predictive Control, following a centralized or decentralized implementation scheme
- The model is now capable of dealing with forecast errors, control algorithms have been evaluated by means of Monte-Carlo Simulations
- Extension of the hub model with specific focus on renewable generation facilities

In 2010 the three bub system will be extended:

- Application to larger networks with a number of hubs
- Implementation of a “realistic” case study

The course of action can be summarized as follows:

Quarter	Activity	Goal	Partner
1/10	Extension to larger networks	Improve scalability of algorithms	N.N.
2/10	Case Study	Modelling and analysis of a realistic case study	N.N
3/10	Writing of PhD Thesis	First draft of the PhD by the end of September	N. N
4/10	PhD Exam		N.N.

III) INTEGRATED ANALYSIS OF POWER AND TRANSPORTATION SYSTEMS (Matthias Galus)

Recently due to the thrive for efficient and sustainable mobility, interest in Plug-In Hybrid Electric Vehicles (PHEV) increased. These vehicles, recharged from the power grid, incorporate the advantages of electric and hybrid electric vehicles while alleviating their disadvantages. Intuitively, they will significantly affect the power generation and distribution system [8]. This project will investigate the potential impacts and benefits of PHEV integration in corporation with the institute for transport planning and systems (IVT, ETH) and the laboratory for aerothermochemistry and combustion systems laboratory (LAV, ETH).

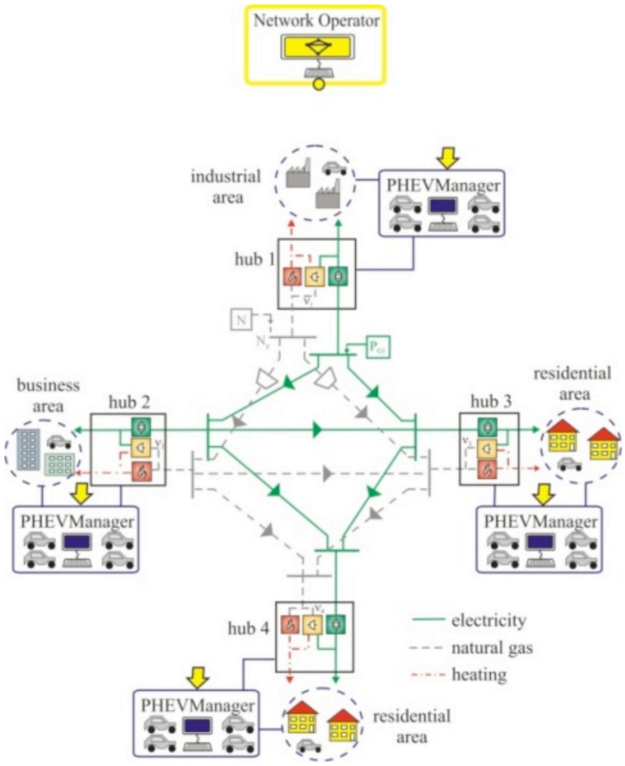

Figure 3: Multi PHEV Manager energy hub network with electricity- and gas lines. The hubs model urban areas with streets modeled in MATSim where the PHEV agents can connect.

The energy hub approach was chosen due to its palpable flexibility offering a modelling technique [4,9] for PHEVs as well as for the power system. First a simplified PHEV model is derived incorporating typical energy management schemes for PHEVs [10]. Using this model, energy levels at arrival and average consumption data for vast amounts of PHEVs can be simulated. The model was used to generate energy consumption input for an agent based transportation tool (MATSim) capable of simulating large numbers of PHEVs. The recharging vehicles are aggregated dependent on their spatial distribution through the concept of PHEVs managers. These are smart entities which can be located at nodes of the electrical grid and control the recharging behaviour dependent on different goals. The manager effectively distributes available power capacity at the respective node to connected PHEVs based on an optimization scheme. It incorporates power system constraints imposed by the converters such as maximal input or output powers, e.g. converter ratings. Much more, the scheme can take possible line overloading into account, lowering the power distributed to the PHEVs. In a first approach, a heuristic scheme was used to shed PHEV load in a multi manager multi hub network [11] depicted in Figure 3. The managers create nodal price signals to which the PHEVs react. These signals directly represent the system state (e.g. converter congestion, PHEV demand, etc.). Clearly, when the desired battery level cannot be achieved because power system constraints are violated, the PHEV agent might well change its transport behaviour. The approach of PHEV managers and MATSim should be integrated in order to account for this as reported earlier in [12]. Therefore, the hub test system was extended to feed the state information, e.g. the nodal price signals back to MATSim. The system was simulated with 16000 agents travelling on a test network representing parts of Berlin, e.g.

incorporating real streets. Numbers of streets were assigned to specific hubs, then representing urban areas. Integrating the transport knowledge of MATsim together with the PHEV Managers proved to deliver results not violating any system constraints at all [13].

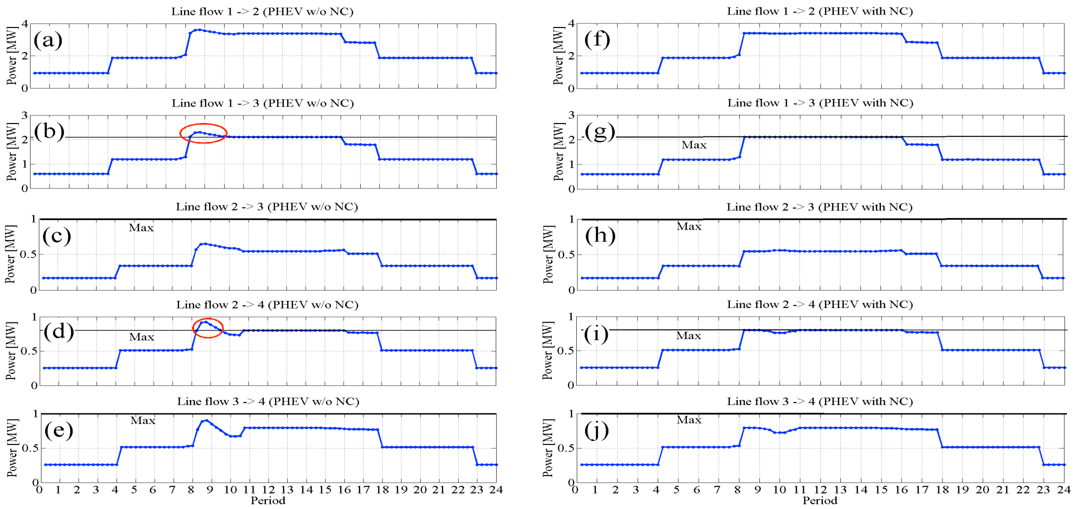

Figure. 4: (a)-(e) Electricity line loading of the multi PHEV manager energy hub network without effective management of direct recharging. Overloadings occur here. (f)-(j) Line loading with effective management via the PHEV Managers. No line overloadings occur.

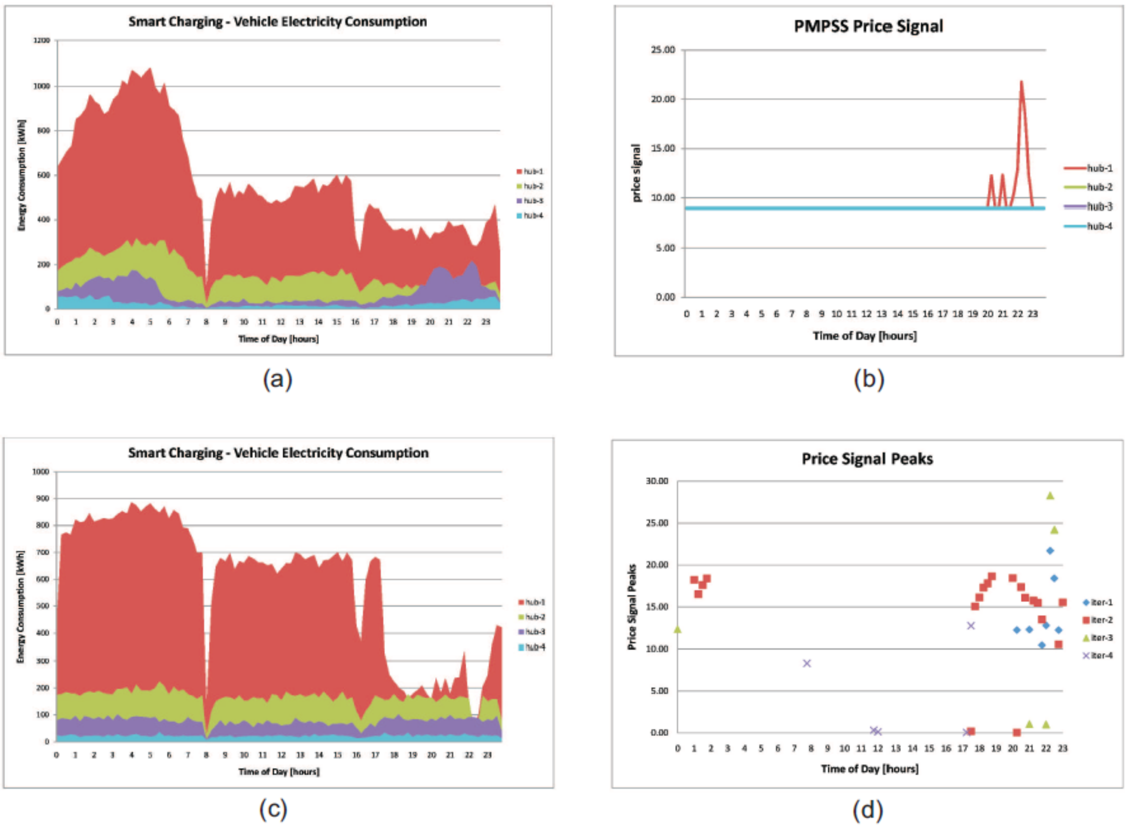

Figure. 5: Integration of PHEV Managers into the MATSim simulation. (a) visualizes MATSim agents recharging dependent on their daily travelling plans. (b) shows the power system reaction. Overloads occur at hub1. (c) shows the recharging behavior after iterating MATSim with the PHEV Managers. Price peaks occur, are lower and finally not apparent. This situation then represents an optimum for the agents and the power system.

Future work will include voltage- and line system state constraints in the PHEV-Manager scheme. Application of the scheme to dynamic pricing will be performed. Further, considerations will be given to balancing stochastic, renewable generation with PHEVs using potential vehicle to grid services. The individual transportation demands will as well be integrated in these services. Finally, case studies will be performed for the area of Zurich investigating system limitations due to increasing power demand by electrified mobility.

IV) HUB TECHNOLOGY (Franziska Adamek)

Political and ecological developments as well as technical progress influence today's energy sector and affect the grid and generation infrastructure. While the current energy supply bases on a centralized supply concept, decentralized generation will increase significantly in the next years and decades [14]. The growing share of intermittent renewable energies will change the existing technology mix and necessitates the use of energy storages [15]. Further factors like political constraints (e.g. refusal of nuclear energy use), increasing energy demand, and climate protection aims additionally require an adaptation and alteration of the power supply infrastructure.

The aim of the work package "hub technologies" is to develop a suitable, affordable and ecological technology mix, including distributed generation and storages, to ensure a safe and reliable power supply. To analyze the different effects, both regarding costs and emissions, of centralized and decentralized supply approaches, a larger geographical region like a community or a county has to be considered. Therefore, the "Multiple-Level Model" was developed [16]. It subdivides the region into its settlement units and assigns each power generation or conversion technology to one unit. The technologies of each unit are modeled as an Energy Hub [17], and then are connected with the other hubs via the grid(s). Each hub tries to supply its unit's demand with lowest costs or lowest emissions by using its own technologies and exchanging energy with the other hubs. Consequently, an energy supply strategy for the entire region results that is optimal regarding a bottom-up optimization procedure.

The Multiple-Level Model is applied to an exemplary Swiss region. The region represents a small part of Switzerland and is built according to Swiss statistics about housing, energy consumption, fuel use, available technologies, and other. The considered agglomeration consists of a main city with several residential and industrial areas, and a hinterland with several suburbs. The Multiple-Level Model covers general effects as the energy exchanged via the grid, the constant efficiencies of the conversion and storage technologies, and information about the load and the price curves. Nevertheless, to evaluate differences between different technologies and different locations within the system (e.g. several small PV plants within a residential area vs. one large PV plant on the community level), further details have to be included. First of all, the grid has to be modeled in some detail. However, as can be seen from other work packages, this implies restrictions to the number of considered energy hubs. Consequently a tradeoff between detailed grid representation and admissible model size has to be found. Furthermore, the storage model has to be adjusted to illustrate differences between various types of storages and their use (e.g. long vs. medium term storage). Both storage and grid modeling are still ongoing.

The Multiple-Level Model is optimized using Matlab. A first version of the optimization procedure is implemented and running. It allows to compare different scenarios regarding their overall emissions or costs. The simulation covers the energy demand of the region for one year, thus taking into account both diurnal and seasonal variations in load demand and renewable energy production. The optimization outcome is influenced by several simulation parameters: the initial values x_0, the optimization horizon and the number of time steps adopted to the solution vector, and the time discretization. Preliminary studies examined the effects of the choice of these parameters on the optimal result, to get a sound idea about how to choose these values in ongoing research. One result was e.g. that an increasing optimization horizon first reduces the overall costs, but then goes into saturation (figure 6). This is compliant to the consideration that the storage needs information about forthcoming events to optimally plan its operation strategy, however a very large forecast horizon only increases marginally the information content, so the costs go into saturation.

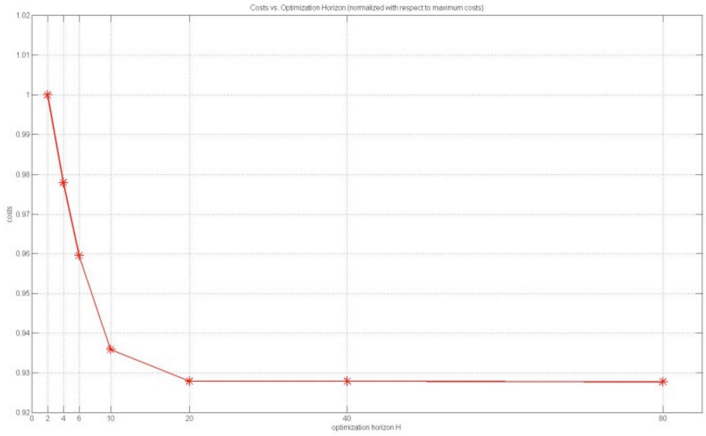

Figure 6: Overall system costs depending on the optimization horizon

The data needed to analyze the exemplary region cannot be taken from a real agglomeration. Consequently, publicly accessible data is used and adjusted to the considered system. Here, e.g. standard load profiles for households and industries, as well as available PV production curves from the southern part of Germany are applied. Information about prices and emissions are largely available in literature. To compare the overall emissions and costs of an energy supply system, life cycle costs and emissions are integrated into the model. This is especially important when contrasting renewable and conventional energy production, as most renewables do not produce emissions during operation, but they do during the construction phase (e.g. photovoltaic plants).

In addition to the work on the Multiple-Level Model, some other aspects of the energy hub, the technologies within, and its application are investigated. A focus lies on the examination and comparison of different storages and their operation strategy. Several storages (e.g. pumped hydro, CAES) are applied to support the energy supply of a large amount of customers. Their operation policies are optimized with respect to minimum emissions. The storage behavior in different scenarios (varying load, prices, etc.) then are analyzed, and the overall benefit for the system is determined. Another topic is the evaluation of CO_2 reduction actions in multiple energy systems (heat and electricity). There, different possibilities to increase the system efficiency, as well as carbon capture and storage and fuel substitution are analyzed with respect to their economic and ecologic potential. Research about these actions in electricity supply has already been carried out, but no connection to multi-energy systems has occurred so far. Finally, the autonomous energy supply of a single-family house is under examination. Different possibilities regarding the conversion and storage equipment are compared with respect to their grid independence, costs and emissions. At present a complete grid disconnection is economically not possible. Nevertheless, it will be analyzed how a grid independence could be achieved during next years.

Evaluation 2009

Objectives:

- Refinement of the Multiple-Level Model
- Refinement of the conversion and storage technology models
- Development of an exemplary Swiss region
- Data acquisition for the example region
- Development of a Matlab simulation program for the Multiple-Level Approach

Evaluation: The first and second point have been mostly achieved, but are in details still going on. The example region is defined and dimensioned, and public data is available to run the simulations. Also, the Matlab simulation tool is running and brings exploitable results. Nevertheless, the program will be adapted to the ongoing model and system refinements.

V) CASE STUDY ENERGY HUB BADEN (Matthias Schulze)

The ongoing case study has started in September 2007 and is going to end in August 2010. Dättwil, a district in the city of Baden (Switzerland), was chosen as the study object. The district contains about 3,500 inhabitants with industrial, commercial and residential area. A decomposition of the area into dependant energy hubs can be seen in Figure 7.

Figure 7: Decomposition of the investigation area into Hubs

The hubs are interconnected with a grid for natural gas, district heating and of course electricity. The heating plant of a large hospital there is the supplier for the district heating network. There are four boilers fired with either natural gas or fuel oil to produce heat and steam. This facility will be substituted within the next few years by a biomass power plant. The new plant uses wood gas from the gasification of woodchips and could produce electricity and heat via a CHP, heat via a boiler and synthetic natural gas and heat via a purification process. For each individual hub measurements for the electricity consumption were taken. The measurements took place at the transformers, about three of them supply one hub's area. From weekly data and the annual curve of the near substation synthetic load curves for seven hubs are available, showing the typical behavior of e.g. industrial sites.

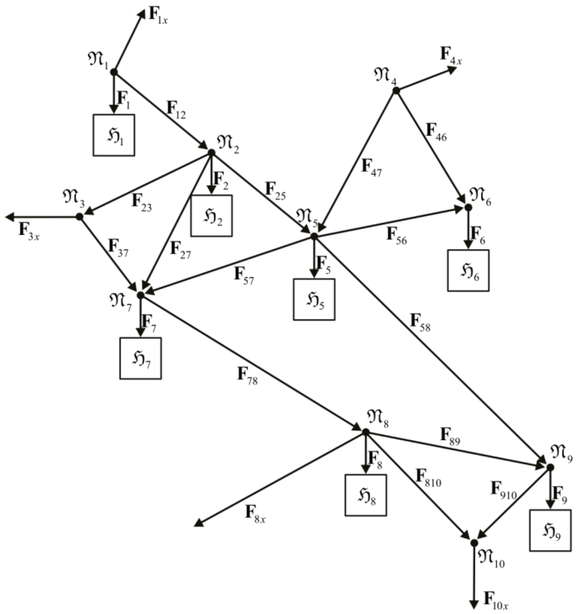

Figure 8: Configuration of Hubs and Nodes

Heat load is either feed from the district heating network, from natural gas or from fuel oil. The data of the network is already available. For the measurements of chemical feed heating probes are going to be used counting the flow rate. Because measurements can only show today's consumption scenarios are needed to provide an outlook into the Dättwil of 2060. Additionally future energy produced by distributed generation, from solar-thermal, photovoltaic or wind energy, was estimated. Both, the present data and the scenarios for future changes will allow an overall simulation of the energy infrastructure in Dättwil. The network topology used in the calculations is shown in Figure 8, where nodes and corresponding hubs represent the essence of the present grid.

Evaluation 2009

Planned activities

- Workshop with P. Ahcin, "Case Studies", organized and held.
- Software including GUI for modeling and optimization of Dättwil built.
- Additional parameters like traffic, renewable energy as well as alternative energy carriers investigated and scenarios for future conditions developed.
- Parallel optimization with Matlab.
- Measuring of two new hubs.

Achieved progress

- More hubs than expected were measured (4) , but only for electricity.
- Heat and natural gas measurements are suspended due to problems with the IT support. Same problem caused delays in parallel computing tryouts.
- From the modeling point of view the hub concept make increasingly sense – an optimization of the electrical grid without regarding the heat load and renewable energy production seems not useful.
- All additional parameters were determined except traffic, which is currently in progress.

VI) CASE STUDY BERN (Peter Ahcin)

Project Status 2008

By the end of 2008 a tool had been developed with which it was possible to model Bern's energy distribution system as a network of interconnected energy hubs. One had to assign a part of the city with its pertaining energy consumption to a hub, define the energy hub structure, that is the generation facilities that supply the area, the available energy storage capacities, installed renewable sources, determine which energy carriers are exchanged between the hubs (electricity, gas, heat, cooling or other) and run an algorithm to optimize the dispatch of the generation facilities. The result of the optimization was an estimate of the incurred operational costs and greenhouse gas emissions as well as the energy flows between the hubs and between the system and its environment.

Research Work 2009

Work in 2009 focused on the following points:

- Energy consumption data: provided by Energie Wasser Bern, these have been integrated and the missing heat consumption data statistically estimated based on water consumption, electricity consumption and year of construction of a particular building. The reliability of the estimates is however questionable. A more appropriate approach might have to be applied in 2010. Also needed are estimates of cooling requirements.
- New incineration plant: a more exact representation of the future incineration plant that is planned to start its operation in 2012 has been achieved. For this purpose an improved approach to describing a generation plant has been thought of. Making the optimization algorithms negligibly slower it allows the simulation of plants in a whole set of operating points.
- Demand response: the energy loads were previously assumed to be given. In 2009 a new feature was added to the existing tools, by which it is possible to simulate energy demand response. Its effects are similar to energy storage but it is somewhat more restricted. It can be applied for processes like space heating and cooling, refrigeration or conventionally for washing and drying.

- Transport: for the purposes of the project a tool was developed that estimates the additional quarter-hourly electrical load required by a given number of electric vehicles. Currently private transport is for the most par run on petrol. Its fuel consumption and the ensuing emissions in the city are already known. The reduction in emissions brought about by an increased share of electric vehicles can therefore be estimated immediately.
- Low energy buildings: refitting or replacing parts of the existing building stock can contribute to considerable reductions in energy demand. This feature has partly also been implemented.
- Local heating and cooling: most consumers are not connected to the district heating system but supply themselves using mostly gas or oil boilers. These consumers are now also included into the distribution system model. This allows to take account of changes in the way these consumers cover their heating and cooling requirements such as replacement of older oil boilers with new gas boilers, installations of new heat pumps or combined heat and power units. Additionally by simply adjusting a few parameters a desired share of these consumers can be switch to the district heating or the district cooling system or vice versa.
- A roadmap to a future energy distribution system: many aspects have to be studied in more detail, but the year 2009 produced a comprehensive tool that integrates almost all of the work done so far. The energy distribution system's configuration can be arbitrarily defined and investigated under different scenarios based on predefined energy price and electricity price consumption trends and a chosen year. The next step will be to organize a great amount of data that follow from these investigations and develop a procedure which generates a roadmap, that corresponds to the wishes of a decision maker, from the system as defined in 2012 to a future system in 2060.

4. Discussion and Conclusion

Currently, the VoFEN project is in its second phase, which started in 2006 and will end in 2010. Six work packages are running dedicated to research ranging from risk assessment and investment considerations, control strategies and Plug-In Hybrid Vehicle (PHEV) integration to exemplary case studies. The principal research results have been presented at major conferences, such as the Powertech 2009 in Bukarest, Romania and the IEEE Power & Energy Society General Meeting in Vancouver, Canada. As last year three project workshops were held to maintain the dialogue between practitioners and the individual researchers. In overall, the project progressed well during 2009. The targeted objectives have been met.

Major results are expected for 2010, as three work packages (risk assessment and investment strategies, distributed control and the case study Baden-Dättwil) will be concluded with a PhD thesis. The individual research objectives have been specified in the work package descriptions. To present specific work package results and document research progress, further workshops are planned for 2010.

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