

*EVS29 Symposium
Montréal, Québec, Canada, June 19-22, 2016*

Integrating EVs and renewables into the Smart Grid:

Results of the leading edge cluster electric mobility project SGI – Smart Grid Integration



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Short Abstract

In 2013 the leading edge cluster electric mobility project “Smart Grid Integration – SGI” started. The project investigates strategies for electric vehicle charging that address both user comfort and grid overload. The work is based on the Traffic Light Control (TLC, “Netzampel”) framework and aims to contribute to the design of the yellow TLC phase to maintain power system stability. A special focus is set on shortage management in distribution grids caused by decentralized, fluctuating renewable generation and local overload due to simultaneous charging of electric vehicles (EVs). Grid simulations have been applied to a meshed grid structure (representing urban areas) and a radial grid (representing rural areas). SGI addressed these challenges by developing an integrated concept for coordinated EV charging based on the TLC framework, proposing an architecture and different methods for the DSO to procure flexibility from aggregators. The three basic control mechanisms (“quota model”, “group tariffs” and “flexibility procurement”) have been integrated in the context of the Smart Grid Architecture Model (SGAM). Also the current German energy regulation is taken into account and future developments have been discussed. Finally, the most relevant use cases have been selected to be shown in a live demonstrator.

1 Statement of the problems addressed

The SGI project addresses the following problems:

- **Bottlenecks in distribution networks by simultaneous charging of EVs**

Simultaneous charging of EVs some grids may become unstable, which could lead to a blackout. In the SGI project different grid architectures were put in a simulation to find out which architectures prove to be the most resilient and which incidents could trigger local blackouts.

- **Endangering network stability by increasing supply of fluctuating renewable energies**

The effects of renewable energies on a smart grid were researched and how EVs could help increasing the network stability although using more and more renewable energies. For this several UseCases and IT concepts were developed.

- **Ensuring non-discrimination in the electricity grid**

In Germany, electricity grids must be non-discriminating, which means everybody has to be supplied with electricity regardless of his type of contract. A manufacturing company may not be preferred over private households. Combined with the characteristics of renewable energies this poses a serious challenge to the present grid architecture.

- **Reviewing the present regulatory framework and giving proposals for a reformation**

As stated above the present regulation in Germany does not reflect the new challenges posed by EVs, IoT and renewable energies. Therefore, it was part of the SGI project to develop some guidance to reform the regulatory framework so it will fit future needs.

2 Approach and Project Results

2.1 Grid Simulation

Two types of electricity grids have been researched in the SGI project. A radial distribution grid, representative for rural areas and a meshed distribution grid, representative for the urban areas. In each grid the load of the transformers etc. were simulated under various scenarios. One scenario was a probability based distribution of EVs which took social behaviour into account and a charging capacity of up to 22 kW AC.

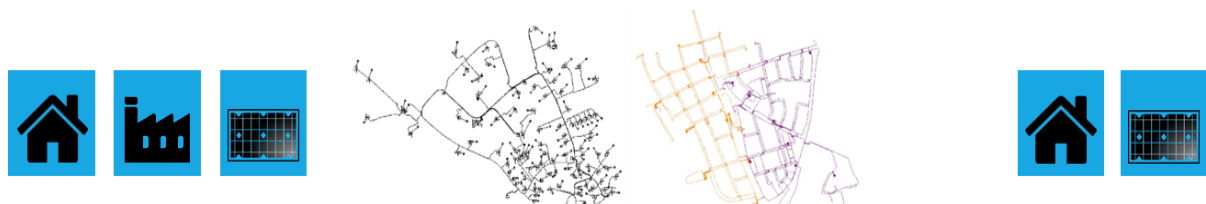


Figure 1 Rural with private homes, small businesses and PV (left) and urban with private homes and PV (right) distribution grid

The grid simulation and the stress analysis made it possible to derive requirements for the control of system load and possible ancillary services. The results are the basis of a controllable load management and show possible control parameters through which the integration of electric vehicles into the distribution networks, from the perspective of the grid operator, can be implemented and optimized.

When comparing AC, DC and inductive charging, the technology does not affect any grid disturbances. However, all technologies can be designed such that they provide additional power benefits in the form of reactive power supply. The latter is easier to implement with DC and inductive charging technologies because the (expensive and heavy) power electronics is outside the vehicle in the charging station. In addition, the service is also available, even if a vehicle is not connected to the charging infrastructure.

From the knowledge gained the requirements for information and communication technology and recommendations for future regulatory framework were derived. The provided grid data and simulation results enabled the exemplary basis for possible tariff models and control concepts for a modern load management.

2.2 Concept of a grid traffic light

To determine in which situation the market can regulate the grid stability and in which situations the grid operator has to enforce his decisions the traffic light concept (“Netzampel”) has been applied. This concept has found acceptance in the German smart grid discussion and is now used by almost all electric utilities. Several of the control mechanisms developed in SGI for integrating grid and market are discussed within the BDEW-Roadmap Smart Grid [1], in the BDEW position paper “Smart Grid traffic light concept – organization of the yellow situation” [2] and in the position paper of the VDE – ITG focus group energy information systems regarding possible future business models for grid operators [3]. The flexibility concept based on the three phases is integrated in the activities of the EU Smart Grid mandate M/490 within the working group “Methodology” [4].

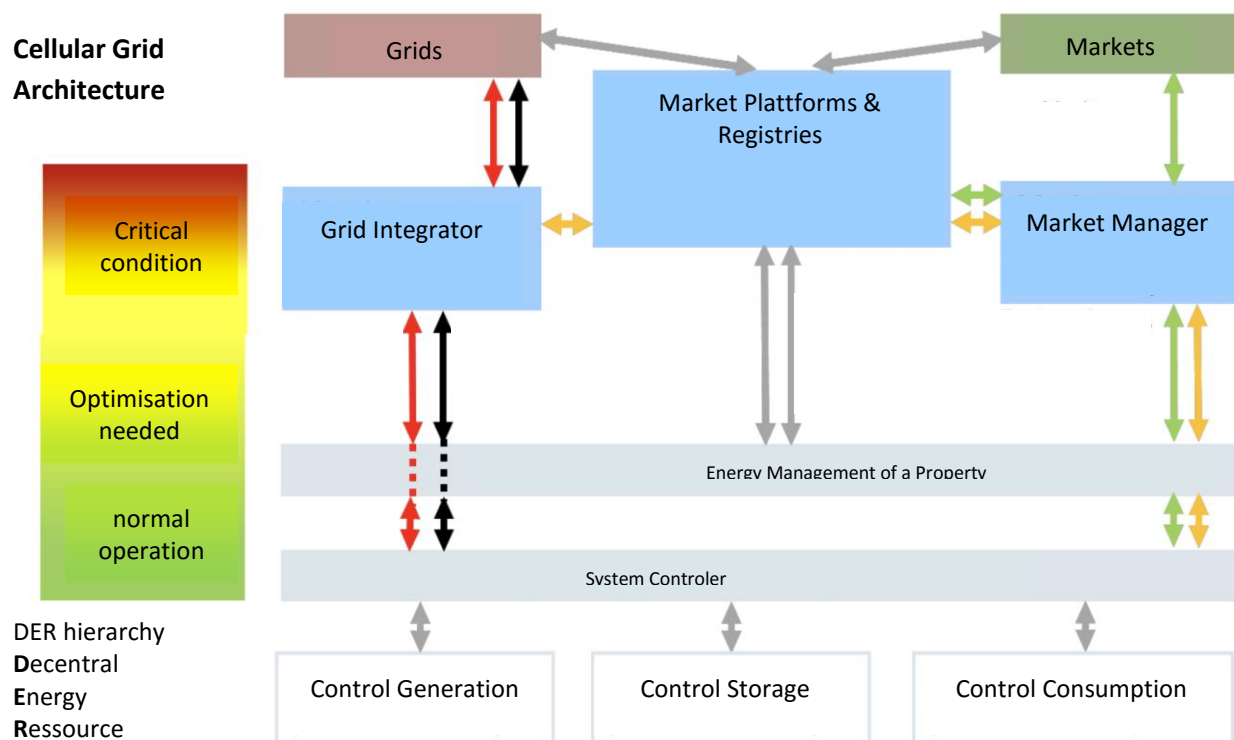


Figure 2 The traffic light concept (“Netzampel”)

2.3 Further development of the SGAM (Smart Grid Architecture Model)

To translate the concepts into an IT architecture the SGAM Model was adapted and further developed in the SGI project. For this development the Use Case methodology was used. With the development of these UseCases the concepts were translated in an IT architecture which was later implemented in a demonstrator. The development of the UseCases showed, that completely new connections on the technical and IT layers between different players in the energy market will be necessary to realise a Smart Grid in Germany, as there are several connections between prosumers, energy generation and distribution, which don't exist in the current grid architecture. This finding was particularly interesting for the development of suggestions for the regulatory framework as well as the development of new business models and billing concepts.

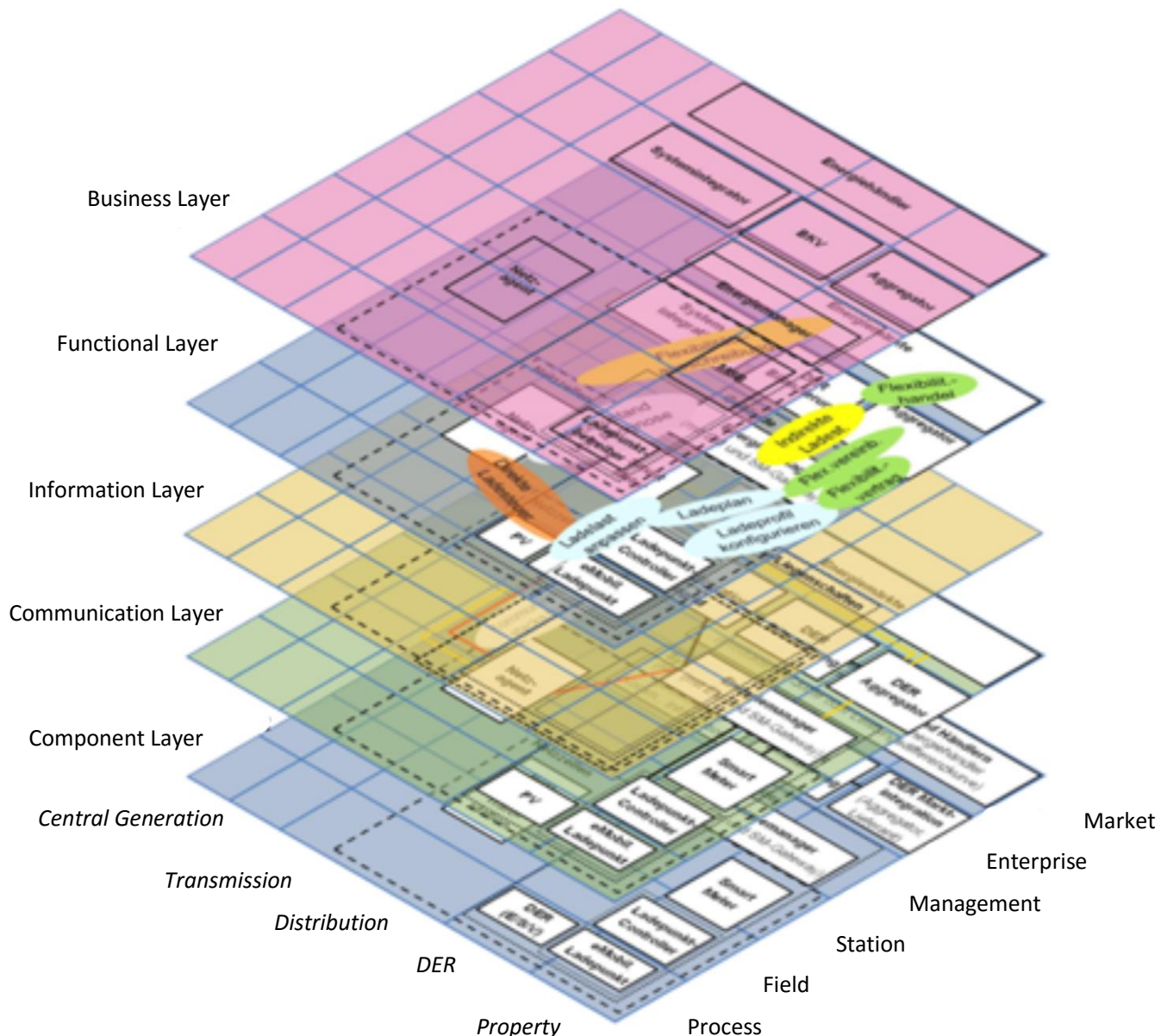


Figure 3 the SGI SGAM

2.4 Regulation and regulatory framework

The current regulatory framework in Germany does not reflect the future requirements of a smart grid with prosumers and new market roles, so a substantial part of the project was to evaluate the current regulation. Based on this evaluation and the concepts developed in the project suggestions were developed to initiate a progression of the German regulatory framework.

2.5 Charging Scenarios

As the project started it was not certain which charging scenarios would be the most fruitful ones regarding the challenge to integrate EVs in a smart grid in a grid supporting way. Therefore, several scenarios were developed and tested which led to two situations in which EVs could be used to stabilise the distribution grid.

A large scale EV roll-out will drastically influence DR potentials in residential areas. EVs have high electricity consumption, are very flexible as they are idle over 95% of a day, and have large storage capabilities. For a basic estimation of flexibility in EV charging empirical mobility data from the German Mobility Panel are applied. In this study a representative sample of about 1,000 German households continuously report their mobility behaviour during one week of the year. For every trip the mobility data set includes information about the means of transportation, distance travelled, and starting and end time in a 15-minute time resolution. Furthermore, socio-economic data, e.g., household size, gender, age and profession of the household residents is collected. For the simulation all trips made by Internal Combustion Engine vehicles are extracted to derive driving profiles and then 1,000 driving profiles from the employee group are selected.

Figure 4 depicts boxplots for the parking and charging durations at three typical locations for parking of EVs. It is assumed that EVs charge between trips to the full battery capacity using the maximum power (simple charging). The individual charge requests of EVs are expressed in hours while applying a fixed charging power of 11 kWh. Thus, enabling the comparison of charging and parking duration. One can clearly see that charging to a full battery between trips takes usually less than half an hour and can be performed at all locations. For parking long idle times can be observed at the work and especially the home location offering large flexibility potentials to schedule charging. Thus, in the project Smart Grid Integration it is assumed that charging is possible at the locations home and work.

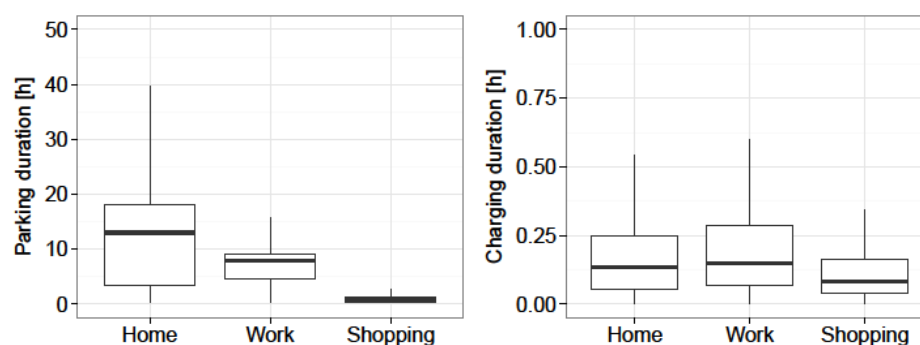


Figure 4 Parking and charging duration for different locations

2.6 Strategies for charge management

After the concepts and the IT architecture were researched, strategies for charge management were developed to realise these concepts. The results are three innovative models which allow an intelligent integration of EVs in a smart grid architecture. The most innovative model, yet the one which would need the most changes in the regulatory framework, is the one below. In this model we propose a new marketplace for demand flexibility. On this marketplace several so called aggregators can trade net capacity. To have some impact on the energy market these aggregators need enough customers willing to pool their flexibility potential. Given a large accumulated flexibility potential, they can trade with other aggregators or with the distribution grid operator to stabilise the power system. To make this possible several changes have to be made in the regulatory framework, for example the rules regarding discrimination free security of energy supply have to be changed. Furthermore new IT systems have to be implemented to realise this new trading platform. One big issue will be the security of this platforms. With the implementation of such a platform various models of load management (charging control in the EV context) will be possible, like the „Quota Model“, „Group Tariffs“ and „Flex Sale“. In the course of this paper the „Quota Model“ and the „Flex Sale“ are described.

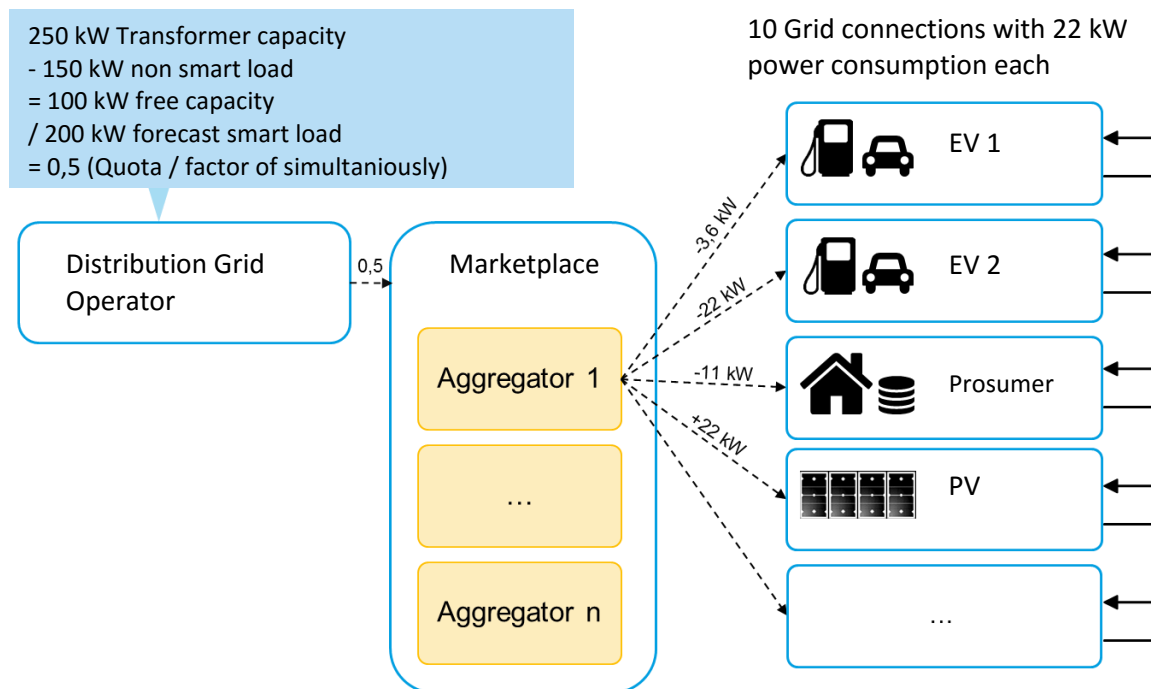


Figure 5 concept of the indirect load control via an aggregator

2.6.1 The „Quota Model“

In the first step, the aggregators (energy suppliers) will negotiate to achieve their goals of keeping the grid stable and secure the energy supply to their customers according to their tariffs and contracts which may include a flexibility potential. After the negotiation they send the scheduled energy consumption and load curve to the grid operator. The grid operator permanently monitors the grid and the load activation of the aggregators. Based on this monitoring and the forecast values, a quota of transformer capacity will be assigned to the aggregators and thus to his customers. Figure 6 shows the basic idea of the quota model.

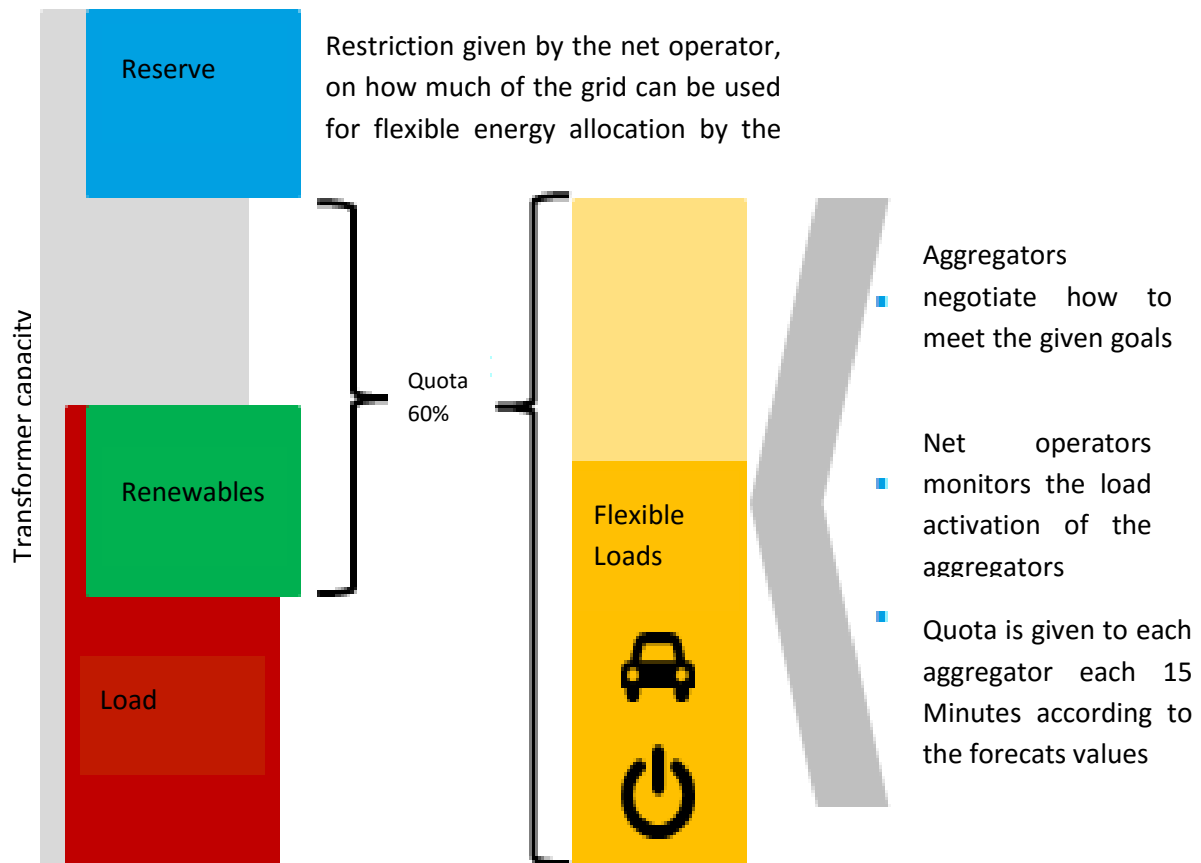


Figure 6 Quota model

2.6.2 Flexibility procurement (“FlexSale”)

“FlexSale”, a mechanism for flexibility procurement is developed based on three steps. The power system structure via nodes and edges is used to allocate flexibility demand. Nodes represent network areas (control areas, embedded distribution grids or customer premise). A network area can be a microgrid. Edges connect the nodes in the network, e.g., connections between an area or microgrid and the embedding networks. The connecting edges have power limits, which are met via load control. An edge can also be defined for the connection point of a network area and an integrated customer premise. Flexibility requests for network stability aim to reduce utilization of an edge connecting two nodes and thus a decrease of the electricity transfer (power per time unit) between the nodes. To this end, continuous grid monitoring and forecasts of upcoming events help to identify critical situations and determine the need for flexibility in one cell. Grid operators place their flexibility requests non-discriminatory at a market, where all aggregators and flexibility suppliers of the corresponding cell can participate. The step flexibility aggregation comprises two functions. On the one hand, it allows aggregators to inform the grid operator about their available flexibilities. In situations where flexibility demand exceeds flexibility supply, the grid operator assigns allocations non-discriminatory. On the other hand, aggregators can trade flexibilities among each other. In order to facilitate clearing of flexibility, aggregation market players form balancing groups to separate the process from existing balancing groups of suppliers. Furthermore, these additional balancing groups allow compensating suppliers for changes in their schedule due to the provisioning of flexibility. In the step flexibility provisioning, customer premises offer flexibilities of consumption or generation components available at integrated facilities (e.g., EV charger) to aggregators or the market. Electric vehicles estimate the available flexibility and create a new charging schedule considering (monetary) incentives and technical parameters of the electric vehicle and the charging infrastructure while considering mobility requirements of the driver at the same time. Finally, the customer premise or the electric vehicle confirms the available flexibilities. As flexibility provided by an aggregator affects also traditional balancing groups, it is required to investigate adapted balancing group clearing and settlement mechanisms for used flexibility [5].

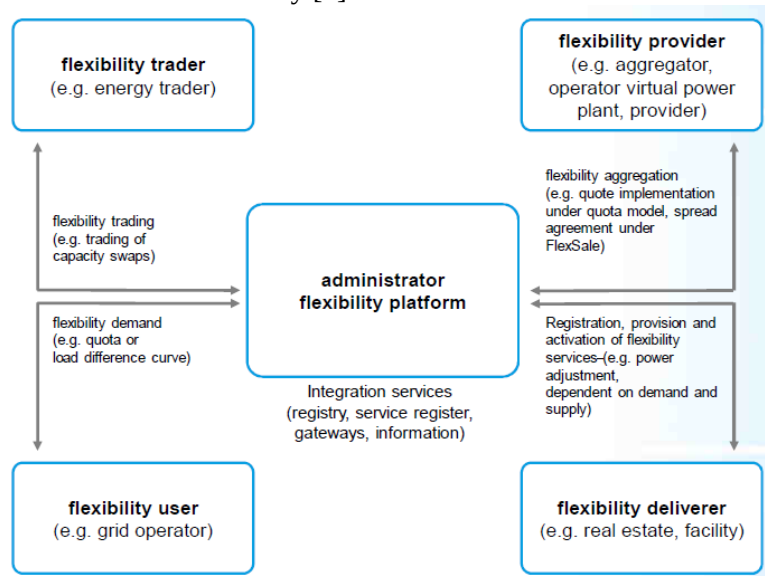


Figure 7 Flexibility procurement (“FlexSale”)

2.7 Demonstration show case

The most relevant use cases identified in SGI have been realized in a demonstration show case. It will be finished until end of March 2016 and integrate all of the above-mentioned concepts into an IT solution. The focus of this demonstrator will be the monitoring and controlling of electric vehicles in a property grid. In the property of the project partner MVV it will be shown how a fleet of electric vehicles can be managed without adding constraints to the property grid and ensure this way that all remaining electricity consumers of the property (e.g., climate control and elevators) can be operated. The basic architecture of the demonstrator is shown in Figure 8.

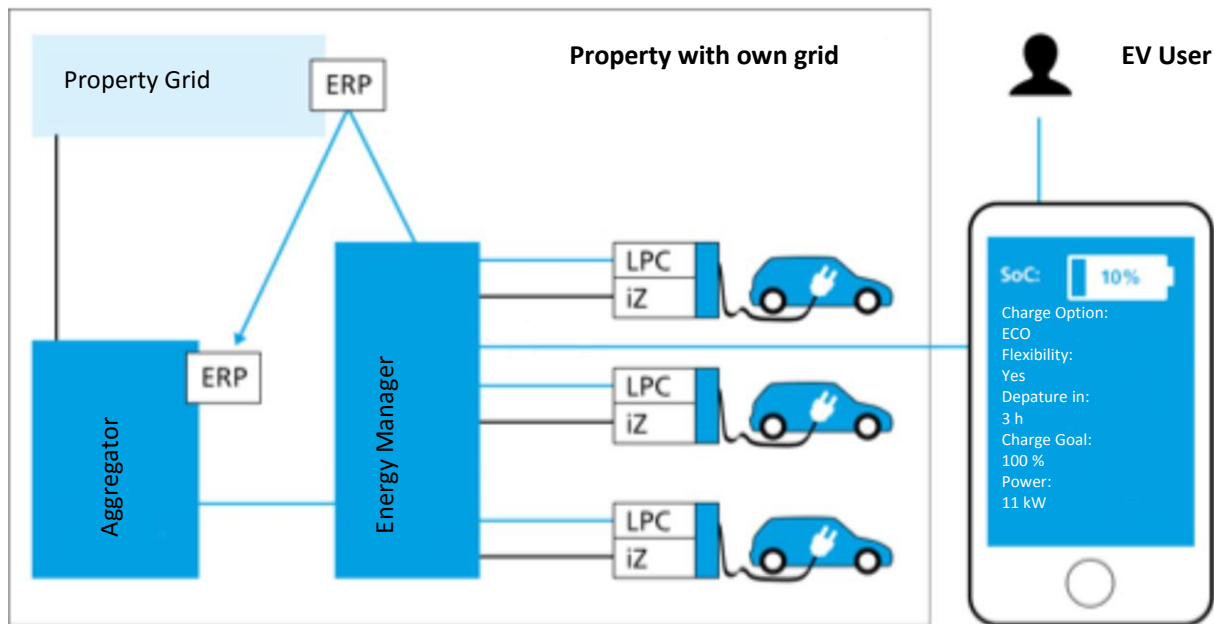


Figure 8 Demonstration show case

3 Acknowledgement

This work has been partially funded by the German Federal Ministry of Education and Research (BMBF) under grant number 16N12366-16N12369. Project partners in SGI are BridgingIT GmbH, EnBW Energie Baden-Württemberg AG, Energy4U GmbH, FZI Forschungszentrum Informatik and MVV Energie AG.

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Authors



Sven Lierzer was born on June 2nd 1982. Following his studies of political science and sociology at the University of Tübingen, he started to work at BridgingIT GmbH.

In the last five years he has been engaged in issues of several industries mainly utilities. He worked on innovations such as Smart Grids, new mobility concepts e.g. electric mobility and smart cities, both on national and international level. At this, Sven Lierzer advises large companies and corporations as well as governmental organizations on aligning their strategy.

Sven Lierzer is a member of several expert circles including:

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- *Expert at the parallel research into effectivity within the German federal program "Electric mobility Showcase"*
- *and author/co-author of various publications plus expert in various special topics as:*
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 - *Electric Mobility E-Roaming, Smart Charging and Smart Grid*

Within the scope of innovation and business development Sven Lierzer is engaged with the current trend topic of Digitization – from Big Data, Industry 4.0 and demographic change through to issues of the whole transformation of industries.



Sebastian Gottwalt is a senior researcher at the FZI Research Center for Information Technology in Karlsruhe, Germany. He received the Diploma in Business Engineering and the Ph.D degree in Applied Computer Science from the Karlsruhe Institute of Technology, Germany, in 2010 and 2015, respectively.

His current research includes the use of information and communication technology to improve the efficiency of power system operation. One recent focus is on the characterization of load flexibility and novel coordination mechanisms for small, distributed loads.



Andreas Kiessling was born in 1959.

He studied physics with specialization in nuclear engineering and nuclear power engineering.

Between 2008 and 2013 he took part in the German E-Energy program within the project Model City Mannheim as scientific-technical project leader.

Since 2013 Andreas Kiessling has been working as management consultant with the focus on system architecture for the introduction of information and communication technology for decentralized renewable energy systems.

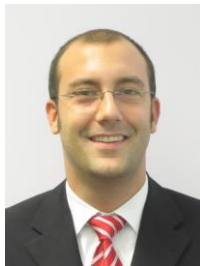
He is member of the German Standardization System Committee Smart Energy and of the Smart Grids Platform Baden-Wuerttemberg.



Christian Schäfer was born in 1980 in Limburg/Germany. During his studies of energy and environmental management at Europa-Universität Flensburg, he got a thorough understanding of the renewable and energy efficiency technologies that have transformed the German energy system only ten years later.

Christian started his professional career at MVV Energie, Mannheim, at corporate strategy department. In the last eight years he has been responsible for innovation projects and business development in various technologies, e.g. electric mobility, smart metering, energy management systems, geothermal projects.

Since 2015 he is project coordinator in Smart Grid Integration project. He is responsible for the corporate e-mobility activities at MVV Energie Group.



Daniel Zimmermann studied international business information technology at the University of Cooperative Education in Mannheim and the Anglia Polytechnic University in Cambridge. He works for EnBW Energie Baden-Württemberg AG in Karlsruhe in the business development division for electric mobility focusing on nationwide roaming solutions for public charging and on smart charging for fleets and private customers at home.