Opportunities of Big Data Tools in Smart Energy Systems

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Abstract. The implementation of an energy supply system based on dispersed, small and volatile electricity sources with limited annual operational availability requires a smart structure and a smart operation. The necessity increases when also efficient but powerful and highly volatile applications like electrical vehicles and heat pumps are integrated. A smart energy system consists of the main components smart market and smart grids. Smart markets intend to balance generation and demand with respect to time, while smart grids are focusing on the optimized use of the grid infrastructure by employing the existing non-linear grid utilization through active capacity management. Smart grids are managing the location aspect. Important technical devices with respect to smart energy systems are the so-called power-to-X (P2G) technologies. They are coupling electricity with other forms of energy, like gas, heat, cold or mobility and thus allow, to cope with a temporary overproduction or the lack of generation.

A smart energy system has a filigree and complex structure, which needs active control and coordination. Therefore, static and dynamic data are required. Energy and digitation are merging in this respect. Instruments like big data tools or neuronal networks become important and allow the implementation of new options like predictive maintenance, generation and load forecast as well as failure identification and evaluation of asset condition. Finally, the data can be used in order to identify options for the increase of energy efficiency in the building stock or the public infrastructure.

Keywords: "Energiewende", system transformation, digitalization, renewables, demand side management, smart grid, smart market, big data, neuronal networks, predictive maintenance, asset condition, failure identification, virtual power plants, cellular systems

1 Introduction

Smart energy systems are the answer to the challenges caused by an electricity generation portfolio based on decentralized and highly volatile electricity sources with a limited annual operational time. The German energy policy defined an electrical target system with a strong 80 % generation pillar based on renewable energy sources. It shall be established by 2050. By implementing this strategy, capital costs are replacing fuel costs.

Renewable energy sources in Germany mean above all on-shore wind and photovoltaic. The annual utilization time of the installed power is in the order of 2,500 h, 900 h, respectively. This implies to overbuild the maximum power demand by roughly a factor 5 on the generation side but also to work on demand side management, short-term and long-term electricity storage options. **Fig. 1** gives an overview which is based on an annual electricity demand of about 600 TWh. The existing diversity in the German renewables portfolio effectuates that a maximum of 50 % of the installed capacity is generating at the same time [1]. This means from a technical point of view the controlling of about 200 GW of volatile and dispersed power. In this context, next to batteries and pumped hydro storages, the coupling of electricity with heat, mobility and gas – with the so-called power-to-X technologies – play a pivotal role for a feasible and economic solution.

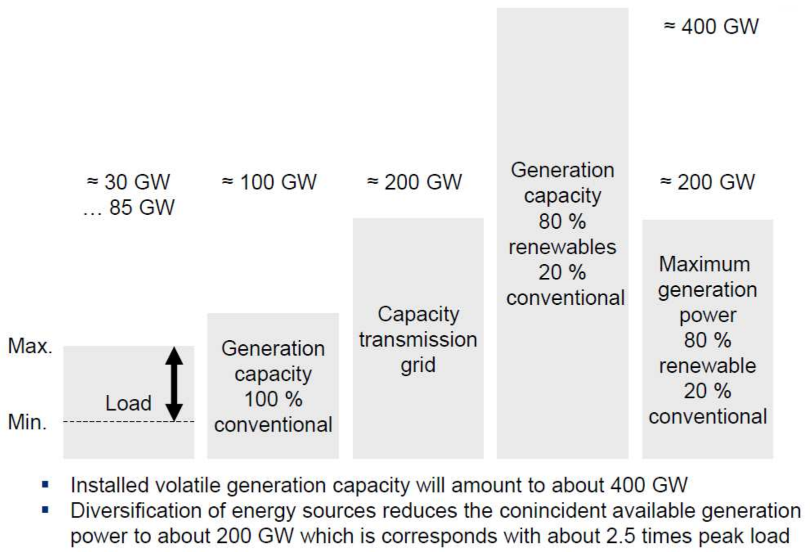

Fig. 1: Generation capacity required to achieve the 80 % renewable energy source target with respect to an annual electricity demand of about 600 TWh

Energy systems of the future will be decarbonized, decentral and digitized. They will have a cellular structure and thus are able to take the specific local situation with respect to generation, consumption, power-to-X technologies and storage into consideration.

Concerning generated energy, more than 95 % of the decentralized energy sources are feeding into the distribution grid. The specific volatility in the future German generation portfolio will lead to the situation that 50 % of the distribution grid capacity will be able to transport about 95 % of the energy. The second 50 % of the grid capacity will be occupied by the remaining 5 % of the energy. This pronounced non-linearity is addressed by smart grids which are able to make more use of the installed grid capacity [2, 3].

Energy efficiency and reduction of greenhouse gas emissions will trigger a transfer of today's fossil fuel based applications to electrical solutions. Examples are electrical vehicles and heat pumps. Due to this, it can be estimated that the electricity demand in Germany will increase by about 50 % and amount to about 900 TWh to 1,000 TWh [4]. Similar to the renewable energy sources, the challenge is on the power side. E.g., 1 % of the cars in Germany – 400,000 out of more than 40 million cars – charged simultaneously with 20 kW – which means about 80 km range extension within 30 min – require a power of 8 GW. This corresponds with 10 % of Germany's current peak power demand.

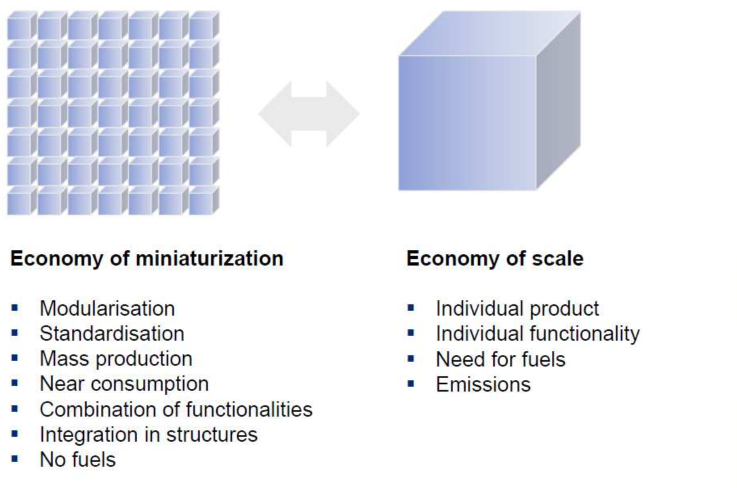

Fig. 2: Traditional economy of scale versus new economy of miniaturization

Finally, a new economic logic is occurring. The so-called economy of scale, which defined the economics of the big central power plants for many years, is released by a new economy of miniaturization. Dispersed, small size, standardized, fuel cost free, mass produced, close to customer installed and potentially building integrated generation units are allowing an improved cost structure. This type of generation will displace the incumbent power plants according to **Fig. 2**. The consequence is the necessity to coordinate swarm structures in order to achieve a stable and robust energy system.

As a result, smart energy systems have the task to safeguard the power balance in a highly volatile, power centred, filigree structure. They have to guarantee quality and reliability of supply as well as safety for workforce. They have to make optimum use of the grid infrastructure in order to minimize the capital employed and thus the system costs. Another task is to achieve operational excellence by using workforce management and predictive maintenance tools. This contributes to lower system costs as well. A last issue is the forecast of power demand and power generation which allows to take pre-emptive measures in order to avoid congestions or restrictions for customers. Finally, a smart energy system also offers new services and options to the customers.

There are two basic components which are building the smart energy system. The smart grid is focussing on transporting energy to the right place by the optimum use, management and operation of the infrastructure. The smart market is focussing on having energy available at the right time by balancing generation, demand and storage.

2 Digitation of the energy sector

The digitation of the energy sector is an indispensable prerequisite in order to establish a smart energy system. The system has to be described by a set of static data – e.g. from the geographical information system – and dynamic data – e.g. from electrical sensors in the operational units. In general, data include technical but also non-technical aspects. It is crucial that data sets are consistent and complete.

As a first instrument, big data tools identify patterns within a set of data. These patterns allow to deduct correlations and interactions without knowing the exact causality. This opens total new options for system design and operation. Bigger data volumes increase the reliability of the results. There are four dimensions of big data: volume, velocity, variety and veracity. A second instrument are neuronal networks. They are self-learning structures which are able to forecast multi-causal developments. **Fig. 3** is showing the principles [5].

In general, dynamic data provide more timely and more detailed information on the process. This allows to improve operational process as well as infrastructure. Process optimization can be attained through a better workflow and the establishment of workforce management systems. The improved use of – existing – infrastructure is achieved through the reduction of so far unused capacities, the better information about asset condition as well as the better coordination and prioritization of available options.

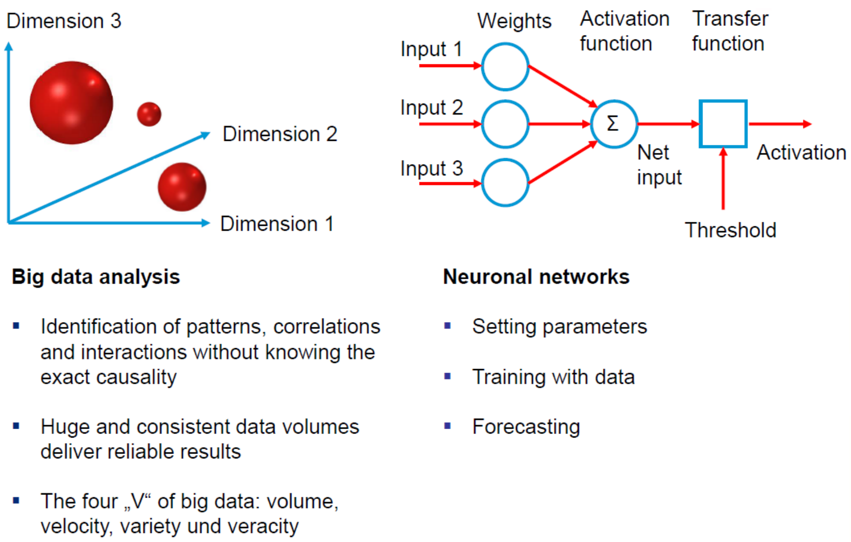

Fig. 3: Big data tools and neuronal networks

In the following chapters, specific opportunities for the use of static as well as dynamic data with respect to smart markets and smart grids are described. Some of them are already in the demonstration phase while others still need some research and development. In detail discussed topics are dealing with virtual power plants, new types of balancing groups, new options of infrastructure analysis, smart grid systems, grid failure identification and detection, asset condition monitoring, congestion forecast and support of power frequency control. Some remarks on new data sources and the use of data for improvement of energy efficiency as well as for predictive maintenance are completing this paper.

3 Big data and smart markets

Smart markets are balancing generation and demand by setting a price for every 15 min time-period through cascaded adjustments between offer and demand. The closest price setting is done by the intra-day trading schema 30 min before delivery. The price signal sent to the market has an influence on generators and consumers and thus is stimulating them to use their flexibility in a system supportive way. Within the 30 min delay time the automated power frequency control is guaranteeing the system stability. The corresponding technical services are acquired by the transmission system operators in charge though auctions. There are markets for minute reserve, secondary and primary reserves. Minute and secondary reserves are distinguishing between positive (power increase) and negative (power decrease) products. Primary reserve includes positive and negative power.

Virtual power plants

Virtual power plant structures allow the synchronized operation of a portfolio of controllable and non-controllable power plants within one frequency control zone. Also storages and power-to-X devices can be integrated in the virtual structure. Owners of the devices can be utilities but also industry and private persons. On-line generation, storage data and available operational flexibility are made available to a control unit. Advanced systems are able to deduct an optimized sales strategy for the generated energy. The different options of the energy only market but also opportunities of power frequency control are taken into consideration. The systems are applying machine-learning algorithms. They are using neuronal networks as well as big data analysis tools. There are the first projects working on a price forecast with respect to the power exchange. **Fig. 4** shows the basic structure.

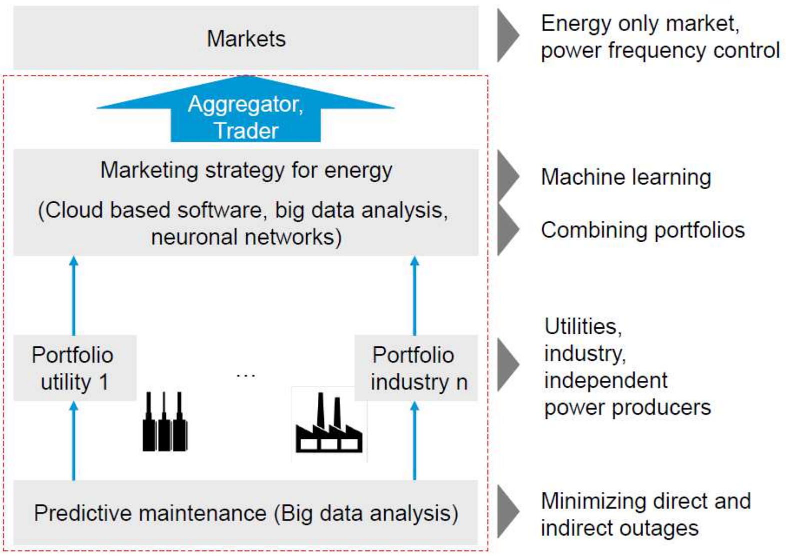

Fig. 4: Virtual power plants

Virtual power plants are able to qualify for primary control. This means the instantaneous and guaranteed availability of a certain value of additional or reduced generation power. The process has to be guaranteed for several cycles. This requirement means an advantage for virtual power plants compared to batteries. Batteries are able to react fast, however, they have a limited capacity. Therefore, they need a back-up –

e.g. a power plant – in case that several cycles of primary reserve request occur successively. This reserve implies costs.

Virtual balancing groups

An increasing number of people is operating a photovoltaic panel on the roof there houses. The low costs of the produced electricity supports the own consumption of the produced energy. As a rule, the photovoltaic panel has the dimension to make the home autonomous from an energy point of view. However, without further measures only about 30 % of the domestic electricity consumption can be compensated by the proprietary photovoltaic panel. 70 % of the generated energy has to be injected into the grid and compensated financially by the distribution system operator according to the rules of the renewable energy act (Erneuerbare Energien Gesetz [6]). As a consequence, the inhabitant has to buy 70 % of the consumed electricity by an electricity sales company. Adding a properly dimensioned battery to the photovoltaic panel the self-sufficiency of the house increases to about 60 %. This means that 40 % of the generated energy doesn't fit into the time schedule and has to be sold to the distribution system operator and delivered at a different time through an electricity supplier. It is interesting to note, that the percentage of self-sufficiency can be increased to about 80 % or 85 % when multi-family-houses are considered. Their consumption patterns are divers and thus they are stabilizing the energy demand and improving the fit with the generation of the photovoltaic panel and the battery.

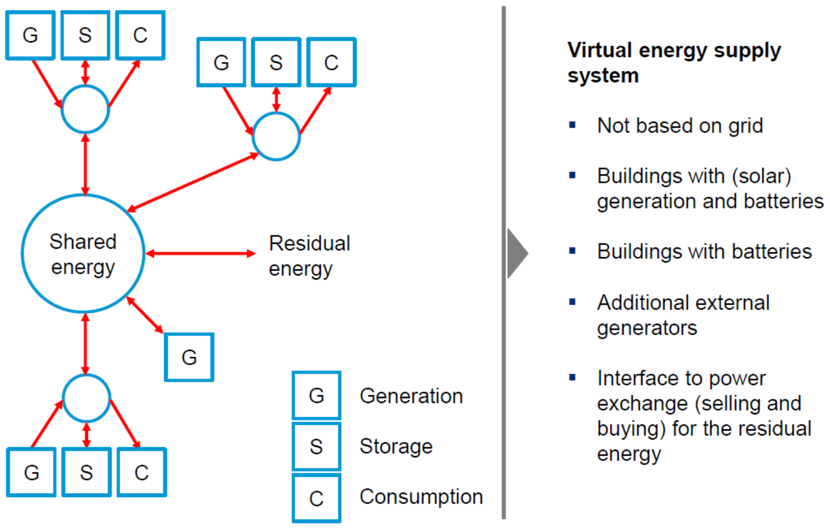

Fig. 5: Virtual balancing groups

A virtual balancing group combines various renewable generation sources – above all photovoltaics – with batteries and customer demand within one specific frequency control zone. **Fig. 5** shows the basic structure. The operator of the balancing group makes sure that a surplus generation is sold to the market and a lack of generation is compensated by the procurement of renewable energies. With respect to marketing, frequently a virtual balancing group is called energy community. With a balanced portfolio of photovoltaic panels, batteries and customers the percentage of self-sufficiency can reach up to 80 %. It is important that a battery can be operated independently from the solar panel. This means that battery and solar panel have individual converters. Also customers without solar panel can own and operate a battery. From a customer's perspective there are real and virtual batteries. Virtual batteries are built by the energy community. The participation in a community means to pay a flat rate per month for the right to store energy in the community – the virtual battery – and to get it back at due time. The flat rate has compensate the handling of the energy, the spread built by taxes, levies and fees between feeding energy into the grid – no taxes, levies, fees have to be paid – and taking energy off the grid at the same place at a different time – taxes, levies, fees have to be paid.

In order to establish virtual balancing groups, data collection, data management, recognition of patterns, forecast of generation as well as forecast of demand are key. The combination with the features described under virtual power plants is possible. In case the data exchange is managed in a fast and reliable way, a virtual balancing group can contribute to the power frequency control and thus generate additional revenues. The performance has to be proven in a qualification process. For the predictable future it is a promising option to organize virtual balancing groups through block chain technologies [7].

Demand side management in industrial sites

Identification of flexibility in industrial production processes is becoming an important tool in order to manage the volatility of renewable energy sources in the electrical grid. It is evident that demand side management in industrial sites must not have a negative impact on quality and efficiency of the production process. Generation of process heat through combined power and heat (CHP) or power-to-heat (P2H) devices are playing an important role. Heat systems have a high thermal inertia and thus allow flexibility in a certain range. Also the operation of heavy mechanical machines like presses have to be considered.

In order to establish a demand side management process in industrial sites, the electricity demand of the industrial process has to be measured by existing or additional sensors. Options are specific current and voltage sensors, smart metes or the control devices. This means the handling of big volumes of dynamic data. A consistent set of data is a prerequisite for the further steps. In addition, a numeric model that allows the simulation of the process and the identification of the flexibility options has to be set up. The use of neuronal network algorithms allows the forecast of the energy demand of the industrial site. Combining this with the simulation tool identifies the flexibility options in the overall power demand. The subsequent question is how to make maximum advantage out of the flexibility. There are several options. E.g., it can be used to minimize grid fees, to optimize electricity procurement, to contribute to the frequency power control or to participate in the re-dispatching schema. In future, the flexibility can also be used to support smart distribution grids.

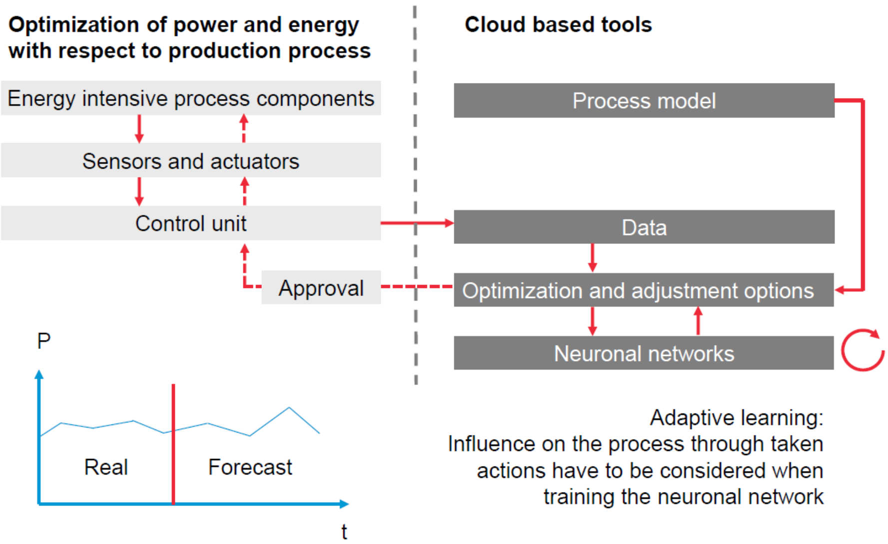

Fig. 6: Demand side management in industrial sites

Regarding today's legal and regulatory framework, the minimization of the grid capacity price (€/MWh) is the most appropriate target for the use of flexibility. It is also possible to operate with overlaying control loops. The inner loop minimizes the grid capacity price and the outer loop is using the remaining flexibility for another purpose, e.g. optimizing the energy procurement. It is obvious that there will be more options to use flexibility in a profitable way in the future.

It is important that the power forecast algorithm is using adaptive learning tools. The forecast will trigger counter measures and process adjustments in order to reach to optimization target. When training the neuronal network, the impact of the counter measures on the electricity demand has to be eliminated. Otherwise the neuronal network will not predict this kind of effect in the future any more.

Additional side effects of such tools are increased transparency, identification of failures, new understanding of the production process and optimization of the process when big data tools are used to identify patterns in the collected data. The basic functionality is shown in **Fig. 6**.

Smart home applications

The targets of smart home applications include the increase of energy efficiency and the minimization of energy costs for the customers. As a rule, smart home applications are combined with smart meters and smart meter gateways. This allows a timely, secure and bidirectional communication with the energy supplier. As a consequence, the costumer has the option to react on price signals in an automated way.

Smart home applications consist of sensors in the various domestic appliances, like electrical dryer, washing machine, heat pump, battery, solar panel or in future electrical vehicle charger. A control device is collecting all these data, calculating the available flexibility and using it in order to minimize the energy costs. This requests an in-house communication that can be based on in-house power line carrier technologies, wireless LAN or an independent remote control. Important elements of a smart home are electrical heating systems or batteries – stand alone or in electrical vehicles – which offer significant flexibility options. With respect to conventional heating systems, e.g. gas heating, smart home tools can contribute to energy efficiency. They can optimize the temperature profile in the various rooms depending on the inhabitants' habits and they can reduce the room temperature when a window is opened. Smart home solutions can not only increase energy efficiency and transparency, they also can contribute to the security of the home through webcams and alarm devices. They allow remote access to the control unit through the internet. They can assist elderly people living alone by supervising their movements and giving advice concerning medication. Also the increase of convenience is an issue of smart some solutions. This includes audio systems as well as light effects in combination with LED technologies.

Smart home devices are multi-purpose tools that go far beyond the energy sector. Even when flexibility is only one issue amongst others it can be used to optimize self-sufficiency and thus minimize the cost of energy procurement with an integrated contract. This option is important when the home has a solar panel and a battery. The principle of overlaying control loops can be applied as well. The flexibility that is not use for the optimization of self-sufficiency can support external issues like balancing groups, frequency power control or smart grids. It is interesting to note that during winter a solar panel is producing only very little electricity. The battery therefore is available to support other purposes.

It is interesting to note that there are the first tools available that are connected to the busbar of a house and that are able to identify the operation of devices in the home through analysis of the shape of the current but also of harmonics and flicker. This feature is still subject to research and development, however, it opens new perspectives.

Customer relationship management

The combination of confidential customer data – e.g. from the utility – and public available data allows to identify the intensions of customers with a certain probability. E.g., big data tools can give advice on the probability whether a customer is prepared to switch the supplier or to install a battery in his home.

4 Big Data and Smart grids

The establishment of an energy system that is based on renewables, reduces fuel costs but needs huge investments in infrastructure. Therefore, the econimics improves when the increase of infrastructure is limited. This is the approach of smart grids. The use of electrical infrastructure shows a significant non-linearity. 95 % of the transported energy need about 50 % of the installed capacity while the remaining 5 % occupy the other 50 % of the capacity. Hence, when 5 % of the energy can be influenced, the transported energy within one grid can be nearly doubled in an ideal case. The impact on the energy flow can be created by price signals or by mandatory physical actions.

Smart grid systems

Today, as a rule, low and medium voltage grids do not offer on-line data of the load flow. As long as there has been a top down energy load flow in the grid with a low volatility this information has not been necessarily needed for an optimized grid design and operation. However, the pronounced volatility that is brought through the renewable energy sources into the distribution grids and that will even be increased through technologies on the demand sides like electrical vehicles or heat pumps is changing this. Therefore, smart grids equip low and medium voltage grids at specific points with sensors for measuring current and voltage. Due to the non-symmetrical load, in low voltage system sensors are installed in the three phases and in the grounded wire while in medium voltage systems one sensor in on phase is sufficient. Sensors deliver data on-line and with respect to the public cables and lines. Smart meters deliver customer and not grid related data. With respect to the grid they are incremental and not integral. Furthermore, they aggregate their data to 15-min-values. The data owner is the customer and the data are subject to data privacy. Therefore, access of third parties is very limited.

Analysis that have been carried out show that it is sufficient to equip a maximum of 10 % of the nodes in the grid with sensors in order to calculate all the voltages and all the currents with a sufficient accuracy of ± 10 %. The dynamic data of the sensors are transported via power line carrier technologies, glass fibre cables or mobile internet to an analysis and control box that is positioned in the MV/LV transformer station in case of a LV grid and in the HV/MV substation in case of a medium voltage grid. The control box contains the state estimation algorithm. It works with a set of static data describing the grid topology and the on-line dynamic data. The control box performs a grid analysis every few seconds. In case of the detection of an infringement of the acceptable voltage band at a node or the maximum current in a line the control box is able to trigger measures. It can address grid related actuators like adjustable MV/LV transformers or voltage controllers in lines but also customer related actuators. These can influence the reactive power or the active power of the customer. The smart home controller can be used as an actuator of the smart grid. **Fig. 7** shows the basic design. Customer related actions have to be minimum invasive. Furthermore, grid related actions are performed first and customer related actions second.

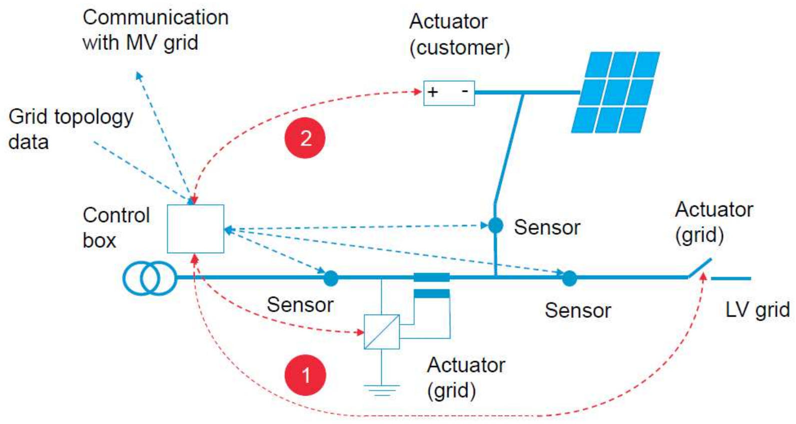

Fig. 7: Smart grid structure

A low voltage smart grid with a smart grid control box in the MV/LV transformer station can operate as a sensor and actuator for the superimposed medium voltage grid. The control box has the on-line information on the aggregated power in the assigned low voltage grid. Furthermore, the control box can react on power adjustment demands of the medium voltage control box.

Data management is key for smart grids. There is a huge amount of dynamic data to be handled but also the static data have to be updated on a regular base in an automated way in the smart grid control box. A geographical information system and an asset database are prerequisites for this. Finally, a smart grid needs new design and operation rules.

Cellular structures

The electricity system of the future will have a cellular structure. This allows to react on the rather different local situations and to control the pronounced volatility in an economic way. Applying the principle of subsidiarity, each cell has to be self-sufficient to a reasonable extent. According to the principle of Pareto, 20 % of the expenditure leads to 80 % of the benefits. Self-sufficiency is power related and not limited to the annual energy balance. Overproduction or additional demand of a cell has to be exchanged with the superimposed cell. This power exchange should be as limited as possible. According to **Fig. 8** the existing voltage levels are supporting the cellular structure. The hierarchy of this structure is established by buildings, villages, quarters or industrial sites, cities, regions and countries. Finally Europe is building the top cell. Every cell contributes to the stabilization of the power balance to its abilities according to the principle of Pareto. Power-to-X technologies, i.e. coupling of energy forms and sectors are playing a pivotal role.

It is obvious that the establishment of such a structure in an efficient and effective way requests on-line data collection and exchange.

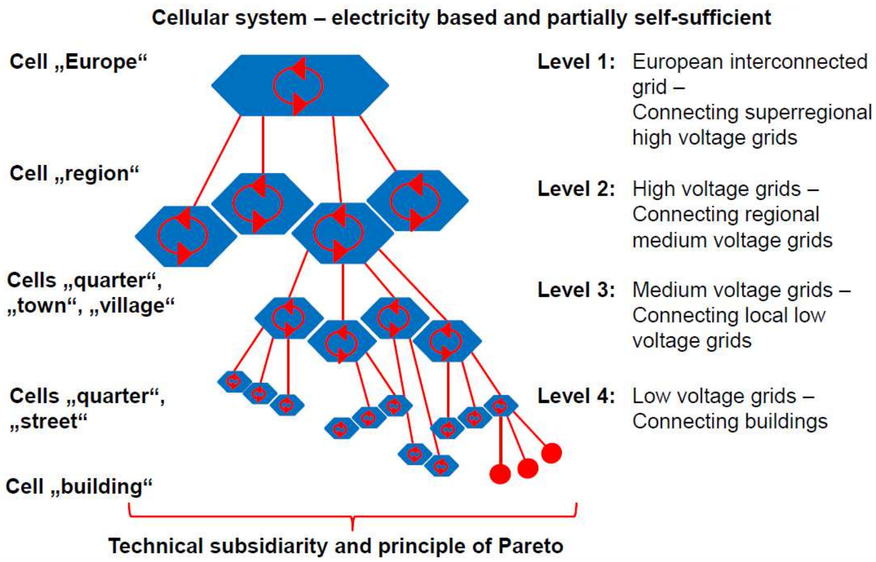

Fig. 8: Cellular structure of the energy system

Traffic light system for system stability

Under the moderation of the German Association or Power and Water Industry (BDEW) a traffic light system for system stability has been developed [8, 9]. The focus is put on the overall power balance and the management of local grid restraints.

With respect to the overall power balance automated power frequency control is considered as a prerequisite. The traffic light system starts with the power market price setting on a 15 min time-period. This concerns trading, balancing groups and supply. When the grid traffic light stands on green there are no grid restraints and the electricity market can operate without any limitations. Normal grid fees and market based electricity prices are influencing the balance between offer and demand. In case the probability for local or regional grid restraints is increasing the traffic light turns on yellow in the cells concerned. Now, the distribution system operator tries by use of adjusted grid tariffs or instantaneous flexibility auctions to release the grid and turn the situation back into the green state. The contribution of the customers take place on a voluntary base. There is no compulsion. However, there is a local interaction with the market.

Low energy prices are increasing demand and temporarily higher grid fees are reducing it. Whatever system is put in place, demand oscillations have to be avoided. In case the situation is getting more serious the traffic light turns into red. Now, the distribution system operator can take immediate action, e.g. in an automated way by the smart grid. The necessary devices in the grid or on the customer side will be addressed in a direct way.

Still many issues concerning the implementation of such a system are still open. E.g. the question of global or specific compensation for customer related measures in the red phase of the traffic light. However, it is evident that the exchange of a huge data volume is a prerequisite for the establishment of such a system.

Detection of grid failures

The smart grid system described above needs a minimum set of mandatory electricity sensors in order to calculate the current in all branches and the voltages in all nodes with a sufficient accuracy. It is possible to add facultative sensors in order to check the quality of the calculation. However, this offers new options as well. In case there is a deviation of the calculated value and the measured value in a facultative sensor, the use of a wrong grid topology for the analysis could be the most probable reason. The set of static data in the control box describing the grid topology becomes wrong if there is a failure in the grid, like a broken wire or an open switch in an interconnected low voltage grid. In order to identify the location of the failure the underlying grid topology has to be modified systematically until the measured value of the facultative sensor corresponds with the calculated value. As a result, smart grids are able to identify grid failures.

Quality assessment of assets

Again, a smart grid system is building the base for this feature. The communication between sensors and control box is done through power line carrier technologies. The damping of the signal in the grid can be interpreted as a function of the overall condition of the insulation. The causality still needs further investigations and the identification of patterns by the help of big data tools has not been analysed in detail so far. However, there is an option to use smart grid data for the evaluation of asset condition and the implementation of predictive maintenance.

Anticipating grid congestions

Another option to extend the features of a smart grid system is to collect in addition to the dynamic load and voltage data of the grid other data like temperature, wind, humidity, date, day, clouds or sunlight. Big data tools can help to identify patterns for the occurrence of congestions in the grid. These patterns can help to predict a probability increase for congestions. Pre-emptive and minimum measures can be taken in order to avoid restraints for the customers. In order to turn this option into a practical tool, still some research and development has to be done. Furthermore, there are legal questions concerning pre-emptive actions. The methodology of adaptive learning has to be applied because the measures taken eliminate the predicted congestion.

Active contribution to power frequency control

A smart grid can also contribute to the power frequency control. In former times the direct coupling of electrical synchronous and asynchronous machines to the grid instantaneously reduced the load in case of a frequency drop. This effect is based on physical effects and is called static of the grid. It is limiting the frequency reduction in the time period between occurrence of the power plant outage and the full activation of the primary reserve. The implementation of power controlled converters for the connection of electrical machines has been reducing this effect substantially. Adding a frequency sensor to the smart grid control box and defining a frequency load curve in the control algorithm reinforces the grid static in an active manner.

In case of a frequency drop the control box has to address actuators in the low or medium voltage grid in order to reduce the customers' loads. Again, this feature still needs some research and development and also the question of cost compensation for the customer is still open.

Workforce management

A final option with a huge data volume are workforce management tools. Since a couple of years, incentive regulation is increasing the pressure on transmission and distribution system operators to improve their operational performance. In addition, the operational environment is getting more complex for distribution system operators. Winning and loosing concession contracts is turning the grid area into a patchwork. A huge variety of task combinations is occurring. All combination of asset management and / or asset service activities for the individual voltage levels of electrical grids, for gas grids, for street lighting, for water grids and electric meters are existing in practice. A workforce management system can support the mobile workforce to improve its performance even in such a situation.

Again, data is core. The first set of data describes the skills and the tools of the workforce. The second set of data describes the requirements of the work to be done. There are planned activities, like performing switching operations, work on a construction site, inspection, maintenance or renewal as well as unplanned activities, like outage management or repairs. A specific priority is assigned to each activity. The system needs a geographical information system with the position of the workforce and the tasks. An algorithm – based on the Knapsack theorem – is assigning the necessary workforce to the tasks in order to optimize the overall performance and to minimize driving time. The system also makes sure that the workforce has the right equipment and the right spare parts in order to perform the work properly. Such a system is in the position to increase efficiency by about 30 % compared to a static and region based organisation of the workforce. Warehouse, procurement and workforce are operating in a concerted manner.

Predictive maintenance is an important tool in order to define the priority of measures. Importance of assets with respect to reliability of supply and condition of assets are taken into consideration in order to calculate the priority of a specific activity. In terms of efficiency, it has to be mentioned that workforce performing activities on site is also doing the necessary inspection simultaneously. This reduced the driving time of teams substantially and allows the gathering of requested data. Workforce management systems are in place in many utilities. However, the analysis of the collected data with big data tools is at the beginning.

All activities concerning work force management have to be closely discussed and coordinated with the trade unions. Workforce management is changing work philosophy and culture within a company. E.g., tracking of workforce is increasing transparency of the individual performance, however, it is also supporting the optimized use of workforce and the safety of staff. In case of an accident the location of the workforce can be identified easily.

5 New data sources for big data

The technologies discussed above provide a huge amount of new static and dynamic data sources. Above all smart meters and smart home applications including convenience, security and health care tools have to be mentioned. But also smart converters for batteries or photovoltaic devices and the smart charging infrastructure for electrical vehicles offer new data sources. There is no doubt that these data can be used to improve the quality of the customer service and to contribute to an efficient use of the infrastructure. However, the aspect of data privacy has to be considered as well.

6 Big data, predictive maintenance and infrastructure improvement

There are two further applications of big data which have the potential to create substantial benefits with respect to technical and building infrastructure.

Additional sensors in generators and machines

All kind of sensors are getting constantly cheaper. Also data transfer offers many options. As a consequence, current, temperature, pressure or vibration sensors are added to generators or machines in operation, while new devices are already equipped with those sensors. When the dynamic data are gathered in a database, with the help of big data tools the correlation between specific circumstances and the occurrence of failures or outages of generators and machines can be identified. Vice versa, in case a specific data constellation is observed the probability of a substantial risk for a breakdown of the device is substantially increased. This strategy allows predictive maintenance. It is applied in power plants but also in trains, metros and tramways. The daily data volume is immense and exceeds by far the daily data volume of social media.

Big data and infrastructure improvement

With respect to energy efficiency, the energy demand for the heating of the building stock is playing an important role. In Germany 50 % of the overall energy demand is assigned to heating, while electricity and mobility amount to 25 % each. Public available data as well as utility data describe quality and age of infrastructure, heating systems as well as insulation. There are information about inhabitants and annual energy consumption. Consistency of data is pivotal. In addition, the potential efficiency measures to be taken – e.g. exchange of heating system or windows – can be described with price and impact. As a result the most effective measures can be assigned to each building and a strategy for the improvement of the energy efficiency within a quarter or a town can be developed. The specific cost for the reduction of carbondioxid can be calculated. This helps the municipality to develop their decarbonisation strategy or the government to set proper incentives for the modernization. Also utilities can take advantage or such an analysis. They are in the position to develop new offers for the customers, e.g. contracting offers.

7 Summary and conclusions

The implementation of an energy system based on dispersed and renewable energy source as well as on energy efficiency is not possible without pronounced collection and exchange of on-line data. This is a prerequisite for system stability. Big data tools allow the identification of new relations without knowing the exact causality. Neuronal networks, combined with adaptive learning help to control the significant volatility in the system. Energy and digitation are converging. Flexibility is key.

The paper describes specific options for the use of these two instruments in order to make smart energy systems become reality. Some of the options are already in the demonstration phase while others still need some research and development.

In order to make big data a success, know-how on energy business, technology and digitation has to be combined. According to [10] the following questions have to be considered by companies in order to make big data approaches successful:

What about the added values of big data? What is the specific benefit of data collection and analysis? What is the cost reduction or the additional revenues?

Do we have the right data sources? What about data quality? How can we get the data? Are there legal restraints?

What about our technology? Do we have sufficient performance in our IT or do we have to invest?

Who or what is the driving force? Big data means a turnaround from an experienced management style to a data based management style. Therefore, big data is not just an IT issue, it is a management philosophy and touches the strategy of the company

Do we have the right people? The implementation of big data tools are not limited to technical and IT questions. Of course, experts dealing with data collection, validation and applying big data tools are needed, however, the chance of the company culture is a prerequisite of success.

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