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Smart Grids in Germany

Fields of action for distribution system operators on the way to Smart Grids

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1. Foreword

Dear Readers,

the German energy system has been going through change for some years. Renewable energies meanwhile account for more than 20 percent of electricity generation; for the most part, they are fed into the distribution and transmission systems irrespective of demand. As a result, today's electricity supply is already subject to considerable intermittent fluctuations.

The increasing share of renewable energies means that this development is going to continue. It has to be brought in line with what has always been a fluctuating demand.

While electricity used to flow from high to low-voltage levels, there is now an increasing trend to backflows from lower to higher voltage levels. It is essential for network infrastructures to be adjusted to these bidirectional electricity flows. The energy transition and the accelerated development of renewable energies will lead to a further increase in the challenges to transmission and distribution systems.

Integrating renewable energies into the grid will entail the expansion and upgrading of large parts of the network infrastructure. Together with the increase in the transmission system's transport capacities, the BDEW has also underlined the considerable need for development in the distribution system[1].

Also in future the pending upgrade of the energy system depends on finding the right balance between the three objectives of an environmentally friendly but also secure and affordable energy supply. Together with merely demand-oriented development of distribution systems, "smart" new technologies and applications can also be used to optimise network capacity for the fullest possible integration of renewables-based intermittent generation into the energy system, while still maintaining the high quality of supply.

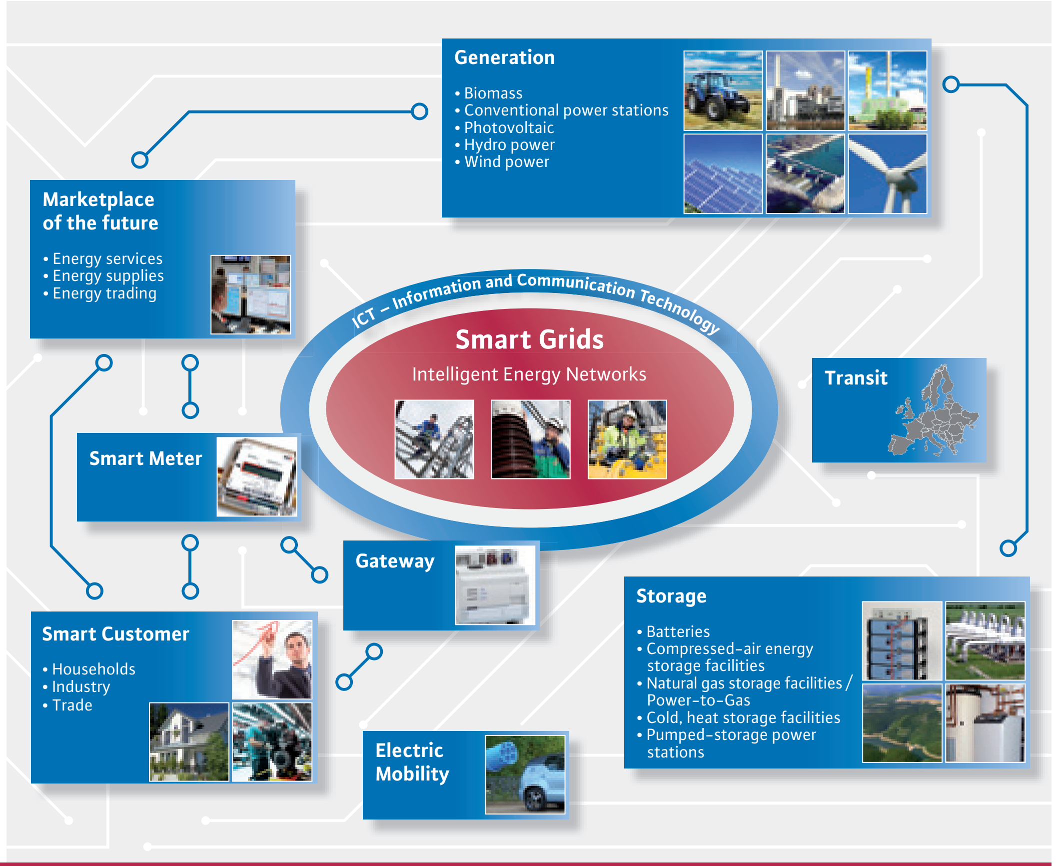
Making the distribution systems efficient leads to greater demand for metering, control and automation. For the distribution system operator, it is important to identify the key technologies and their effectiveness. The question arises as to what technologies are already available today and what potential they offer for solving the specific problems of distribution systems.

The German Association of Energy and Water Industries (Bundesverband der Energie- und Wasserwirtschaft – BDEW) and the German Electric and Electronic Manufacturers' Association (Zentralverband Elektrotechnik- und Elektronikindustrie – ZVEI) have worked together in analysing these questions and give recommendations on the concrete start-up of Smart Grid technologies.

Roger Kohlmann, BDEW

Dr. Klaus Mittelbach, ZVEI

[1] Cf. BDEW-Verteilnetzstudie 2011 (www.bdew.de)



Definition of "Smart Grid": A Smart Grid is an energy network that integrates the consumption and feed-in patterns of all market participants connected to it. It ensures an economically efficient, sustainable supply system with low losses and high availability.

2. Introduction

Germany is pursuing ambitious targets in terms of the development of renewable energies. Until 2020, their share is to be increased to at least 35 percent related to electricity consumption. In 2050, 80 percent of electricity consumption is to come from renewable energies. To make it easier to reach these targets, electricity consumption is to be reduced by 10 percent until 2020 and even by 25 percent until 2050.

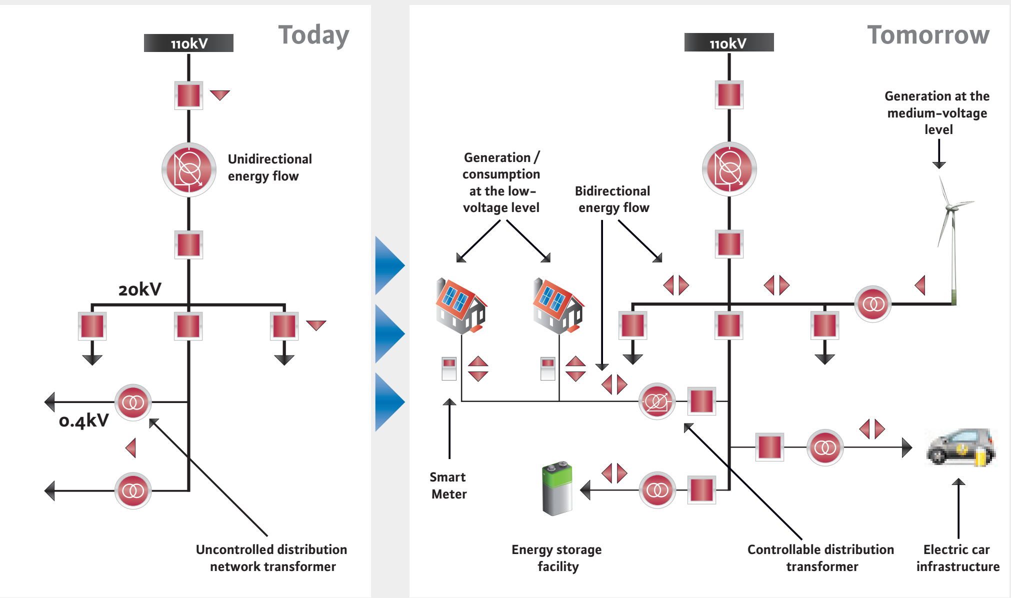
At times, renewables-based electricity already exceeds the transport capacity of some network areas (see information box on the right). It is essential to control these energy flows by means of smart system management. Generators, networks, suppliers and consumers are called upon to act in a flexible manner in their common interest. This requires new information and communication technologies in the grid. Smart Grids are intended to contribute to improved integration of decentralised energy generation and the necessary coordination of generation and demand, while generating greater customer benefit. To this end, it is necessary to develop business models which provide appropriate incentives.

Network development and modernisation must henceforth go hand in hand with the development of generation from renewable energies. Any investment in renewables-based generation must be accompanied by investments in the grid. Otherwise, further system integration of renewable energies will be restricted by the lack in network infrastructure. Regulation has to allow network operators to proceed with the necessary capital expenditure in infrastructures. The use of energy lines with additional "smart" functions can ensure the enhanced communicative interconnection of network installations which will be required in future. Today already a wide range of power cables are available with integrated glass fibre elements for information transfer and online cable condition measurements.

Many key technical solutions are already available. In order to achieve the 2020 or 2050 target scenarios while maintaining the high security of supply in Germany, it is necessary today to lay the basis for the functioning of tomorrow's energy system. This requires capital expenditure in smart and energy-efficient technologies and upgrading of the existing grid infrastructure. At the same time, these investments promote growth and employment and make sure that Germany as a location for industry is given a chance to establish itself as a global leading market and leading supplier of Smart Grid technologies.

Northern Germany:
The development in Northern Germany shows that the future has already begun in certain networks. Here, network operators already issue warnings about overloading of energy networks due to the rapid development of renewable energies in rural and windy regions. In and around Lower Saxony today, the installed renewables-based feed-in capacity exceeds the annual maximum load by almost 70 percent. Already 50 percent of the total electricity volume transported by certain network operators originates from renewable energy sources.

Southern Germany:
Bavaria has seen a considerable increase in the number of photovoltaic plants over the last two years. More than 350,000 photovoltaic plants with a capacity of more than 7,000 MW are currently connected to the network. This figure not only exceeds the Bavarian demand during low-load hours but it also corresponds to about 35 percent of the PV capacity installed throughout the country, and far exceeds the installed total PV capacity in the USA of 3,000 MW.



- ☐ Radial system
- ☐ Single protection
- ☐ No / simple automation
- ☐ No / simple communication

- ☐ Meshed system
- ☐ Differential protection of lines
- ☐ Comprehensive automation
- ☐ Bidirectional communication

Germany's electricity supply is currently based on a reliable and powerful network infrastructure. But to manage the energy transition, it is essential to keep distribution networks efficiently in balance by means of sensor, management and control systems depending on the relevant requirements.

3. The distribution network today and tomorrow

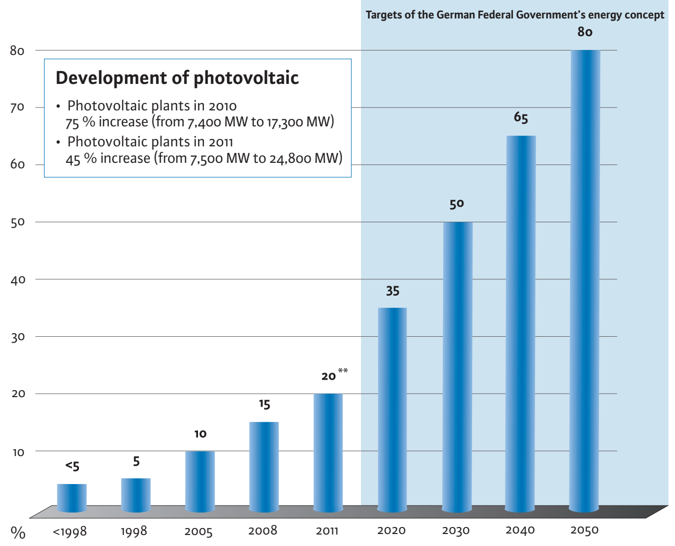
Germany's electricity networks have been the most reliable in Europe for decades. Electricity customers only have to expect power interruptions of 16 minutes on average during the year. This corresponds to a reliability of 99.99 percent. More than 800 electricity network operators maintain and operate Germany's networks covering a distance of 1.78 million kilometres. For the most part, these are low-voltage networks, connected by regional distribution networks (medium and high voltage) to the extra-high voltage grids. The existing infrastructure of distribution networks has developed over decades. A large part of the network elements have been used since the sixties and seventies and were not designed for the intermittent feed-in of renewables-based electricity. Moreover, hitherto passive customers are turning into active market participants, the so-called "prosumers".

The medium and low-voltage distribution networks are changing into a multidirectional dynamic network. Monitoring and control of this system are a prerequisite for keeping the network efficiently balanced, working in cooperation with network users. It is important to take account of the fact that every distribution network must be individually assessed in terms of its network structure (e.g. consumers and generators connected to it) and public infrastructures (e.g. load and population density).

In the past, distribution networks were operated in a single direction to distribute electricity from the higher voltage level, with the network structure designed for this specific task. Through to today, only very few distribution networks proceed with detailed visualisation and analysis of the network situation together with real automation. Furthermore, only limited use is made of the efficiency of control and regulation possibilities. This must be changed if the energy transition is to be managed. Transmission and distribution networks must respond even faster and more frequently to changes in generation and load-flow directions, particularly through the feed-in of increasing amounts of energy from wind power and photovoltaic. More information and control possibilities will have to be available in order to keep the network efficiently balanced, working in cooperation with electricity producers and consumers. The need for these functions will continue to grow: greater use of decentralised volatile feed-in and the expansion of electric mobility in the field of individual passenger traffic together with additional controllable load will make further demands on the networks and their operators. Further improvements in energy efficiency will also be a driver for making the medium and low-voltage distribution networks fit for the future.

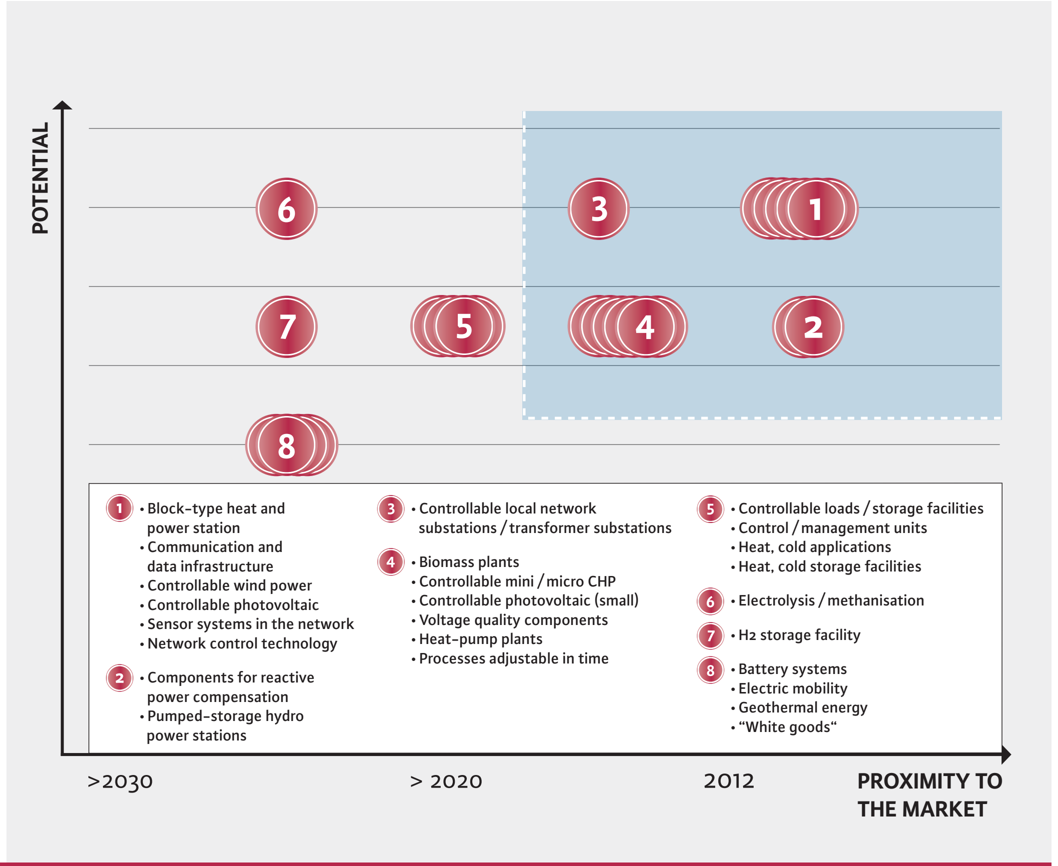
Transformation of energy supply

Share of electricity from all renewable energy sources*



* Related to gross national electricity consumption in Germany

** Provisional figure



"Proximity to the market" = technical and economic availability at the present time
"Potential" = contribution to safeguarding network quality in technical terms and to efficient network loading in economic terms

4. BDEW survey

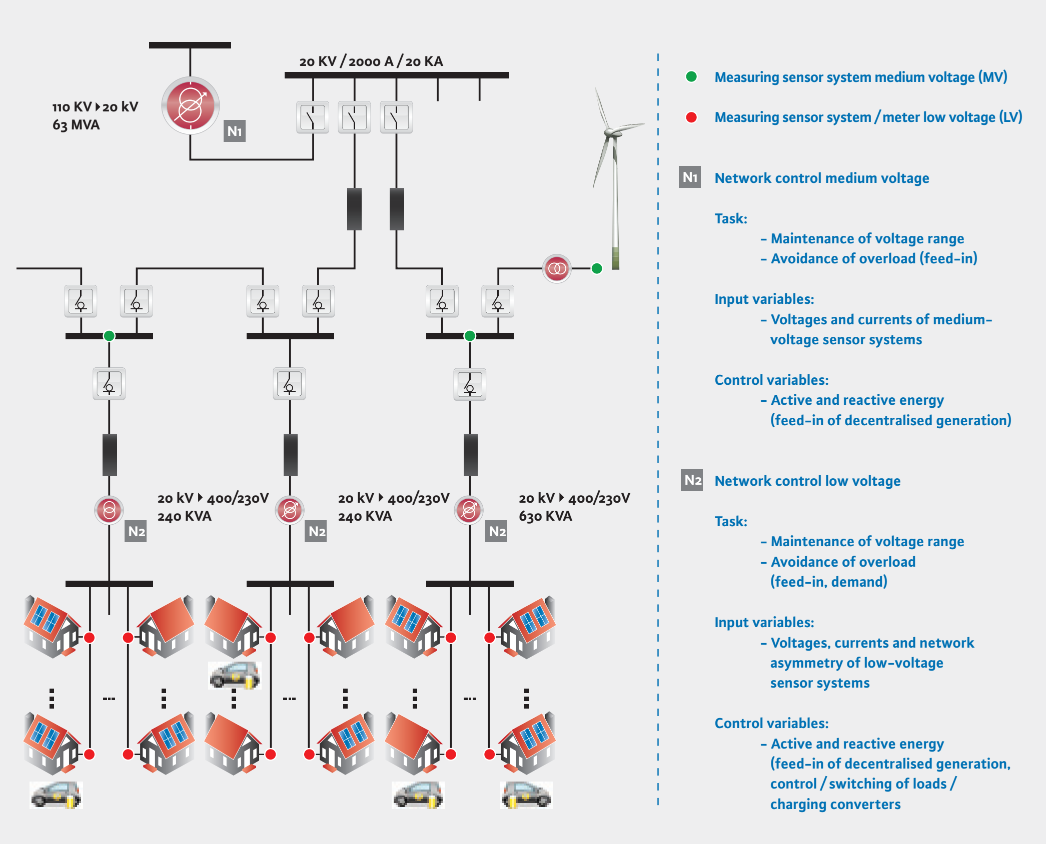
The energy transition is taking place in the distribution networks: more than 90 percent of renewable energies are connected to these networks. Already today, many distribution network operators are therefore facing the task of not only extending the network but of making it as "smart" as possible at the same time.

In cooperation with distribution network experts, the BDEW has analysed technical components that may offer a particularly great potential and that today are already considered to be relatively close to the market (or ready to be put on the market).

This analysis was reviewed together with experts from the manufacturing industry organised within the ZVEI. The result of this review led to the present evaluation of 25 technical components from the areas of networks, buildings, generation / storage and information and communication technologies in terms of their potential and their market proximity (see diagram on page 10).

The experts' analysis of market proximity focussed on how the technical and economic availability of the different components is currently rated. The potential was evaluated by identifying components that contribute to safeguarding and improving system stability and to efficient network loading or efficient network operation.

The experts' analysis has shown that 15 components can currently be considered as promising. It is unlikely that the potential of the remaining components can be tapped in the short term. Additional R&D efforts have to be undertaken here in order to put these components successfully on the market. The results of this analysis are represented below, with descriptions of altogether eight technical components which currently appear to be particularly promising, also taking a look at how these interact.



The installation of sensor systems to identify the network situation becomes a “must” of smart network use and control. This involves appropriate IT infrastructures for information processing.

5. Fields of action on the way to Smart Grids

5.1 The basis: network sensor systems

The implementation of a system-optimising network, feed-in and demand-side management necessitates an improved information basis for all players in the energy system.

Knowledge about current network conditions needs to be improved to ensure that networks in Germany can continue to provide a high quality of supply. Only on this basis will it be possible for instance to proceed with reasonable load management, a norm-compatible maintenance of the voltage range or an assessment of network segments loading. Setting up network sensor systems for identifying the network situation is therefore practically a must for smart network use and control where required by the consumption and load structure in the affected network area. This also involves a corresponding IT infrastructure for information processing (see section 5.2.3 on communication and data infrastructure). So there is a need to invest in the development of communication links, server structures and computing centres.

Network sensor systems provide a wealth of current measured values. These values can be supplemented at selected points by additional measurements, using Smart Meters. The Smart Meter is capable of providing system condition data that may be used for network control or asset management.

The Smart Meter lets the meter operator proceed with remote meter readings. Under certain conditions, this may lead to savings in operating costs. However, additional system costs are also incurred so that the aforementioned potential savings may be overcompensated particularly in densely populated areas where further synergy effects will have to be used for an economically efficient utilisation.

Other advantages from the use of Smart Meters benefit retailing and sales aspects rather than the network operator and are thus not the focus of this analysis.

These include:
- optimisation of consumption profiles and forecasting
- possibility of new tariffs and demand-side management
- processing of data for the customer and, where possible, provision of energy efficiency services

The information obtained from network sensor systems facilitates optimum network utilisation, combined with the use of technologies described below. It is essential to have comprehensive knowledge about the key system parameters (voltage, current strength and frequency) in order to determine the system-stabilising instructions to active components (adjustable/controllable feeders and loads) and network elements. Apart from sensor systems, temperature monitoring may also provide information about the actual loading of cable runs.

5.2 Management / control combined with distribution network automation

Cost-efficient measures and concepts for network operation will be a key factor for economically efficient energy supply to meet the requirements of customers and of the regulatory framework.

Essential reasons for capital expenditure in the automation of distribution networks include among others:

- integration of decentralised energy generation into distribution networks
- upholding the high reliability of the distribution networks / enhancing the quality of distribution networks and avoiding of negative impacts on the voltage quality
- improvement of the operation and maintenance of distribution networks
- fast disruption analysis and fault location
- monitoring of the existing infrastructure and strategic management of capital expenditure
- load-flow transparency
- active dispatch and re-dispatch of load in the operation of distribution networks
- use of sophisticated technologies for communication nodes with broadband infrastructures

Economic analysis restricted just to the use of individual technologies is not appropriate. Investment in only partial aspects will fail to utilise the optimisation possibilities, as illustrated by the large number of described benefits. In many cases, potential for efficiency is only derived from combining new technologies together with the associated possibilities of automation.

It must be borne in mind that distribution network automation is not necessary on a comprehensive scale, but depends on the challenges faced in the respective network.

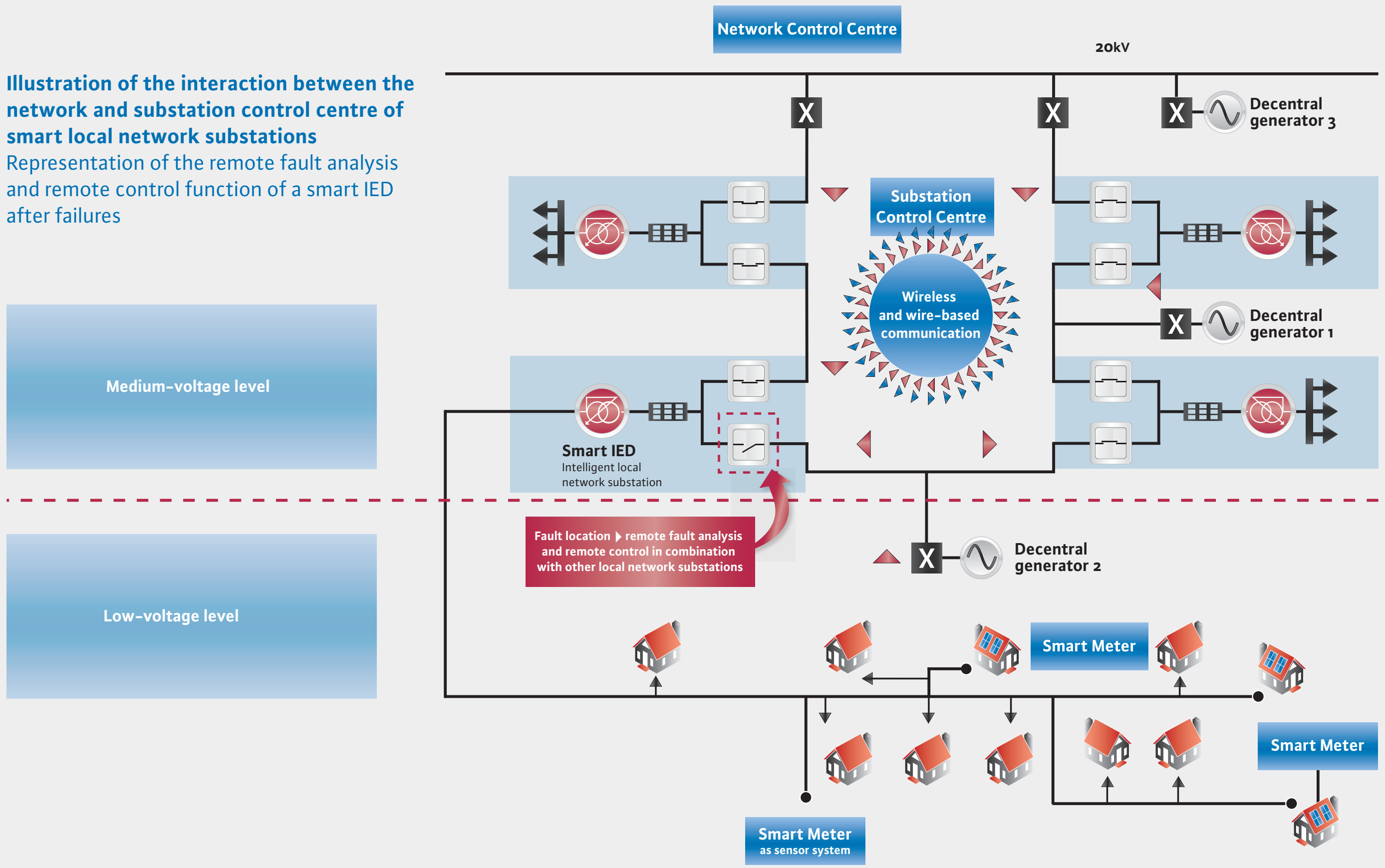
Smart local network substations

One essential target for making local network substations "smart" is to maintain the reliability of supply. Outage durations of equipment (not customers) currently last for several hours because service teams first have to localise the fault before organising fault clearance. Even short-circuit indicators bring little improvement. Outage periods can be further reduced by using remote control devices with functionalities exactly tailored to the specific tasks. Current fault clearance operations still entail travelling times: omitting these leads to a further essential reduction of outage periods and costs.

The highest possible reduction of outage periods will therefore only be achieved by efficient automation going beyond mere remote control. The devices offer a high level of integrated performance with automation, remote control, communication and some protection functionalities so that we can speak of an "Intelligent Electronic Device" or "Smart IED" (see diagram on page 15).

Smart IEDs can be used for full automation of distribution networks, whereby the restoration of supply can be implemented by means of switching logic without the use of service staff. Decisions can be based on both switch position messages and also the current load situation. Respective communication in future will be facilitated by networks using the international system standard IEC 61850. This worldwide system standard enables smart IEDs to exchange data and provide information about the current network condition.

Illustration of the interaction between the network and substation control centre of smart local network substations
Representation of the remote fault analysis and remote control function of a smart IED after failures



Examples of voltage quality measures

The availability of low-cost solar technology and the funding instruments of the Renewable Energies Sources Act (EEG) have led to widespread use of photovoltaic systems in many network regions. Approximately 25 GWp of photovoltaic had already been installed in Germany through to the end of 2011. The currently installed capacity of wind turbines amounts to a good 29 GW. Onshore wind use accounts for by far the largest share with corresponding relevance for the distribution networks. The considerable increase in volatile energy generation poses new challenges to the medium and low-voltage networks: Load fluctuations, changes in load-flow directions and maintenance of the voltage range prescribed according to EN50160 can only be managed by the simultaneous development of infrastructures and additional intelligence at the distribution system level.

High solar irradiation or strong winds lead to a rise of voltage whereas clouds and wind calms give rise to voltage drops which have to be compensated by the network. In comparison with unidirectional distribution, only half the voltage range is available for offsetting the effects. This affects both the medium and the low-voltage networks. Both network levels are directly connected via the transformers in local network substations so that management of the voltage range must always be considered for the two network levels together.

Contrary to the low-voltage level, feed-in into the medium-voltage level today takes place in many cases through tap-changing transformers which can be used for voltage stability by corresponding regulation. Nevertheless, it has to be assumed that larger decentralised generating plants will lead to a substantial increase in the range of voltage fluctuations in the medium-voltage network.

Where problems in terms of voltage range may arise in spite of an adjusted power factor, the use of a controllable transformer has to be compared to a network development. A further measure consists in using a controllable inverter capable of feeding reactive power into the grid. Depending on the kind of feed-in, the two approaches can facilitate optimised grid operation while simultaneously reducing adverse effects on the network. The two technologies described in greater detail below offer significant potential for minimising the costs related to the necessary network development.

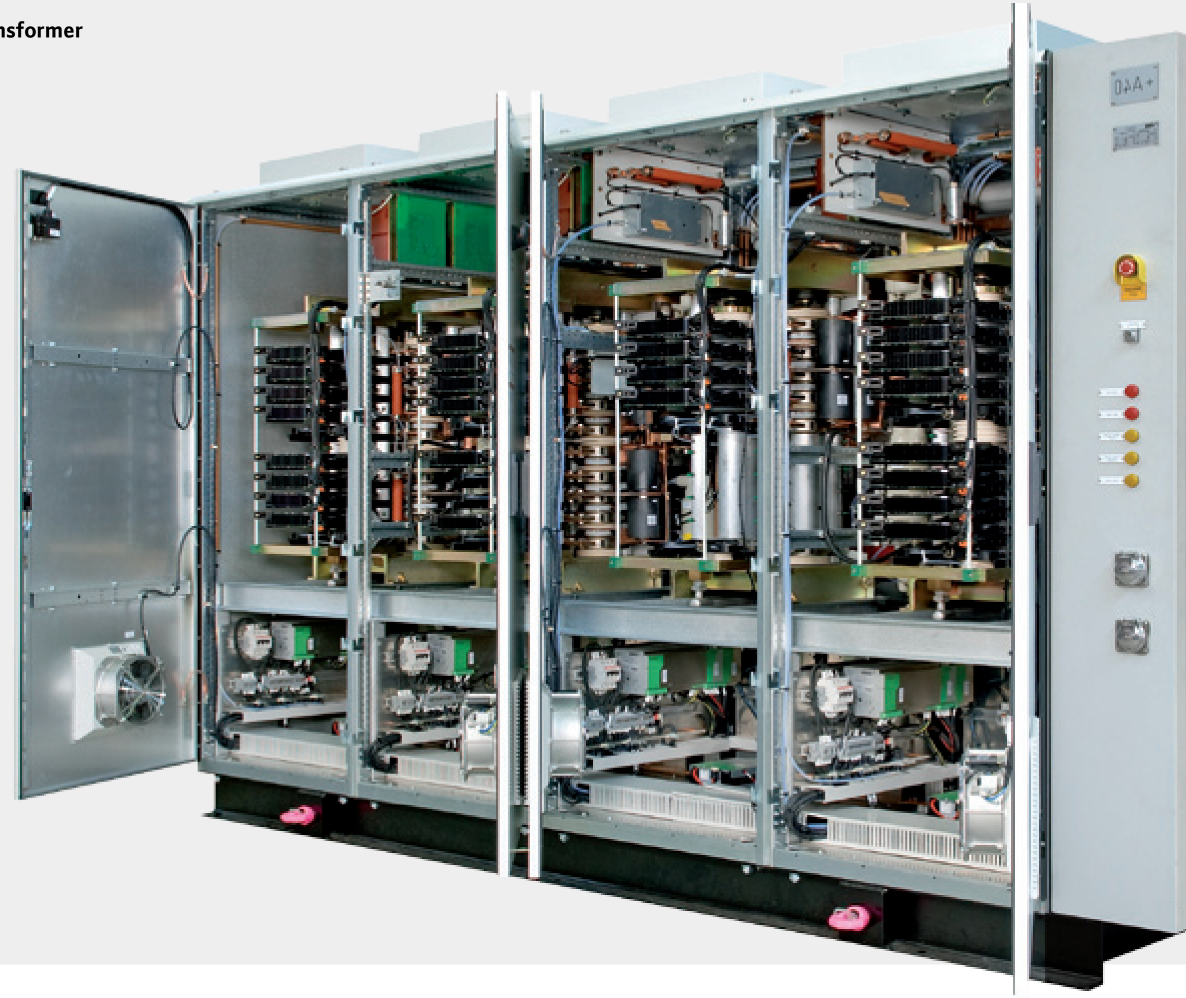
However, this presumes that a certain intelligence is available (smart IED in the local network substation and systematically distributed measuring sensors in the network) for performing optimum control adjusted to the network situation.

5.2.1 Controllable local network substations

Measuring sensors installed at strategically selected places in the low-voltage network, e.g. at the end of distribution and at important loads, are used to transfer the measured values to the next higher node in a hierarchy, in this case to the smart IED installed in the local network substation. Algorithms specifically developed for that purpose are responsible for computing the necessary transformer tap, which is adjusted automatically by the smart IED. Controllable local network transformers effectively solve the problem of voltage range infringement (admissible range: +/- 10 percent).

Experience gained from pilot projects shows that about 90 percent of voltage deviations can be offset by using controllable local network transformers. Where converters capable of feeding reactive power into the grid are also available in the respective network segments, they may also be used to support voltage stability. Controllable local network transformers for low-voltage networks are likely to go into series production from summer 2012.

Controllable local network transformer
Voltage range violations can be effectively remedied.



5.2.2 Controllable inverters capable of feeding reactive power into the grid

Modern converters are capable of functioning in 4-quadrant operation. They can simultaneously absorb or supply reactive power to the network during both active power supply (photovoltaic plants, wind power, batteries etc.) and active power absorption (recharging of storage facilities and electric cars). It is thus possible to integrate inverters into the network management and to compensate active power conditioned voltage deviations at the network feed-in point by reactive power.

By specifying characteristics (parameter settings) at the converter, reactive power is compensated today up to a value of cos Ø = 0.9 (overexcited or underexcited, respectively) depending on the active power feed-in or the network voltage measured at the point of connection.

The optimum solution however consists in the direct integration of converters into an automated control of a smart local network substation. The measured data of the converters are transferred to the central control unit of low-voltage distribution of the smart local network substation. The smart IED computes the optimum target values for the network and controls reactive power compensation of the inverters at the feed-in points.

Apart from voltage control in the admissible voltage range, it is also possible to prevent potential oscillations of the network voltage and optimise the distribution network's loading.

According to expert opinion, under certain conditions the use of smart control together with new inverters and a smart local network substation (smart IED) can bring about local improvements in the loading of existing distribution network infrastructures by 20 to 25 percent.

5.2.3 Communication and data infrastructure

The communication infrastructure will be the backbone of future Smart Grid systems. Without communication links it will not be possible to use information and proceed with the resulting targeted control of actuators in the grid. It seems reasonable to use IEC 61850 which provides well-established communication standards in energy distribution. The IEC 61850 allows secure and effective data exchange between smart IEDs and the shared use of sensors and actuators. In addition to international IEC standards, it is possible to apply protocols such as M-Bus or Modbus RTU for interaction with technologies from the field of building control systems and already existing communication-capable meters.

Networked or wireless communication technologies can be used as transmission media. Networked options are glass fibre networks, copper networks (with xDSL), narrowband PLC and broadband PLC. Wireless options include GSM, UMTS, LTW, WiMax, directional wireless, digital mobile radio (DMR) and Tetra. However, attention always has to be paid to the necessary transmission rates and aspects of data security. The disadvantage of public networks such as GPRS is that supply segment transmitters are not available in the event of network disruptions so that it will not be possible to reach the local network substation. Using the energy utility's own infrastructure makes it possible to reach local network substations and other elements of the distribution network structure over the entire supply area. The same applies to power line communication: in this case, the existing distribution network is used, evading out-of-range problems as in the case of wireless links. Consistent implementation of the common system standard IEC 61850 across all voltage levels provides the precondition for standardised communication and data infrastructures. This is a necessary prerequisite for the economic development of distribution network automation. Modular network development and reorganisation will guarantee the compatibility of old and new communication infrastructures.

5.2.4 Network control technology

On the basis of the technical components described above, numerous new applications / algorithms are available to distribution network operators for automation and control. Once tripped by protection relays, the fault analysis collects the data provided by the protection equipment and short-circuit indicators, then determining the fault location with the greatest possible precision, based on the known network topology. This area can be automatically reconnected after isolation of the fault location.

The data available from the network control system enable much better conclusions to be drawn for network planning and asset management. Hitherto, asset strategies were mainly based on the installation date and the manufacturers' specifications regarding equipment, and also on fault statistics. The availability of online data enables the evaluation of further valuable assessment criteria or overload times and currents of transformers. On that basis, maintenance work can be carried out systematically and certain types of cables or cable joints can be included in a component replacement programme. Asset management software supplied with operational information from the distribution network thus permits efficient replacement at minimum risk together with a maintenance strategy, while simultaneously reducing the risk of failure caused by primary components as a result of previous damage or ageing stress.

The medium and low-voltage networks are optimised by decentralised network control technology applications in the smart IEDs of local network substations. They control the network segments in terms of voltage range, load flow etc. independently based on targets set in the network control centre. The new applications for network control technology include in particular the feed-in management described in greater detail below.

5.3 System-oriented feed-in and withdrawal

5.3.1 Photovoltaic plants and wind turbines

In some regions, distribution networks are already reaching their capacity limits as a result of the development of generation based on photovoltaics and wind. Network operators endeavour to ensure the complete integration of renewable energies into the grid. However, it is becoming apparent that in spite of appropriate optimisation, reinforcement and development measures it is not possible to keep pace with the rapid expansion of renewable energies. This may lead to situations where unlimited feed-in of all renewable energies is temporarily not possible.

Experts assume that curtailment or storage of 3 to 5 percent of the generated annual energy during the period until 2020 and possibly even up to 2030 can double the network connection capacity in particular cases. The feed-in management in terms of wind and photovoltaics thus offers great optimisation potential to distribution network operators.

EEG plants (generating facilities using renewable energies under the Renewable Energy Sources Act; German abbreviation: EEG) with a capacity of more than 100 kW are already controllable today and thus offer the possibility of feed-in management under the provisions of the EEG. In future, this feed-in management will also gain in importance in the low-voltage level; special focus: photovoltaic plants (cf. Article 6 in conjunction with Articles 11, 66 EEG 2012). Controllable inverters already provide the appropriate technologies for the control of wind turbines and photovoltaic plants.

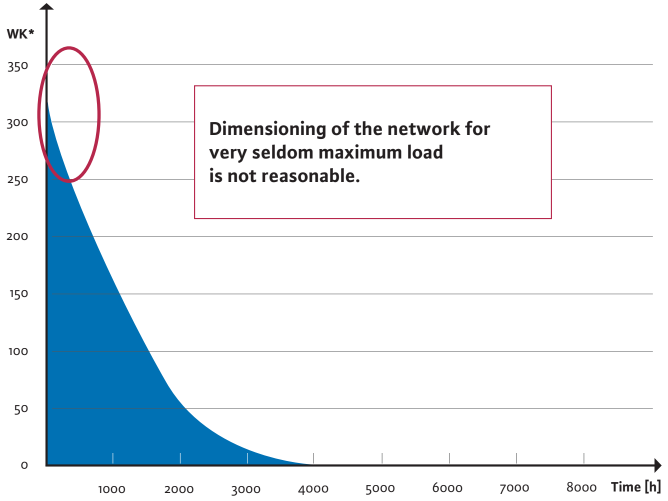
In case of a potential risk to the network, network operators must reduce decentralised feed-in by steps of 0/30/60/100 percent[2]. This is supported by the network control system with automatic combination of renewables-based feed-in at several levels ("visualisation") and with provision of making the relevant dialogues and instructions ("control"). This can take place at the level of an individual plant, a medium-voltage bay or a transformer station.

Based on the current load-flow situation, the loading sensitivities of the different operating elements to the level of injections are determined online. The network control system automatically prepares an EEG report for publication.

Should the network load increase it is no longer sufficient to analyse only the current network condition. The future network condition can be calculated on the basis of demand and supply forecasts and the knowledge of notified switching measures. This provides the control centre staff with greater security to determine and initiate countermeasures if necessary in case of expected overloads.

[2] VDE application rule N-4105

Example: Annual photovoltaic duration curve



* Active power in kW

Source: Investigation of EWE Netz GmbH

5.3.2 Heat pump systems

Based on thermodynamic principles, heat pumps use ambient heat (earth, water, air) to provide up to five times the electric driving energy as useful energy for heating and cooling. It can be switched and controlled without any loss in convenience (if a system for sufficient heat storage exists) and thus provides potential for being used in Smart Grids. Heat pumps can store local feed-in surpluses from wind turbine and photovoltaic plants in the form of heat. Depending on the legal provisions, many network operators consider that heat pumps offer great potential for system relief through local use of electricity from photovoltaic plants.

Heat pumps can be used in a flexible manner and controlled e.g. via a price signal (sales-oriented load management). A substantial potential for load management is already offered today by the existing heat pumps with a total number of approximately 450,000[3]. In order to extend the useable output and the period of time while offering relevant amounts of control energy, individual heat pumps can be pooled and combined to form virtual major consumers. By local network integration, heat pumps are ideal particularly for purposes of decentralised system relief. Additional capital expenditure in larger buffer storage facilities or with buildings of high thermal storage capability can integrate heat pumps into a regional load management over considerably longer continuous periods.

The main potential for heat pumps currently lies in the field of heating and frequently coincides with seasonal wind peaks. Hot water use can be utilised for load balancing throughout the year. Additional potential may be obtained from the reversible operation of heat pumps for cooling which seasonally coincides with photovoltaic feed-in, and from the generation of industrial process heat and cold[4].

5.3.3 Mini/micro combined heat and power plants (CHP)

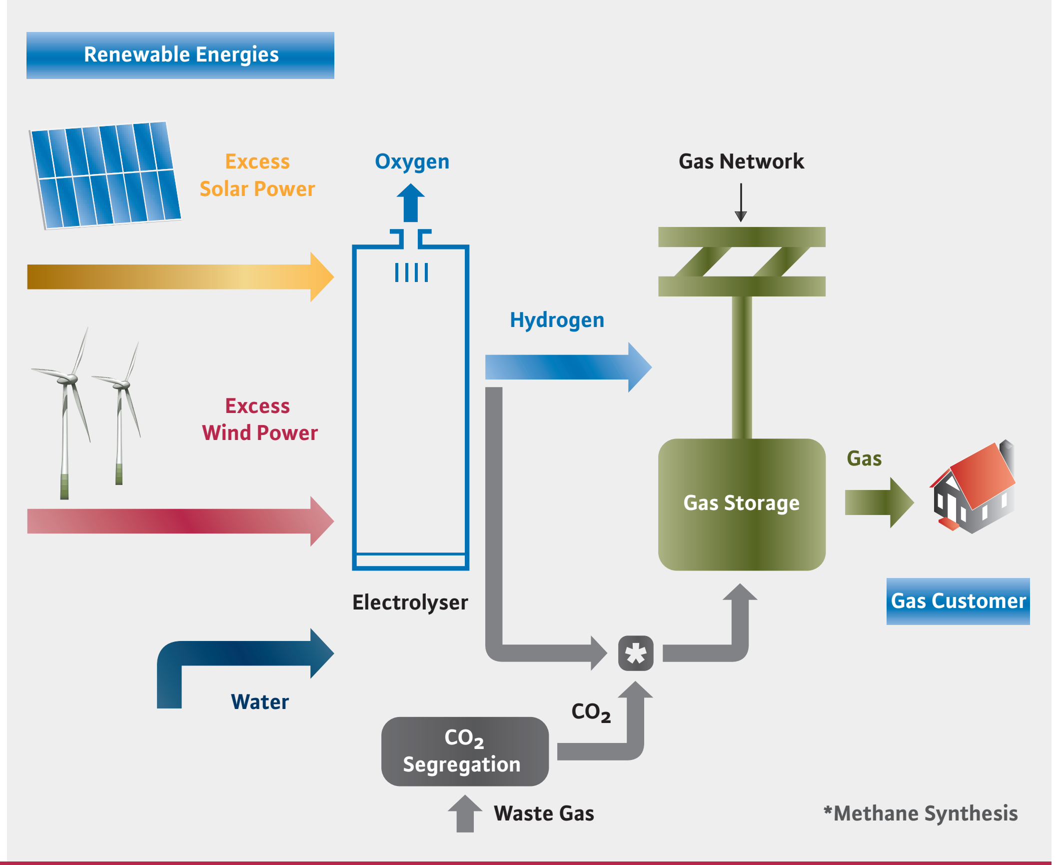
CHP means the combined generation of thermal and electrical (mechanical) energy. The resulting heat is produced locally at the consumer's premises and can be used for heat supply to the building. The resulting electricity can be used to cover the producer's own demand or fed into the electricity network.

The term "micro CHP" refers to the smallest CHP plants. They can replace old inefficient plants in buildings. Larger facilities ("mini CHP") can also feed electricity into the supply network for system support purposes. Provided there is adequate availability, the output of mini CHP plants can be reduced or increased after load shifting of controllable loads to cover the remaining energy demand. To this end, it makes sense for the block-type heating and power station to be also equipped with a correspondingly dimensioned heat storage facility for current-regulated operation. Besides, it is conceivable that pooling, with other electricity generating plants to form major capacities (virtual power stations) can make a significant contribution to balancing group management (balancing energy, control energy).

Market proximity can be considered as medium to high. It is essential to develop current-regulated operation with adjusted heat management (e.g. heat storage facilities) for shifting electricity and heat demand in terms of time, as well as the necessary control mechanisms.

[3] The Bundesverband Wärmepumpe – BWP (German association for heat pumps) expects that about 1.2 to 1.5 million systems will be installed by 2020 representing a rated electrical output of approximately 4,400 MW. Depending on the framework conditions, the BWP expects that 2.0 to 3.5 million heat pump systems will exist in 2030.

[4] In some cases, cold storage (e.g. air-conditioning of large buildings in the service sector) offers large potential that can be tapped without major technical efforts.



Energy storage by connecting electricity and gas networks (Power-to-Gas) offers great potential for making future excess renewables-based electricity usable to the energy system and offsetting seasonal fluctuations.

6. Future options: storage technologies

Storage facilities are capable of absorbing "excess" energy at times of high feed-in from renewable energies and making this energy available again in case of demand. This enables generation and demand peaks to be managed and additional wind and photovoltaic generation capacity to be utilised without requiring network development, provided that the storage facility is located close to the generator.

Storage facilities provide distribution network operators with the following system services:

- Capacity support by shifting feed-in from peak to base-load periods
- Dynamic voltage control through feed-in / consumption of active and reactive power
- System support in the event of component failure

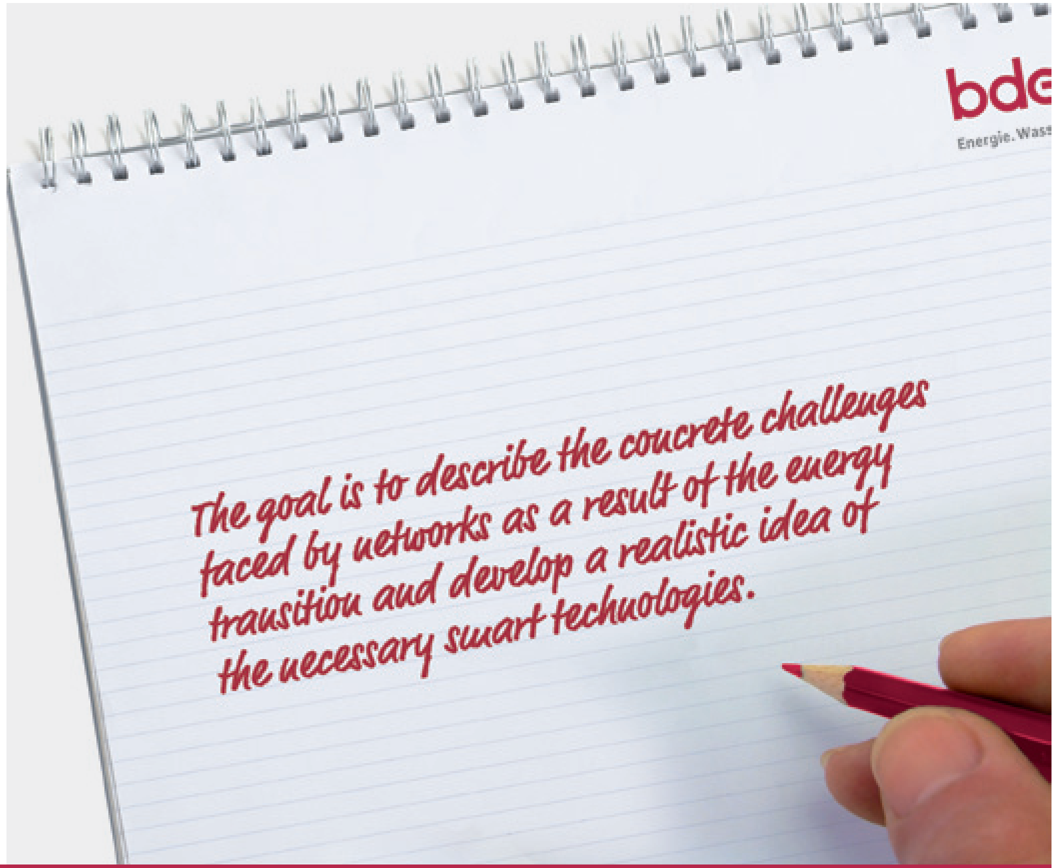
Today already, storage facilities are an essential instrument at the medium and high-voltage level for system stabilisation in the daily load profile, in the event of system disruptions and for network restoration. By providing control and reactive power, electricity storage facilities make an important contribution to network security.

With regard to available electricity storage technologies, pumped-storage power stations represent the only currently available large-scale technology for electrical energy storage that has been successful for decades. The aim of current research projects therefore is to make this storage technology also available to smart distribution grids by means of technological innovations.

Many storage options at different stages of development are currently being investigated (such as batteries, compressed air storage, cold and heat storage, power-to-gas or flywheels). Batteries are considered to be promising for short-term storage, whereas the Power-to-Gas technology is taken into consideration rather for storage over longer periods of time.

Batteries are generally available in technical terms. Their chief point of interest is in the flexibility they provide, and they may be capable of making excess electricity from renewable energies usable for the energy system. In future, intelligent connection of the electricity network with central and decentralised batteries could be part of efficient load and generation management. Electrochemical energy storage facilities offer great potential for the future. R&D efforts should mainly focus on higher power density, lower weight, longer service life (number of charging cycles) and efficiency. In terms of the economic efficiency of battery, due consideration must be given to a clear decline in marginal unit cost resulting from economies of scale.

Power-to-Gas technology (PtG) would appear to be interesting especially under the aspect of flexibility and linking the electricity and heat or gas market; it could make excess renewables-based electricity usable to the energy system. But primarily, PtG is currently the only option for long-term bridging of regular shortfall phases during which intermittent sources of renewable energies are not available. R&D efforts should focus on more efficient conversion, reduced costs, smart interconnection and flexible control of electrolysers, together with the development of efficient catalytic processes for methanisation.



Dr. Erik Landeck
Vattenfall Europe Distribution Berlin GmbH
Speaker of the advisory group “Smart Grid” in the German Association of Energy and Water Industries (BDEW)

Expert statement

Dr. Erik Landeck

Are electricity networks already fit for the energy transition or do they still need to be upgraded into Smart Grids?

Dr. Erik Landeck: Frequently the simple formula is used that “energy transition equals Smart Grid”. But we need to make a differentiation here. On the one hand, the energy transition is aimed at making sufficient transport capacity available at the level of distribution and transmission system operators. On the other hand, it is necessary to ensure a continuous balance between power supply and demand. This means that the necessary transport capacity needs to be made available by further development of the networks. Moreover, it is imperative to develop new intelligent operation concepts and technologies which help to balance consumption and generation. These technologies are then frequently designated as components of a “Smart Grid”.

So there are no Smart Grids yet today?

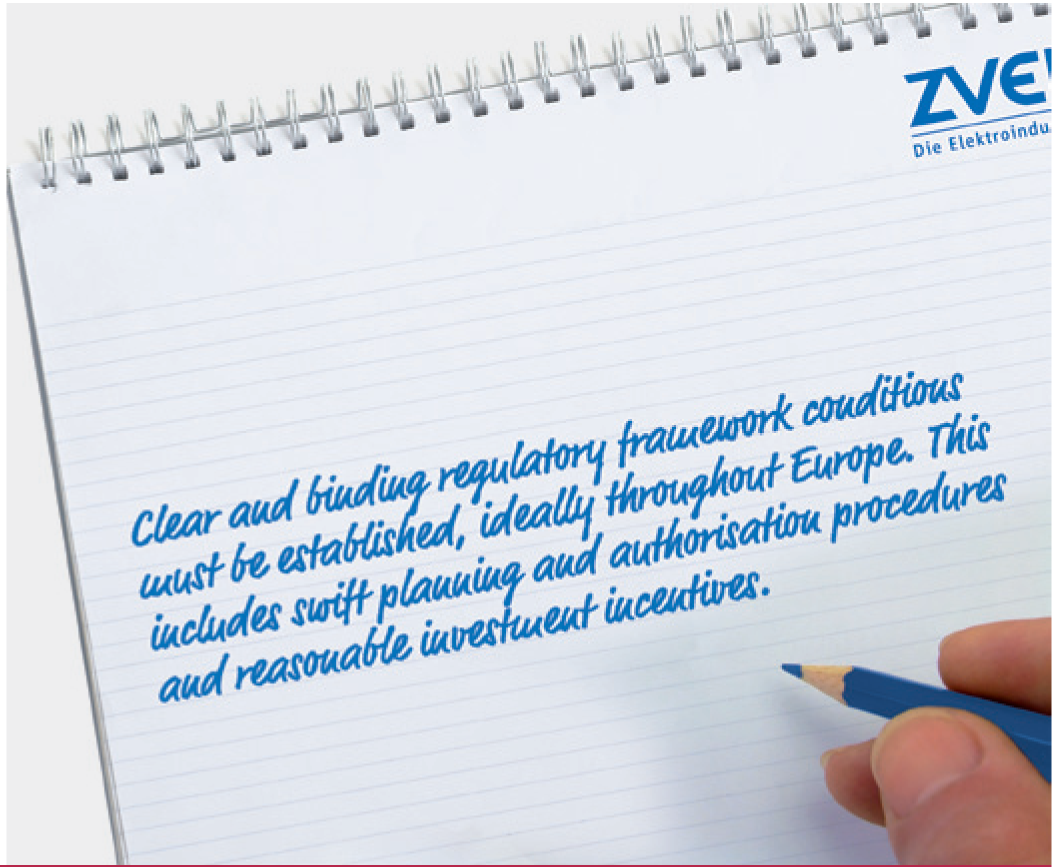
Dr. Erik Landeck: Given the increase in decentralised feed-in, particularly with the control options to be used for loads and injections, sensor systems will have to be installed for monitoring in distribution networks. Smart Grid technologies are integrated in an evolutionary manner when and where it becomes necessary. Demand in rural areas with a higher rate of renewables-based generation differs from that in urban networks which are rather influenced by block-type heat and power plants and electric mobility. The same “Smart Grid solution” therefore does not fit all network problems or tasks. It is already foreseeable today that the many hundreds of thousands of loads and generation plants should not be equipped with proprietary control devices. Standardisation is the only way to reach optimum benefit to the customer, the necessary data protection and above all the requisite network security.

So standardisation is the prime precondition for the energy transition?

Dr. Erik Landeck: Today’s networks have already enabled the rate of renewable energies to increase to more than 20 percent. Further integration of renewable energies depends primarily on network development – some would say “classical network development”. Furthermore, essential principles are being established together with the customers for disconnecting major renewables-based plants. In addition, many network operators are exploring new smart technologies which among others increase the transmission capacity of networks. All this will help when it comes to the implementation of standards. But it is also true that network operators are currently facing higher costs at the present stage, and that the regulatory framework does not provide for an acknowledgement of the costs involved in this development work.

How can manufacturers and the energy sector optimise cooperation?

Dr. Erik Landeck: The cooperation between ZVEI and BDEW for preparing this joint brochure is a good example. The goal is to describe the concrete challenges faced by networks as a result of the energy transition and to develop a realistic idea of the necessary smart technologies. The term “Smart Grid” is certainly used in an almost inflationary manner. We should try first to develop and standardise the essential technologies.



Ralf Christian

CEO Low and Medium Voltage Division, Infrastructure & Cities Sector, Siemens AG

President and CEO of the ZVEI specialist Association and Member of the ZVEI Board of Managing Directors

Expert Statement

Ralf Christian

Where are Smart Grids developing already today?

Ralf Christian: Generally it can be said that Smart Grids are on the advance, given the ever increasing complexity in the requirements for network management and load management. The municipality of Wildpoldsried in the southern Bavarian region of Allgäu shows how Smart Grids can function. Residents generate twice as much electricity from renewable energies than they need for their own demand. The installed Smart Grid ensures stability and balances generation and demand. There are many other initiatives, such as the „E-Energy" funding programme which is currently testing Smart Grid technologies in six model regions throughout Germany.

How urgent is the need for action in distribution networks?

Ralf Christian: There is a great need to act in terms of the strong fluctuations of feed-in from renewable energies which may considerably affect network stability. In addition, energy consumers are increasingly becoming producers. One of the prime tasks therefore is to keep energy generation and consumption permanently in balance. This is achieved in distribution networks by means of sophisticated measurement, control and regulation technologies.

How can the different requirements of distribution networks be met?

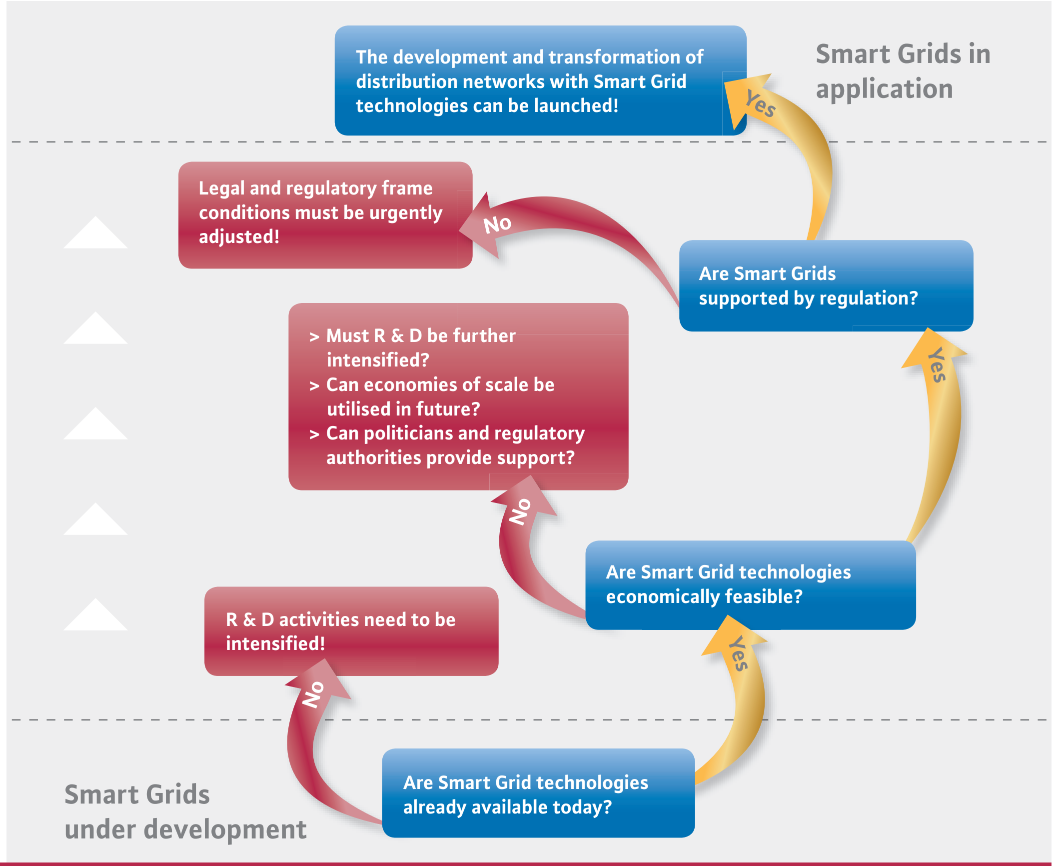
Ralf Christian: As already mentioned before, one of the core tasks is to keep the networks in balance. To this end, information and communication technologies are required. However, at the moment, the communication infrastructure and controllability at the medium and low-voltage levels is mainly heterogeneous. Overall, the intelligence in the networks needs to be increased. Various technologies are already available for that purpose: from smart local network substations and demand-response solutions to Smart Meters. Furthermore, software applications help to determine the optimum design of the network.

What information do manufacturers need from network operators?

Ralf Christian: In order to support the development and reconstruction of networks by the right solutions, it is important to know the system situation in detail. For instance, attention has to be paid to the current load situation and the necessary strategic planning in order to draw conclusions about the future dimensions of the network. Therefore, there cannot be one "Smart Grid" as such: instead, individual solutions will have to be found.

What can politicians do to support the development of Smart Grids?

Ralf Christian: Clear and binding regulatory framework conditions must be established, ideally throughout Europe. This includes swift planning and authorisation procedures and reasonable investment incentives for the provision of reserve capacity, storage possibilities and network development. Furthermore, standards and norms are of essential importance to define the technical framework.



From the system operators' point of view, the time delay for investments in the distribution network must be remedied just like in regulatory systems of other countries. Regulation must offer the right incentives for building Smart Grids.

7. Regulatory conditions

More than 800 electricity network operators and 700 gas network operators are subject to regulation by the Federal Network Agency and the regulatory authorities of the German Laender. The incentive regulation scheme aims at efficient operation of existing networks and provides particular incentives for cost cutting. The Federal Government's energy concept defines an overall strategy for a fundamental transformation of the energy system with renewable energies serving as a mainstay. An efficient network infrastructure is a basic prerequisite to this end. Both at the transmission and the distribution system levels, considerable investments have to be made in the described development and upgrading of network infrastructures. The present regulatory framework needs to be updated for that purpose to promote the use of smart technologies.

For network operators to be able to make the corresponding network investments, they need investment security for their projects through reliable conditions and adequate, internationally comparable rates of return. The crucial problem of lacking economic efficiency for capital expenditure in distribution networks comes from the system-inherent delay of up to seven years between the capital expenditure and the consideration of costs by the regulatory authority. As a result, the rate of return to be obtained from capital expenditure in networks clearly falls below the equity interest rates determined by the regulatory authorities. A rate of interest in line with the capital market is no longer feasible. Even network operators with 100 percent efficiency therefore have no economic incentives to proceed with conventional or smart replacement or extension investments.

The instruments provided hitherto by the incentive regulation ordinance (Anreizregulierungsverordnung – AregV) cannot completely remedy the time delay, as capital budgets for distribution system operators are used only in exceptional cases. The extension factor takes account of changes in the supply task by means of modified structural parameters, regardless of whether the network is developed in a conventional or smart manner. When it comes to investments in information and communication technology, it remains to be seen what effect they will have in future efficiency comparisons. From the system operators' point of view, the time delay for investments in the distribution network must be remedied with the same approach taken by the regulatory systems of other countries. At the same time, it is essential to create incentives for transforming networks into Smart Grids. The research project "Innovative regulation for Smart Grids" funded by the Federal Ministry of Economics and Technology set out to examine how incentive regulation should be developed against the background of an increasing share of decentralised generation and the related necessary network extension. The analysis focused on the future regulation of electricity networks which are to be transformed into Smart Grids in the medium term. One of the central conclusions was that incentive regulation did not provide sufficient incentives for capital expenditure on smart network infrastructures.

Smart Grids will be required in future for adjusting energy demand to generation. They might contribute to reducing the need for conventional development in the distribution system. But they may also have contrary effects, depending on framework conditions and implementation. Potential synergetic effects from pending capital expenditure on equipment replacement may arise if there is a need for development at a certain place where a renewal is required in any case. However, the construction of decentralised generation usually makes it necessary to replace equipment well before it was due to be decommissioned. Smart Grids are based on innovation. It is essential for regulation to provide incentives for research and development activities and demonstration projects by network operators. Current regulatory provisions focus on short-term cost-cutting and do not reward innovative solutions. The BDEW believes that a mixture of instruments consisting of a lump-sum innovation allowance and capital expenditure budgets could be used as an incentive for general or basic R&D projects and efforts. Capital expenditure budgets are suited for application-related pilot and demonstration projects. There is an urgent need to simplify this instrument and make it accessible to distribution system operators.

In future, network development and modernisation must go hand in hand with the development of renewable energies. It is not sufficient to have a promising component available in technical and economic terms. It must also be acknowledged by modern and flexible regulation.

8. Conclusions

The integration of renewable energies is a great challenge for distribution networks. Already today, certain network areas show 100 percent loading by electricity generated from renewable energies. Medium and low-voltage distribution systems need to develop into multi-directionally operated dynamic networks based on Smart Grid technologies. But not all technical components under discussion are equally close to the market and offer a high potential for maintaining system stability and ensuring efficient system operation. This paper on recommended action has described eight components which meet these criteria already today and which may be used to launch the realisation of a Smart Grid "made in Germany".

In the opinion of BDEW and ZVEI, there are three concrete fields of action for distribution system operators. The prime objective must be to improve the information situation by systematically installing sensor systems in the network. As a second step, an intelligent approach and automation of distribution networks will be possible on the basis of controllable local network transformers, controllable converters capable of feeding reactive power into the grid, corresponding standardised communication and data infrastructures and network control technology. A third field of action is system-oriented feed-in and withdrawal. Here great potential is offered in particular by controllable photovoltaic plants and wind turbines, heat pumps as well as micro and mini CHP plants.

In future, network development and modernisation must go hand in hand with the development of renewable energies. Regulatory authorities must make it possible for system operators to carry out the necessary investments in infrastructures, tap available potentials and create new potential by practice-oriented research and development activities. It is not sufficient to have a promising component available in technical and economic terms. It must also be acknowledged by modern and flexible regulation. Adjustments in this respect are urgently required in order to be able to meet the political targets of the energy transition.

The potential provided by storage technologies must also be taken into account. They could make an additional contribution to flexibility in future energy supply and make it possible to use energy generation that currently has to be reduced for system stability reasons. From 2030 at the latest, they will even be a prerequisite for bridging the deficit phases of renewables-based electricity generation.

The challenges and potential solutions described in this brochure show the necessity for close interaction between the energy sector and the manufacturing industry. BDEW and ZVEI will therefore continue to closely follow the implementation of the energy transition and work together to produce recommendations and solutions.

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