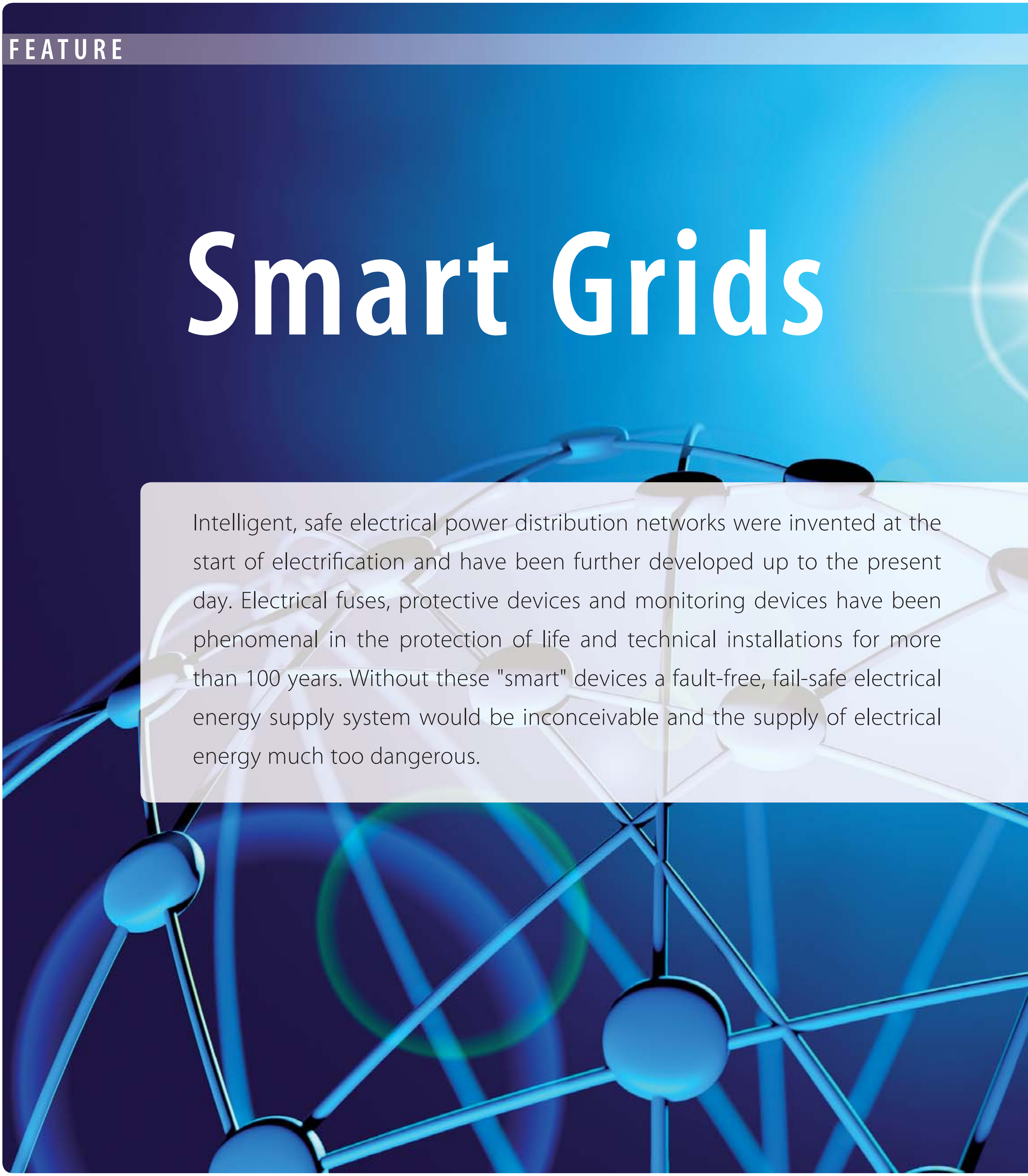
FEATURE

Smart Grids



Intelligent, safe electrical power distribution networks were invented at the start of electrification and have been further developed up to the present day. Electrical fuses, protective devices and monitoring devices have been phenomenal in the protection of life and technical installations for more than 100 years. Without these "smart" devices a fault-free, fail-safe electrical energy supply system would be inconceivable and the supply of electrical energy much too dangerous.

RELIABLE ENERGY DELIVERY

– A 19th century invention

Since the 19th century engineers have developed, tested, used on a large-scale and continuously improved suitable solutions for the safe and reliable operation of the rapidly growing supply of ever more applications with electrical energy. During the sustained further development of the supply systems, it is necessary to handle the available resources (energy sources, technical installations and individuals with experience) as well as the laws of physics both responsibly and in a "smart" manner.

Smart grids help to make it possible to use physics safely and reliably for the benefit of man – in the past, today and in the future

Smart energy supply

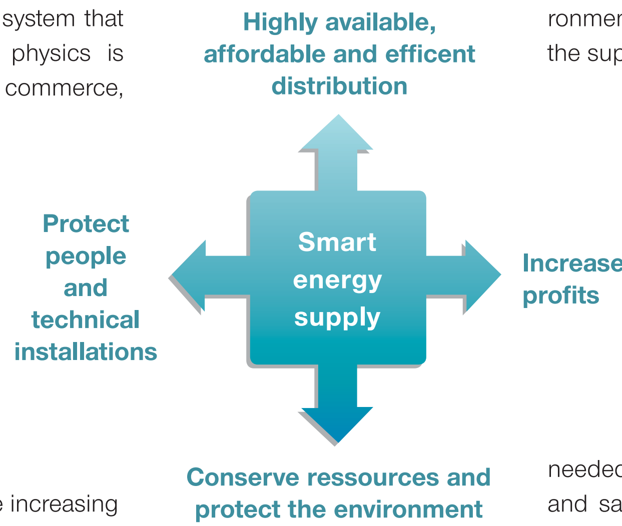
The system for the supply of electrical energy has been in construction for more than 130 years. Along with the high-availability provision of electrical energy, the protection of lives and technical installations has had a significant impact on the development of the supply system. Special concepts, processes and devices were "smart" from the start – the intelligent, selective shut down of a faulty electrical circuit or an intelligently planned redundant system topology result in minimal interruption in supply in the event of a malfunction.

ENERGY COMMUNICATION AT THE FORUM "LIFE NEEDS POWER" AT THE HANNOVER MESSE

Electrical distribution network operator:
"We cannot change Ohm's or Kirchhoff's laws."

Lawyer:
"Objection! Every law can be changed.
Even the constitution with a 2/3 majority."

Such a smart energy supply system that strictly follows the laws of physics is increasing viewed by politics, commerce, science and the public in relation to the conservation of natural resources and the protection of the environment, as well as in relation to the aim of generating profits. Smart grids are viewed as an effective instrument to achieve these goals.



The energy revolution and the increasing interest in renewable energy sources and storage options (for instance pumped storage, gas or heat storage systems) are increasingly frequently viewed in conjunction with new technological capabilities for the quick and safe exchange of information – a core topic of smart grids.

The term "smart grid" as an intelligent energy supply system involves, according to the DKE and IEC smart grid road maps, "the networking, monitoring, control and regulation of intelligent energy producers, storage systems, power consumers and network equipment in energy transmission and distribution networks with the aid of information and communication technology (ICT). The objective is, based on transparent energy-efficient, cost-efficient, safe and reliable system operation, to achieve the sustainable and environmentally acceptable assurance of the supply of energy."

These days a differentiation is made between **smart markets** (in which the market participants who offer or require energy organise themselves) and **smart grids** (the technical installations and processes to be further developed that are needed for high availability, efficient and safe supply based on the laws of physics). Even though both are closely linked, they do provide some orientation in the maze of discussions.

Smart markets with the high volatility of renewable energy sources place comprehensive requirements on smart grids; meeting these requirements requires above all that the solutions are in harmony with the laws of physics for the electrical system. Controlling the volatility of the availability of water and sunlight in the supply of foodstuffs by means of storage, transport and distribution can be taken as an example for the smart supply of energy of the future. The volatile availability of solar and wind energy could contribute to a secure, high-availability, efficient supply by means of increasing storage.

How secure is our supply of energy?

The current raw materials for energy (gas, oil, coal, uranium, ...) and also the volatile sources of energy such as the sun, water and wind are only secure to a limited extent. This uncertainty preoccupies above all the future smart market – it is of lesser importance during the consideration of smart grids.

Smart measures to make the supply of electrical energy secure (in the context of high availability) have been developed and continuously improved since the 1880s. During network planning for the higher voltage networks, the so-called (n-1) and (n-2) criteria have been used for some time – these criteria state that in the event of one (or two) failures due to malfunctions in any item of equipment (generator, transformer, cable, ...) the network as a whole must safeguard the supply within the stipulated limits. Higher costs for their implementation are justified because, for instance, interruptions in the supply to large areas can be prevented by redundant cable routing or power stations.

The European transmission systems are coupled together into an integrated European network and some are also integrated into a grid control network so that, on the failure of a component in a system, or in case of an imbalance in the generation and consumption of power in a sub-system, help can be obtained from a neighbouring system. These transmission systems can quite rightly be termed high-voltage smart grids.

In distribution networks (medium voltage, low voltage) on the other hand the risk of an interruption in the supply for minutes or hours is accepted in the majority of cases. Here the distribution network is often not constructed based on the (n-1) criterion. Accordingly few or even no technical features are provided that could automatically compensate for the failure of a component or an imbalance between generation and consumption.

In the area of energy supply systems a large number of system-related limits and parameters (trigger current for circuit breakers, frequency, voltage, insulation on a cable, ...), secondary devices (measuring systems, controllers, regulators, ...) and primary devices (transformers, circuit breakers, inverters, ...) as well as in future many components at the integration levels (above all the communication infrastructure such as Ethernet switches, routers, backup power supplies) must be constantly monitored, and that mostly in real-time. In the case of developing malfunctions it may be necessary to intervene with control measures within milliseconds. If action is not taken until a component fails, then an entire system may easily collapse with unpredictable consequences for people and the environment if a fail-safe supply is imperative.

Since the start of electrification, particularly high value has been placed on the protection of individuals against physical contact with the electrical system. Worldwide it is state-of-the-art to protect people against the hazards of electrical power. A series of IEC standards and other standards define suitable measures that have made possible a high safety standard.

In relation to electromagnetic compatibility (EMC), electronic devices in the area of the supply of electrical energy must meet particularly high requirements that go way beyond the requirements in the office or industrial environment. The "IEC Smart Grid Standardization Roadmap" from 2010 clearly refers to these requirements. In the second version of the familiar American "NIST Framework and Roadmap for Smart Grid Interoperability Standards" (2012) these requirement were recently placed alongside the requirements for communication security. The availability of an automation or communication component must be much higher in an energy supply system than in the office or residential sector.

Furthermore physically extensive integration levels require high security in relation to the availability and vulnerability of the infrastructure and the supply systems, in the past the topic of security has been largely ignored during the implementation. In the future energy supply, this topic must be taken significantly more into account in the implementation and the solutions must be much more rigorously applied.

Smart solutions for a secure energy supply are required for generation, transport, distribution and the power consumers – in public distribution networks just as in public buildings and offices, as well as in other items of infrastructure such as transport systems or the Internet.

What will be new in the future?

The reliable and secure operation of the future electrical supply system places new challenges on engineers, businessmen and politicians, and has done so particularly since the turn of the century. Necessary changes are to be expected due to:

→ The rapidly growing number decentral feed points, the transition from central to more decentral electricity generation,

→ The development of renewable energy generation,

→ The development of the integration level and

→ The ageing distribution network infrastructure.

These changes must be made "open heart" (that is while providing supply) against the background of the following issues:

→ An increasingly ageing and therefore reducing technical expertise,

→ The demand for more energy efficiency,

→ The short time for implementation and

→ The high expectations on profitable investments in increasingly networked supply systems for electrical energy, gas, heat and transport.

The broad and intense discussion to be observed in recent times and the publication of comprehensive studies and opinions from politics, research institutes, associations, federations and industry is unprecedented in the construction of the electrical supply system. What is so interesting about the supply of electrical energy in the future? For many manufacturers who traditionally operate in the area of industrial automation, or in the area of network technology, the Internet or cloud computing, the increasingly necessary equipment for the integration infrastructure in distribution networks appears to be a massive new market.

Can Internet technologies and general automation solutions help?

„**Energy-on-demand** is considered by many to be solution for the efficient usage of energy."

Internet for energy

The BDI (Bundesverband der Deutschen Industrie e.V.) stated the following on the topic of the smart grid: "Information and communication technology will have a key role during the development of a supply of energy suitable for the future. It is the basis for the realisation of a future **energy internet**, that is the intelligent electronic networking **of all components in the energy system.** ... The biggest challenge here is to create an **integration level between business applications and the physical network** that makes possible the communication between complex IT components distributed across heterogeneous networks and organisational boundaries."

Is such an integration level primarily of service to the smart market or the smart grid at the distribution level, or both? The components installed today at the higher voltage levels are already effectively networked (CIM for grid control centre internal communication, telecontrol for communication with grid control centres and power generation systems as well as IEC 61850 for substations and power generation systems). With the need to integrate thousands of times more components in the lower voltage levels than in the higher voltage levels, it is still largely unclear which tasks they will have and how these can help also in the long-term to maintain the stability of the supply of electrical power at its current level.

Energy-on-demand is considered by many to be solution for the efficient usage of energy. In the context of social networks power consumers could suddenly develop volatile consumption behaviour and synchronously increase or reduce their consumption either in a limited area or over a large area, an event that could have unexpected effects on the systems and in some cases could result in the collapse of the system.

A key question for the realisation of future systems is knowledge of possible and probable failure scenarios. How many feed points

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and loads in the distribution networks can be controlled at which points using communication, and which regulation mechanisms could compensate for these effects adequately and quickly enough such that the distribution networks can be operated stably at all levels at all times?

Even under the assumption that all effects are known and corresponding mechanisms for stable system operation have been developed and tested, key questions remain unanswered: who is to finance this automation infrastructure and the related Internet-based integration levels foreseen and, above all, who is to implement, install, integrate, utilise and further develop it? ■

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CONCLUSION

The construction of automation infrastructures and integration levels for the supply of energy requires resources that go way beyond current notions and the resources that are available in the short-term. Financial aid for smart energy supply systems must not be primarily an "economic stimulus package" for the integration levels. The aspects such as the electrical safety, the high availability of the supply of energy, the ageing electrical and information technology infrastructure and above all the ageing personnel for the further development and operation of the electrical system must have a significantly higher priority.

The future supply of energy must be understood as a whole. Development must be understood as continuous "further" development of the existing systems with all their complex aspects. Only then can the familiar security of supply of the past also be ensured in the future. The scope and also the required short implementation period will overshadow all the experience of the past 130 years.

The energy revolution currently in planning and the concomitant development of a step-by-step structural change and a closer meshing of the energy networks for electricity, gas, heat and electric mobility, as well as the related necessary infrastructure will be more of a marathon than a sprint. Inter-disciplinary collaboration above all among the electrical engineers and power engineers must be significantly expanded. IEC standards and other standards can, above all against the background of limited development resources, make an important contribution to the simplification of solutions at the integration levels.

The smart grids that will result from the energy revolution will combine the inventions of several hundred years.