Smart grid: new prospects or new problems?

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In recent years, the term "smart grid" has lost its original meaning. Today, it seems to refer to almost the entire power industry – from power production systems and grid structure and configuration to metering and information-measuring systems, automated control systems, communication between power facilities and relay protection.

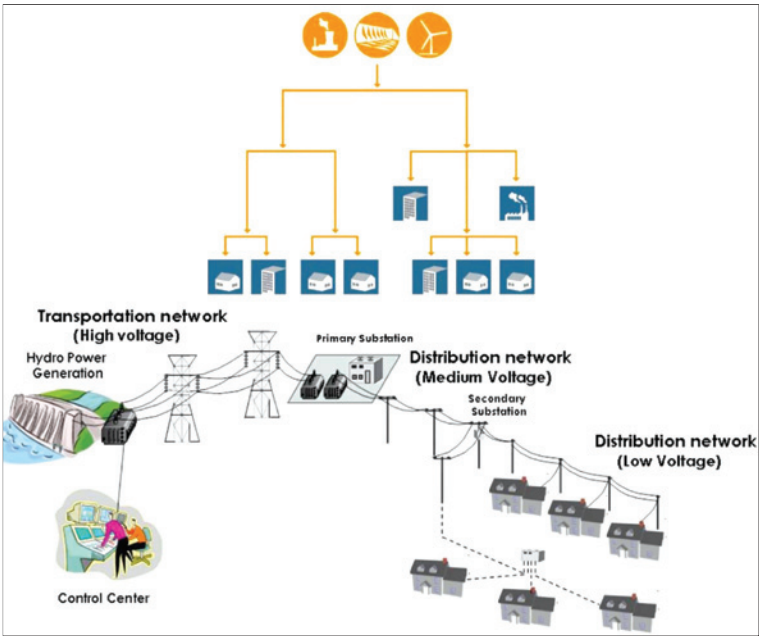

Fig. 1: Today's electric grids are hierarchical.

The term has lost its definition and is assigned different meanings by different authors. In some articles, it is used in connection with principles of construction and configuration features of power mains. Other smart grid articles focus on establishing communication channels and data transmission principles, or on environmental issues and sources of alternative power.

Power production systems

Climate change issues and dwindling supplies of organic fuel have prompted the development of alternative energy sources. These are expected to be connected to different points of a common network. This means that, in future, power production facilities will be distributed rather than concentrated as they are today. These sources, however, have relatively low capacity and unstable power parameters.

An intelligent control device is required to stabilise the parameters of alternative energy sources and to provide their automatic synchronisation with the grid. The smart grid's functions would include the development of new power generation systems and the improvement of the technical and economic efficiency of existing plant, as well as the design of appropriate automatic control devices and communications systems facilitating information exchange between such sources and other power system units.

Electrical grids

Today's electrical grids are hierarchical (Fig. 1.) Most modern electrical grids consist of radial lines with one-way energy flow. This will not be the case with future smart grid networks, where large power consumers will be mixed with relatively low-power energy sources, individual high power plants, voltage regulators, reactive power compensators, etc. It will be a very complex, unstructured and extended network.

Power flows within this network will not be strictly deterministic. Such a complex, unstructured grid (which can, in a sense, be compared to the internet) would need a powerful control system to align the operation of all network components with each other. All components of the network must communicate with each other and with the control centre via wireless communication networks. Development of powerful, fully-managed network components equipped with self-diagnostic systems and monitoring capabilities, as well as with reliable data transmission and input channels, is one of the directions of the smart grid concept development.

Monitoring and self-diagnostics

The sophistication of powerful grid components, together with recent progress made in computer-controlled systems, have paved the way for health monitoring systems for electric equipment to prevent network component failure.

Special indicators and reliable diagnostic procedures for the constant monitoring of the health of important network components are made possible by the law of the aging of electric isolation; knowledge of the trends in composition of supply transformer oil, as well as by known features and properties of partial discharges in solid, liquid and gaseous isolation, as well as in vacuum.

Communications and data transfer

Today, communication and data transfer across power facilities are realised through different circuits. This includes low-voltage communication networks (low-frequency control cables, coaxial high frequency cables), optical cables, high voltage power lines, protected directional radio circuits, etc. In recent years such network technologies as ethernet and the internet have become increasingly applicable. This resulted primarily from their affordability, prevalence and ubiquity, well-developed technology and communications protocols, as well as from an increase in the sizes of data files exchanged across multiple power network components scattered over large territories.

The market offers various electronic sensors, transducers and sensing devices equipped with affordable built-in ethernet/intranet modems.

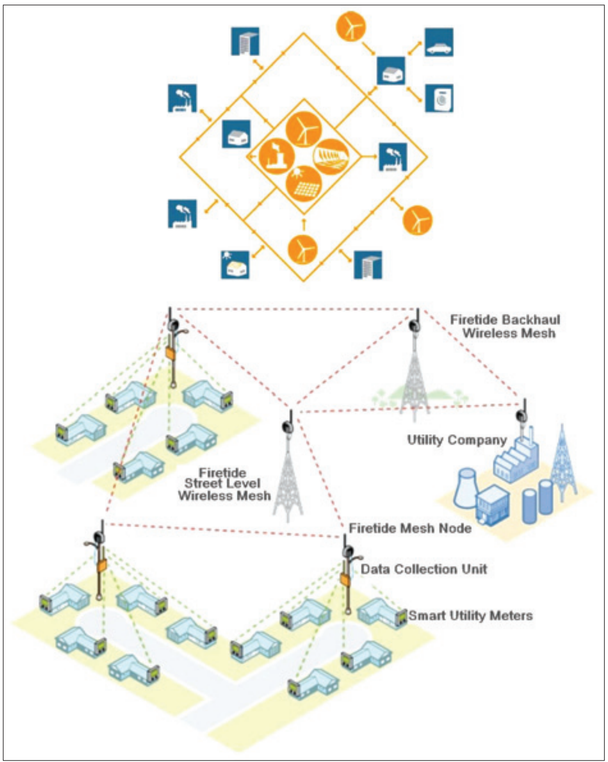

Fig. 2: Smart grid will use a verity of data networks.

Optical communications used in relay protection are considered too expensive to be extended and applied universally within the future smart grid concept. Companies occupying particular sectors of the communication and data market are competing to promote the use of their systems within the smart grid concept.

For example, along with allegations that the future belongs to standard network applications such as ethernet/intranet exclusively, it has been claimed that the only valid means of communication would be a broadband high-voltage power line solution. Discussions on the application within the smart grid of wireless communications solutions such as cellular networks, WiMAX, Wi-Fi, etc. are also underway (Fig. 2).

Electric power metering system

Microprocessor-based power meters entered the market many years ago without any connection to the concept of the smart grid. On the contrary, the term smart grid initially only to promoted meters that were developed for a future globalised power industry.

Multi-rate microprocessor-based meters capable of performing calculations, communicating with other, similar meters, and disseminating data over the network have been used in energetics for many years. Recently, simplified versions of such meters have been applied in everyday life. Advancements in this field have made this technology ideally suited for application in the smart grid.

Operating principle of the smart grid

Reliable operation of a system as complex as a smart grid can be achieved by minimising the number of individual multi-function data processing modules (implying further concentration of functions in single modules). Data sent from multiple components of the smart grid must be transferred to powerful servers through networks, processed by computer centers and sent through the network to actuators.

Relay protection

The new smart grid concept considers a combination of relay protection with the functions of information measuring systems. The reason for this is that microprocessor based relay protection devices (MPDs) measure current and voltage in vector form, and collect emergency and actuation data.

This data can be used directly in future control data measuring systems of the smart grid concept, within which the relay protection would be assigned to additional functions of measurement, monitoring and diagnostics of electrical power systems.

Apologists of the smart grid foresee future MPDs converted into data centers connected to the ethernet only. Such MPDs would have no traditional input or output circuits as all the components of the smart grid, including high-voltage switches, would take advantage of network connectivity. All commands, including those to release circuit breakers, would be transmitted as GOOSE messages under IEC standard 61850.

Input current and voltage circuits are not expected to be included into MPDs due to the transition to non-conventional current and voltage transformers with digital output. Furthermore, such transformers will presumably transmit to MPDs "ready-to-use" digital data about currents and voltages over the network.

Relay protection algorithms are likely to undergo significant changes due to the modification of electrical network design, as well as to fully managed network components such as high-speed reactive power compensators and current limiting devices that can affect network operation modes.

These are, however, only the first steps towards the restructuring of relay protection. Serious discussion abounds in current technical literature on adaptive and multidimensional relay protection, proactive, relay, fuzzy logic, artificial intelligence, and neuron protection systems.

Smart grid: panacea or road to hell?

Reconstruction of the whole power supply system would require enormous investments, and it is necessary to weigh the potential benefits: what economic returns can we expect from these investments? As it happens, none of the numerous publications proclaiming the advantages of the smart grid makes any business case for the realisation of the smart grid concept.

Doesn't the existing structure of electrical networks provide a steady electrical supply to end-users? Aren't microprocessor-based electric power meters more widely applicable beyond this concept? Does the development of modern microprocessor-based automated diagnostics systems suffer from the lack of a smart grid? Aren't modern MPDs capable of meeting all current challenges of relays?

The radical change of network configuration and appearance of numerous power sources in a network can change functions and algorithms of relay protection dramatically. However, how can nation-wide electrical network structures which have been developed over decades change so fundamentally? And why? It is doubtful whether a large number of small power generating sources (wind generators, solar batteries etc.) will be included in the electrical network of the future as champions of the smart grid expect. In countries like Germany, Italy, the Netherlands and Spain, wind generators or solar batteries were not used as single network power units (except for the individual devices powering separate facilities). The common practice is to combine them with large power units. For example, the capacity of the Thanet wind generator in the UK, which currently consists of 100 turbines, is 300 MW.

Available microprocessor-based automatic operation systems manage such large power installations successfully and synchronize them with the networks without any smart grid. Besides, the wind-power industry is not all that profitable. According to the British Energy Research Centre, electricity produced by wind power stations is 90% more expensive than power produced from traditional fuel sources and 50% more expensive than the energy produced from nuclear generation.

However, if we view the smart grid concept as a fundamental reconstruction of electrical grids resulting in sophisticated structures and operations, we should bear in mind the predictability of such modes. We should also determine the extent to which the set points will be able to reflect actual grid emergency modes. The complexity of the network and the large amount of cross-coupled active components will make finding the reason for a failure a real challenge, even when self-diagnostics devices are used. This would require the modeling of network operation modes, as well as considerable research.

Such networks will be far more difficult to operate and will require more skilled staff than do existing grids. The smart grid's concept of "one-and-all" computing is already in full use in industry and energetics alike. The tendency to integrate all kinds of power equipment with the computer network and to move from analogue electronics to digital microprocessor based units very often has catastrophic consequences.

Relay protection is another issue. Expected developments within the smart grid include the concentration of more functions within single microprocessor modules; the combining of relay protection with power equipment monitoring and diagnostics functions, and the application of fuzzy logic algorithms, proactive functions, artificial intelligence, neuron nets, etc. To this day, MPDs are less reliable than electromechanical (EM) relays. This doesn't mean, however, that the transition from EM relays to MPDs should be slowed down. There are a few important pointers to bear in mind during the transition process:

- Do not flood MPDs with functions other than relay protection such as the monitoring of electric equipment
- Limit the number of functions in a single microprocessor terminal
- Refuse fuzzy logic algorithms providing relay protection unpredictability
- Simplify the program interface as far as possible based on a unified MPD software platform
- Manufacturers of computer-based test equipment for MPDs should develop a set of programs fully compatible with the unified MPD software platform. This will allow complete automation of MPD testing, thus minimising human error
- Develop new MPD design principles based on universal interchangeable functional modules such as PCs
- Conduct research and development to ensure the required functionality of relay protection under malicious destructive electromagnetic impacts by, for example, improving MPD sustainability against such actions or by providing a redundant emergency set of electromechanical RPs

The advantages of comprehensive implementation of the smart grid concept are not as obvious as its apologists would have them be. No-one has demonstrated its economic feasibility yet. Projects with proven economic efficiency are undertaken without any connection to the global concept of the smart grid.

Smart grid vulnerability

If all elements of the smart grid are controlled by means of TCP/IP protocols, the danger of external intervention in power system operation becomes very real. Many experts emphasise this hazard and devote international conferences to it while smart grid apologists only show concern with isolating the internal network of the smart grid from the external web. They speak of access passwords and other trivial safety measures which can limit access for most people, but not for experienced hackers able to crack even the well-protected networks of national defense ministries and banks.

The armies of many countries have special divisions consisting of skilled professionals trained to crack and sabotage enemy computer networks. Smart grid computer networks will almost certainly be the target of these divisions.

The concept of the smart grid as the widest application of microprocessor devices in all aspects of electric power systems and the tendency to increase the density of elements in microchips, combined with advances in the field of remote destruction, form a very dangerous vector.

Today, these threats are realities while full, practical implementation of the smart grid concept is still very far off. But what will happen once this concept is developed and implemented? Full implementation of the smart grid concept will render electric power systems vulnerable and decrease their sustainability.

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