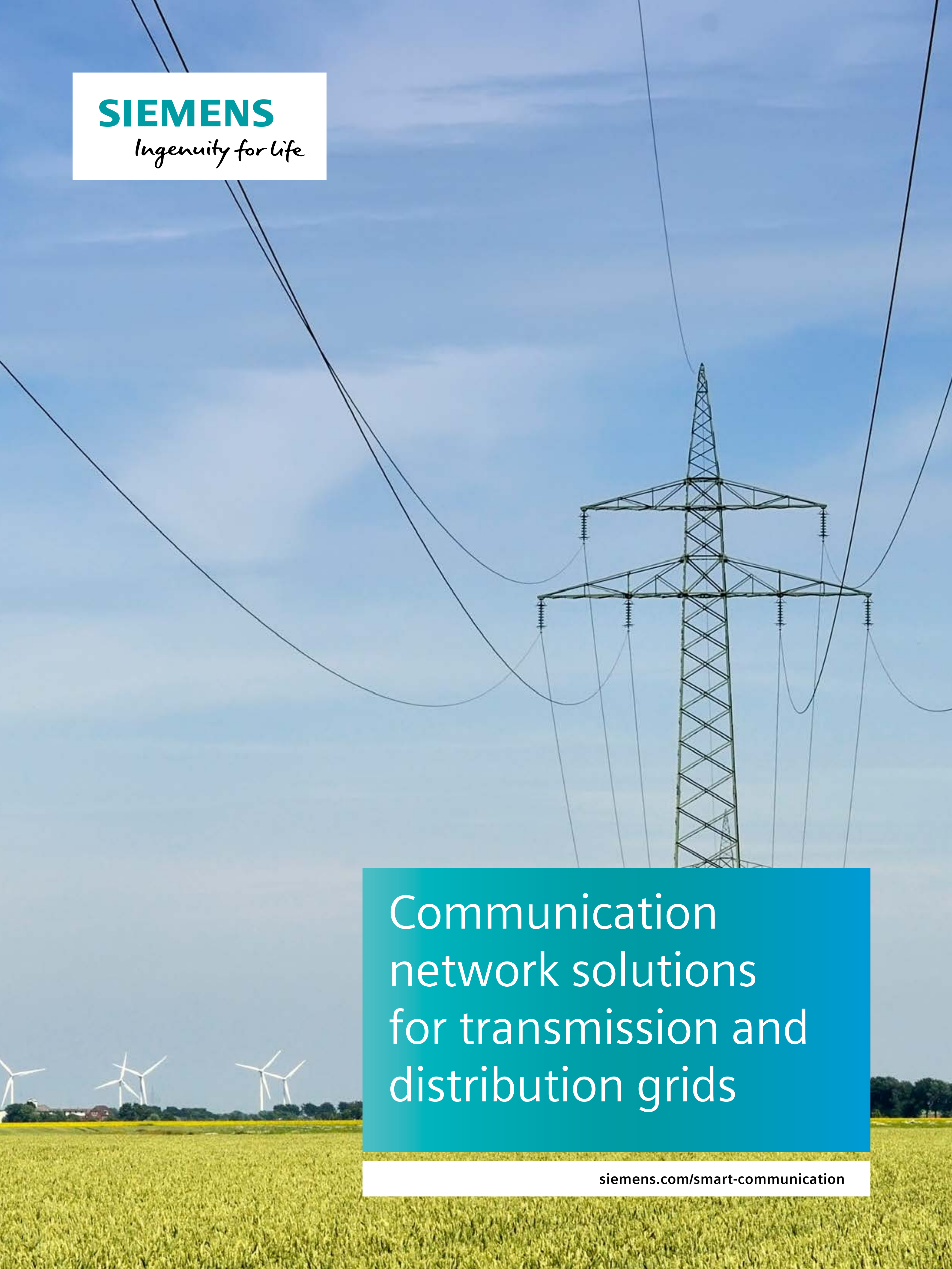


Communication network solutions for transmission and distribution grids

siemens.com/smart-communication

Communications solutions are manifold – but we put it all together

A secure, reliable, and economical power supply is closely linked to a fast, efficient, and dependable communications infrastructure. The planning and implementation of communications networks require the same attention as the installation of the power supply systems themselves.

New challenges for energy networks …

As a result of the deregulation of the energy markets, the separation of the vertically integrated structures of the past, and the sharp increase in decentralized power generation, the reliable management of power supply systems is increasingly challenging. This development goes hand in hand with the rapid growth in the demand for communications. This is not just a question of higher bandwidths but also of communications requirements for new energy applications, including meter data management, distribution automation, and demand response, to name just a few examples. At the same time, energy network components like ring main units, distributed energy resources, virtual power plants, microgrids, public charging, energy storage, and private households need to be integrated into the power utilities' communications infrastructure for smart grids.

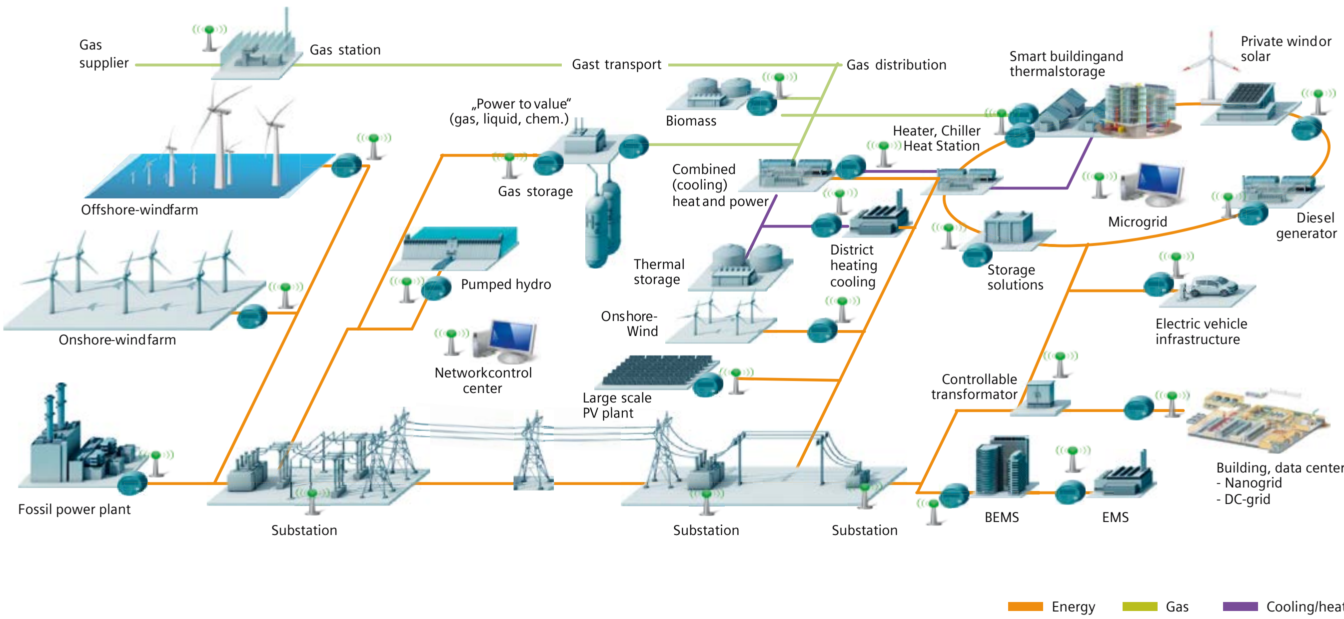
Evolution of communications technology …

In a parallel process, communications technology has continued to develop rapidly over the past few years, and Ethernet has become the established standard in the power supply sector.

International communications standards like IEC 61850 will further simplify the exchange of data between different communications partners.

Migration to a smart-grid communications network …

This means that the power utilities' mostly heterogeneous communications networks, with their gaps in coverage and bandwidth, need to be migrated to a smart-grid communications infrastructure. That will provide IP/Ethernet connectivity between most components. The gradual migration of most conventional communications interfaces and products toward TCP/IP-based networks and the extension of network access down to the consumer level are therefore an important task for decision makers at power supply companies. To meet these challenges, a team-oriented and interdepartmental planning of migration concepts is required.



Siemens offers complete communication network solutions to build a Smart Grid for power utilities

We offer a tailored solution

For these communications requirements, Siemens offers customized and rugged communications network solutions for fiber-optic, power line, and wireless infrastructures based on the accepted standards of the energy industry.

Naturally, this also includes a full range of services, from communications analysis to the operation of the entire system.

Your advantages at a glance:

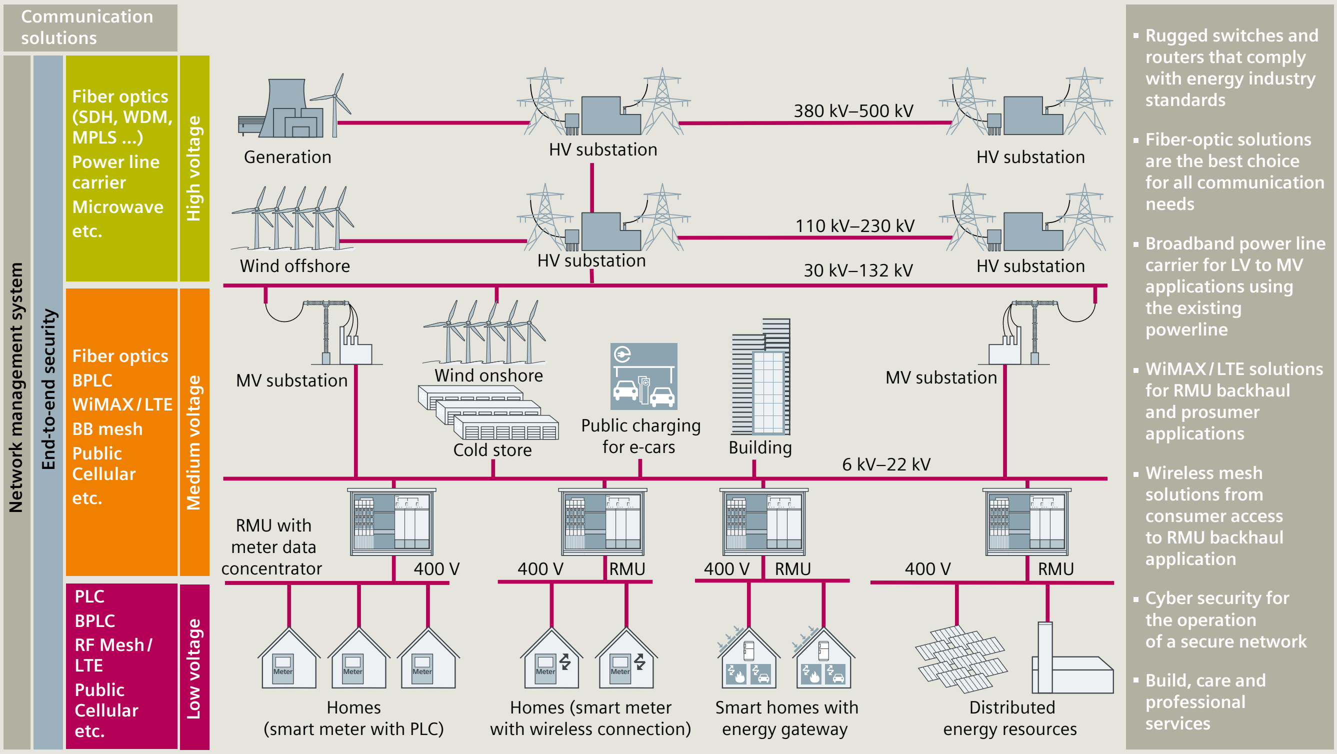
- We offer tailored turnkey solutions for building a power utility communications network.
- We shape the future in terms of technology, standards, and solutions.
- Our customers benefit from Siemens' security expertise.
- We offer customized after-sales services.
- We provide financing models.
- Our customers benefit from Siemens' global presence and long experience in the utility industry.

Customer-specific communications solutions required

There is a lot to do – on the journey to the grid of the future.

Telecommunication for utilities has a long history in the transmission level of the power supply system and Siemens was one of the first suppliers of communication systems for power utilities. Since the early 1930s Siemens has delivered power line carrier equipment for high-voltage systems. In today's transmission systems, almost all substations are monitored and controlled online by Energy Management Systems (EMS). The main transmission lines are usually equipped with fiber-optic cables, mostly integrated in the earth (ground) wires (OPGW: Optical Ground Wire) and the substations are accessible via broadband communication systems. The two proven and optimal communication technologies for application-specific needs are Synchronous Digital Hierarchy (SDH) and Multi-Protocol Label Switching (MPLS) solutions. Fiber-optic cables are used whenever it is cost-efficient. In the remote ends of the power transmission system, however, where the installation of fiber-optic cables or wireless solutions is not economical, substations are connected via digital high-voltage power line carrier systems.

The situation in the distribution grid is quite different. Whereas subtransmission and primary substations are equipped with digital communication as well, the communication infrastructure at lower distribution levels is very weak. In most countries, less than 10 % of transformer substations and ring-main units (RMU) are monitored and controlled from remote. The rapid increase in distributed energy resources today is impairing the power quality of the distribution network. That is why system operators need to be able to respond quickly in critical situations. A prerequisite for this is the integration of the key ring-main units as well as the volatile decentralized wind and solar generation into the energy management system, and thus into the communication network of the power utilities. Because the local environment differs widely, it is crucial that the right mix of the various communication technologies is deployed. This mix will need to be exactly tailored to the utilities' needs and the availability of the necessary infrastructure and resources (e.g., availability of fiber-optic cables, frequency spectrum for wireless technologies, or quality and length of the power cables for broadband power line carrier).



Communication network solutions for Smart Grids

In the consumer access area, the communication needs are rising rapidly as well. The following Smart Grid applications request a bidirectional communication infrastructure down to consumer premises, or to the loads.

- Exchange of conventional meters with smart meters, which provide bidirectional communications connections between the consumer and energy applications (e.g., meter data management, marketplace, etc.).
- Management of consumers' energy consumption, using price signals as a response to the steadily changing energy supply of large distributed producers.
- If a large number of small energy resources are involved, the power quality of the low-voltage system must be monitored, because the flow of current can change directions when feed conditions are favorable.

The selection of a communication solution depends on the customer's requirements. If only meter data and price signals are to be transmitted, narrowband systems such as narrowband power line carriers or GPRS modems are sufficient. For smart homes in which power generation and controllable loads (e.g., appliances) or e-car charging stations are to be managed, broadband communication systems such as fiber-optic cables, power line carriers or wireless solutions (e.g., LTE) are necessary.

For these complex communication requirements, Siemens offers tailored ruggedized communication network solutions for fiber optic, power line or wireless infrastructures, based on the standards of the energy industry. Naturally, this also includes a full range of services, from communication analysis to the operation of the entire solution.

Distribution networks

Solutions for distribution grids (backhaul / access communication)

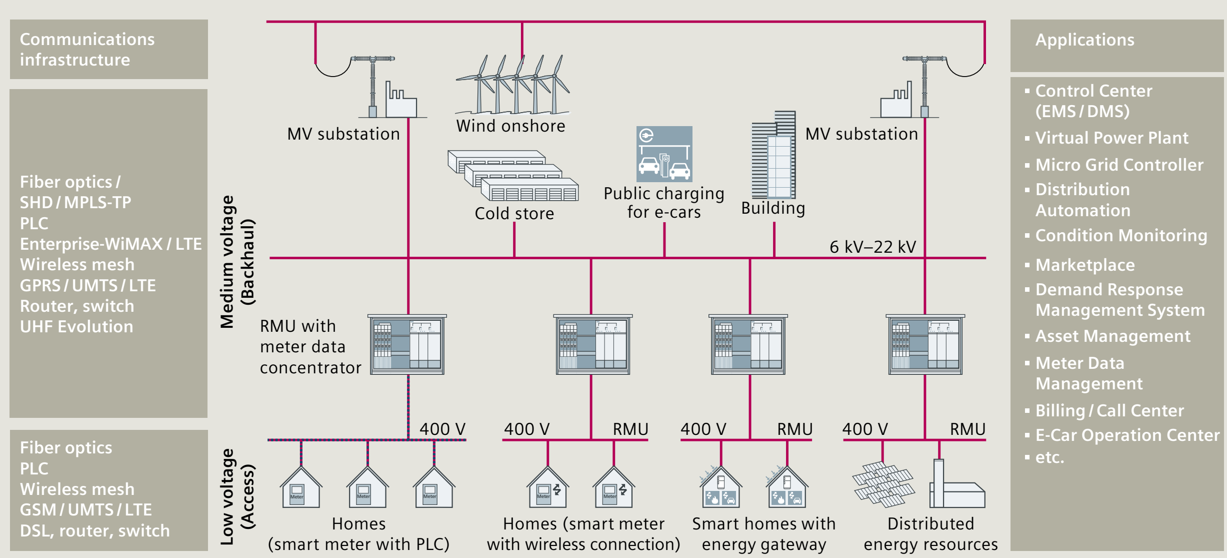
In the past, electricity was mainly produced by bulk generation at central locations, and distributed to consumers via the distribution systems. Energy demand peaks (e.g., at midday) were well known and balanced out by reserve capacity of central power plants. It was therefore usually not necessary to specially control the lower-level distribution networks, or even to integrate the consumers into the grid monitoring system.

Ever since renewable energy has been significantly expanded, electricity is being fed into both the medium-voltage and low-voltage systems, depending on changing external conditions (e.g., weather, time of day, etc.). These fluctuating energy resources can severely impair the stability of the distribution grids.

Buildings account for 40 % of the world's energy consumption and 20 % of total CO_2 emissions. Therefore, smart buildings also play a central role in the Smart Grid as they provide a huge potential for energy efficiency. Actively influencing their consumption and generation, smart buildings support the system stability and allow generators to consider other options before adding new generation facilities.

One of the key challenges of a Smart Grid therefore is quickly balancing out the energy supply and energy consumption in the distribution system.

Typical power distribution network integrating ring-main units, consumers, prosumers, distributed energy resources, etc.



New challenges for the operation of distribution grids

Communication infrastructures for backhaul and access networks

A prerequisite for implementing a solution for this demand is monitoring and managing as many components of a power supply system as possible all the way to the consumer. The basis for this is a reliable communication infrastructure. For medium-voltage, at least the following system components must be integrated into a Smart Grid and managed:

- The key ring-main units
- All large distributed producers (solar / wind farms, biogas / hydroelectric power plants, etc.)
- Large buildings, campuses, refrigerated warehouses, etc.

For low-voltage, primarily households and small producers of renewable energy are involved.

With respect to their role in the power supply system, consumers can be divided into two groups:

- "Standard consumers", who have smart meters and optimize their electricity costs via ongoing price signals depending on supply and demand
- "Prosumers" (prosumer = producer + consumer), who can feed surplus energy into the power grid – such as solar power or energy generated by combined heat and power systems (CHP); many can also intermediately store energy using possibilities such as night storage heaters or e-cars.

While the communication requirements for standard consumers are concentrated on smart metering including price signals, time-critical control signals and power quality data must also be transmitted for prosumers. Therefore, in addition to smart meters, prosumers have energy gateways, which process and forward these control signals accordingly.

The young history of Smart Grids has already shown that utilities do not implement it as a whole from the scratch. They usually start with smart metering projects with later extensions of Smart Grid applications.

Already with the first roll-out, the design of the communication infrastructure has to consider the growing requirements for these extensions. After a large deployment of metering infrastructure in the first step, it is not acceptable to replace the communication network a few years later because the requirements for the next subsets of Smart Grid applications cannot be met anymore.

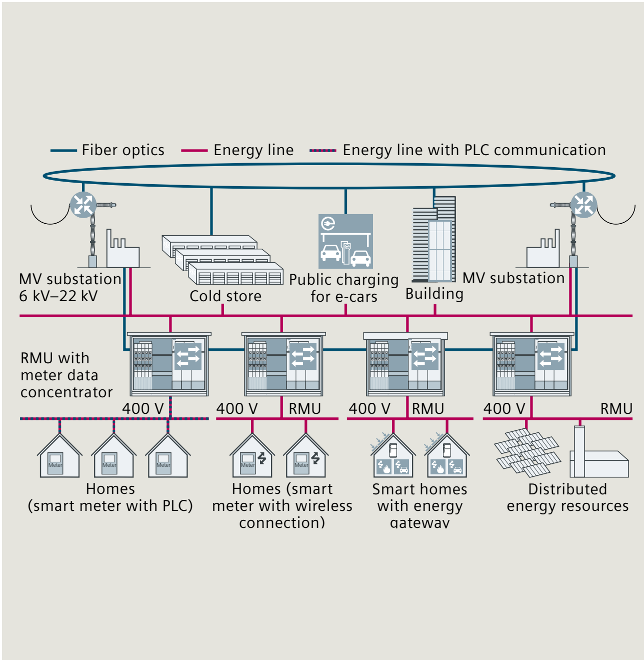
Communications infrastructures for all conditions

The communication infrastructure in the medium-voltage and low-voltage distribution systems is usually heterogeneous, and the suitable technologies depend to a large extent on the local topology (large city, rural region, distances, etc.). It must therefore be specifically tailored for each customer.

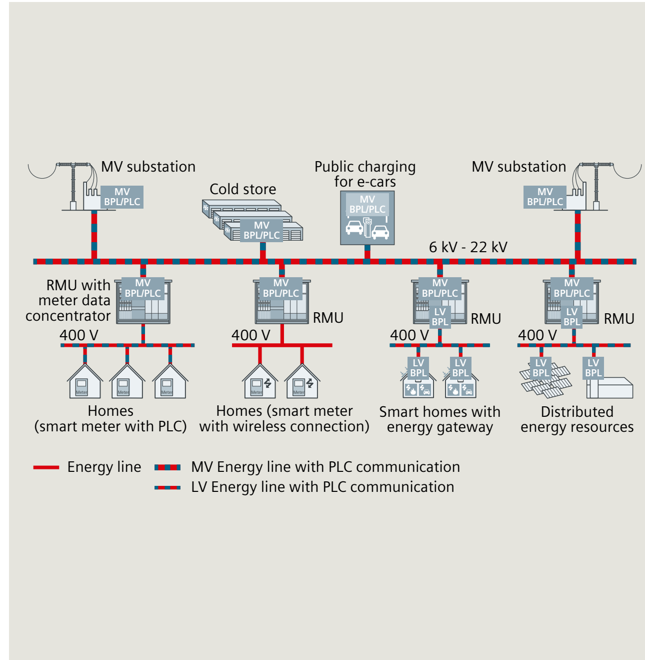
In general, the following communication technologies are available:

- Fiber-optic or copper communication cables are the best option, if present
- Power line carrier systems for medium-voltage and low-voltage networks
- Setup of own private wireless networks (e.g., wireless mesh, private Enterprise-WiMAX / LTE, or UHF Evolution), when spectrum is available at reasonable prices or local regulations allow for it.
- Public wireless networks, depending on the installation for narrowband communication in the kbps range (e.g., GPRS), or in the Mbps range (e.g., LTE). Attractive machine-to-machine (M2M) data tariffs and robustcommunication in case of power outages are key ingredients to make this communication channel a viable option.

Depending on the applications being installed inside the RMU, an Ethernet switch / router might be needed in order to concentrate the flow of communications. These data concentrators can be implemented as customized solutions or integrated, for example, in the RTU (remote terminal unit). To meet these requirements, Siemens offers a full range of all above-mentioned communication technologies including rugged switches and routers that comply with energy industry standards.



Fiber-optic infrastructure for distribution network



Power line carrier communication solutions for distribution networks

Fiber optics

The best choice for all communications needs
Fiber optics is the best transmission medium for medium- and low-voltage applications because it is robust and not susceptible to electromagnetic disturbances or capacity constraints. That's why grid operators who choose this technology will be well prepared when their communications needs multiply in the future. Fiber-optic cables are laid underground to connect individual substations. This work is associated with heavy civil works, and therefore with great expense. However, when new power cables are installed the cost-benefit analysis paints a clear picture. Fiber-optic cables should generally be the first choice in this case.

Benefits in detail:

- At the core of a variety of communications systems, from passive optical networks (PON) to Ethernet and SDH
- Durable, insusceptible to electromagnetic disturbances
- Practically unlimited transmission capacity

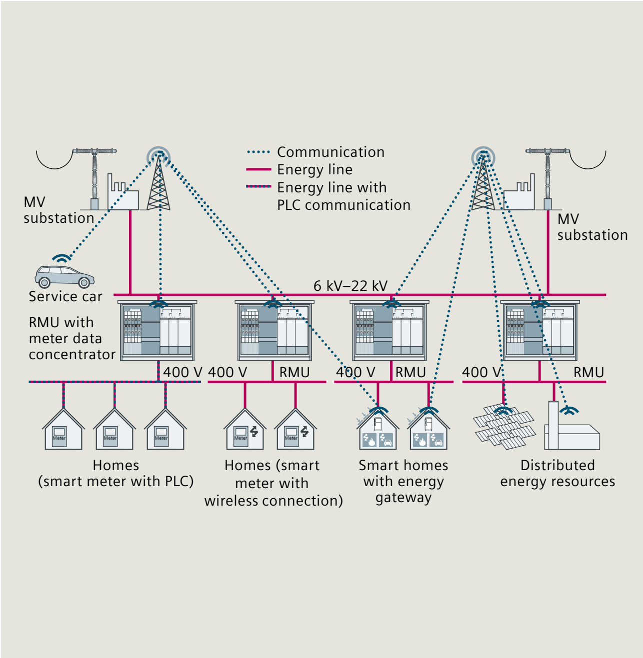
Power line carrier solutions

For low- to medium-voltage applications, using the existing power line
Standards-based power line carrier solutions provide an attractive communication channel for all applications in medium-voltage and low-voltage Smart Grid scenarios. They use the utility-owned infrastructure in the distribution network, and provide a reliable and affordable communications channel. Therefore, PLC solutions are especially useful for connecting elements in grids, where no other reliable communication channel is available. They transform the DSOs assets into a highly capable Smart Grid communication infrastructure. With its throughput, low latency and high reliability, PLC solutions serve for distribution automation applications as well as for backhauling data from metering applications in the medium-voltage grid.

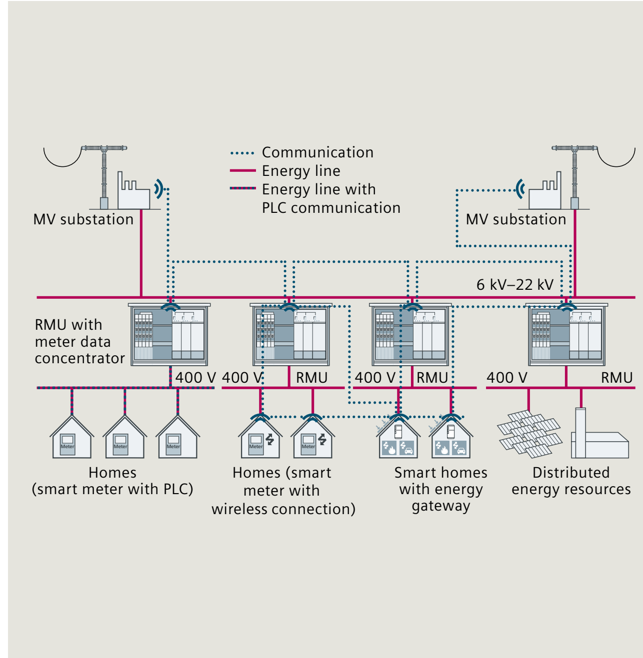
As with every communication technology, the transmission range and bandwidth provided by the PLC solution depends on the quality of the used transmission medium. In case of the transmission over power lines, type and age of the power cable as well as the number of joints have an impact on the achievable results. Consequently, a PLC network needs to be engineered and planned correctly to provide maximum performance.

Benefits of power line communication solutions:

- They transform the utility-owned infrastructure into a highly capable communication network.
- They are especially useful for connecting all elements in the grid where there are no other reliable communications media available.
- They provide a communication solution for all MV power grids.



Enterprise-WiMAX / LTE solution for distribution networks



Wireless mesh network

Enterprise-WiMAX / LTE

The main application area for private WiMAX / LTE systems, specifically tailored to the needs of enterprises in vertical markets, is backhauling of RMUs, data concentrators or Distributed Energy Resources (DER). Single prosumers could technically be served, but this is economically reasonable only in selected cases. WiMAX (Worldwide Interoperability for Microwave Access) is a standards-based telecommunications protocol (IEEE 802.16 series) that provides both fixed and mobile broadband connectivity. The advanced point-to-multipoint technology is field-proven and deployed globally. In the past, certain manufacturers have evolved the system for the requirements of specific vertical markets such as oil and gas or power utilities. Differing from telecommunication-carrier-oriented systems, these implementations support special features such as asymmetric prioritization of uplink traffic, layer-2-based traffic (multicast / IEC 61850 GOOSE), redundancy options, as well as economic system scaling fitting also for smaller, privately owned regional or local networks.

Besides the application requirements, it is important to assess regional conditions like area topology and availability of radio spectrum. Professional radio network planning and network engineering are mandatory when setting up private broadband radio networks.

Benefits
The WiMAX technology is field-proven, globally deployed, and continues to evolve. In parallel, manufacturers are also preparing enterprise-grade shapings of LTE-based networks leveraging economy-of-scale benefits from the widely spread deployment of this technology in the public cellular domain. Enterprise-WiMAX / LTE networks can be scaled from small to large, which allows for privately owned networks even on regional and local levels.

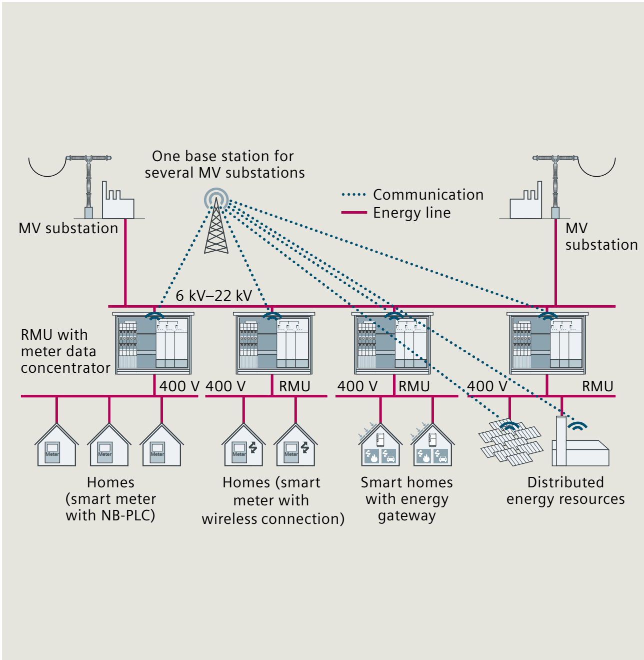
Wireless mesh

In general, wireless mesh networks are composed of cooperating radio nodes that are organized in a mesh topology. The link communication technology from one hop to another can be standardized (e.g., IEEE 802.11 series [WiFi] or IEEE 802.15.4 [LoWPAN, Low-rate Wireless Personal Area Network]) or proprietary (e.g., FHSS, OFDM technologies). The mesh protocols and corresponding forwarding algorithms are on the other hand still predominantly proprietary. Standardization efforts in this area (e.g., 6LoWPAN protocol suite / Zigbee-NAN) are currently still ongoing. Thanks to their mesh properties along with self-setup and self-healing mechanisms, mesh networks inherently offer ease of operation and redundancy for fixed applications. The system performance can be characterized by the hops' throughput capacity, the average reach of a hop-to-hop link, and the max. number of hops on a single path.

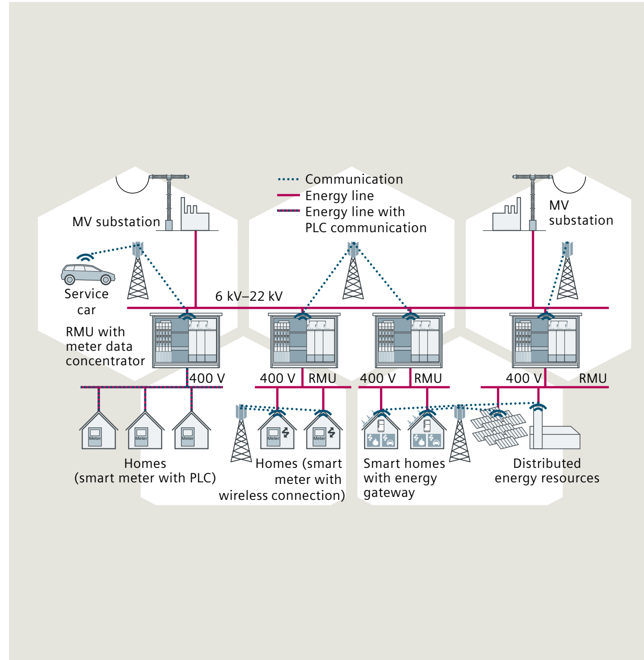
Detailed requirements as well as specific regional conditions must be carefully assessed in order to select the best-suited technology.

Broadband wireless mesh for RMU / DER backhaul
Broadband wireless mesh systems have sufficient transport capacity to backhaul a high amount of data, that is to say aggregated data of various RMUs / DER plants, with multiple RTU devices or data concentrators / access gateways.

Narrowband radio frequency (RF) mesh for access / metering
The term "RF mesh system" is used to denominate narrowband wireless mesh technologies. Their capacity suffices to connect individual devices with moderate data transmission requirements, such as meters, grid sensors, measuring transformers, etc. The single RF mesh nodes communicate



UHF evolution solution



Public cellular network

via each other towards an access gateway, which serves as take-out point into other WAN / backhaul communication networks.

Benefits
Thanks to their mesh properties along with self-setup and self-healing mechanisms, mesh networks inherently offer ease of operation and redundancy for fixed applications.

UHF evolution

The private wireless communication technologies covered in the previous sections (Enterprise-WiMAX / LTE and broadband wireless mesh) represent the preferred solutions for easily extensible multi-purpose wireless communication networks. However, for singular applications with just modest data rate requirements and end points spread over a large geographical area, an extensive private broadband wireless infrastructure can not always be implemented with a positive benefit-cost ratio. In these cases, the recently enhanced UHF radio systems (for the sake of distinction from classical UHF, here denominated as UHF evolution) constitute a better match for these kinds of requirements.

Basic technical data:
- Data rates: purpose-fit bandwidth ~ 100 kbps
- Coverage: up to dozens of kilometres
- Implementations in licensed radio spectrum, with narrow-band spectrum usually readily available to utilities.

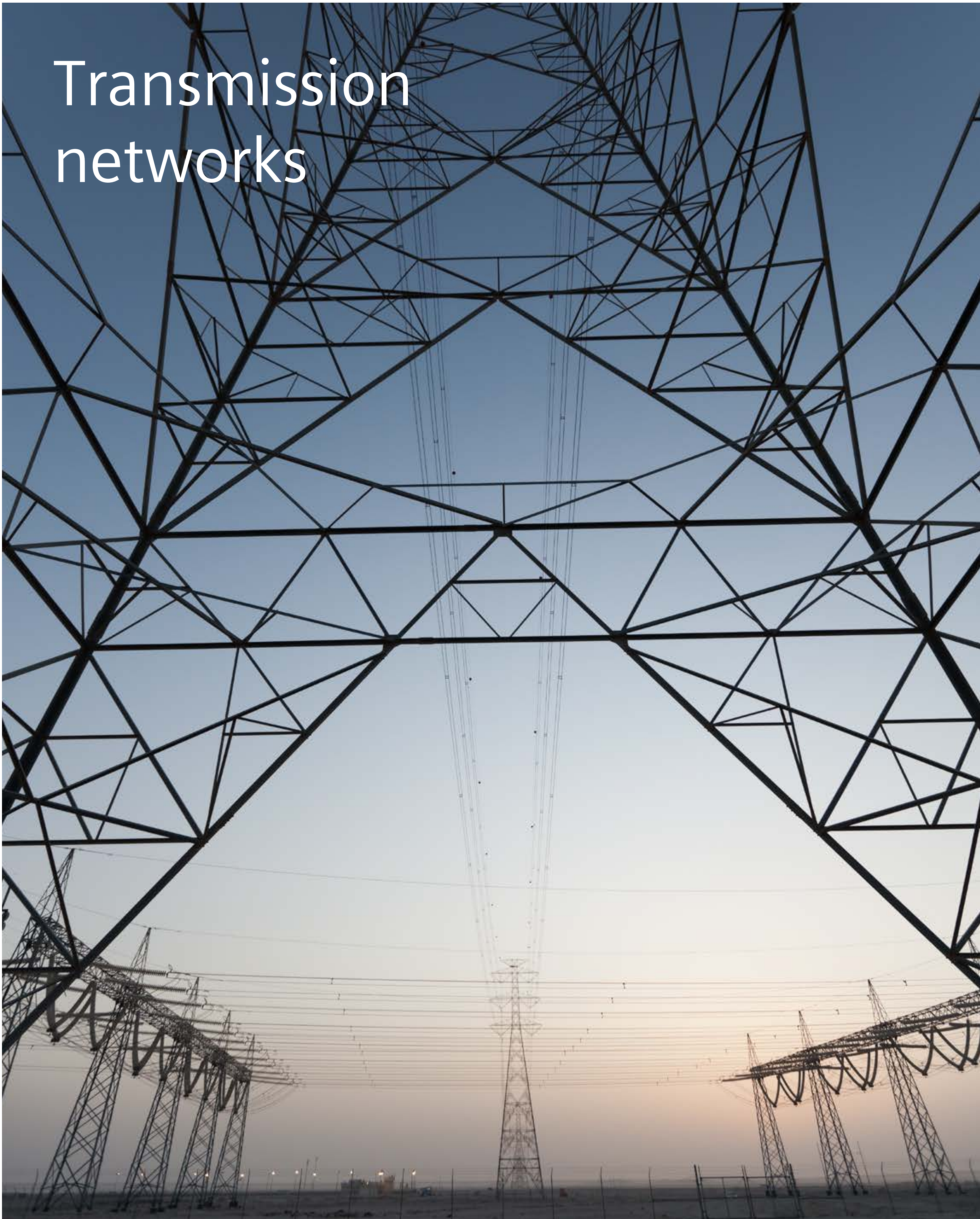
Benefits
UHF evolution is ideally suited for applications with moderate bandwidth requirements (e.g., monitoring or automation via IEC 60870-5-104), even in case of just selective rollouts and including rurally distributed grid assets. The systems provide the merits of modern radio communication including automatic scalability between throughput and range. Due to the deployment of licensed spectrum and the flexibility of private network design, they are also appropriate for mission-critical applications.

Public cellular networks

For the extension of private communications networks
The main application areas for public mobile radio networks in the smart-grid context are meter reading and energy grid monitoring functions.

In contrast to constructing new, proprietary networks for smart-grid communication, there is also the option of using existing cellular radio networks owned by communications service providers. These networks are standards-based, deployed worldwide, and continuously upgraded and expanded. Activities like acquiring spectrum licenses, building, operating, and maintaining the network as well as assuring sufficient coverage and bandwidth on a nationwide scale are naturally managed by the communications service providers. Data rates normally available range from 50 kbps (GPRS), over 15 Mbps (HSPA), to over 20 Mbps (LTE). Attractive data tariffs and the availability of the network are key to use public cellular networks for smart-grid applications.

Transmission networks



Solutions for transmission grids (communication backbone)

Fiber-optic communications on the way to carrier and utility grade packet transport networks.

Today – Synchronous Digital Hierarchy (SDH) plus Plesiochronous Digital Hierarchy (PDH) access multiplexer solutions

Today, SDH solutions in combination with PDH access multiplexer are used mostly by utilities for the communication requirements in high-voltage networks. Siemens offers for these demands the latest generation of SDH equipment, commonly referred to as NG (Next Generation) SDH systems or Multi-Service Provisioning Platforms (MSPP).

NG SDH technology combines a number of benefits that makes it still well-suited to the needs of power utilities. Among those benefits are high availability, comprehensive manageability, and monitoring features. Ethernet-over-SDH provides the capacity to transport packet-based traffic over the SDH backbone with high reliability and low latencies. State-of-the-art NG SDH systems are highly integrated, providing the requested capabilities for utilities in a single device.

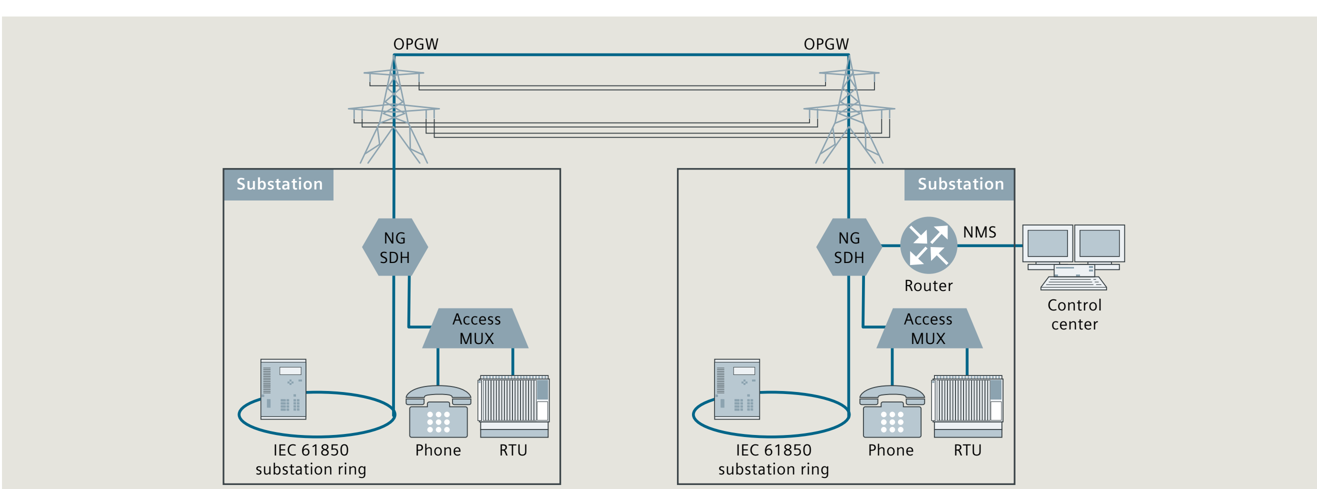
At the subscriber side there is still a need to operate a number of different systems with conventional communication interfaces in today's substations (e.g., FXS, FXO, E&M, V.24, X.21, etc.). For this purpose, so-called PDH access multiplexers are used, which provide the requested interfaces, bundle the communication signals, and pass them on to the NG-SDH systems.

The fig shows a typical NG-SDH solution with connected PDH Access Multiplexer.

Migration to highly available (carrier and utility grade) Multi-Protocol Label Switching (MPLS) networks

The SDH technology, combined with PDH multiplexer, is a well-proven solution for the manifold communication requirements of the transmission utilities.

But meanwhile new requirements arise, which clearly identify the limits of the SDH / PDH technology. Especially the demand for further cost savings, above all the OPEX part, is the main challenge for the communication departments of the utilities. At the same time, the portion of packet-based data (Ethernet and IP) in the wide area net-works, caused by new Ethernet- and IP-based systems (e.g., new IEC 104 RTUs, IEC61850 protection systems, sensors, IP telephony, IP CCTV, etc.) is increasing dramatically.



Typical NG SDH solution for transmission grids

In order to follow the general trend of the telecom industry and the roadmaps of the network manufacturers, the existing traditional communication networks need to be migrated into highly available, packet-based hybrid systems with low latency.

However, these packet-based optical networks need to meet the specific communication requirements of the transmission network operators.

The most important requests are:

- Cost-optimized installation and operation of the network
- Low latency, jitter- and connection-oriented services
- Use for critical Smart Grid applications (e.g., distance and differential protection)
- Easy network extension
- Support of conventional PDH communication interfaces.

In order to meet these requirements, it is advisable to stepwise migrate the installed SDH / PDH communication infrastructure to a packet-based, highly available (carrier and utility grade) and standardized MPLS transport network, which integrates, besides Ethernet, also conventional interfaces.

This means that MPLS systems offer the integration of voice, data and protection signals into one system. This allows the operation of older systems during a transition period.

The fig shows a typical MPLS communication network.

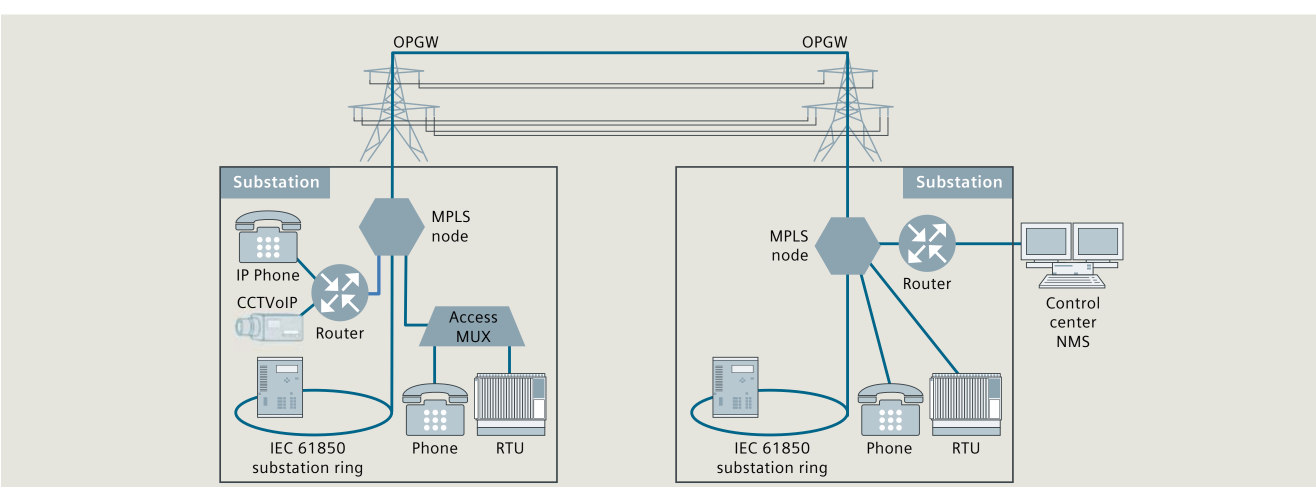
In a final stage, Ethernet would be the single communica tion interface, which will be used in the backbone as well as in the access network.

Based on this easy network structure in combination with a powerful Network Management System (NMS) and intelligent network functions, daily network configuration tasks and other service work can be performed fast and straightforward. This is the basis for further OPEX reductions.

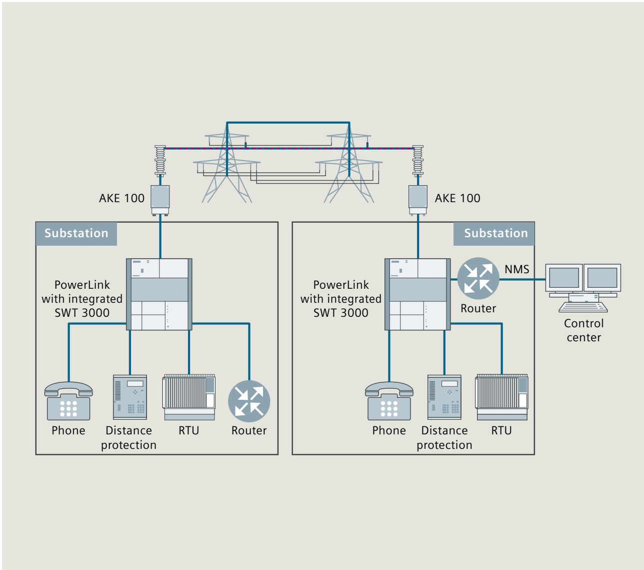
Benefits of a MPLS communication network

- Exceptionally cost-efficient operation of the network
- Supports all latency critical Smart Grid applications
- SDH-like look-and-feel (e.g., central NMS, fixed communication paths)
- Efficient use of the available transmission bandwidth
- Supports the conventional interfaces, and is therefore perfectly applicable for a stepwise migration from SDH to an Ethernet- and IP-based NG network.

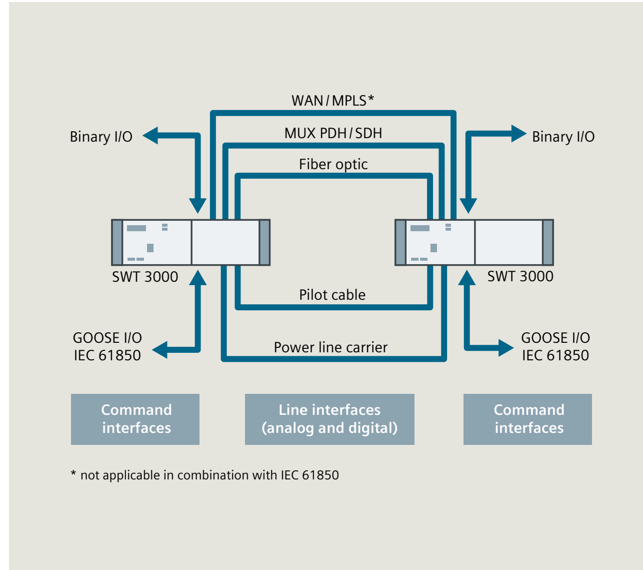
Siemens offers a wide range of end-to-end solutions for utility grade telecommunication networks, and supports with its Smart Grid knowledge a smooth migration from today's TDM-based networks towards packet-based networks.



MPLS communication solution for transmission grids



PowerLink high-voltage line communication



SWT 3000 teleprotection system – wide range of Command and Line interfaces

PowerLink – power line carrier for high-voltage lines

No separate communications cable required
PowerLink uses the high-voltage line between transformer substations as a communications path for data, protection signals and voice. This technology, which has been tried and tested over decades and adapted to the latest standards, has two main application areas:

- as a communications link between substations where a fiber-optic connection does not exist or would not be economically viable, and
- as a backup system for transmitting protection signals parallel to an installed fiber-optic link.

Thanks to the continuous development of this technology, it remains as important as ever. Over long distances with relatively low data volumes, PLC is still hard to beat in terms of cost-effectiveness.

PowerLink provides the highest communications standards for power network protection. Its smooth integration into other types of communications technology like fiber-optic and satellite links opens the door to a variety of new features and functions. With its ability to switch from analog to digital transmission, it can work with both transmission modes at the same time.

The advantages:

- Cost-effective for small to medium data volumes over long distances
- Use of utility-owned resources (power lines)
- Highest reliability (for example, for protection signaling)
- Can be used in effective combination with broadband technologies for highest availability

SWT 3000 – teleprotection for high-voltage lines

To quickly identify, isolate, and resolve network failures
The SWT 3000 Teleprotection system is the highly developed solution worldwide for identifying and isolating faults in the high-voltage grid. Combined with existing distance protection relays, it allows operators to reduce downtime to an absolute minimum. A proven technology that is continuously being refined to meet future needs.

A closer look at the migration of existing substations
The SWT 3000 also demonstrates its high degree of flexibility when existing substations are migrated to protection devices via the IEC 61850 communications standard. The SWT 3000 supports all necessary command interfaces. This always keeps investment costs economically manageable, because the substations can be updated step by step for a new network age.

SWT 3000 as a binary command interface
The Siemens SWT 3000 with bidirectional individual channels for direct, permissive or blocking applications, offers the connection of traditional distance protection devices.

SWT 3000 for IEC 61850 (GOOSE)
When distance protection is already operating with IEC 61850 interfaces, GOOSE commands can be transmitted via SWT 3000 from substation to substation.

The advantages:

- Keeps downtimes to an absolute minimum
- Supports IEC 61850 interfaces as well as conventional binary interfaces
- Flexible integration into various customer communications networks
- Path protection via two different transmission routes for increased reliability

Published by
Siemens AG 2016

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Article-No. EMDG-B90013-00-7600
Printed in Germany
Dispo 06200
gB 160662 B 1016