Data pipeline

Transmission technology for communication in MV switchgear

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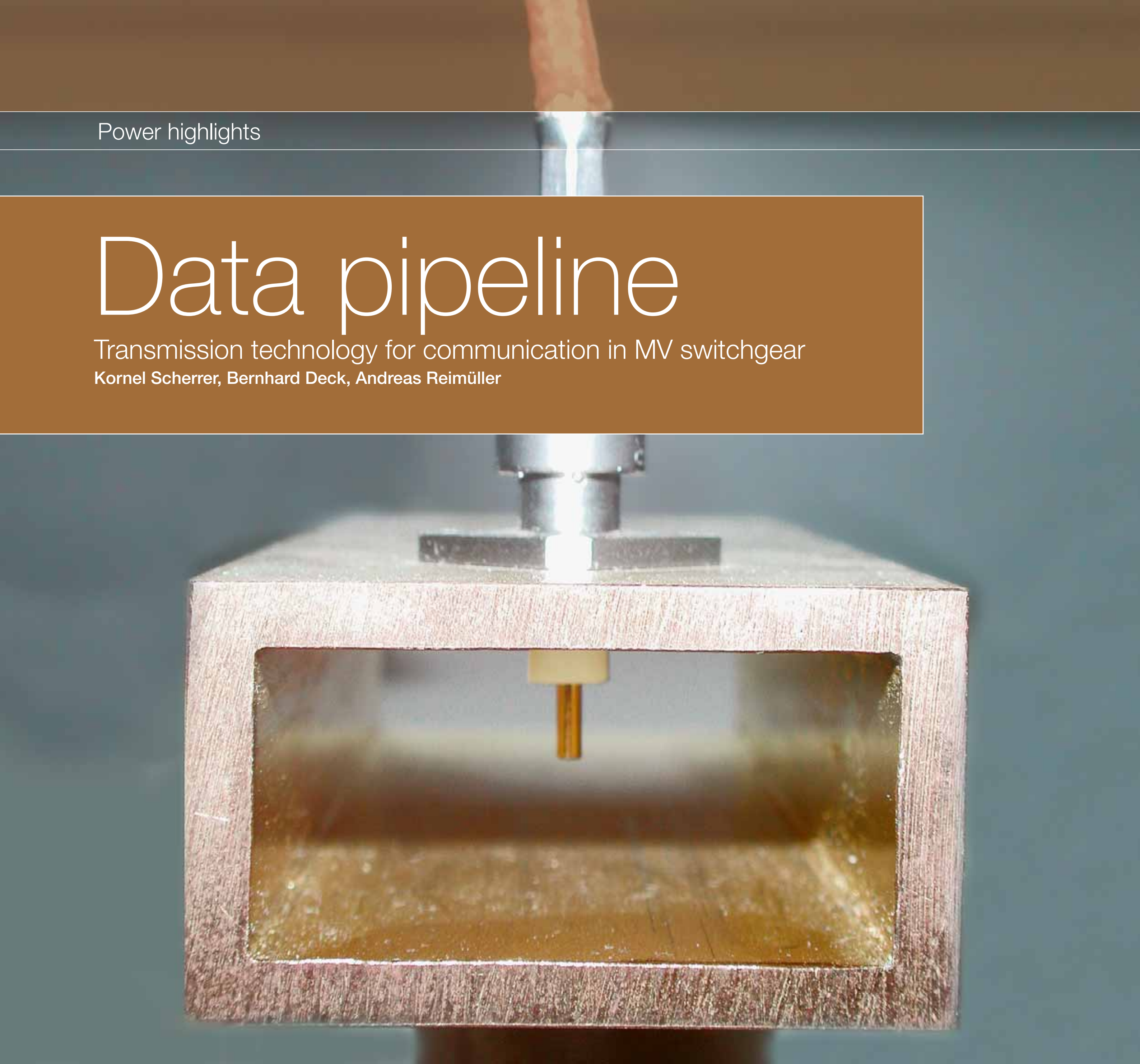


From the point of view of electromagnetic compatibility, switchgear presents a highly challenging environment. The correct functioning of the equipment, however, depends on reliable communication between its components. Copper wiring is prone to electromagnetic interference whereas optical fibres are fragile and expensive to install. Both also present a risk of cabling errors. As an alternative, ABB is proposing broadband radio-based communication using hollow metal conductors – Waveguide. Radio signals are transmitted through these conductors where they are immune to external interference and do not themselves interfere with other devices. Furthermore, such conductors can be used by multiple communication channels simultaneously and are robust and easy to install.

In view of the introduction of the IEC 61850 series of standards, ABB considers that the time has come to encourage a paradigm shift in switchgear communication. This change will not stop at the transmission medium. The solution proposed is a closed-system, low-power broadband communication using Waveguides.

Wireless LAN radio technology in combination with IEC 61850

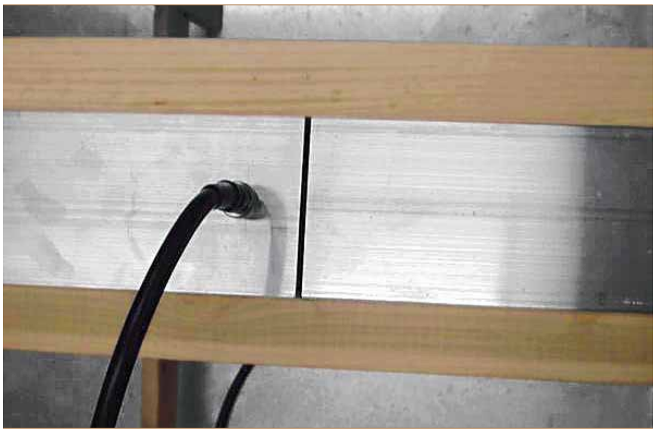
The world of standards has changed and expanded in recent years. The last major innovation appeared on the market with IEC 61850, and more are awaited with IEC 62271-1. The IEC 61850 series of standards, "Communication Networks and Systems in Substations", is being increasingly adopted in the global power engineering market. Initial pilot projects – still limited in their scope – are already in progress to implement these standards. Furthermore, an extensive exchange of experience on current solutions and present limitations of these standards is taking place. The future will require further rethinking in this context.

In a joint development effort involving several divisions of ABB, an innovative (although proven in other industries) data transmission method has been established. This will allow data within switchgear installations to be transmitted with high reliability and simplicity. The approach relies on the use of high frequency electromagnetic waves of low power in a closed system. The principle is simple and versatile. What is needed is a correctly dimensioned Waveguide, a probe that can both receive and transmit, and a coaxial connection to the protection and control device used (see title picture and 1).

Radio technology has been an indispensable part of modern life for a long time. There are hardly any areas in which data is not transmitted through the air. Wireless communication technology is in use everywhere, for radio itself, television, telephones and network connections.

1 Waveguide is set to become an integral part of medium-voltage switchgear.

2 Where Waveguide sections are joined, a narrow sleeve is used. This assures galvanic isolation without any degradation of transmission.



The present state of the art in transmission systems for all these applications is the digital, wireless network. The first radio signal was transmitted as early as 1886 by Heinrich Hertz using a spark gap. The development of antennas replaced the spark gap in the course of time, but radio operators are still nicknamed "sparks" today.

If radio signals are to be propagated in a Waveguide with low attenuation, a few simple conditions must be fulfilled. The dimensions of the conductor and the frequency of the radio signal, for example, have to be matched. This means that signals are transmitted with low attenuation only when a certain limit frequency is exceeded. Wavelength and frequency are inversely proportional, and so the wavelength λ has to be smaller than the limit wavelength λ_{Limit}. The following formula is used for the dimensioning of the system:

$$\lambda \leq \lambda_{Limit} = 2 \cdot x \qquad (1)$$

where x is the width of the rectangular Waveguide.

State of the art

In today's switchgear, the internal communications links (substation bus) are normally established from panel to panel – irrespective of whether serial or binary signals are to be transmitted. With parallel wiring, this is appropriately implemented using loop lines that are plugged into the terminal strip of each panel. Depending on the size of the installation, the complexity of the interlock system and the operator's need for control functions and information, it can involve cable harnesses with over 60 individual cores. Adding or changing signals in the loop lines immediately implies complex rewiring. The work required and the corresponding tests entail high costs for the operator. Only the use of serial communications techniques allows the number of loop line cores to be reduced. With this transmission method, the signals and measured value data are as a rule transmitted serially to a central point. Furthermore, the control commands can be transmitted to the relevant medium voltage panels.

In response to various ambient influences in switchgear applications, optical fibers (optical waveguides) have become established as the preferred transmission medium. In contrast to copper alloys, optical fiber cables are insensitive to electromagnetic interference, but they are also more costly due to their mechanical properties, the greater amount of work involved in installation (eg, fitting of plugs, protected routing in conduits) and the need for specialized tools and skilled personnel.

Waveguide relies on the use of high frequency electromagnetic waves of low power in a closed system.

Indoor switchgear with Waveguides

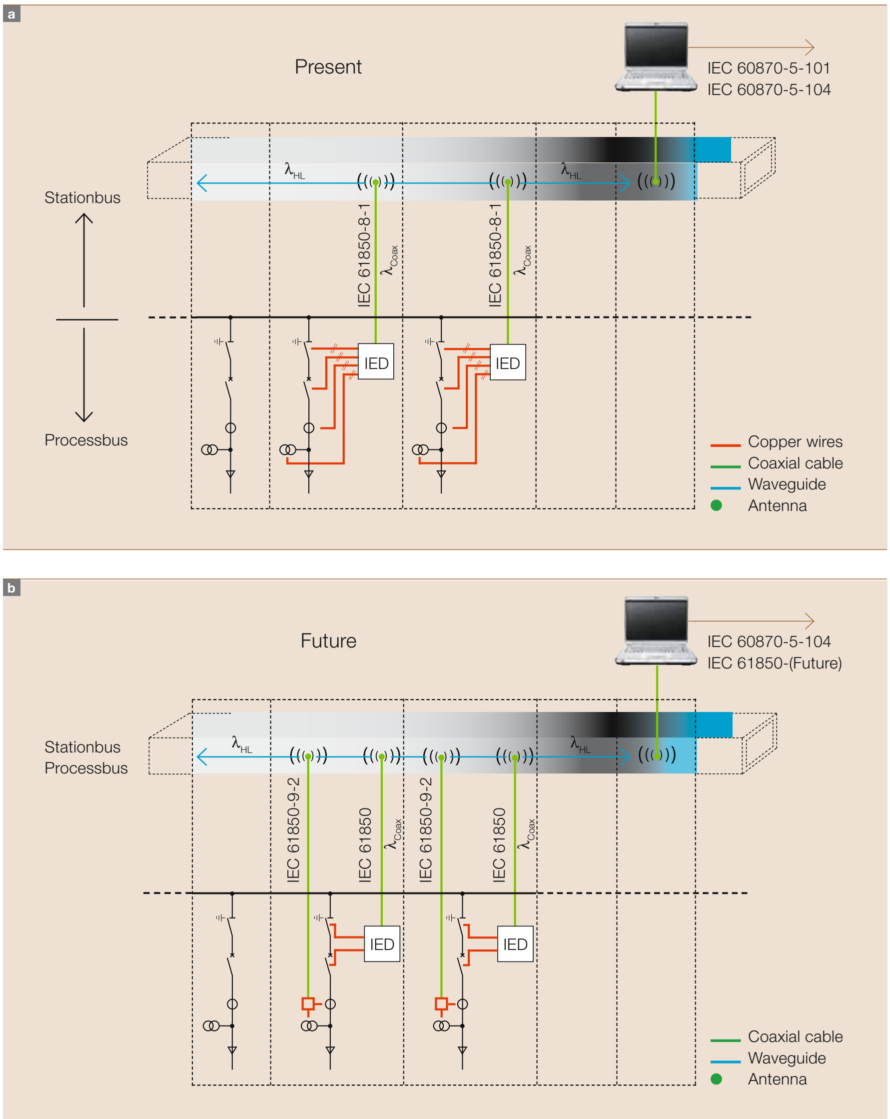
The demands for reliability and durability of systems are continously increasing. Therefore, it became an objective of ABB to find a more suitable transmission medium for panel to panel communication that would fulfill the criteria outlined above, and at the same time, would be simple to use. In addition, this medium had to satisfy the new requirements of the IEC 61850 series of standards. The achievable bandwidth had to be in the range of an optical waveguide (fiber optical cable), but installation had to be significantly easier. The advantage of electrical isolation between the data transmitters and receivers, which is guaranteed by the material of optical waveguides (but not copper conductors), was also to be retained in the new system.

The principle of the Waveguide is very simple and versatile in its application. Similarly to the optical waveguide, reflection from one, or rather two, parallel boundary surfaces is required for quasi loss-free transmission of the signal. To achieve this, the two walls (boundary surfaces) must be at a defined distance from each other, which is calculated from the wavelength used (see equation 1). Input and output of the signals are accomplished by spherical antennas. Shielded coaxial cable is used to bridge the short distances between the protection and control devices. and the Waveguide. Factbox shows a comparison between the various transmission media.

The dimensions of the conductor and the frequency of the radio signal, have to be matched.

The electrical energy which is injected into a Waveguide by means of an antenna (probe) builds up an electromagnetic wave with E and H (electrical and magnetical) fields inside the conductor. As soon as the limit frequency for the particular system is exceeded, an electromagnetic wave spreads out in the Waveguide and propagates at almost the speed of light. On input, first an E field is created, which results in an H field. Waveguide antennae are in principle reversible, ie, can be used both to transmit and receive HF energy. If the Waveguide is correctly dimensioned,

3 Waveguide solutions – a present, and b future.



the electromagnetic waves are propagated almost without losses (attenuation approx. 2 dB/km). With the form selected, a low power 5 GHz signal is used. The technology employed corresponds to that of modern wireless local area network (LAN) systems. With a Waveguide, the radio signals are optimally protected from external interference and vice versa – the environment is protected from the radio signals.

The Waveguide segments are arranged in such a way in the low voltage compartments of the switchgear that they are automatically connected together when the panels are installed. Using Waveguide technology, the work involved in establishing panel to panel connections during site installation of a switchgear system is reduced to a minimum, in comparison with conventional loop line systems (typically up to 60 cores). When the panels are joined together, the sections of Waveguide are lined up with each other. The small gaps between the Waveguide sections in each panel unit are hermetically sealed with sleeves 2 so that no contamination from outside can enter the conductor. At the wavelength used, the gap has no adverse effects on the attenuation of the transmission system. In direct comparison with a conventional shielded Ethernet cable, the Waveguide is mechanically more robust, shielded from high frequency interference and, in contrast to cables, electrically isolated panel by panel (similarly to an optical waveguide connection). With this "plug and play" system, the entire communications system can easily be tested during inspection at the works.

Two Waveguide systems a few meters apart, eg, a switchgear system installed on opposite sides of the substation, can be connected by means of a passive system consisting of antennas and coaxial cables. From the point of view of network topology, a redundant network would have to be structured in such a way that failure of either a switch or the connection could be tolerated (n-1 principle). In direct analogy to copper or optical waveguide communications systems, this problem is reduced to duplicating the Waveguide access point, as it may be assumed in this case that a communications link via the Waveguide can be regarded as highly robust and therefore safe from failures. In this respect, a highly dependable network can be achieved at comparatively low cost 3.

With a Waveguide, the radio signals are optimally protected from external interference.

Prospects

The new IEC 61850 series of standards not only describes a simple communications interface on the basis of a substation bus. It also describes a process bus, which permits the connection of intelligent primary devices. These can, for example, be voltage and current sensors or transformers, or switching devices, which have a communications interface according to IEC 61850. When current and voltage measurements (sampled measurement values) according to IEC 61850-9-2:2004-04 [9, 10] are to be transmitted in real time from the sensor/instrument transformer to the Intelligent Electronic Device (IED), or distributed horizontally among the IEDs in a substation (eg, for busbar protection), a robust communications link is of decisive importance. Furthermore, it must be ensured that the physical connection provides sufficient bandwidth for fast transmission, so that no delay that would have an adverse effect on the protection system can occur. With a Waveguide connection, a large bandwidth is achieved using multichannel technology. In this way, up to 24 independent channels, each with 56 Mbit/s, can be connected to the Waveguide. This design permits not only transmission of vertical and horizontal information to IEC 61850, but additionally allows further services to be implemented via the system. Electricity meters installed in the switchgear can, for example, be read via the Waveguide, or web-based services implemented. Coupling of other active components can be achieved with a corresponding media converter. Especially for sampled measurement values, the Waveguide provides a connection that satisfies the safety demands of a protection system and the technical requirements of IEC 61850-9-2:2004-04 [9, 10].

Factbox Waveguide in comparison with other media

medium	system availability	EMC	thermal resilience	mechanical resilience	installation	extendebaility
electrical connection (Twisted Pair CAT 5, RJ 45)	+	-	+	+	0	0
optical fiber (Multimode 2G 62.5/125µm)	+	+	0	-	-	-
waveguide	++	+	+	++	+	++

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