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IEC 61850: Transmission technology for communication in MV switchgear

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

Wireless LAN radio technology in combination with IEC 61850

With the introduction of the IEC 61850 series of standards, we regard the time as ripe to encourage a change of paradigm, and one which does not stop at the transmission medium. In the following article, approaches are to be explained, discussions encouraged and initial solutions presented as to how in future a new, even more reliable transmission technology which is more resistant to ageing can be incorporated in medium voltage switchgear. The solution proposed is closed-system, low power broadband communication in hollow conductors.

Hollow conductor for transmission of radio signals

In joint development work within ABB, an innovative – although long proven in other sectors of industry – data transmission method has been established, allowing the flood of data in switchgear installations to be transmitted reliably and simply in future. The approach relies on the use of low power electromagnetic waves in a closed system. The principle is simple and versatile in use. What is needed is a correctly dimensioned hollow conductor (HC), a probe which both receives and transmits, and a coaxial connection to the protection, control or combination device used.

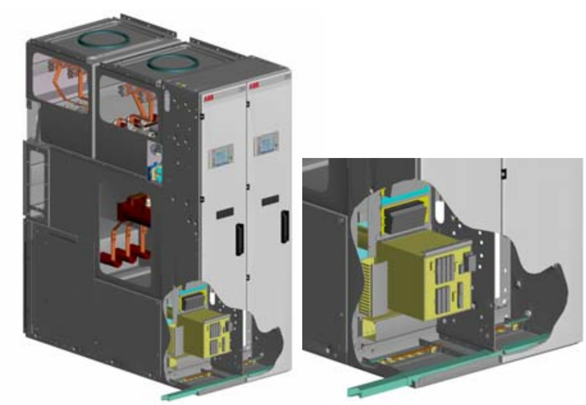

Figure 1. Gas-insulated MV switchgear type ZX2 with hollow conductor (l.), enlargement of the hollow conductor arrangement in the low voltage compartment (r.).

Radio technology has been an indispensable part of modern life for a long time now. There are hardly any areas in which data are not transmitted through the ether. Radio technology is in use everywhere, for radio itself, television, telephones and network connections. The present state of the art in transmission systems for all these applications is the digital, wireless network. The first signal was transmitted as early as 1886, using a spark gap (Prof. *Heinrich Hertz*). Development of antennae replaced the spark gap in the course of time, but radio operators are still nicknamed "Sparks" up to the present day.

If radio signals are to be able to propagate themselves in a hollow conductor with low attenuation, a few simple conditions have to be fulfilled. The dimensions and frequencies, for example, have to be matched. This means that signals are only transmitted with low losses when a certain limit frequency is exceeded. The wavelength and frequency are inversely proportional, and so the wavelength has to be smaller than the limit wavelength.

Figure 2. Typical hollow conductor with probe

State of the art today

In today's medium voltage 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 which are plugged into the terminal strip in 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, this can involve cable harnesses with over 60 individual cores. Users are familiar with the limits to this technology, which are therefore only mentioned briefly here. Adding or changing signals in the loop lines immediately means complex rewiring. The work required and the complex tests entail correspondingly high costs for the operator. Only the use of serial communications techniques allowed 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 on medium voltage switchgear, optical waveguides have established themselves as the transmission medium. In contrast to copper alloys, optical fibre cables are insensitive to electromagnetic interference (EMC), but poorer mechanical properties, the greater amount of work involved in laying them (e.g. fitting of plugs, protected routing in conduits), special tools and specially trained personnel make the use of optical waveguides more costly.

Medium voltage switchgear with hollow conductors

The demands for reliability and durability of systems are constantly rising. For that reason, gas-insulated switchgear is used more and more often for primary systems, both in medium and high voltage applications. Gas-insulated technology stands for long-lived, compact and low maintenance design, in which the high voltage components are enclosed in SF_6 insulating gas and therefore unaffected by any ambient influences. The objective for the secondary equipment was to find a new, more suitable transmission medium for panel to panel communication which would fulfil the criteria stated above and at the same time be simple to use within a switchgear installation. In addition, this medium has to satisfy the new requirements of the IEC 61850 series of standards. The achievable bandwidth should be in the range of that of an optical waveguide, but fitting should 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 hollow conductor is very simple and versatile in 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. Input and output of the signals are simply accomplished by spherical antennae. Screened coaxial cable is used to bridge the short distances between the combination or panel devices and the hollow conductor.

The electrical energy which is injected into a hollow conductor by means of an antenna (probe) builds up an electromagnetic wave with *E* and *H* fields inside that conductor. As soon as the limit frequency for the particular system is exceeded, an electromagnetic wave spreads out in the hollow conductor at almost the speed of light. On input, first an *E* field is created, which results in an *H* field. Hollow conductor antennae are in principle reversible, i.e. usable both to transmit and receive HF energy. When the hollow conductor is correctly dimensioned, 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 LAN systems. With the hollow conductor, the radio signals are optimally protected from external interference and vice versa – the environment is protected from the radio signals.

The hollow conductor 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 hollow conductor 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). The medium voltage panels of the ZX series have had plug-in connections on the primary side for over ten years. When the panels are joined together, the sections of hollow conductor are now also lined up flush with each other. The small gaps between the hollow conductor parts in each panel unit are hermetically sealed with sleeves 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 screened Ethernet line, the hollow conductor is mechanically more robust, closed off from high frequency interference and, in contrast to cables, electrically isolated panel by panel (cf. optical waveguide connection). With this “plug and play system” the entire communications system can easily be tested during inspection at the works.

Two hollow conductor systems a few metres apart, e.g. a switchgear system installed on opposite sides of the substation, can be connected by means of a passive system consisting of antennae and coaxial cables (as described above). 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 is tolerated (*n*-1 principle). In direct comparison with copper or optical waveguide communications systems, this problem is reduced to duplicating the hollow conductor access point, as it may be assumed in this case that a communications link via the hollow conductor can be regarded as highly robust and therefore safe from failures. In this respect, a quasi redundant network can be achieved at comparatively low cost.

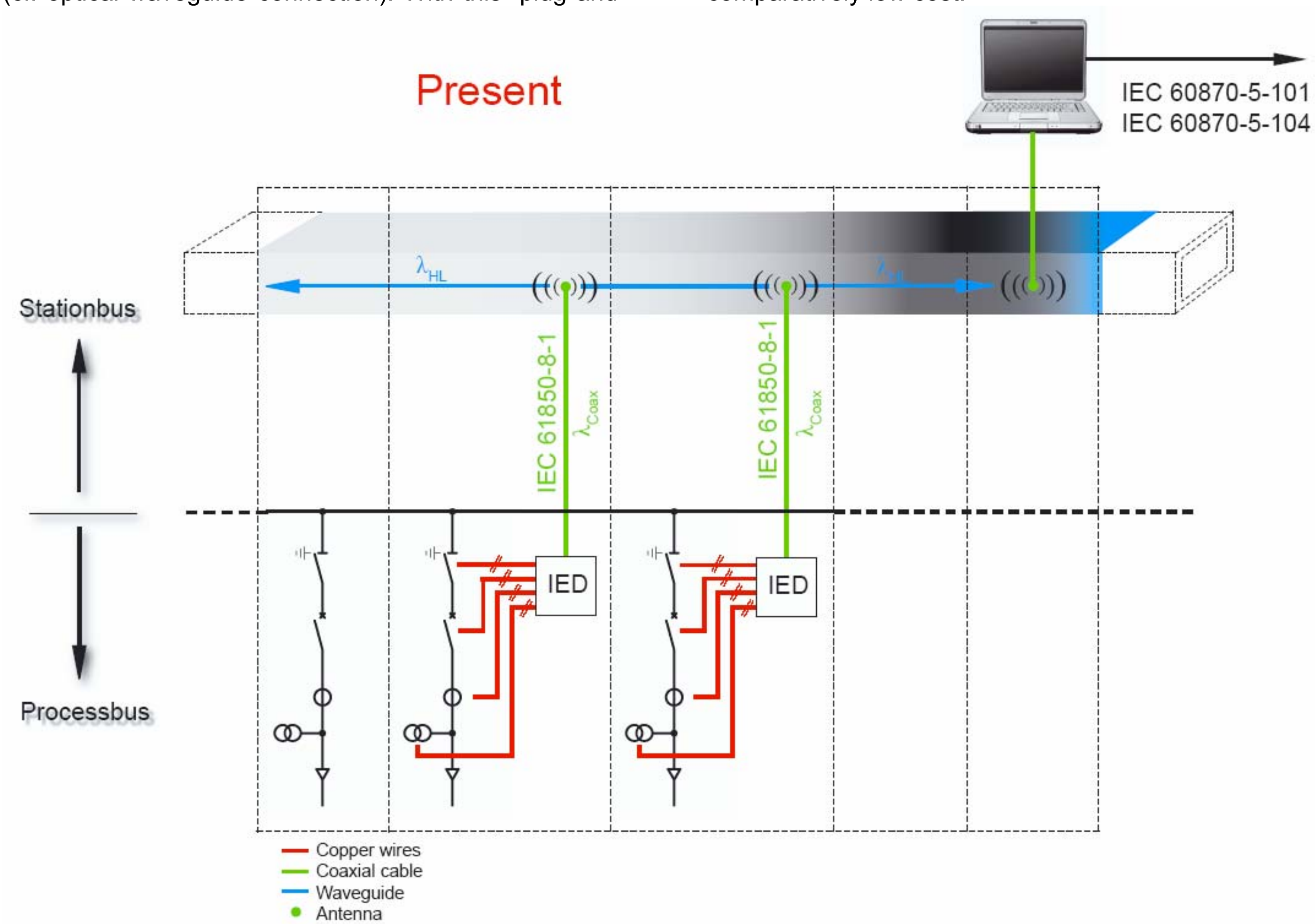

Figure 3. Hollow conductor solutions present.

Prospects

The new IEC 61850 series of standards does not only describe a simple communications interface on the basis of a substation bus. On the contrary, it also describes a process bus which permits the connection of intelligent primary devices. These can be, for example, voltage and current sensors or transformers, or switching devices, which have a communications interface to IEC 61850. If current and voltage measurements (sampled measurement values) 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 (e.g. 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 which would have an adverse effect on the protection system can occur. With a hollow conductor connection a large bandwidth is achieved by multichannel technology. In this way, up to 24 independent channels, each with 56 Mbit/s, can be connected to the hollow conductor. 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. Meters installed in the switchgear can, for example, be read via the hollow conductor, or web-based services included. Coupling of other active components can be achieved with a corresponding media converter. Especially for sampled measurement values, the hollow conductor provides a connection which satisfies the safety demands of a protection system and the technical requirements of IEC 61850-9-2:2004-04 [9, 10].

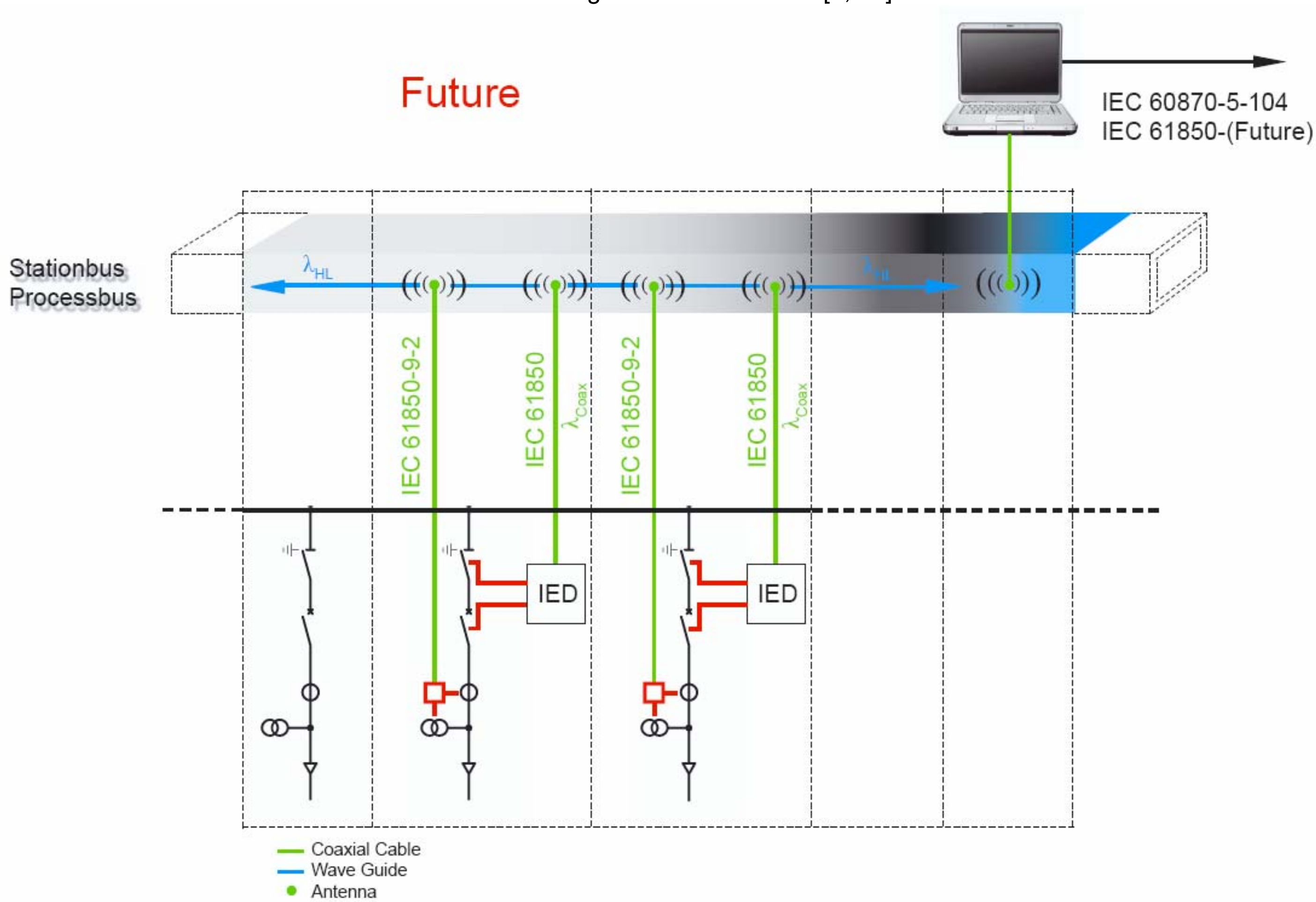

Figure 4. Hollow conductor solutions future.