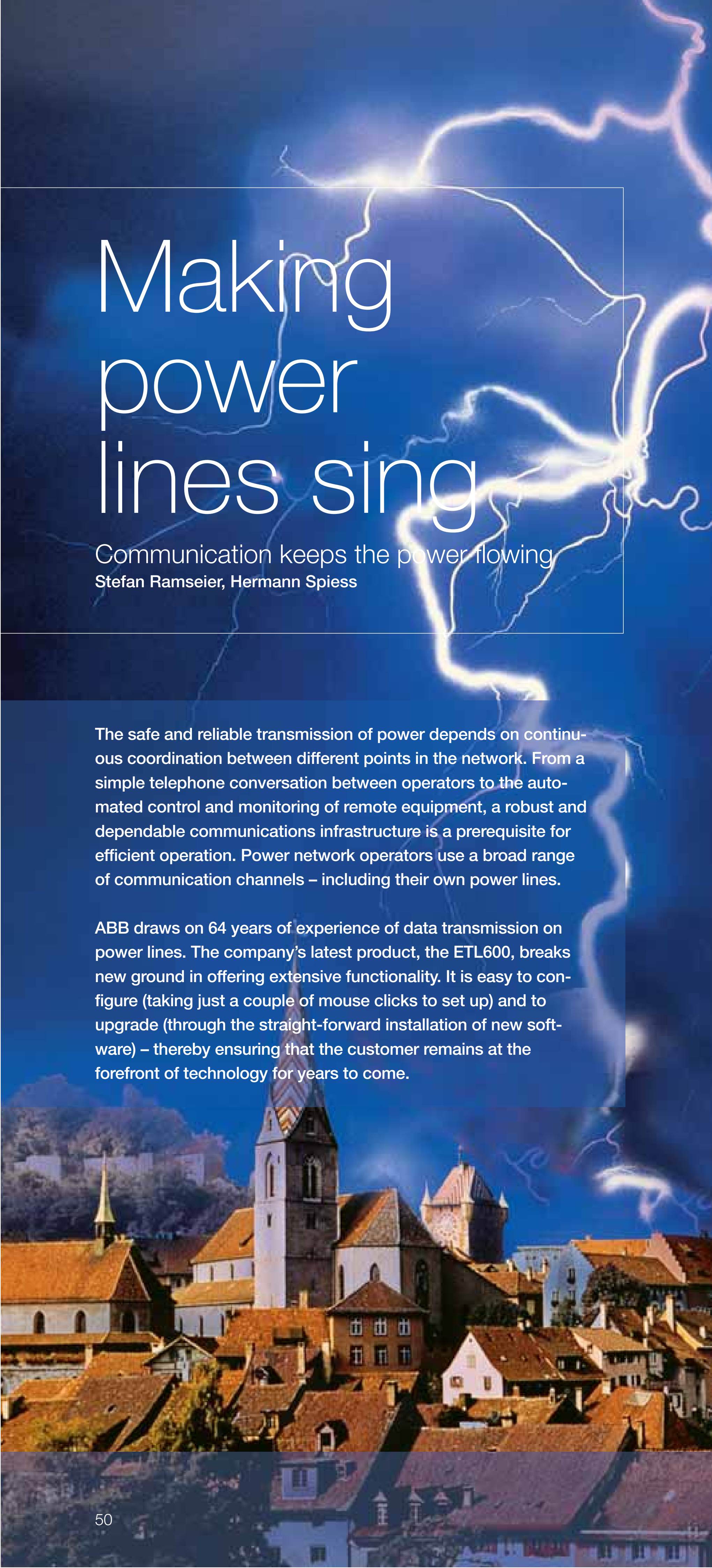


Making power lines sing

Communication keeps the power flowing

Stefan Ramseier, Hermann Spiess

The safe and reliable transmission of power depends on continuous coordination between different points in the network. From a simple telephone conversation between operators to the automated control and monitoring of remote equipment, a robust and dependable communications infrastructure is a prerequisite for efficient operation. Power network operators use a broad range of communication channels – including their own power lines.

ABB draws on 64 years of experience of data transmission on power lines. The company's latest product, the ETL600, breaks new ground in offering extensive functionality. It is easy to configure (taking just a couple of mouse clicks to set up) and to upgrade (through the straight-forward installation of new software) – thereby ensuring that the customer remains at the forefront of technology for years to come.

An efficient communication network is the backbone of modern power systems 1. Power utility operators communicate with each other to coordinate actions and exchange all kinds of operational information. The communication network conveys signals for the remote control of unmanned stations, transferring data and load values from sites across the power system to central control, and transmitting central control commands to sites. Most crucially, the communication network carries many of the vital signals that are exchanged in real time between different locations to ensure optimum control and protection of the power system. In short, communication networks help power utilities keep electricity flowing all the way from generator to consumer.

Traditional utility communication systems were predominantly hardware-based modules, tailored to customer specifications. Today's embedded systems, such as ABB's ETL600 Power Line Carrier (PLC) system, are based on a powerful, flexible hardware platform and a number of versatile software modules. This technology allows the configuration of a complex system "with a few mouse clicks", and even to extend functionality in the future with the download of additional software modules.

What and how do electric utilities communicate?

ABB's utility-communications expertise is founded on experience gained from installations in electrical power utilities in over 140 countries. This experience, allied to proven solutions, is especially important in protection signaling where communication enables protection systems to clear a line fault in the shortest possible time, or to isolate primary plant components directly affected by a fault, while maintaining the availability of all other components.

The enhanced functionality and performance of ABB's communication systems increase both the quantity and quality of information available for operational and management functions. Enabling all business units within a power utility to have ready access to this information means the same information can be used for the remote control of substations and for evaluation purposes, minimizing operation and maintenance costs. For modern power utilities, powerful and reliable communications services are absolutely vital for the control, supervision and administration of power system operations 2.

Rapid developments in technology in recent years, together with the continuing deregulation of power markets, have significantly changed the communications requirements of power utilities. There are three major communication technologies used in the Wide-Area-Network (WAN) to meet these requirements: PLC, optical fiber and microwave radio.

Established PLC techniques play an important role owing to their high reliability, relatively low cost and long distance reach. For higher transmission capacities, broadband systems based on optical fibers can handle both operational and administrative power utility data, and – depending on a utility's strategy and on legal regulations – even provide commercial telecommunications services. Because microwave radio communication is not restricted to power line routes, it can, in certain circumstances, offer an advantageous alternative, especially in difficult terrain (on mountains and islands, for instance).

1 Ready to talk? An overview of a communication network

Power lines are used not only to carry electrical power, but also to transmit communication signals.

Typical applications supported by utility communication systems include Local Area Network (LAN) interconnections, video surveillance, remote diagnostics and support, distribution automation, automatic meter reading and standard telecom services.

The main applications for "operational communications" are power system control, power line protection and operational telephone services. As the first two are most crucial to the operation of the power system, they are explained in some detail here.

The availability of electric power is largely dependent on the reliability of the power control system. Accordingly, control systems, and in particular the associated communications equipment, must function reliably under worst-case operating conditions. Typical power system control applications include telecontrol (supervisory control and data acquisition or SCADA) and Energy Management Systems (EMS).

Teleprotection equipment, operating in conjunction with line protection, must be capable of reliably transmitting a signal to the remote end of the line, in the shortest possible time and under extreme interference conditions that might be caused by a fault in the power system. On the other hand, interference on the communications channel must never cause unwanted operation of the protection, for example, by simulating a tripping or blocking signal at the receiving end when no such signal has been transmitted at the sending end.

Power Line Carrier

Power Line Carrier Systems have long been used by electric power utilities for the transmission of vital information for the operation and protection of the electric power grid, ie, voice, protection commands and control signals. Thus, power lines are used not only to carry electrical power (at 50 Hz or 60 Hz), but also to transmit communication signals (typically at frequencies between 40 kHz and 500 kHz). Special coupling devices are used to connect the communication terminals to high-voltage power lines.

The use of existing power lines for communications is a meaningful choice, because these provide the most direct link for teleprotection (where speed is crucial), they are reliable and they are completely under the control of the power utility, which is important, especially in countries with deregulated telecommunication markets. Furthermore, power lines are an excellent communication medium that can bridge very long distances (several hundred kilometers) without a repeater.

From valves to embedded systems

The first PLC link was put in operation by ABB in 1942 3, and in the past 64 years, thousands of links have been installed in more than 120 countries, at voltage levels of up to 1100kV AC and 500 kV DC, covering a total length of more than one million kilometers.

Over more than six decades, each new generation of PLC equipment has been developed using the cutting

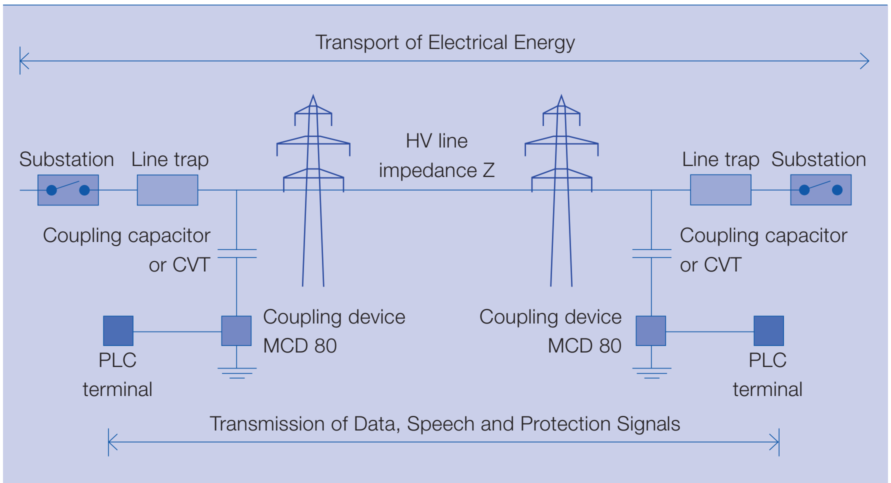
Embedded system technologies

edge technology of its day,as indeed is still happening today. Hence, many of the technological breakthroughs in electronics and telecommunications of the last few decades are reflected in the development of PLC equipment.

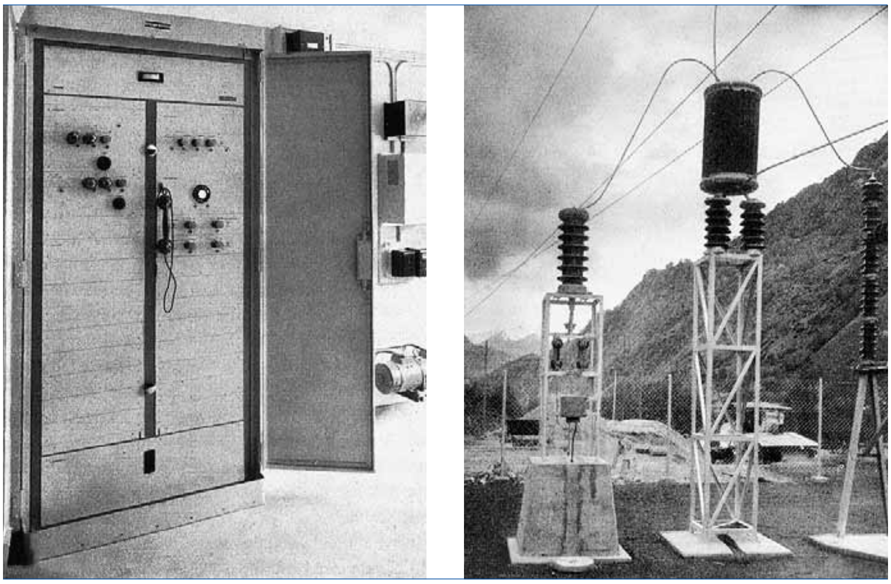
The first PLC systems used valves, and information was transmitted much as it is in today's AM radio systems: Analog waveforms (no digital signals or bits) are modulated to the desired frequency (eg between 40 kHz and 500 kHz). The signal on the power lines appears twice – there is a mirrored copy of the original (double side band). In the early fifties, the required frequency band – a very scarce resource – was reduced by a factor of two, eliminating the mirrored signal (single side band, SSB). This SSB technology is still used in today's systems, and also in some short-wave radio systems. In the mid-fifties, valves were replaced, first by germanium transistors, then in the early sixties by silicon transistors, and, most recently, in the mid-seventies by integrated circuits. In the early nineties, it became possible for the user to tailor the PLC system to actual needs by "programming" it with switches and jumpers.

The next technological breakthrough came in the late nineties with the introduction of ABB's ETL500, the first embedded numeric PLC system. The system was no longer configured only by switches and jumpers, but mainly with a graphical user interface (GUI) running on a personal computer (PC). The signals inside the ETL500 system were no longer processed in analog waveforms, but in digital bit streams. Many of the complex analog components, such as oscillators, mixers and filters, were replaced by mathematical operations executed inside a Digital Signal Processor (DSP). Such a DSP (similar to a processor inside a PC, but designed for specific "number-crunching" applications) can perform complex operations at blazing speed.

2 PLC system overview



3 One of ABB's first PLC installations, circa 1944, published in Brown Boveri Mitteilungen, the predecessor of ABB Review, in Jan/Feb 1944 (Abb. 169 & 170).



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Another technology leap was made possible by the pioneering work in digital modulation and coding. Digital communication is now part of everyday life, be it in cellular phones, fax machines, CDs, DVDs, digital satellite or terrestrial TV and radio broadcast or MP3 players, to name but a few. In order to visualize the way in which technical advances have altered the conditions of daily life, consider how telephone lines were and are used to carry digital information with the help of so-called modems. Initially, a technology called Frequency Shift Keying (FSK) was used and, in 1962, a data rate of 300 bit/s was achieved (later standardized as V.21). More than 30 years later, that speed had increased by more than two orders of magnitude to 56 kbit/s (V.90/V.92)! With ADSL, even higher data rates are possible, albeit requiring a much larger bandwidth (not otherwise used on telephone subscriber lines).

Similar progress was possible with PLC systems. Modulation and coding principles had, however, to be adapted to cope with the scarce spectral bandwidth resource and difficult channel conditions of PLC systems.

Then there was the additional hurdle of huge distances that needed to be overcome. In 1999, ABB introduced the world's first digital PLC system with automatic speed adaptation (AMX500), allowing a data rate of up to 28.8 kbit/s in a 4-kHz bandwidth, or up to 64 kbit/s in 8 kHz. Again, this is an improvement of several orders of magnitude.

ETL600: A flexible and future-proof embedded PLC system

In recent years, technology advances presented new opportunities for PLC applications, particularly those related to higher bandwidth provisioning, integration into digital networks, combined with functional enhancements, and ease and flexibility of use. These new possibilities – taken together with the economy and reliability considerations for which PLC is known – have led to a remarkable revival of PLC systems worldwide.

The latest generation of ABB's PLC equipment, ETL600 4, is a truly embedded system that integrates and extends many components of its predecessor in a most flexible way. With this new, integrated, multi-service platform it is possible to integrate all PLC applications in one single system.

The ETL600 system architecture is based on a combination of proven technology with cutting edge hardware and software for digital signal processing. This allows the user to configure the system with a few mouse clicks, where previously integration of additional hardware modules required programming with jumpers and switches, or even soldering. In addition to user-friendliness and unprecedented application flexibility, ETL600 also guarantees unconditional compatibility with legacy as well as state-of-the-art digital telecommunication environments. ABB's ETL600 provides data transmission speeds four-times that of other systems currently available on the market.

4 A PLC frontrunner, the ETL600

The novel high-speed operating mode of ETL600 paves the way for providing Ethernet/IP connectivity over high-voltage power lines.

In order to provide security and reliability, ETL600 incorporates extra measures for high availability and protection against electromagnetic interference and damage due to over-voltage stress. Besides complying with all relevant EMC/EMI[1)] standards, all interfaces, including data ports, are electrically isolated; hence providing additional protection against over-voltages, ground potential rise and ground loops. The ETL600 also provides improved reliability through built-in self-test functions and support for easy commissioning and maintenance.

Looking ahead

Each new technology leap offers faster and better ways of executing routine tasks. More importantly, it also opens the door to a wide variety of new applications. Traditional PLC systems were basically point-to-point links, enabled for point-multipoint connectivity through upper-layer protocols of SCADA systems. With the introduction of digital PLC and digital multiplexers, switches or routers, multiple PLC links can now be interconnected to form a meshed network. Such a network provides a high degree of resilience against link failures and supports new applications, such as wide-area monitoring, control and protection. Furthermore, voice signals, which are today still largely transmitted as analog signals, can be converted into digital bit streams, which consume less of the precious bandwidth on power lines.

The new features of digital PLC technology permit the use of modern PLC systems as a reliable backup of mission-critical services like SCADA and teleprotection that are normally conveyed over broadband media. In particular, the novel high-speed operating mode of ETL600 paves the way for providing Ethernet/IP connectivity (eg for LAN-LAN interconnections) over high-voltage power lines – an application that was unthinkable with traditional PLC technology.

Because of the flexible and future-proof architecture of embedded systems, additional functionality can later be introduced with new software releases, without needing to replace the hardware.

Although this article focuses on PLC, impressive technological advances have been made in the entire utility communication portfolio, particularly in fiber optics and microwave radio. ABB offers integrated communication solutions for mission-critical applications for electric utilities, the oil and gas industry, and railways. Thanks to the latest developments, it is now possible to use a single network system for the remote management of an entire communication network.

For more information see:
http://www.abb.com/utilitycommunications

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Footnote

1) Electromagnetic compatibility (EMC) is the ability of equipment to operate without interfering with other devices. Electromagnetic interference (EMI) focuses on the amount of energy that emanates from electronic equipment that can cause performance degradation in nearby equipment.