Don't touch!

Passive voltage indicator – telling when the line is live

Jan Czyżewski, Maciej Wnęk, Marek Florkowski, Thomas Liljenberg, Kurt Kaltenegger

As any school physics teacher will go to great lengths to remind us, a voltage measurement requires two points. A point does not have a voltage of its own but has a voltage in relation to a reference point. But for people working on switchgear it is important to know whether a particular conductor has voltage or not with respect to any point in its vicinity, be it a neighboring conductor or a grounded component. To help them, ABB has developed an indicator that will show exactly that – without a defined reference point. How did they do it and what happened to Physics?

Voltage indicators are vital for staff working on medium voltage (MV) distribution installations. Such indicators help track faults and show when it is safe to earth the system. When working on components, even though a certified measurement and safety procedures are required, a redundant device functioning independently contributes to safe working practice.

Typically, a voltage detecting system consists of a voltage divider (capacitive or resistive) reducing the voltage to a directly measurable level (ranging from a few to around 100 volts). A simple voltage-indicating device is then connected to the divider. In most systems, the primary impedance of the divider is incorporated in a MV component, for example in a bushing, a current transformer or a supporting insulator. A wire connection leads from that component to a panel incorporating the secondary impedance of the divider and the detecting device. Generally, such systems are applied only on enclosed switchgear panels.

There are, however, a vast number of locations on a distribution system, at which a voltage indication is desirable but not installed due to the additional complexity this would entail (need of expensive outdoor compatible systems, lack of primary impedance, etc.) Typical examples are distribution transformer bushings or terminals, outdoor cable ends where they feed onto overhead lines or terminals of outdoor switch-disconnecting units.

Ideally, provided the price of a system can be made low enough, the voltage indication should be present at every point of the system.

> Two types of PVI indicators have been designed for two sensitivity ranges to help with fault location as well as providing additional voltage testing safety for earthing applications.

As a vision, one can imagine a power system in which each bus bar or conductor turns a particular color when energized. In this way, live conductors can easily be distinguished from those that are temporarily switched off.

Using the field

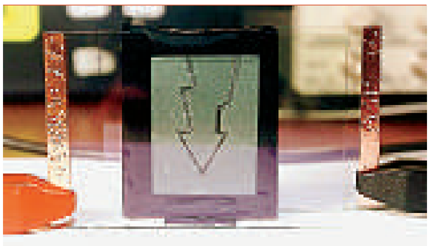
As each energized conductor is surrounded by an electric field caused by its voltage, one approach would be to develop a material or device that modifies its optical behavior in the presence of a field of a particular magnitude.

This led the researchers of the ABB Corporate Research Nanotechnology program to explore display technologies. In principle, virtually any display technology could be suitable in which an electric field leads to a change in the optical properties of the active material or structure, and that change is perceivable to the human eye. This is straightforward in theory, but the electric field around the conductor of a typical air-insulated distribution system ranges from a fraction to a few kilovolts per centimeter (kV/cm), a low value in terms of electro-optical materials. No known display material was able to respond directly to such low electric fields.

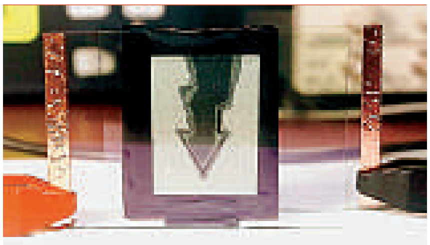
Despite these technical difficulties, a first working demonstrator of a device showing the required sensitivity was created in 2002. The demonstrator 1 was made using a novel flexible electrophoretic display material, often described as "electronic paper". The display material is not able to respond directly to the electric field in question, however. An adaptation developed by ABB enabled the accumulation of energy from a number of AC

1 First demonstrator of principle of operation of passive voltage indicator. In 50 Hz AC electric field of average magnitude of 1 kV/cm the display panel shows a well visible sign of high contrast.

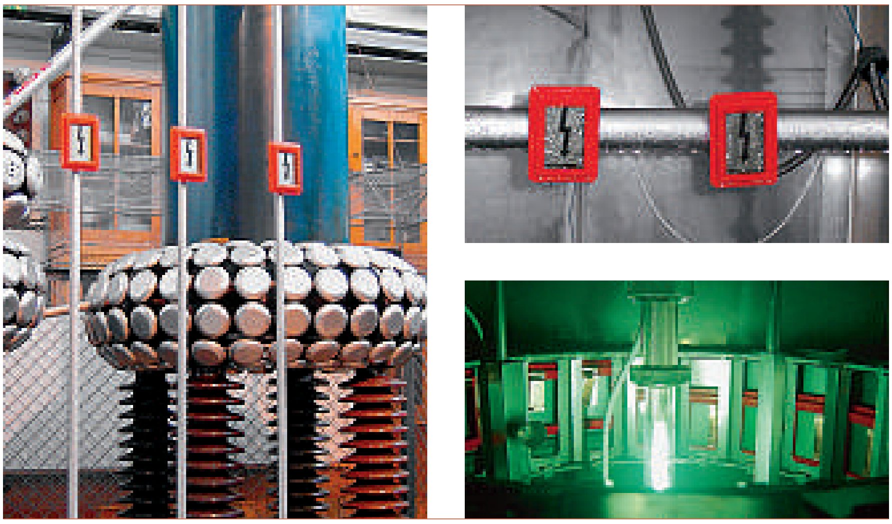
No electric field



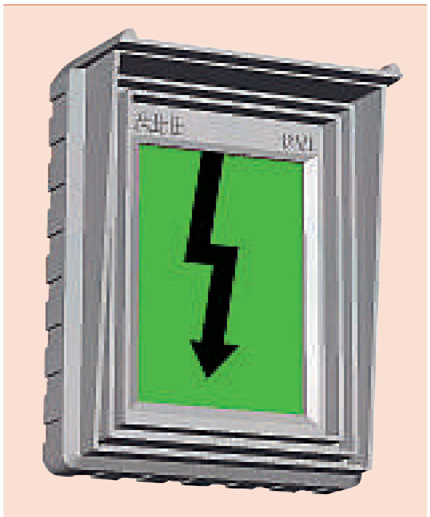
Electric field 1kV/cm



2 Passive Voltage Indicator (PVI) prototype.



3 PVI indicators on test on 3-phase line under 6 kV voltage. Pole distance is 20 cm. Voltage presence is indicated by clearly visible, large lightning arrow signs (left). PVI indicators operating under saline fog (top right) and being tested in Xenon arc lamp chamber (bottom right).



4 Design of the pilot PVI product featuring a silicone elastomer enclosure suitable for permanent outdoor operation.

oscillation periods (taking less than one second in total) thus enhancing the effective sensitivity. In the result the local electric field inside the display material is built up whose amplitude is much higher than the peak of its external value. This allowed the device to respond to electric fields of less than 1kV/cm.

Nevertheless, to be able to apply the technology to power equipment, sensitivity is not the only criterion. On medium voltage equipment, particularly in an outdoor application, it must survive tough environmental conditions such as broad temperature ranges, humidity variations, rain and direct sunlight. Additionally, once installed, it must remain operational for many years without maintenance. Fulfilling such demands with the all-plastic electronic-paper technology would require considerable further development.

Considering the required temperature range and the overall robustness of the system, the project team turned its attention to glass-encapsulated twisted-nematic liquid crystal display (LCD) technology – the simplest but most robust of all LCD technologies. Although the sensitivity of this technology fell short of the requirement by a factor of 10-100, a microscopic display panel structure could again be created to permit a local amplification of the electric field. The desired sensitivity could again be reached without sacrificing advantages of this display technology, such as the well-established manufacturing process and low price.

The success of this development step encouraged the team to develop a prototype voltage indicator 2, named Passive Voltage Indicator (PVI). Particular care was taken to make the prototype suitable for outdoor use. These first PVI prototypes, of which about 100 were manufactured, were put through a broad range of tests 3. This included functionality tests on 3-phase medium voltage systems, a saline fog test, xenon arc lamp tests simulating extreme sunlight and accelerated climatic aging tests. The test results show that the device is able to survive such tough treatment. Currently, a pilot product is being developed 4. PVI will operate without external power supply and once installed, will be entirely maintenance free.

Two types of PVI indicators have been designed for two sensitivity ranges. Their specification will cover the whole range of IEC and ANSI nominal medium voltages from 3kV to 36kV. Instructions will advise which PVI type should be used for which application – depending on the nominal voltage of the system and the geometrical arrangement of its conductors. For example, for 6kV nominal voltage PVI is functional for any pole distance from 125mm (lowest typical value) to 400mm. The voltage threshold is as recommended by the IEC standards for voltage detecting systems (IEC-61958 and IEC-61243), ie, the threshold for indication of voltage presence is always below 45% of the nominal voltage of the system.

PVI will be suitable for installation during servicing, when the system is dead, as well as on live lines using a hot stick. PVI will definitely help with such tasks as fault location and provide additional voltage testing safety for earth application.

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Wireless ad-hoc networks

New enablers for plant connectivity

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A wireless self-configuring network provides an interesting alternative to a classical network, for example as a communication bus within a plant. Devices can easily be added or removed and the network will smartly reconfigure itself after any change.

Network infrastructures form an important part of everyday life – whether this is the telephone network, a local office network, or any other. The rapid spread of wireless technologies has increased mobility but fixed infrastructure remains important. Recent troubles in the telecommunications business have, however, questioned the ubiquitous deployment of expensive and environmentally unfriendly cellular networks. An increasing number of voices are calling for a more pragmatic approach to combine traditional networks with local wireless clusters, between which users can switch depending on their needs [1].

Parallel to these developments, another trend with its roots in military research is surfacing. In the '70s, US defense agencies set a strong emphasis on enabling soldier-to-soldier networking capability in an infrastructure-free environment. So-called packet radio networks were the first attempt to supplant a fixed infrastructure through self-organizing network nodes. Successive breakthroughs in hardware miniaturization have now made it possible to deploy millimeter-scale sensing devices that spontaneously form a communication network. The University of California in Berkeley's Smart Dust project is a widely advertised realization of this concept [2].

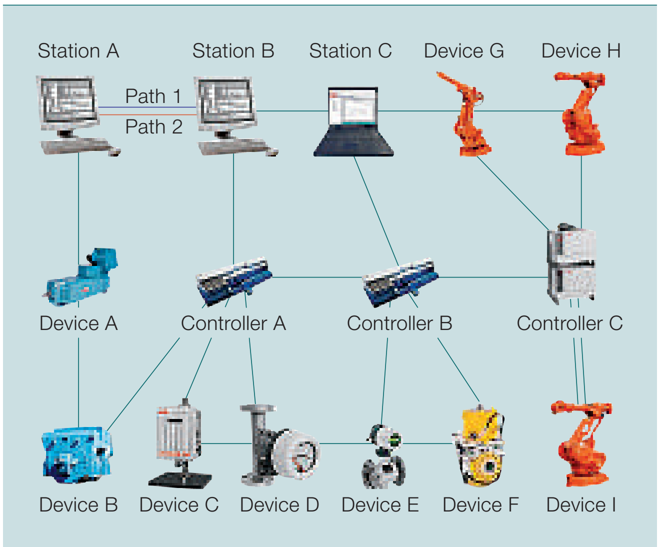
A new paradigm for wireless communications

The outcome of these trends is a new paradigm called ad-hoc networks (AHN) or wireless sensor networks where large-scale sensing is the primary purpose. Networks of this type consist of a set of mobile nodes that freely join or leave the network with minimal administrative overhead. Nodes within transmission range communicate directly with each other, while communications over longer distances use intermediate nodes as relays in a multi-hop fashion 1.

> Ad-hoc networks (AHN) consist of a set of mobile nodes that freely join or leave the network with minimal administrative overhead.

Network operation is said to be self-organized but also self-healing: should a transmission path fail, alternative ones are automatically found to maintain network integrity.

1 Example of a multihop ad-hoc network. Dotted lines represent possible wireless connections. Path 1 (in blue) is the normal path to reach Device I from Station A. If Controller B fails, rerouting is carried out to provide, for instance, Path 2 (in red) that hops through Station C and Device G to avoid Controller B.



In addition to areas such as relief operations, vehicle cooperation and public telecommunications, AHNs can bring significant benefits to industrial automation. Plants are indeed fervent consumers of communications, with fieldbuses transporting information across manufacturing or process installations. In addition to offering greater flexibility when installing or upgrading automation networks, AHNs can drastically shrink deployment and maintenance costs. Their use also supports increased decentralization of automation functions across the whole plant.

Toward new standards

Communication technologies always need widely accepted standards to strengthen market presence. Bluetooth was introduced some years ago as a possible candidate but failed to gain sufficient momentum. Wireless local area networks (WLANs) implementing the IEEE 802.11 suite of standards have been much more successful and are spreading at a fast pace. Although they still rely on distributed base stations and do not accommodate more than one routing hop, WLANs are the first step toward more advanced AHNs.

Where cost and power consumption are driving factors, ZigBee is profiling itself as a strong candidate. Based on the IEEE 802.15.4 specification, ZigBee is a cost effective alternative for industrial applications that do not require high data rates. Transmitting in unlicensed frequency bands, it accommodates both star and mesh topologies with minimal administration overhead and dynamic routing capabilities [3].

Getting to the plant floor

Gathering diagnostic data for machine monitoring is an obvious AHN application. Preventive maintenance programs for key plant equipment are critical to industrial operations. Remotely assessing the condition of devices such as rotating machinery or an automated assembly line can yield additional status information and help schedule maintenance tasks. Because industrial activities often operate in hazardous or inaccessible locations, wireless communication provides a safer and cheaper way to monitor assets. Extending network reach or going around obstacles such as concrete walls is achieved through multihop transmission. Self-organization means network planning and management is made easier than ever before.

Introducing wireless links not only at field device access level but also in the control loop opens up new horizons for process and discrete automation. A fully decentralized architecture supported by an AHN can implement significant cost savings and supports faster design and painless upgrade of control functions. From a networking point of view, the adding or removing of devices is a transparent modification. Ultimately, critical data exchanges can be guaranteed by customizing specific routing algorithms.

Challenges and opportunities ahead

ABB is well positioned to benefit from this emerging technology. Automation networks support a vast range of products in ABB's portfolio. More than enhancing today's fieldbuses, AHNs have the potential to change the face of industrial automation. Cost reductions, support for mobility and portability, ease of installation, improved accessibility, new insights into industrial operations are all made possible by these new plant connectivity enablers. Technical challenges are still on the way, such as scaling up to hundreds or thousands of network nodes and devising optimized control and communication algorithms to guarantee highest reliability. Maintaining the research momentum in innovative communication solutions is therefore more important than ever. This is clearly on ABB Corporate Research's agenda.

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Autonomic computing

Automating IT Asset Management of industrial automation systems

Thomas E. Koch, Esther Gelle, Richard Ungar, Johan Hårsta, Laurie Tingle

The increasing complexity and functionality of IT devices is making industrial automation systems more complex to configure, diagnose and maintain. This tendency is also leading to higher costs and an increased risk of configuration and setup errors occurring. Industrial automation systems must learn to self-configure, self-repair and operate as autonomously as possible.

The installation and administration of large heterogeneous IT infrastructures (ie, multiple networks, devices, computer hardware and software) has become increasingly complex and time intensive. With the exponential growth of the Internet and device sophistication, it is becoming increasingly arduous to manage such a system centrally. Additionally, it is more and more difficult to find the necessary expertise to manage all these areas.

Industrial automation systems (such as those delivered by ABB) present a further challenge: typically, they support mission critical businesses and must be up and running 24 hours a day, 7 days a week. Much of the installation and administration of such systems is still performed manually and thus expensive and potentially error prone.

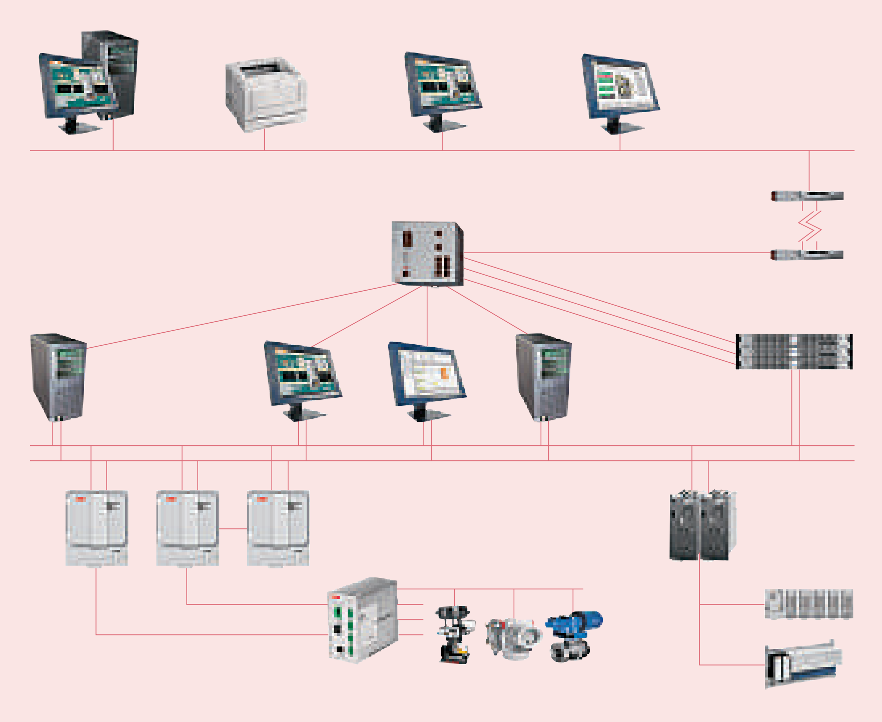
The long-term vision for these systems is that they must behave *autonomously*. For the short and medium term, various levels of automated IT asset management tools and practices are being introduced.

Vision: autonomic computing

In its recently published autonomic computing perspective [1,2], IBM explains: *"Autonomic computing is an approach to self-managed computing systems with a minimum of human interference. Autonomic computing is an emerging area of study and a challenge for the entire IT community to address in earnest."* The best example stated so far is *"the autonomic function of the human central nervous system. Autonomic controls use motor neurons to send indirect messages to organs at a sub-conscious level. These messages regulate temperature, breathing, and heart rate without conscious thought. The implications for computing are immediately evident; a network of organized, 'smart' computing components that give us what we need, when we need it, without a conscious mental or even physical effort."*

There is no absolute definition or standard on the meaning of the term 'autonomy'. In research, however, there is a general agreement that future industrial automation systems should fulfill the following requirements:

- *Self-installation and configuration:* Components such as computers, 1 Diagnosing the cause of a network failure can be extremely time consuming. With PNSM, software users have access to limitless data detail.



routers, switches and controllers (for example ABB's AC800M) should acknowledge, install and configure themselves. If necessary, they also inform neighboring components of their existence, eg, by announcing services offered.

- *Self-Optimization:* Components optimize their behavior – performance and efficiency - depending on their environment and seek to provide the best possible services. In cases of overload and other bottlenecks, a component informs its neighbors or the whole system and attempts to distribute the workload to other under-utilized components. The system as a whole seeks a stable and well-balanced state.
- *Self-Healing:* Components automatically detect software and hardware conditions deviating from the standard and then diagnose and repair the problem (eg, broken hardware replaces itself or components automatically install a new software patch).
- *Self-Protection:* Components automatically recognize intrusion attempts such as hacker or virus attacks. Each component administrates its own data and protects these. Methods of authenticating and approving other components and users are thus required. Additionally, components must learn from bad experiences and improve their protection behavior. A single unprotected component can endanger the whole system.

In order to achieve these goals, the components must use a common language. Data structures, protocols and services must be openly standardized and preferably implemented by all suppliers. Some examples implementing such measures are: the Intelligent Platform Management Interface (IPMI); Web-Based Enterprise Management (WBEM) of the Distributed Management Task Force organization (DMTF)[3]; Structured Management Information (SMI) definition; and the Simple Network Management Protocol (SNMP) of the Internet Engineering Task Force (IETF)[4] community. (DMTF and IETF are responsible for standardizing the architecture and integration technology for corporate and Internet environments.)

ABB PC, Network and Software Monitoring (PNSM)

The present day state-of-the-art error handling technique is to inform a master process control system such as ABB's Industrial IT 800xA of errors and faults detected during operation. These reports are passed to an operator who then decides on remedial action.

Autonomic computing is an approach to self-managed computing systems with a minimum of human interference.

For example: A router in an industrial automation system is over-loaded, becoming a bottleneck and so reducing the throughput of the whole production process. The ABB PC, Network and Software Monitoring (PNSM) OPC server polls the device and relays returned data to the 800xA console 1. If any parameter is approaching a critical limit, 800xA informs the operator who intervenes accordingly.

PNSM is an ABB proprietary monitoring software; it is part of the tightly integrated suite of products included in the 800xA system. PNSM provides a pre-configured library of IT Assets representing devices and system processes widely used within industrial businesses today. Nevertheless, it is very difficult to compile a complete inventory of the IT infrastructure of a customer. When monitoring new IT Assets possible issues are:

- What are the components of an industrial automation network?
- What variables should be monitored?
- If a component has to be exchanged or added, how can the required variables be found?

For a new IT Asset today, the steps behind this installation and configuration are still manual requiring significant time, technical insight and knowledge of different technologies and tools, such as network protocols (IP, SNMP), Windows Operating Systems, Windows Management Instrumentation (WMI) and the component or device itself. Such an engineering effort can be time consuming, potentially delaying the integration of new assets and devices for PNSM monitoring.

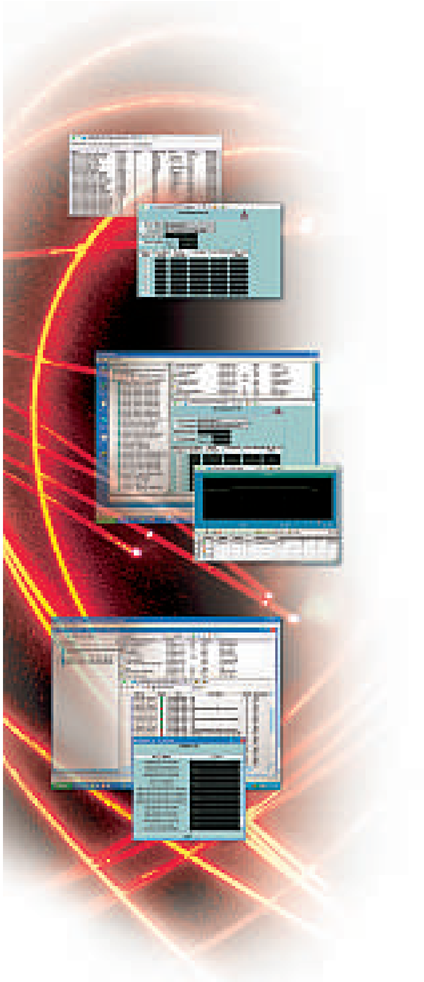


ABB Network and Device Scanning (NDS) tool

Why not apply the vision of autonomic computing to industrial automation systems and process control software? From the installation, configuration and administration perspective, Automated Network Management of industrial automation systems has been introduced. This is a first step towards autonomic network management. The term "automated" indicates that there is still user interaction, but this interaction is kept to a minimum. During the installation and configuration process (of an automation system, 800xA and PNSM) and in order to correct faulty behaviour of the system once detected by PNSM, the user is still required to enter basic data, answer some questions and choose between alternatives. But, overall, many steps of the manual IT asset and device definition process can be hidden from the user.

ABB Corporate Research, CHCRC, in cooperation with ABB, CAABB, in Burlington, Canada, have, through the "Auto-configurable IT-Assets" project, implemented a new tool: a Network and Device Scanning tool (NDS) for PNSM. NDS has been deployed with the SV 4.0 release of the 800xA system. The main features of NDS are:

- Scan an industrial automation network using SNMP
- Obtain all available information on potential devices and their properties
- Map the detected data sets of IP nodes and SNMP variables to supported functionality
- Look-up and load missing information
- Setup functionality of selected information sets in the Windows operating system for later monitoring
- Provide variables and path information to PNSM and verify the corresponding functionality using standard Windows interfaces

NDS is a discovery tool for IT Assets in an automation network and is used by system engineers and integrators for the auto-configuration of recognized IT Assets within PNSM. The main benefits include reduction of time-consuming and complex engineering efforts, improvement of the quality of configuration data, and faster integration of new Assets into the Windows operating system repository and PNSM library. Therefore, NDS may result in significant cost savings for ABB and its customers. In addition, the technical project results will be published within the scientific community thus securing ABB's technology against competition.

Future steps toward the autonomic computing vision are already being considered. The standard SNMP version 3 was released at the end of 2003 and up to now only a few suppliers have implemented this new version in their products. SNMP v3 defines mechanisms to provide services missing in previous versions, in particular authentication, privacy, and authorization definitions. This will protect and secure managed components of automation systems, as the system will know who is asking for information, from where and whether it is authorized.

Other more sophisticated approaches may use open standards such as IPMI and WBEM using software agents and even better technologies still to be identified.

ABB as a world leader in automation technology will play a decisive role in developing, implementing, and applying these new technologies.

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