Technical Information

Communication in the Field

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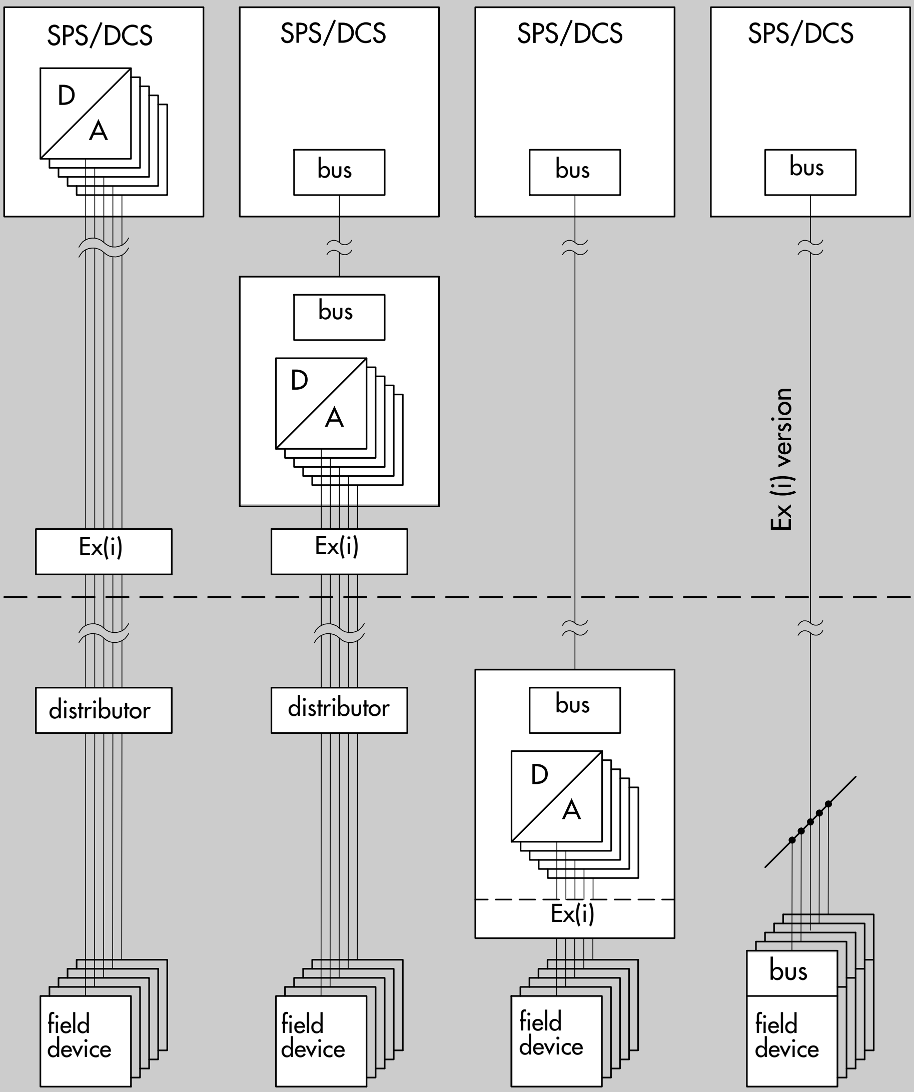

Part 4 Communication

Technical Information

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Communication in the Field

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Introduction

The automation of production and manufacturing processes is continuously increasing. Process and device data must be made available to the various, often widely distributed automation and visualization stations. Hence, safe and reliable communication is mandatory.

Fieldbus systems have performed the task of connecting the field devices with the control station in manufacturing and drive engineering for many years now. Today, more than one million networked field and automation devices are successfully implemented.

manufacturing engineering uses fieldbus communication

On the other hand, the conventional 4 to 20 mA wiring technique is still being used in process engineering applications (see Fig. 1). This type of data

process engineering mainly uses analog signal processing

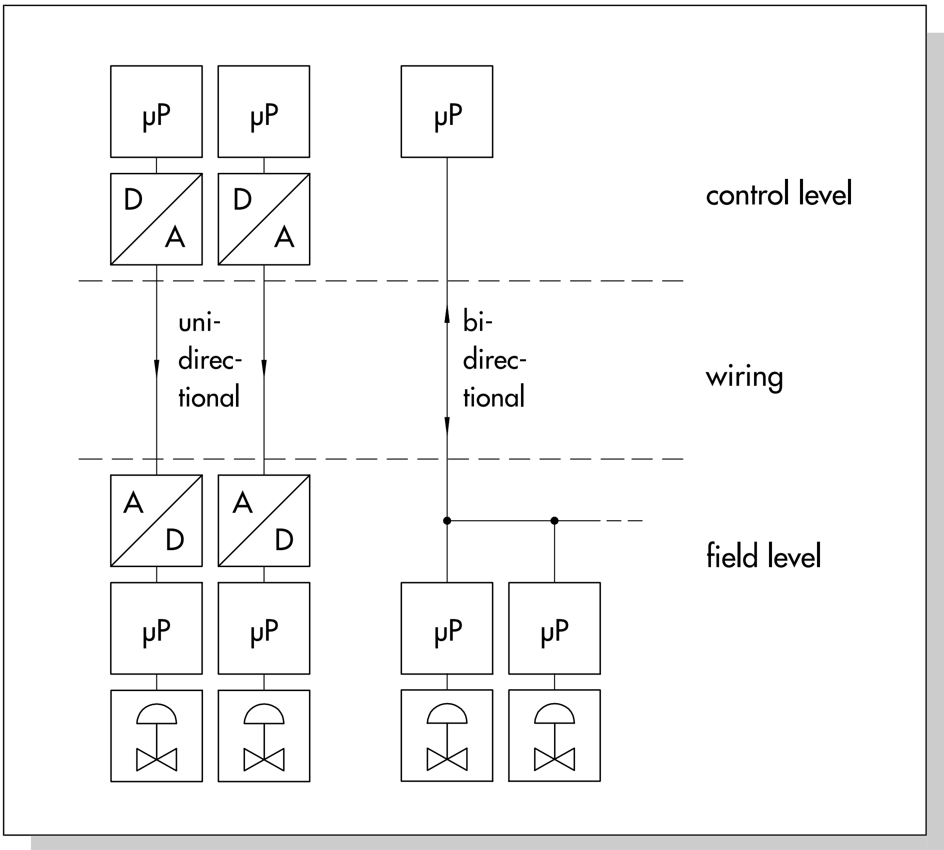


Fig. 1 Comparison of communication techniques: 4 to 20 mA technique vs. bus wiring with bidirectional communication

transmission has proven successful for a long time. Nevertheless, this technique has two considerable disadvantages:

4 to 20 mA technique

- wiring is very complex – one pair of wires per device – and
- communication takes place in only one direction – unidirectional.

bidirectional communication for powerful services

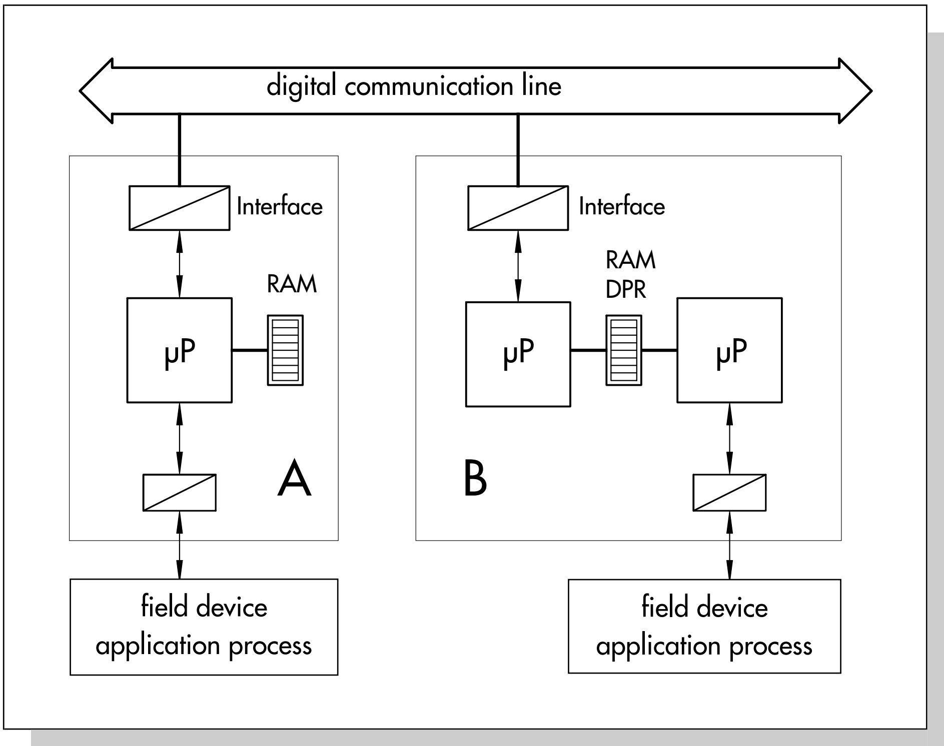
However, for many applications unidirectional data transmission is no longer up-to-date. State-of-the-art process monitoring and control systems require bidirectional communication.

Smart field devices can store information that is relevant for the process as well as for the devices and send messages to higher-level control units. Powerful devices can additionally perform diagnostic routines so that clear maintenance messages can be generated for the plant operator. Another option is to store calibration values in the field device itself, enabling retrieval on demand, e.g. if the device is exchanged.

Since modern control stations and field devices are based on microprocessors, D/A or A/D signal conversion, which would otherwise be required, is no longer necessary (see Fig. 1). Additionally, many devices can be connected in parallel to a single line. This is made possible because the digital signal transmission does not permanently occupy the line. The destination device stores the transmitted data packet and subsequently carries out the requested action. As a result, the transmission line is immediately available for other data and devices.

communication replaces 4 to 20 mA technique

The bus connection of the field devices illustrated in Fig. 1 considerably reduces wiring and with it the number of required components. However, this instrumentation method requires not only communication for the start-up and parameterization, but also digital transmission of all values - also set point and actual values. Also it must be ensured that each field device is requested for data or receives new set point values within precisely defined time intervals.



A: one processor

B: two processors for communication and application

Fig. 2: Microprocessor technology in field devices

microprocessor performs application and communication tasks

In fieldbus capable field devices, the application processor often additionally controls communication. For high-capacity utilization or complex communication services, two separate processors are used, one for communication and one for application. Data exchange between the processors can then be carried out, e.g. using common memory space – Dual-Port-RAM – (Fig. 2). As a result of the increasing functions and the higher scale of integration of the electronic components, this solution can also be implemented very cost-effectively – especially for large-scale manufacturing.

Requirements of Process Engineering

Prerequisite for any communication in the field is a reliable data transmission which functions properly even under rough industrial conditions. It is also important that all components are always readily available.

Standardization

open specifications

To enable the user to network or interchange field devices of different manufacturers (interoperability or interchangeability), an open specification, preferably defined in a standard, must be available. Open bus systems or protocols are not managed and put on the market by an individual manufacturer, but by a user organization (e.g. HCF – HART Communication Foundation, PNO – PROFIBUS Nutzerorganisation, FF – Fieldbus FOUNDATION).

In process engineering, additional requirements must be met so that the field networks (PROFIBUS-DP, Interbus-S, CAN, etc.) used in manufacturing engineering are often not applicable.

Characteristics of a flexible and versatile communication system

- open protocol specification
- application in hazardous areas
- low installation costs
  - ⇒ variable connection of all components (network topology)
  - ⇒ two-wire technique
- sufficiently high baud rate
- connection and disconnection of devices during operation

Fig. 3: Communication in process automation

Application in hazardous areas

Process engineering tasks often require that field devices be used in hazardous locations. Therefore, the transmission medium as well as the devices must meet special explosion protection requirements.

'Fieldbus Intrinsically Safe Concept' for intrinsically safe communication

For fieldbus systems, the German Physikalisch-Technische Bundesanstalt PTB (federal physicotechnical institute) created the FISCO model in cooperation with renowned manufacturers. This model describes one way of realizing intrinsically safe communication systems. According to this model, the most important conditions for intrinsically safe operation are the following:

- compliance with the European standard: EN 50020 (intrinsic safety "i")
- only one power supply unit per line segment
- all communication participants act as passive current sink (min. power consumption: $I_A \geq 10$ mA)
- the participants' inductances and capacitances acting externally are negligible concerning intrinsic safety (inductance ≤ 10 mH, capacitance ≤ 5 nF),
- limitation of the current and voltage at the power supply unit (e.g. EEx-i ia IIC: $U_{max} \leq 15$ V, $I_{max} \leq 110$ mA).

type of protection: EEx i

The intrinsic safety of a component is certified according to EN 50020 by assigning the type of protection 'i', intrinsic safety. This type of protection im-

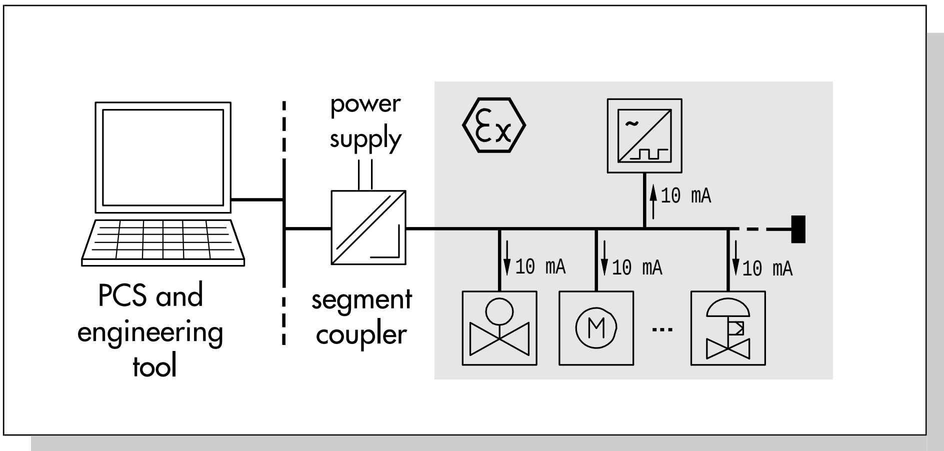


Fig. 4: Fieldbus system according to the FISCO model

plies that the energy produced by arcs and sparks and the temperature on the surface are restricted so that an explosive atmosphere cannot be ignited. In an instrinsically safe field network, the voltage and current must therefore be restricted by means of appropriate power supply units and safety barriers. Also for safety reasons, devices must be connectable and disconnectable during operation without causing interaction. Only field networks which meet these requirements may be used in hazardous areas, such as tanks or chemical production plants.

Topology

adaptable network topology

The wiring of the communication network must be adapted to the topological conditions of the plant. An optimum solution would be a network topology allowing the devices to be networked as required.

A good approach is the tree structure. However, for many plants wiring in line structure where the devices are connected via short stub lines is absolutely sufficient.

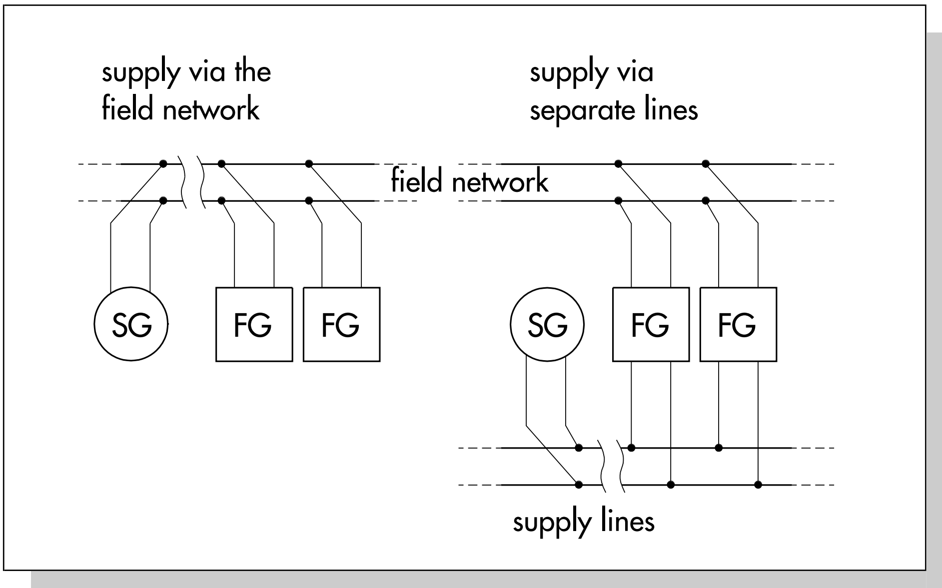
In any case, the maximum possible line length must satisfy the demands of the plant. So it is often permissible to extend the network by using repeaters (power amplifiers).

Two-wire technique

bus-powered two-wire devices reduce installation costs

To save costs, wiring must be minimized, and in hazardous areas, the number of safety barriers must be kept as low as possible. Minimization of wiring and safety barriers is achieved, as for the 4 to 20 mA instrumentation, using the two-wire technique (Fig. 5). In this case, the field devices take the required power from the signal line. With fieldbus systems, this technique is also called bus supply. To be able to combine signal transmission and energy supply on the same line, the data signals as well as the supply currents and voltages must not affect each other.

NOTE: The conventional method with separate signal and supply lines is termed four-wire technique.



SG: supply unit
FG: field device

Fig. 5: Two-wire technique compared to four-wire technique

Ensuring the information flow

To be able to analyze sensor outputs and activate actuators, the response time of the communication system must be adapted to the process sequence. Data security can only be guaranteed when the request cycle of the communication system is shorter than the renewal rate of the data to be collected.

moderate cycle times

In manufacturing plants, the process sequences demand communication cycles of a few milliseconds, whereas in process engineering applications, the cycle times are often longer. Here, analog process variables can be sufficiently controlled with sampling rates of 0.1 to 2 seconds. With these time periods, the reduced baud rate in hazardous areas (IEC 61158-2 specifies 31.25 kbits/sec) does not cause problems in controlling.

Device exchange during operation

connection and disconnection even in hazardous areas

The complex processes in the chemical, petrochemical and mining industry cannot be interrupted for the maintenance or the exchange of a field device. An important criterion for the application of a field network is therefore that field devices can be connected and disconnected during operation.

Communication Systems for Process Automation

Communication systems for use in process engineering applications must fulfill the technical requirements already mentioned and, at the same time, provide flexibility, extensibility and an open structure. The acceptance in the market largely depends on economical aspects. So different factors are taken into consideration when the economic feasibility of an application is to be analyzed.

solutions for diverse applications

The following cases must be differentiated:

- only a small number of smart devices must be installed
- an existing plant must be extended for communication purposes
- a complex plant with different communication levels must be planned
- fast real-time applications must be integrated in the data exchange

The available systems – such as the HART protocol, sensor buses, fieldbus systems, Remote I/O – each provide completely different advantages. It depends on the individual application which communication system yields the best results.

HART protocol

HART uses the existing current loops

HART communication uses the conventional 4 to 20 mA current loop for data transmission. The communication systems requires (almost) no additional wiring. The HART protocol is therefore also a good solution when smart field devices are to be integrated in an already existing plant.

The acronym 'HART' – Highway Addressable Remote Transducer – shows that the protocol originally was defined for measuring transducers. The protocol specification available today, however, supports data exchange with sensors as well as with actuators.

flexible application

HART provides a very simple point-to-point connection between an operating device and a field device. With the appropriate instrumentation, however, HART is also suitable as communication system for extended plants. The only prerequisite is that the field devices are connected according to the conventional 4 to 20 mA technique (see Fig. 6 and L452EN).

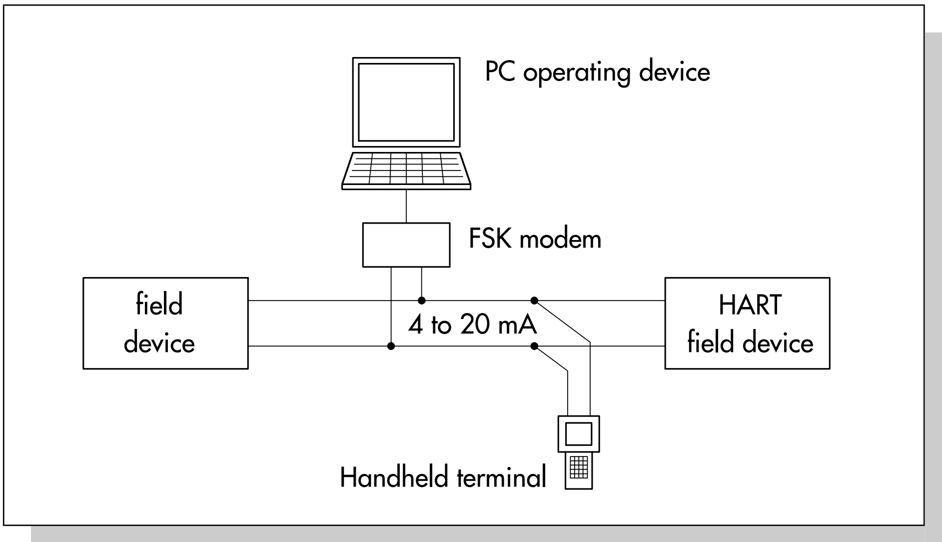


Fig. 6: Connection of HART field and operating devices

Fieldbus systems

Fieldbusses are wired in a completely different manner. Communication can take place on several hierarchical levels – the control level, the automation level and the field level. What makes fieldbus systems so interesting is the very simple and cost-effective wiring.

devices communicate over a single bus line

A fieldbus system replaces the analog 4 to 20 mA current loops with a simple two-wire line running from the control station to the field. This bus cable connects all devices in parallel. The entire information is transmitted exclusively digitally. This includes the data necessary for control and process monitoring as well as the commands and parameters required for start-up, device calibration and diagnosis.

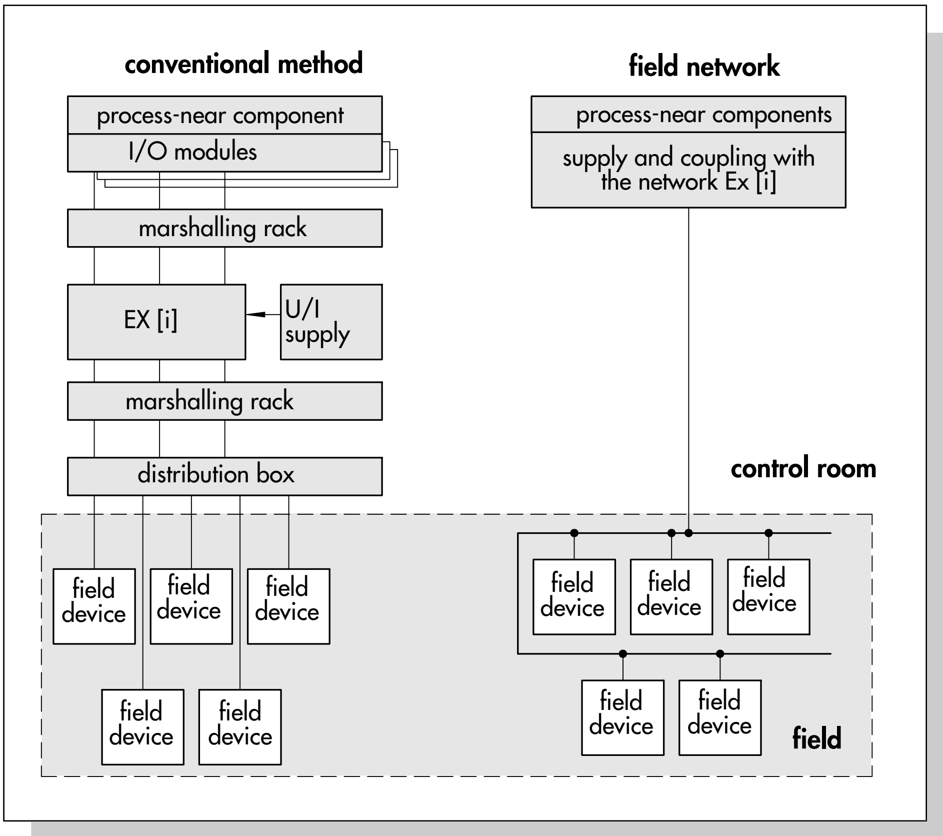


Fig. 7: Comparison of conventional transmission method and field network wiring in hazardous areas

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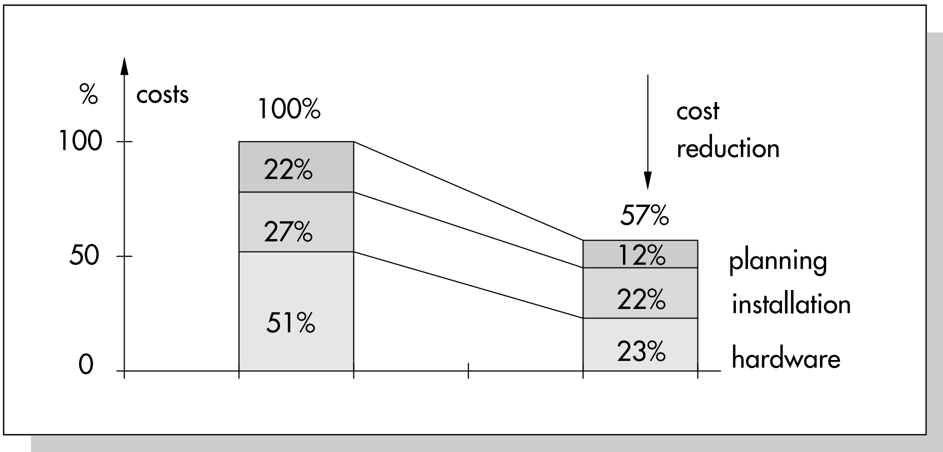

Fig. 8: Cost reductions with fieldbus system
(Dr. Rathje, Bayer AG: calculation example for PROFIBUS-PA)

reduced wiring in the field

Reducing and simplifying wiring has in many ways a positive effect on the plant and operating costs. In a study carried out by NAMUR (standardization committee of the instrumentation and control industry, AK 3.5), the costs of a pilot plant equipped with the conventional transmission technique have been compared with those of a plant with PROFIBUS-PA instrumentation. The calculation example yielded cost reductions of more than 40 % thanks to cost savings in planning, cabling, start-up and maintenance (Fig. 8).

cost reduction with fieldbus systems

An additional asset of fieldbus technology is the considerable gain in functionality and safety. Apart from the easy start-up and self-diagnosis, which is also true for smart HART devices, the fast fieldbus communication is also suitable for real-time capable control systems. Comprehensive status and error messages can be analyzed simultaneously.

comprehensive status and error messages

The advantages provided by today's field networks become obvious when we take a closer look at them:

advantages of field networks

- wiring is reduced from several hundred or thousand lines to only a few lines,
- even long distances of several kilometers are no problem,
- savings in material, required space and weight,
- unlike conventional cabling, high flexibility is achieved when it comes to modifications,

- computers and programmable controls can be easily integrated in the process,
- transparent process monitoring with high functionality can be implemented,
- uniform interfaces reduce maintenance, start-up, development and documentation costs,
- division into small units enables modular system programming and start-up,
- networked field devices enable numerous improvements concerning process and system monitoring thanks to data preprocessing, data security and self-diagnosis
- and since the measuring and control signals are transmitted digitally, the entire system is less liable to errors

The above list of advantages shows that the use of field networks changes the distribution of tasks between the automation devices and the field devices. As a consequence, the field devices operate more autonomously and are therefore equipped with microelectronic components. This trend is reasonable also from the economical point of view, because of

field devices using microprocessor technology

- improved operating and service friendliness,
- increased flexibility (smaller product range) and
- shorter development and implementation periods.

These advantages alone – even without considering the cost-effective field network wiring – are often sufficient to compensate for the extra costs of the communication interface.

functional safety must be guaranteed

The advantages mentioned above can only develop their positive effects when reliable functioning of the plant can be guaranteed upon implementation. Therefore, it is important to define what will happen when the individual components or the field network fail. Which error will be detected and which one can be immediately remedied or, at least, limited as to its effects. Field communication systems vary considerably (regarding protocol, function, topology) so that these questions can only be answered for each implementation individually.

More than 100 different fieldbus systems are commercially available, but only a few of them were able to become established as standard within their area of application. As can be concluded from the statements on page 8 ff, very special requirements must be met in the process engineering industry. The most important prerequisites are the high safety demands, the need to function in hazardous areas as well as openness and extensibility of the system.

standardization for a uniform solution

Repeatedly, efforts have been undertaken to establish an internationally recognized, manufacturer-independent specification that defines the fieldbus for process automation. Such an open standard would ensure a large choice of manufacturer-independent products for the user and, on the other hand, a broad sales market for the manufacturer.

PROFIBUS-PA and FOUNDATION Fieldbus

Today, there are two competing fieldbus systems that fulfill the requirements mentioned above. This is the PROFIBUS-PA – originated in Europe – and the FOUNDATION Fieldbus – focused on America and Asia. Both fieldbus systems operate on the same intrinsically safe physical bus structure (IEC 61158-2). However, the provided communication services and, hence, the protocol definitions differ greatly from one another (see L453 EN and L454 EN).

Both bus systems were primarily designed for use in hazardous areas. The two-wire technique, however, is also a good basis for other applications. The cost-efficient, bus-powered compact devices help simplify production systems for many process engineering applications without the need to eliminate common device standards and connection techniques.

The flexible fieldbus systems enable the connection of completely different field devices. It is possible to control discontinously as well as continuously operating actuators and sensors. However, such a wide spectrum of applications is not always required.

AS-I: bus system for discontinuous-action field devices

When only switching states need to be transmitted (simple sensors, solenoid valves, etc.), the relevant system components can be networked via an adequately simplified bus system. For applications in hazardous areas, the open bus system AS-I (Actuator/Sensor Interface) is a good solution. If required, the AS-I network can be integrated via a special connection in more powerful fieldbus systems (e.g. PROFIBUS).

Rackbus and Remote I/O systems

Apart from the common 4 to 20 mA technique and the fieldbus wiring, there are two other technical solutions which adopt a middle course.

field multiplexer connect 4 to 20 mA with bus systems

In both cases, the field devices are wired according to the conventional 4 to 20 mA technique. However, the lines are not run up to the control station because the signals are digitized and finally supplied to a bus system. This task is accomplished by the field multiplexer.

Rackbus or Remote I/O system

When the D/A conversion takes place in the control room, the system is called Rackbus, whereas conversion in the field is performed by a Remote I/O system (see Fig. 9).

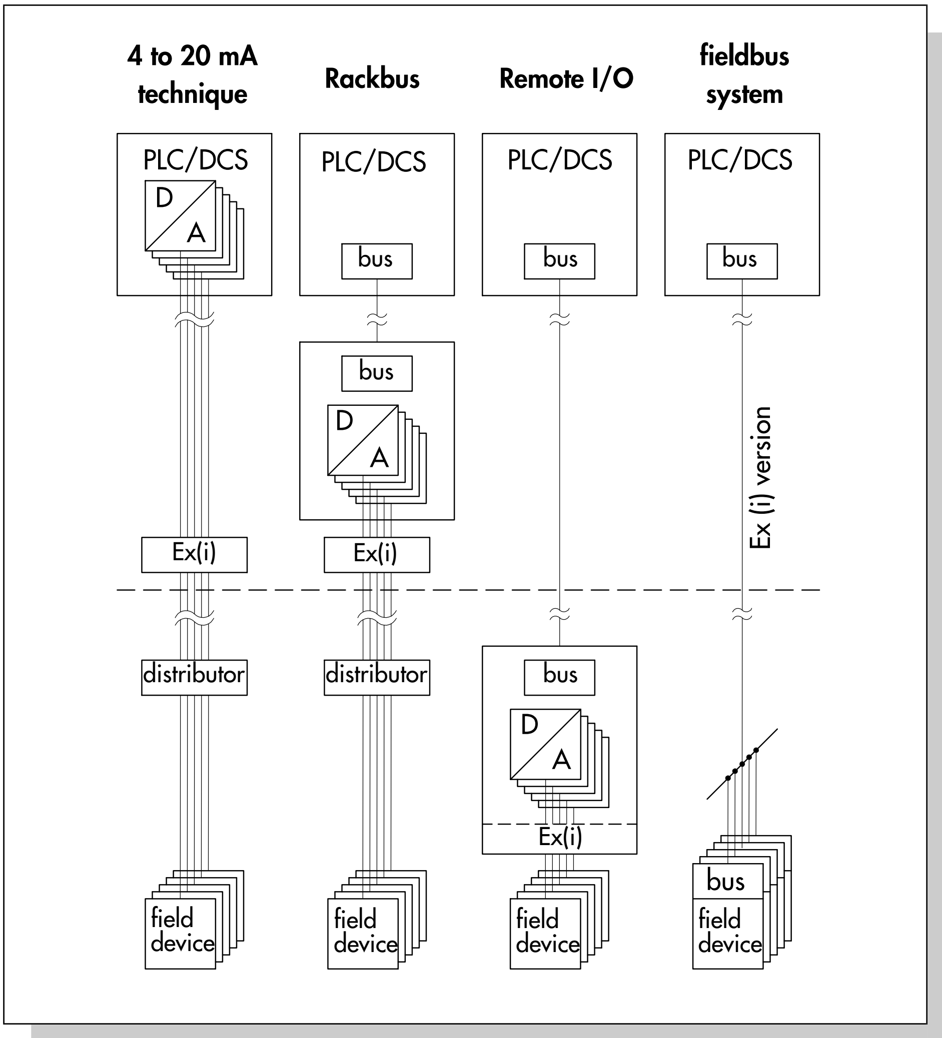

Fig. 9: Rackbus and Remote I/O systems compared to conventional and fieldbus wiring

The most important advantage achieved by this method is the reduction of investment costs, resulting from the fact that fewer lines are required and parts of the marshalling rack can be omitted. As is the case for fieldbus systems, substantial cost savings can be achieved in planning, installation and maintenance.

measures in hazardous areas

Remote I/O components can also be installed in hazardous areas. The device components and the terminals towards the bus must then be designed to meet the appropriate type of protection – e.g. Ex (d), Ex (e). Rackbus components are always installed in non-hazardous areas so there is no need for them to be subjected to special measures. For field devices installed in hazardous areas, the type of protection is often Ex (i) intrinsic safety.

Neither Rackbus nor Remote I/O support bidirectional communication with field devices. Only measuring and control signals are transmitted between the control system and the field devices. Bidirectional data exchange with the control system, providing information on line breakage, short-circuit, etc., is only performed by the field multiplexer.

HART communication also possible with field multiplexers

Some manufacturers offer field multiplexers that are supported by the HART protocol. In these systems, multiplexers are used to decouple the Hart protocol from the current loops and transmit it via a bus system to the engineering terminal. However, this type of field device communication requires comparably complex technical measures since the HART protocol and the fieldbus technique are used simultaneously.

<u>**NOTE:**</u> For further information on the HART protocol, PROFIBUS-PA and FOUNDATION Fieldbus, please refer to the relevant Technical Information (Lit. 4, 5 and 6).

Appendix A1: Additional Literature

[1] L150EN: Digital Signals
Technical Information; SAMSON AG

[2] L153EN: Serial Data Transmission
Technical Information; SAMSON AG

[3] L155EN: Networked Communications
Technical Information; SAMSON AG

[4] L452EN: HART-Communication
Technical Information; SAMSON AG

[5] L453EN: PROFIBUS PA
Technical Information; SAMSON AG

[6] L454EN: FOUNDATION Fieldbus
Technical Information; SAMSON AG

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Figures

NOTES

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