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The Fieldbuses – a Modern Technology at Production Management

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1. The fieldbus place

One of the most modern concepts during the recent years in the world of informatics is "the distributed system". At the same time systems with different destination are concerned – for control, for monitoring, for gathering, processing and data storage etc.

The fieldbuses find their big application exactly in the distributed systems, because via them autonomy is reached at the execution of concrete problems without loading the central production control. Speed and effectiveness are reached at the same time when processing the information and assigning of certain production parameters. The creation of whole networks on the base of the fieldbuses is of great interest and also the connection of the fieldbuses/networks with other networks – local and global.

As a result from the specific requirements to the communications about the production process a hierarchical communication structure with several levels could be made under the form of a fieldbus (Fig. 1). Researches in Europe and USA show that such hierarchical conceptions are of great interest in the industrial field. The advantages of such fieldnetwork in structures with several levels are mainly in the high flexibility. Besides the topology to a great extent is freely elected, the reliability is projected (multistage redundancy, tolerance with respect to the errors) the reaction time is eligible and in this way the real time behavior could be adopted to the concrete requirements.

The most distributed characteristics of the fieldbuses are presented in details in the present paper. The problems with their realizations are also reviewed.

2. The fieldbus usage

The fieldbus technology increases the quality and effectiveness and decreases the expenses. Besides the intelligent device takes the control, the organization and the diagnostic functions on the local level and in this way it is in condition to signalize at

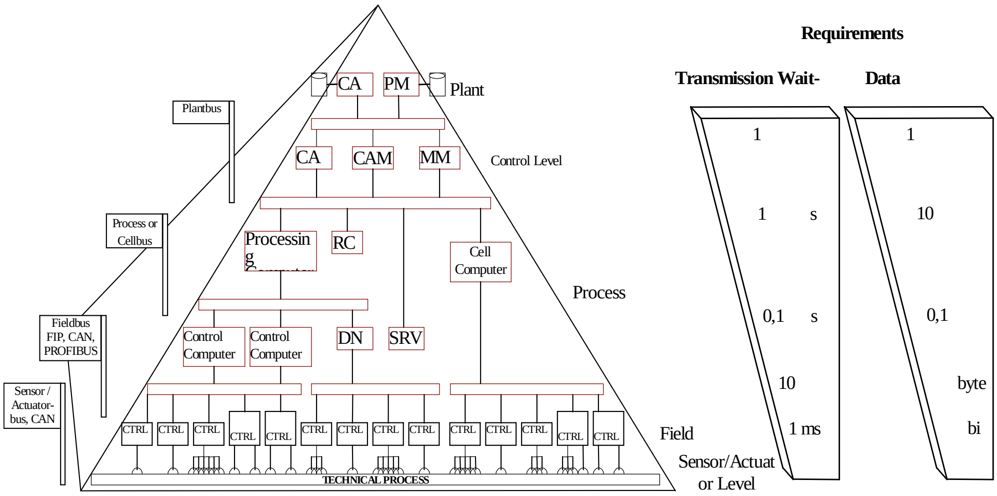

Fig. 1. Communication hierarchy at computer controlled production

errors or necessity of manual calibration etc. With the increase of the calculating capacity the flexibility of the given device also increases and it could replace several devices of the previous generation. The implantation of the fieldbus has two phases: the building of the structure of the system and the configuration of the devices.

The system architecture with fieldbus presents a contemporary variation of the systems with distributed control as the devices can already communicate multipoint and not only point to point. And also, the functional possibilities are transferred to the field device. The control strategy is implemented with the available functional blocks. The devices could be chosen on the base of necessary functions and functional blocks situated in them.

The system configuration requires connection of the functional blocks aiming fulfilling the strategy. Many producers offer packages for configuration to simplify the input of the connections between these functional blocks and other parts for configuration as for example names of devices, labels of contours and frequency of carrying out. After the input of this data the configuration package generates and charges the specific data for each field device. And so with this the system is ready to start.

3. More famous fieldbuses

3. 1. Fieldbus ASI

The bus ASI (Actuator-Sensor-Interface) is a common development of 11 producers of sensors, actuators, and control devices and two higher schools. Topologically ASI could be built like a star, like a tree or lineally. Deviations are possible. The bus can maintain up to 31 slaves with up to 124 binary elements and distribution up to 100 m. When having two directions regime of work the binary elements may reach up to 2 448. By repeaters the distance could be increased up to 300 m, but more sub-knots could not be connected. The conventional sensors and actuators are connected to the bus by connecting modules and the intelligent parts with integrated ASI chip – directly.

The nods communicate by the method "Master-Slave", as the master polishes the sub pages directly and in cycle. One session consists of calling the master, pause, message from the slave and one pause. Data, parameters, addresses or commands are transmitted in accordance of the kind of the calling. As the protocol at this field is

Table 1. Application areas of some of the more famous fieldbuses

Bus	Application	Producer / User
ARCNET	LAN	Datapoint
ASI	Lowest level	Siemens, combination ASI, Intel, Phoenix Contact
BITBUS	Communication on high level distributed control	Intel, PhoenixContact, etc.
CAN	automobile building, medicine, automatics	Bosch, Philips, Intel, Motorola, NEC, Siemens
DIN-M	Computing and testing equipment	
FAIS	control, input/output and network	
FIP	Sensor / Actor	Telemecanique, Cegelec
FOUNDATION	Automatic control in distributed systems	Foundation Fieldbus
Interbus-S	Sensor / Actor	IBS-Club Phoenix Contact
LON	Control of buildings, energetics, telecommunication	Echelon, Gesytec, Weidmueller
PROFI-BUS	Automatic systems, level control, Sensor / Actuator	Bosch, Siemens, Kloeckner/Moeller, AEG

simplified at maximum, it could not be done exact correspondence with the level of the model ISO/OSI.

3. 2. BITBUS

This is one of the oldest buses. Recently it has turned over in something like industrial standard.

BITBUS is a line, but by repeaters may be branched. The method of work is Master/Slave. The master polishes the slaves and expects an answer from them. The slaves cannot begin exchange of information alone and are connected between themselves through the master. Another operation regimes are the messages of the type "Broadcast" and "Multicast ". The protocol is based on the definition SDLC, known with its reliability at industrial applications. The frame of SDLC is formed in a chip and the real message is formed by a program.

BITBUS is used in intelligent systems in which control tasks are distributed between the separate slaves. The bus is convenient for transmission of big quantity of information, when the requirements for work in real time are not critical.

3. 3. CAN

Primarily the bus or sooner the network CAN (Control Area Network) is created by Bosch and Intel for the auto industry. The reliability here is the most important thing. Its prime cost is very low. Recently the bus is very distributed and takes a very big part in the automatics.

CAN has linear architecture. At speed 1 Mbit/s the maximum distribution is 40 m, but it can be increased up to1 km, if the speed is decreased to 50 Kbit per s.

CAN has a special arbitrary system. Each station can start transmitting if the bus is free at the moment. The message identification is simultaneously its priority. When

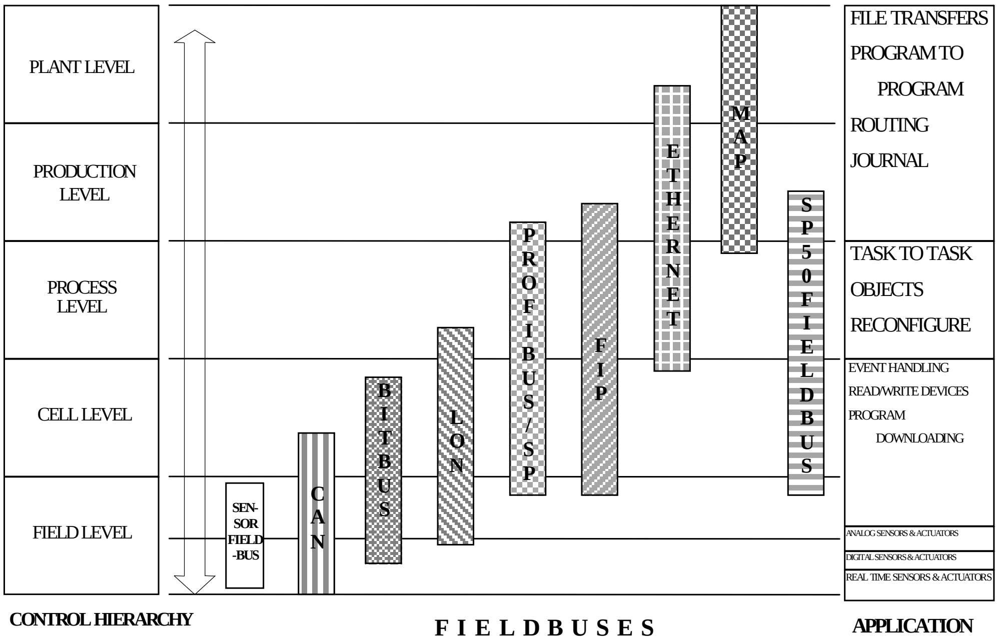

Fig. 2. Application levels for the fieldbuses [Jim Pinto, Action Instruments, 1995]

two stations begin at the same time transmission, the station sending the message with lower priority interrupts the transmission. Besides the message with higher priority is not destroyed as the dominant bits in his identification ("0") cover the recessive bits ("1") in the identification of the other message. At the same time each transmitter overhears the bus and finding dominant bit while sending recessive goes in a regime of receiving. This means that the message with higher priority is send without any delay. For the messages with lower priority the stations make new attempt for transmission. This method of transmission is called non-destructive bitwise CSMA/CD (Carrier Sense Multiple Access/Collision Detection).

Because of the peculiarities of the arbitration the maximum time for distribution of the signal in the network should be significantly lower of the duration of each bit. So each node will be able to announce its reaction in the frame of this time. That's why the maximum distance in the network to a great extent is connected with the transmission speed. Here the fading of the signal is of secondary role. Repeaters can be used, but you have to mind that they additionally slower the signal.

As it was mentioned the reliability in CAN is very high. For the error recognition it is used a combination of five mechanisms: CRC, Format Check, Bit Send/Receive Check, Bitstuffing, Acknowledgment. The nodes are observed themselves and at certain error frequency are switched in a passive mode; if the frequency of the errors increases, they are absolutely switched off by itself from the network.

3.4. Fieldbus FIP

FIP (Factory Instrumentation Protocol) is created in France. Logically the topology is a line, but placing of repeaters, distributors and connecting elements, physically there could built tree or star structure.

The maximum length of the bus is 2000 m. The transmission rate is 1 Mbit per s, but at peculiar application it could reach up to 5 Mbit per s. The basic mode of work is "broadcasting".

The network access control is done in three work cycles, which execution time (elementary cycle) could be configured voluntarily. The length of the three parts could be defined.

A. Cyclic traffic - Polling: The station which owns the function "Arbiter", plays the role of a master in accordance to the bus access. The arbiter requires objects (variable) by they identification number. The node which produces this object immediately sends an answer with the variable content by broadcasting. Each other station, which needs the called object, takes it in this moment from the bus. All bus nodes are *producers*, *consumers* or *producers and consumers* of messages. The order in which the calling is being done is taken from a configuration table. The length of the elementary cycle determines the highest polishing frequency. Lower frequencies are reached as in the object list are input variables only in each *n*-th elementary cycle. The repeating of these actions is called macro-cycle.

B. Acyclic traffic – VARIABLE: When one station wants its variable to be polished out of the cyclic traffic, it sends its wish as an answer to the cyclic polishing. In the acyclic window of the time the arbiter asks the station for the identification number of the variable and puts it according to the priority in a list (two priority levels are possible). These lists are processed in the rest of the time by the acyclic traffic.

C. Acyclic traffic MESSAGE: The acyclic transmission of messages is similar to the acyclic transmission of variables. In answer of the cyclic traffic the corresponding station shows that wants to send a message. In the acyclic part the arbiter gives its possibilities to send it. It has a sender and a receiver.

As the wish of the acyclic communication is send in the cyclic part it is necessary in all stations which will have such messages to be in the list with variables for cyclic processing so that the station could give its wishes.

The arbitration is a process, which observes the station in which it is configured like ordinary such with a certain number communication objects. That's why it is said that this bus has no real master. Anyway this process is created in the main station. After its configuration it is transparent for users software.

The topology, the size and the speed of transmission of the fieldbus FIP make it appropriate for usage in networks, requiring quick periodic processing of digit data and communication between intelligent nodes. It has a very big distribution.

3. 5. Filedbus FOUNDATION

The filedbus FOUNDATION is created as a result of the efforts of the foundation creating the standards for the fieldbuses. This explains the slowness at the defining and its real application. The physical level is defined in 1993. But its confessing for a capable bus has maintained the tests meets many difficulties.

The fieldbus FOUNDATION can use as carrying medium a torsion couple or screen cable. The transmission rate then is 31.25 KB per s on a distance up to 1900 m. Some higher speeds are foreseen – 1 MB per s and 2.5 MB per s. For signal coding is used the techniques Manchester Biphase-L. The arbitration is realized by a central switch, called Link Active Scheduler (LAS). Two types of devices exist - basic and master. The master contains LAS and can control the communication by the bus, and the basic station has no LAS. LAS is given by a list of all participants on the bus as all needed data is determined to be accessed in a certain time. This procedure is done during the configuration of the system. When the time for data transmission from some device comes, LAS sends it a message to publish them by broadcast, so that they become accessible for all participants. All stations configured to use that data receive them simultaneously.

The fieldbus FOUNDATION has defined application level, divided in two sublevels – Field Access Sublayer, (corresponds to 3, 4, 5 and 6 in the model OSI) and

Fieldbus Message Specification (level 7). FMS codes and decodes the commands from the user level and has "object dictionary", permitting access to the data by name, index or address in the dictionary. A user level is also defined, which looks after the **network control** (configuration of LAS, observation of the execution, error detection, configuration of functions in the communication stack), **system control** (assurance of access to assigned device addresses, synchronization of the users clock, localization of devices with labels, switching of operations of functional blocks) and **users application** (built by functional blocks for maintenance of the compatibility between the devices and helping the process control and the automatic production).

3.6. Interbus-S

Interbus-S is created for the aims of the automation and gives possibility of quick access to the digit inputs and outputs. Recently the protocol is widened to give possibilities for parameter transmission between intelligent groups.

The bus has "ring" topology, as the conductors in the two directions are connected in one cable so there is a line on practice. Two types of buses exist: peripheral and for remote connection. The maximum distance which is covered with peripheral bus is 10 m, and the transmission rate – 300 Kbit per s. The remote bus connects several peripheral buses by bus terminals, which at the same time are repeaters. The maximum speed is 500 Kbit per s. The segment at the remote bus can reach up to 400 m, and the maximum distance – 12,8 km.

Interbus-S works on the principal Master/Slave and is optimized for transmission of digit input/output data. The network is organized like a cycle register. Each building peripheral group is presented by one or several 16-bit input/output words. The message consists of a word called "look-back", the input/output words of the modules ordered in correspondence with their physical position on the bus, CRC-word and a word for error. The master "pushes" this message on the bus until the "look-back" - word again reaches it. So each input/output word reaches its position in the corresponding bus module. When the word consists of output data, the module remembers it and after that sends it to the output devices. When the information in the module memory is accepted by the input devices it is written like a word in the corresponding input/output word of the bus. It is expected to switch the sensors directly to the network by special chips and connecting module. When having parity error the data from the current cycle is rejected by the master and for further operation the data from the next cycle is used.

At acyclic data transmission is used more complex mechanism. In this cases the master adds several frame words to the communication data in the telegram and creates a telegram stack by software. From this stack are input up to 8 words in a cycle in the cycle register of the telegram. The receiver correspondingly confirms the message receiving. At work the number of the data words in the telegram remains constant. This means that if there is no communication the telegram will circle around empty.

The bus has diagnostic functions. It is automatically started segment by segment and in this way it can be given not only the type of the error but also its place.

Interbus-S is one of the most used in Germany with special application at the automobile production.

3. 7. Network LON

LON (Local Operating Network) is a communication system with application in the distributed control systems. Often it is used at the automation of buildings. And this fieldbus can be added as to the level of sensors/ actuators as to the communications of high level. The control problems are distributed in separate nodes of the network. This reminds the idea for work with the method client-server. In the node big quality of information must be processed and solutions should be taken, without charging the other components of the system. The transmission rate and correspondingly the network size vary significantly, as the data transmission can be done by different carriers and the topology can be defined by the user: LON gives possibility for building of hierarchical network structures which consist of domains, sub-networks and network nodes. LON proposes all seven levels of the model ISO/OSI as firmware.

The used protocol is called LonTalk. For the access to the bus is used an optimized variant of the CSMA/CD (Carrier Sense Multiple Access/Collision Detection) – the so-called predicative **p**-persistent method (stable, predictable method, working with a certain reliability **p**). By this similar method of CSMA /CD to a big extent of collisions are avoided, so the behavior of the system is bettered significantly when having a big amount of messages. After each sent package times lots are created. Each node, which wants to transmit, waits for a certain period of time before receiving access. After a certain window of time the node begins to transmit data as the probability for successful access to the bus is **p**. The number of the times lots depends on the number of the nodes participating in the transmission and varies from 16 to 1 024. Each node could "foresee" how many other nodes will have communication as a result of message answer. This information is received assessing the number of the expected transmissions, which are forced by the message answers. In correspondence with this expected charge the bus dynamically determines the number of the times lots for waiting. If for example one node sends a broadcast message, a big quantity of communications could be expected. At bigger charge there will be more times lots, so that with bigger probability the collisions to be avoided. At small loading of the bus a little number of time slots are added and so a quick access is assured. In this way the behavior of LON becomes predictable.

LON is created for applications in control and that is why the optimum mode is with short packets, transmitted for a short period of time which usually are of around 20 bytes. At real time applications nodes can be configured with possibility for transmission of priority messages. For this aim priority times lots are added. At higher requirements in accordance with the recognition of collisions the so-called collision hardware is added. In this case special transmitters fulfill the recognition of the collisions and repeating of the message is done immediately without waiting the end of the transaction timer on protocol level.

3. 8. The P-Net Network

P-Net is created in Denmark and has universal application. The transmission rate is 76.8 Kbit/s, and the maximum length without transmitter is 1200 m. Several segments can be connected in a network. The whole number of the participants can reach 125, as up to 32 of them may become masters so that the system can be defined like Multimaster/ Multislave. When several masters available, the participant which has to take the function master is determined at the moment by the method Token Passing.

3.9. Profibus

The PROFIBUS has rim topology. At speed 500 Kbit per s the maximum length is 200 m without repeaters (or 800 m with 3 repeaters). If the speed is decreased to 93.75 Kbit per s, the distance could be increased up to 1 200 m (corr. 4 800 m).

PROFIBUS has hierarchical structure with several masters and many substations with two priority levels. The high priority is used mainly by unpredictable errors. The access to the bus is a combination of the method Token Passing and polling of the substations from the corresponding master. The telegram with the token is transmitted in a certain order in a logical cycle from one main station to another. Each one of them owns the token a certain period of time which is fixed before. During this period of time it can communicate with the other included masters and substations. The priority messages are first processed. After that the substations are polished for cycle data and at the end the low priority acycle messages are processed. If after finishing these activities more time remains the master makes a life list of the active stations polishing all included nodes.

To more of the services which PROFIBUS offers, you have to react immediately positively or with an answer. The broadcasting mode makes an exclusion. The bus has many types of messages with varying length of the data up to 256 bytes. For error recognition 8-bit CRC-word is used. For the user level a message specification is made (Fieldbus Message Specification - FMS).

If there is more than one active station the time for the circle of token is given (TTR). It is calculated in the following way:

TTR=na*(TTC+high_TMC)+k*low_TMC+mt*RET_TMC,

where

na: number of the active stations;

TTC: token cycle time;

TMC: message cycle time;

mt: number of the cycles for repeating;

RET_TMC: cycle time for message repeating.

Each active participant can transmit high priority message when receiving the token not minding the real time for cycling of the token in the circle. For the execution of low priority cycle with messages the real time for passing the circle of the token has to be shorter than the given time, otherwise the next receiving of the token should be waited.

PROFIBUS has a big software overhead, as all model levels ISO/OSI are realized by software.

For application on level sensor-actuator the firm Siemens has developed the modification PROFIBUS-DP. It permits higher speeds (1.5 Mbit per s), correspondingly using higher speed carrier media. At this speed the maximum length could be 200 m, and with four repeaters – 1 000 m. At lower speeds some producers permit even up to 7 repeaters. In this case the phase should be regenerated by them. Meanwhile Siemens offers also devices with a speed of 12 Mbit per s.

PROFIBUS-DP has less functions than PROFIBUS with the aim of quicker exchange of input/output data. With this fieldbus it is also possible the usage of several masters and in this case they determine between them the transmission of the token. The masters together with their adjoining sub-nodes can create independent between them subsystems and also can share mutual sub-nodes. In the last case the input and output images of the sub-nodes can be read by all masters and the record is made only by a determined master. The message cycle is made at the configuration of the network and can not be changed dynamically.

3.10. Other fieldbuses

The fieldbuses DIN-M and Dotnet are developed in Germany. The first is created for the aims of the computer and test techniques and is a cheap interface giving possibility for transmitting data from sensors to computer and control devices. The channels for transmitting and receiving are divided and the transmission speed is 1 Mbit per s. The bus works by the method Master/Slave and the slaves can be up to 31. The maximum distance covered is 500 m.

Dotnet is developed by the firm Delta-t and the Institute for applied microelectronics IAM, and the aim is creating of software processors for fieldbuses which have to be in a state for processing different protocols. It is a network of the type sensor/

actuator. It works in the mode "Multimaster/Slaves", where the sensors are the slaves and the control device is the master. Sub-slaves can also be defined which are used for connecting of pure digit sensors and actuators to the network.

The bus FAIS (Factory Automation Interconnection System) is Japanese. The protocol is Token Passing. It is supposed to work more like a connection system of individually working groups and not on level sensor/actuator. The transmission speed reaches up to 10 Mbit/s and is used in the control processes. It has not found distribution in Europe.

4. Standardization

In spite of the fact that the technology of the fieldbus as philosophy is proposed before more than 10 years, its speed of distribution is slow. One of the reasons is that an international standard for communication protocol is missing, which to assure interchangeability and mutual operation of the field devices from different producers.

In 1985 Instrument Society of America (ISA) begins the development of standard two-side multipoint digit communication between the field devices (instruments) and systems for processes control and production. Because of the necessity of creating of international standard several organizations - ISA, IEC (International Electrotechnical Commission), Profibus (standard in Germany), FIP (standard in France) – decide to form the committee SP50 Fieldbus (1994). The aim is to integrate the huge number of control devices, to assure them interface for work with different devices simultaneously and to determine communication protocol for maintaining.

ISP (Interoperable System Protocol - Profibus) and World FIP (Factory Instrumentation Protocol) have different points of view according the application of the fieldbus but at the end the producers of the two buses decide to maintain the standard SP50.

SP50 decides the fieldbus in 4 levels:

Physical: defines the communication media.

Channel: responsible for the communication between the different devices and finds the errors.

Application: turns the data in messages which are understandable for all devices in the network and makes services for process control providing them on application level.

Users: connects the separate factory spaces and gives field for application.

The specification of the fieldbus is still in development and there are great expectations towards it from the main users and at least ordered maintenance from the device sellers.

But it is delayed in endless commissions and committees. Besides this when comparing with other buses (for example CAN, LON), questions around the business vitality are raised on the competitive alternatives, owning the glory "de facto" standards. Because the standard is of use for the end user and not for the seller. In fact for each seller it is logic to maintain some differences in order to offer products which bring more money. So it can not be waited for it to maintain something which eliminates its advantages. All sellers say that they maintain the **compatibility**, but in fact the users want **interchangeability**. In a certain aspect "the standard" in fact is getting older in the contemporary quickly changing technological media. And nobody will agree to pay the price for creating the standard, if the execution is accessible for part of this price. So that the only possible standard in the industrial instrumentation is the "de facto" standard. These "standards" are not the best but had their way up through the market. They usually are created by an organization which at least at the beginning is responsible for the application of the extensions and modifications, which are imposed again by the market.

5. Conclusion

In spite of the fact that the factories work for years with fieldbuses in reality nobody knows the full variety of advantages which gives the use of this communication technology. Usually whatever advantages to be seen or measured they are assigned to the technical progress at all.

Some of the straight advantages of the fieldbus are:

*** less money for the equipment installation**

– multipoint connection
– mutual use of the input/output interface
– less defending barriers
– added functions in the field devices (for example PID)

*** less money for maintenance**

– self-diagnostic
– possibility/potential for forecasting maintenance
– easier following of the tuning for ISO 9000
– less routine tunings by digit devices

*** operations saving**

– better work of the factory / stability by the digit devices
– less stay and waste because of better recognition and removal of the problems
– more control data for better tuning and copying actions in case of embarrassment

About the application fields of the fieldbuses we can say, that the buses of the type FIP, Profibus, and also SP 50 (the used standard) are used in the cases when there are complex field devices and the quantity of the exchanged information is big, while the buses of the type sensor/actuator are used at simpler cases and less information float. The filedbus CAN and the network LON are like a bridge between them. It is expected that in the next years the last will penetrate in the area of the buses of the type SP50, and in this case the necessity of more complex standard may be avoided. The lower price and the same execution of the networks CAN and LON, combined with better market control and active maintenance of third sides and end users probably will assure this development. On the contrary the heavy procedures in the protocols and the execution of the many prescriptions of the standardization commissions and committees make obstacles for the buses of the type SP 50 to take a part of the bus market working on the lower levels in the production.

The market trends show that towards the network communication of the lowest level a great interest is paid. In spite the advantages which the compatibility and the open standards would have given, the connected with delays bureaucratic procedures make vary slow influence upon the natural market development. Honeywell and Allen Bradley already offer open systems and the last creates a separate organization - ODVA (Open DeviceNet Vendors), in order to guarantee openness and compatibility. The prices of the building elements for fieldbuses drop continuously as for CAN and LON they are especially attractive.

References

1. Lawrenz, W. U. CAN Controller Area Network - Grundlagen und Praxis. Heidelberg, Huettig Buchverlag, 1994.
2. Schnell, G. U. Bussysteme in der Automatisierungstecnik. Wiesbaden, Verlag Vieweg, 1994.
3. Schulze, W. Der CANbus in der Automatisierung - Eigenschaften und Applikationen. Firmenschrift.
4. Rabbie, H. M. Control Networking Using Local Operating Networks - Local Operating Network LONWORKS - Vortraege und Begleittexte zum Entwicklerforum. Verlag Design & Elektronik, 1994.

5. Pinto, J. J. Fieldbus: A Neutral Instrumentation Vendor's Perspective - Action Instruments, Inc. (in Internet).
6. Pinto, J. J. Action Instruments, Inc., 1995 (in Internet).
7. Bradshaw, A. T. Fieldbus Foundation or FOUNDATION Fieldbus? - Honeywell (in Internet).
8. Coutinho, J., S. Martin, G. Samata, S. Tapley, D. Wilkin. Fieldbus Tutorial - Curtin University of Technology, Western Australia (in Internet).
9. The P-NET Fieldbus for Process Automation - Brochure of the P-NET User Organization.

Полевые магистралы – современная технология управления производства

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Необходимость конечных производителей перейти со старых централизованных стратегий к распределенному управлению определяет развитие технологии полевых магистралей.

Архитектура этих систем представляет современный вариант распределенных систем, причем устройства могут коммуникировать многоточечным спсобом, а функциональные возможности переходят к полевому устройству.

Полевые магистралы принимают функции переноса данных со самого ниского уровня управления производства - ниво сенсоров и выполнительных звенев - до фабричной магистралей (руководное ниво предприятия).

Тендеции развития полевых магистралей направлены к упрощению конфигурации и к интегрированию измерительных, ведомых и задающих звенев с коммуникационными звенами. Следствием этих тенденций является стремление к созданию интегральных схем, обединяющих всех этих функций.

В настоящей статьи представлены подробные характеристики самых распространенных полевых магистралей. Также рассмотриваются проблемы их стандартизации.