Measurement and Control Systems with Smart Sensor and Actuators in Industrial LAN Environment

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1 Abstract

Smart sensors and actuators, industrial nets (ILAN) and program support SCADA/MMI software on the environment of PC computers introduces importance alternatives to implementation of modern configured multilevel measurement and control systems. The paper describes implementation of smart sensors (SS) at the distributed measurement and control systems (DMCS).To the main advantages of smart sensors belong: - compact form with common supply and standard output signals, with good functionality at hard conditions, - minimisation and compensation of the disturb influence to measuring transducers and to the output signal (temperature influence, static characteristic non-linearity, transfer disturbing), - local signal processing with duplex communication, function testing and data validation. Some results will be present with design, structure and properties of displacement smart sensors with two types of optical fiber transducers. These subsystems are interconnected with microcomputers and controllers by ILAN with SCADA/MMI program support that enable to reach very good functional parameters with higher flexibility, reliability, testing and maintenance.

Keywords: Multilevel Distributed System, Smart Sensor, Fibre Optical Sensor, Control System, Industrial LAN, Fieldbus, SCADA/MMI,

2 Distributed measurement and control systems

DMCS representative continually more significance tools for realization of large technological processes control tasks. Microcontrollers and programmable logic controllers (PLC) provide smart direct control of drivers, actuators, valves. All devices on the separate control levels are connected together by bus or ring structured industrial net ILAN (for instance PROFIBUS, CAN, AS-I,...). Industrial buses (Fieldbus) are digital, full duplex serial net connecting separate measurement, control and operate unites. DMCS (see Fig. 1) have:

- *multilevel structure,*
- *network connection (ILAN, LAN, WAN),*
- *transfer of „intelligence" to the pre-processing (SS, IMC, PLC),*
- *interpretation and visualization of the date to the lower levels of control (PC),*
- *installation of microcomputers and PLC direct to the technological aggregates.*

Microcontrollers and programmable logic controllers (PLC) provide smart direct control of drivers, actuators, valves on the *Field Control Level* (see Fig.1). All devices on separate *Process Control levels* are connected together by bus or ring structured industrial net ILAN (for instance PROFIBUS, CAN,...). Industrial bus (fieldbus) is digital, full duplex serial net connecting separate measurement, control and operate devices. On the higher levels CAM and MES technological microcomputers (PC) are improved with real time system operation or more power UNIX workstations. To the fore database systems „client-server" get clearly (MES, ERP).

Control system architecture includes input devices to the controller that serves as the decision-making element, and output devices that make things happen. Feedback is accomplished through the controller to advise operators, technicians, and engineers of abnormal behavior and gather data.

Control systems must know the status of the process and its environment. Input devices are the eyes, ears, and touch that the controller needs to determine necessary actions. Typical input devices range from pushbuttons and selector switches, through proximity and photoelectric sensors, to temperature and pressure sensors. Today's sensors provide more than simple binary (on or off) inputs or varied current or voltage (4-20 mA or 0-10 V dc), although these are still very important. Vision systems providing complex information have become stable and affordable. Bar-code equipment is also part of the information providing system as well as status to the system.

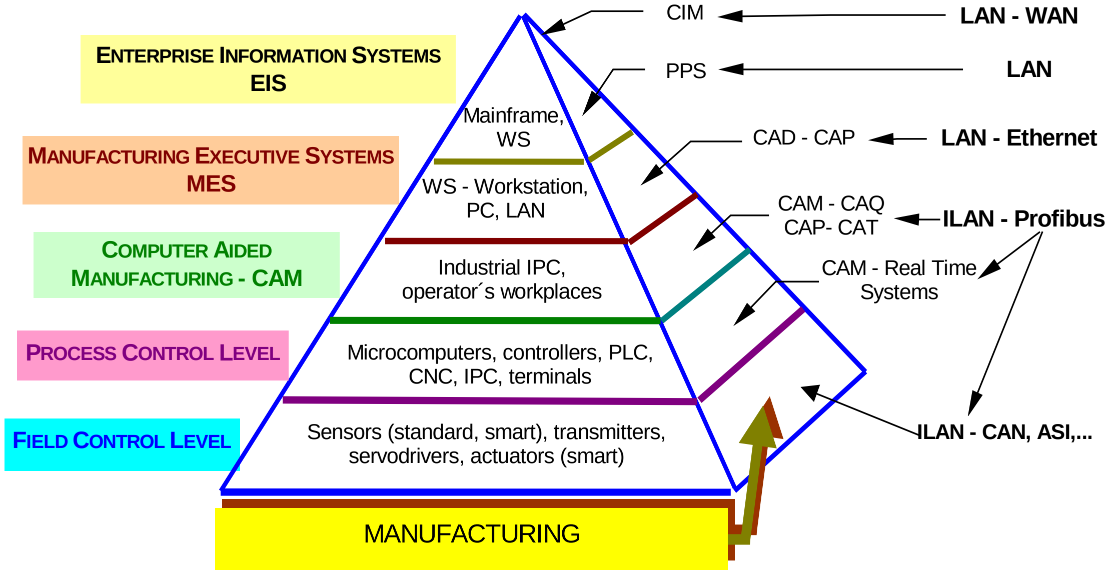

Fig. 1 Multilevel distributed control system with ILAN/LAN support

Modern networks enable economical and fast data communication from sensors and other input devices to the controller. Since manufacturing management software now demands more and better information from the lowest level in the plant, these advances help power complete manufacturing enterprise progress.

When we analyze both types of manufacturing systems - process and discrete, we see that border has now been breached. It is becoming increasingly difficult to tell process controllers (DCS) from discrete manufacturing controllers (PLC). To add to the confusion, computer numerical controllers (CNCs) are now blending with PLCs to handle automation as well as machining. Robotic controllers are also now able to handle more automation and data management chores.

The newer system architectures (see Fig. 2) highlight separating I/O modules from the controller chassis. This means a single cable serves in long wiring runs, rather than bundles of parallel wiring. Wiring from sensors and actuators to the I/O modules is reduced to the shortest possible route. Tracing wires becomes much easier, and common wiring problems are reduced.

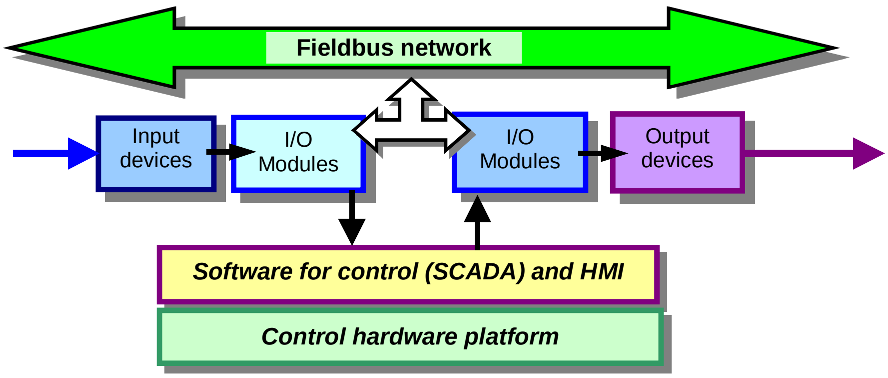

Fig.2 Today's control architecture - typical PLC structure of controllers with separating I/O modules communicating by Fieldbus network

To a large part, this is because of market and technology penetration of personal computers (PCs). PCs now are used as controllers, operator interface, communications interface, programming terminal, and data concentrator. As a result, such things as the computer operating system, control software, and other components have become topics of discussion. Few people knew, or cared, what the operating system, chip set, or backplane bus structure was in a PLC or DCS. Now engineers openly debate the merits of Microsoft Windows NT, or embedded operating systems like Windows NT Embedded or CE.

Problems of distributed measurement and control systems of technological processes are more and more associated with program aid of their projecting even operating. Program products SCADA/MMI (Supervisory Control and Data Acquisition / HuMan-Machine Interface) enable quick and effective development and tasks running on distributed multilevel technological control systems small, middle even large dimension on the Process Control Levels.

Once the controller scans input status ascertaining the environment and makes decisions based on programmed logic, it turns outputs on or off as required. Output devices are usually denoted as coils in programs because the typical response is to energize a coil in a motor starter, relay, or solenoid. Other outputs can be an analog signal to a variable frequency drive controlling a pump or fan or a message sent to a display. Intelligent devices will form loops of local control networked to a supervisory controller. Communication loss to the controller will not immediately shut down the process or machine unless a safety has been triggered. Networks and software will become more important and embedded control will reside at the device level. The system will be monitored by Web browser technology, often on a wireless pocket computer [MINTCHELL 2000].

3 Industrial communication networks ILAN

Industrial communication networks ILAN can be grouped into three basic categories: general-purpose networks, fieldbuses, and device buses (also referred to as bit-level buses). Various physical topologies and arbitration schemes exist for each type [ZEZULKA 1999].

General-purpose communication networks provide broadcast and point-to-point messaging between nodes, and perhaps to other networks via bridges. Networks such as Ethernet, ARCNet, FDDI, IBM Token Ring, and MAP, are used for data gathering, interprocess exchange of control data and sequencing information, and remote access.

Fieldbuses are optimized to exchange periodic data - also known as producer/consumer information - with I/O devices, while providing time-slices for point-to-point messaging and network management tasks. Both messaging and network management capabilities assist in remote coordination of I/O devices (such as configuration and diagnostics) among other possibilities. Many provide bus electrical isolation among nodes, and add device profiles which virtualize equipment from different manufacturers, thus providing a common access model in applications. Fieldbus Foundation, Profibus are typical examples.

Device buses, such as AS-I (AS Interface), provide cost-effective connectivity to I/O devices. Although the cabling and data rates are not typically advanced, actual throughput can be quite high due to the reduced frame size and simplified bus arbitration and addressing schemes.

Other networks and buses tend to fall between these categories. Newer, so-called **sensor buses**, such as DeviceNet, CAN, and SDS offer some benefits of a fieldbus, while keeping connectivity costs closer to device buses. Some offer remote configuration of I/O devices and programmability [ECKERT, G. 1997].

4 Smart sensors in distributed measurement and control systems

There are many different as well as common ***definitions of intelligent (smart) sensors***:

- Sensor with an off-chip µP used to communicate to the user and modify its response is considered to be smart [POWNER, YALCINKAYA 1995].
- Smart sensors are those devices in which the sensors and circuits co-exist, and their relationship with each other and with higher-level processing layers goes beyond the meaning of transduction. Smart sensors are information sensors, not transducers and signal processing elements. Smart sensors are not general purpose devices. Everything in a smart sensor is specifically designed for the application targeted for [WEB SIDES 2000A].

ISA Expo 98 Conference in Houston demonstrated first specification of the smart sensor communications standard. The document, IEEE 1451, specifies a standardized output from smart transducers and other types of sensors. It includes performance parameters so it will greatly simplify calibration that can be a time-consuming task when systems are installed or sensors are replaced.

The interface also simplifies system design by providing a single interface for sensors from various providers.

Smart sensors have this basic characteristics [SMUTNÝ 2000.]:

* ***Direct computation*** of the physical magnitude of a measurement at the transducer level after correcting for parasitic effects.
* ***Self-calibration, compensation and diagnostics*** for proper operation and preparation of data for maintenance assistance (offset, drift, non-linearity, zero and span adjustment, temperature compensation).
* ***Communication*** between the smart sensor and host data collection system (master-slave, two-way communication (token passing, client server, interrupt output).
* ***Multisensing*** - the ability of the single transducer to measure more then one physical variable (for instance piezoresistive pressure transducer with pressure signal and temperature signal outputs).

A prototypical smart sensor node consists of three elements: a physical transducer, a network interface, and a processor/memory core (see Fig. 3). The transducer senses the physical quantity being measured and converts it into an electrical signal. Then the signal is fed to an A/D converter, and is now ready for use by the processor. The processor will perform some signal processing on the data, and depending on how it is programmed, may send the resulting information out to the network. The network interface block handles network transactions.

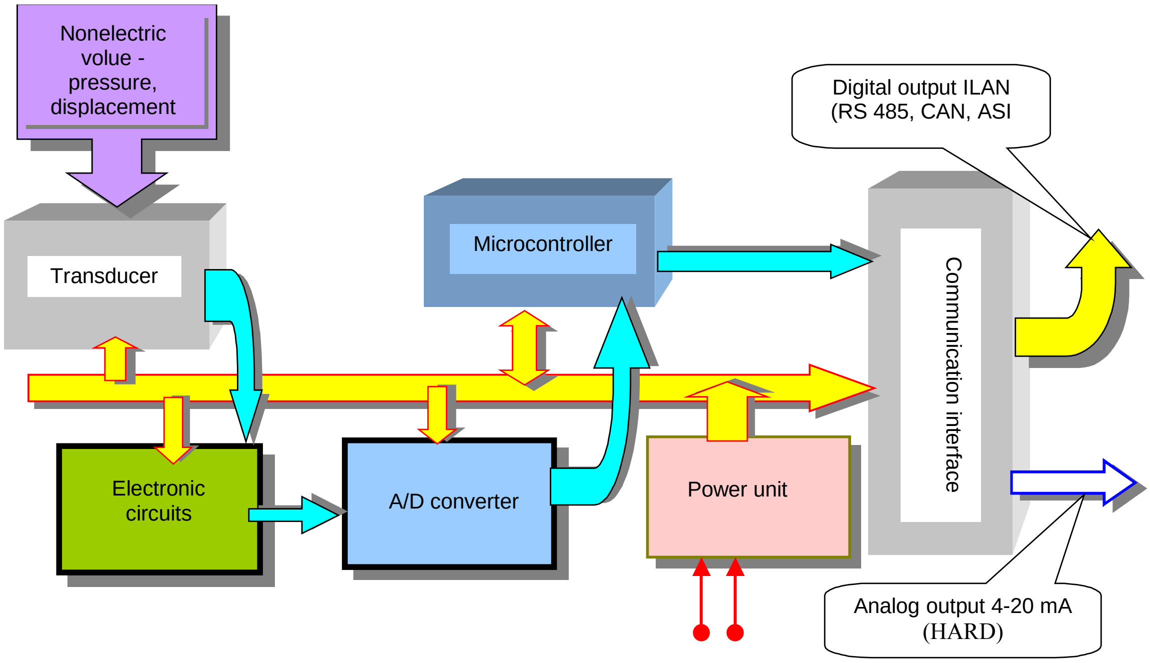

Fig.3. Block schema of SMART SENSOR connected to the Industrial LAN

5 Design and conclusion of smart sensors

On the Department of Control Systems & Instrumentation on the VŠB-TUO were designed and implemented smart temperature sensor, ultrasonic sensor, amplitude optical fiber sensor with analogue output (AOFS) and feedback optical fiber sensor with frequency output (FOFS) connected together in smart sensor form [SMUTNY 2000].

Output signals from optical fiber sensors are frequency modulated or on serial digital form (8 bits) and are modified by RISC microcontroller PIC (see Fig. 4). Linearity of displacement smart sensor (DSS) is better then ± 1%, on the range 0-6 mm (AOFS) or 0-0,5 mm (FOFS) (see Fig. 5, Fig. 6) [SMUTNÝ, L. 1997].

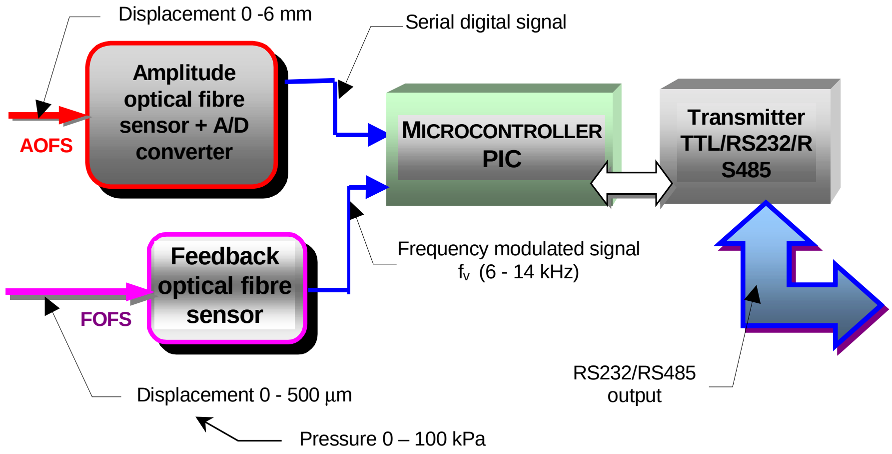

Fig. 4 Block schema of two optical fibre transducers connected to the Smart displacement sensor (SDS) with digital output

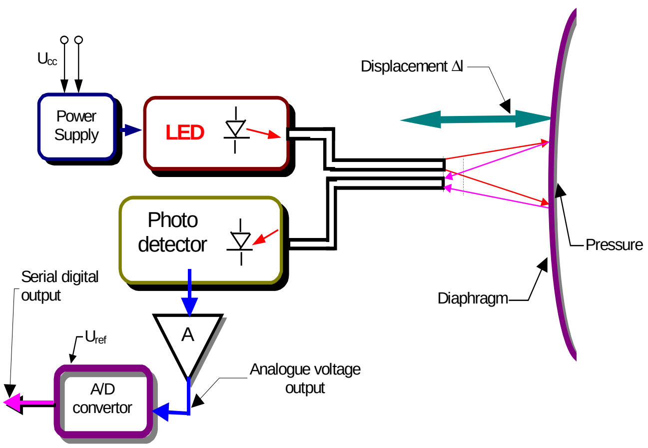

Fig. 5 Principle block schema of amplitude optical fibre pressure sensor with voltage output - AOFS

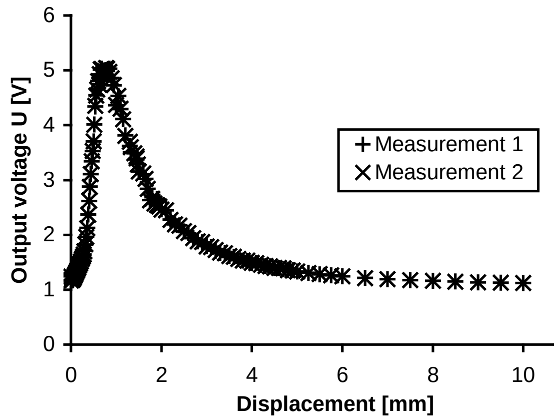

Fig. 6 Experimental characteristic of amplitude optical fiber displacement sensor with voltage output - AOFS

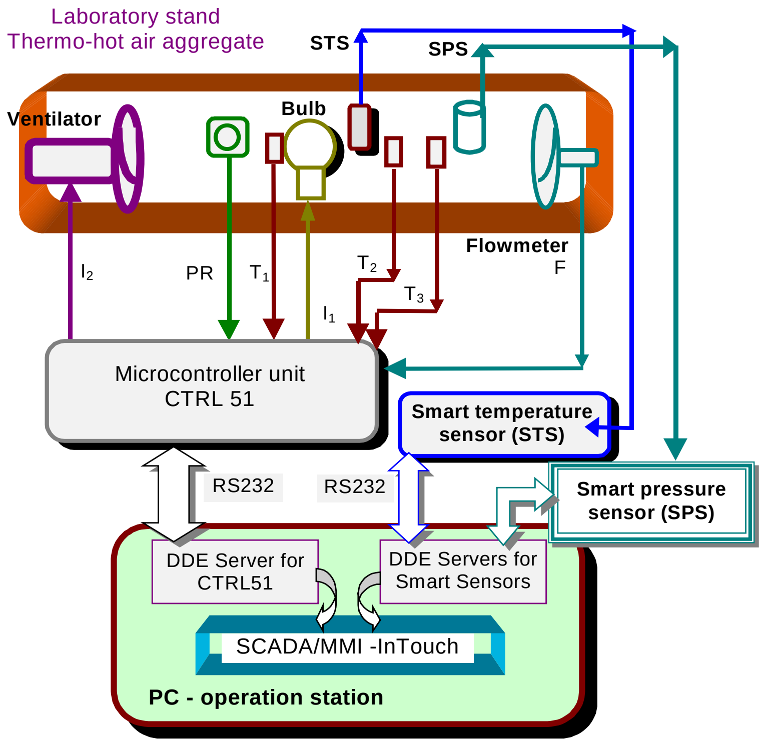

Fig. 7 Block schema of laboratory stand with CTRL 51 and smart sensors connected to PC with SCADA/MMI program system InTouch

On Fig. 7 is block schema of laboratory stand - *Thermo-hot air aggregate* (model of air-conditioning plant) connected by microprocessor external serial unit CTRL 51 and two smart sensors (SMS) to PC. Model of technological aggregate is created by bulb and ventilator (controlled inputs I_1, I_2). Sensor outputs from model are temperature RTD (thermistors) sensors T_1, T_2, T_3, photoresistor PR and flowmeter F. Signal outputs and controlled inputs are connected with microprocessor unit CTRL 51 and other unit STC (PIC microprocessor) to computer PC. Measurement and control tasks were realized by SCADA/MMI program system InTouch (WONDERWARE - USA)

6 Conclusions

The basic idea of the multilevel distributed architecture is to process the information at the source and target (i.e. the sensors, actuators). Thus, in the vicinity of group of sensors, called a "measurement site", a small microsystem is dedicated to the tasks of signal conditioning and sampling, calculation and communication. A complete system is made of a collection of smart sensors which can communicate each others and/or with a system controllers through a communication network. The system controllers perform different tasks such as high-level computations, smart sensors configuration or synchronization, data recording, global tests, etc.

Smart sensor of displacement and pressure with optical fibre transducer for the hard and explosive surrounding are good examples of new implementation trends in multilevel control systems. There are introduced also the example of optical fibre smart sensors their verification on stands with PC and program support of visualisation and control by SCADA/MMI program ***InTouch***.

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