Digital bus based signal exchange for sampling stations

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Introduction

This paper addresses questions related to digital bus based communication between water-steam online analysers and the DCS of a power plant.

Digital communication between local devices and the DCS of a power plant is becoming more and more common. Many users are still used to 4-20mA hardwired signals which have been the standard in most power plant applications, in particular for online water sampling and analysis stations.

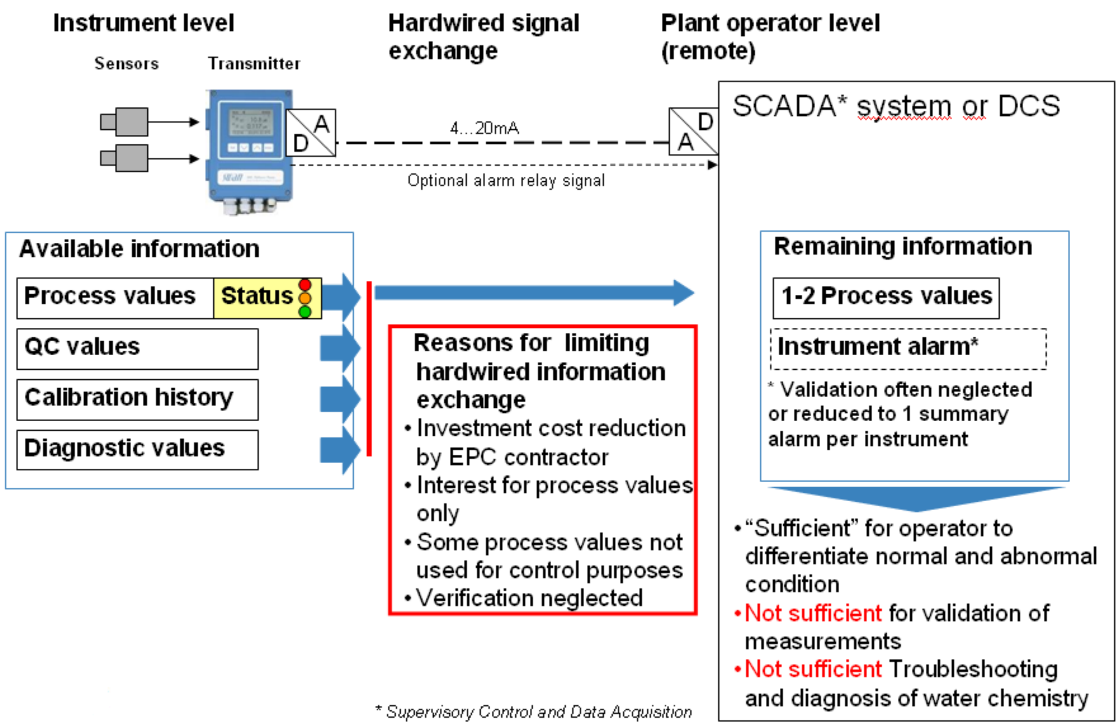
The following topics are addressed:

- Key advantages of bus based communication versus hardwired analog signals
- Basic concepts related to typical digital bus systems (hardware, protocols, applications)
- Details about hardware architectures for selected high level fieldbus systems to connect sampling stations to a DCS.

Advantages of digital bus vs. hardwired signal exchange

An online water analyzer is a device that can hardly be compared with a field instrument (i.e. single sensor directly installed in the process line). A water analyzer receives a continuous flow of cooled and depressurized water sample and performs measurements which sometimes involve chemical modification of this sample (e.g. cation exchanger or reagent addition). A measurement can be subject to several disturbances and the analyzer must therefore monitor not only the measured parameters but also several additional parameters (e.g. sample flow, sample temperature, reagent availability) to ensure a reliable measurement.

Modern instrument transmitters process all this additional information, display it locally and perform a log of key events. Most of them still support 4-20mA signal exchange for compatibility reasons with older installations.

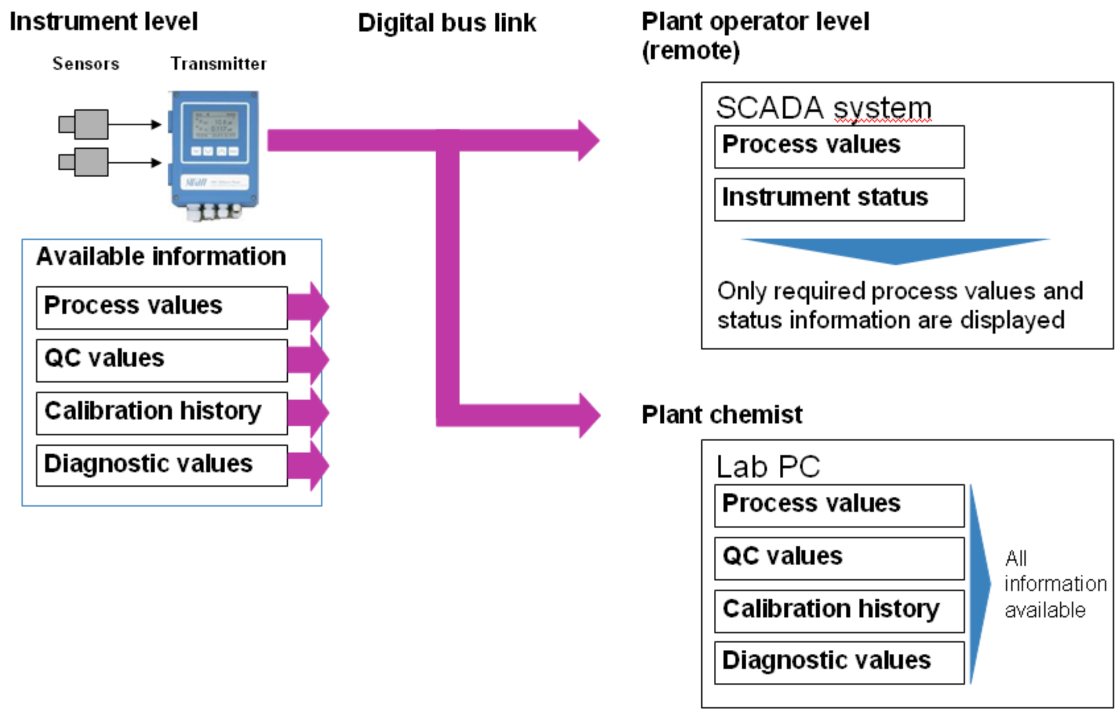


4-20mA introduces an artificial bottleneck in the information flow to DCS. The main reasons for analog signal exchange are clearly a) sticking to traditions and b) perceived investment cost minimization for the sampling station scope. In the end, the installation cost will still be higher than a bus based system due to on site cabling and configuration work, as many independent studies have shown[1]. When the complete signal chain is considered, savings amount to 1'500 – 3'000 EUR per DCS I/O point. For a water-steam sampling system exchanging 20-30 signals the savings potential at plant level is significant compared to the cost of the turn-key sampling station.

Digital bus systems offer the following advantages for remote signal access:

- Signals of several analysers can be bundled (ideal for sampling systems where several instruments are gathered)
- Several users can access the bus data and define independently which data they access
- High flexibility in case of extensions or changes in information needs

For further details, please ask for the Swan Systeme presentation “Profibus Signal exchange”.



[1] “The Economic Impact of Digital Bus Technology on New Plant Construction,” JDI Contracts, MN USA

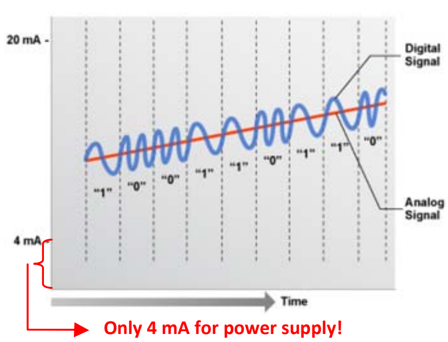
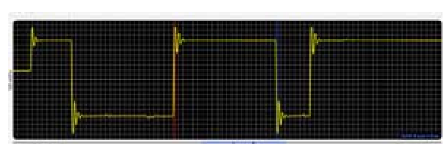
Basics of digital fieldbus systems

Fieldbus is the name of a family of industrial computer network protocols used for real-time distributed control, now standardized as IEC 61158. The different Fieldbus systems are classified within IEC 61784-1 as *Communication Profile Families* (CPF), as shown in overview table below. The bus families usually mentioned in the context of water steam sampling systems are shaded in blue.

Familiy	Version	Trade name
CPF1		FOUNDATION Fieldbus (FF)
	CPF1/1	FF-H1 (Low Speed)
	CPF1/2	FF-HSE (High Speed Ethernet)
	CPF1/3	FF-H2 (High Speed)
CPF2		CIP (Common Industrial Protocol)
	CPF2/1	ControlNet
	CPF2/2	Ethernet/IP
	CPF2/3	DeviceNet
CPF3		PROFIBUS und PROFINET
	CPF3/1	PROFIBUS DP
	CPF3/2	PROFIBUS PA
	CPF3/3	PROFINET CBA
	CPF3/4	PROFINET IO Conformance Class A
	CPF3/5	PROFINET IO Conformance Class B
	CPF3/6	PROFINET IO Conformance Class C
CPF4		P-NET
CPF5		WorldFIP
CPF6		INTERBUS
CPF7		SwiftNet
CPF8		CC-Link
CPF9		HART
CPF10		VNET/IP
CPF11		TCnet
CPF12		EtherCAT
CPF13		ETHERNET Powerlink
CPF14		EPA (Ethernet for Plant Automation)
CPF15		Modbus
	CPF15/1	MODBUS-TCP
	CPF15/2	RTPS
CPF16		SERCOS
	CPF16/1	SERCOS I
	CPF16/2	SERCOS II
	CPF16/3	SERCOS III
CPF17		PAPIEnet
CPF18		SafetyNet p
CPF19		MECHATROLINK

What strikes immediately is that communication **profile families of Fieldbus, Profibus and Modbus all include several profiles.** Each family has a profile for low level digital communication (e.g. Profibus PA, Fieldbus H1) which is compatible with loop powered field transmitters. **The HART profile family includes only a single low level profile.**

As it is quite often used for field instruments for pressure, level and temperature, HART communication is sometimes also specified for online water analysers. Such a requirement often originates from generic I&C requirements. For water steam sampling stations in new power plant projects, HART communication is simply not adequate. The table below shows a direct comparison between HART communication (low level digital bus) and Profibus DP, a typical high level digital bus.

Characteristics	**HART**	**PROFIBUS DP**
Typical application in power plants	Used for low level communication with distributed in situ field instruments (e.g. flow, level, pressure)	Used for fast communication between subsystems (e.g. black-box equipment with multiple instruments and signals) and DCS.
Availability for online water analysers	Available only for pH, conductivity and oxygen transmitters	Available for all online water analysers used in power plants, incl. silica, sodium and degassed conductivity.
Typical information exchanged over bus	Mainly configuration data: Calibration settings of replacement sensors Application specific set points	Mainly cyclic data: Measurement values Status information / measurement Alarm information / instrument
Bandwidth	LOW: Max. 1.2 kBit/s, due to physical limitation of FSK modulation	HIGH: Up to 12'000 kBit/s (usually 187.5kBit/s)
Modulation	FSK (Frequency Shift Keying) on top of 4-20mA analog signal  	Voltage pulses via dedicated digital bus wiring 
Bus topology	Only star network	Serial and star network
Bus cable	Limited to 4-20mA wiring	RS-485 & several other signal cables. Fibre optic converters available.
Bus masters	Direct master – slave connection, max. 2 Master devices (HART enabled I/O)	Multi master configurations possible.

Considering the previous table, we can draw the following conclusions:

1) Do not introduce an artificial bottleneck by specifying a digital bus with limited bandwidth!

A sampling station is always an accessible regular working area (rack or shelter) where several analysers are grouped (typically 5 to 30 instruments). The information stream from all analysers and accessory monitoring devices can easily be bundled on a digital bus to reduce cabling, hardware and configuration cost. The bandwidth required for all signals of a typical sampling station is between 10 and 20kBit/s this is more than an order of magnitude higher than what HART can handle!

2) Loop powered transmitters bring no advantage in a water-steam sampling system application

Loop powered instruments receive their power by the 4-20mA signal cable. This allows the saving of extra power cable to distributed field instruments. However, there are clear limitations:

Limited power availability: a loop powered instrument must be able to run on 4mA current only (less than 0.1W). Due to this physical constraint, SEVERAL ANALYSERS WILL NEVER BE AVAILABLE IN LOOP POWERED CONFIGURATION: the accessories (e.g. pumps, photometers, heaters, mixers etc) required to perform these measurements draw much more power. This applies in particular for key measurements such as Silica, Sodium and Degassed conductivity.

Saving of power cable brings no advantage: a sampling station always has a local power supply available because of accessories such as lights, ventilators, power plugs. This power supply will also supply the instruments. As a result 2-wire signal loop powered transmitters not bring any added benefit for this application as a separate power supply is available anyway. The extra power cable required is only a few meters long and has no significant cost impact.

Bus architectures – sampling systems to DCS

The above considerations are a limited comparison of selected bus systems, similarly to comparing road vs rail vs air transportation. Similarly as in a logistics network for transportation of goods one would never specify a single mode of transportation between all points in a network, in a power plant application, one should not specify a single type of bus for all digital communication with measuring devices.

As stated above, a water steam sampling station gathers numerous signals and is therefore a candidate for higher level fieldbus protocol. **When defining the bus platform to be used, one must also address the following points related to bus network architecture.**

- Should the DCS address each individual instrument in the sampling station as individual slave or should the sampling system include an interface layer (e.g. a PLC) gathering the information from the slave devices?
- Is the digital bus at risk for electromagnetic disturbances? If yes, what measures are being taken (choice of appropriate bandwidths, repeaters, fiber optic links etc.)?
- Is a single bus link between DCS and sampling station acceptable? If not, on which bus segments is a redundant configuration required? What is foreseen to ensure the required level of redundancy (bus network architecture)?

In the end, the answers to the above questions will define which high level bus types and topologies are optimal for a particular application.

Conclusions

Water-steam sampling stations are ideal subsystems for bus based communication to DCS. However, a high level Fieldbus is recommended as each sampling station includes multiple instruments and thus **sufficient bandwidth** should be available.

Low level bus systems such as HART, Profibus PA, Foundation Fieldus H1 have no practical application for water steam analysers. They have their justification for distributed field instruments (in situ) and special applications (e.g. loop powered transmitters with Ex-protection requirements)

Specifying a digital bus is not the remedy to all worries related to signal exchange. For efficient implementation, a clear bus topology and well defined limits of supply are required. Swan Systeme is one of the few suppliers of sampling stations that can also provide system integration services required for digital bus communication (on Profibus DP, ProfiNet, Modbus RTU, Modbus TCP basis). Please contact us if you are interested in our reference projects or if you require further assistance on a particular project.