New VDI Guideline 4201 – Digital Communication for Emission Monitoring Systems at Regulated Sources

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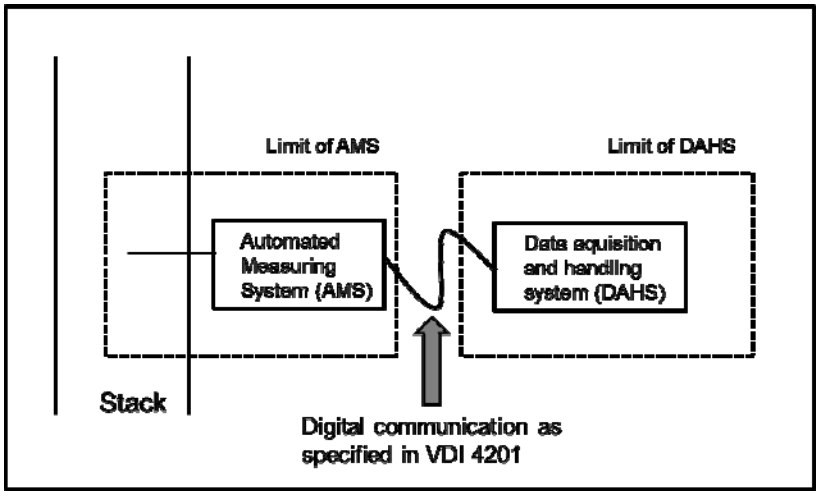
Introduction

Data transmission between AMS (Automated Measuring Systems) and DAHS (Data Acquisition and Handling Systems) at regulated sources usually uses today 4 … 20 mA-outputs for the measuring signal and digital contacts for the status signals. The analogue data transmission is simple, but has drawbacks e.g. to high cost for wiring or limited measuring ranges. Until recently, there was no European or national standard available for the description of such a digital interface.
Since September 2010 this gap is now filled with the first two parts of the VDI 4201 series „Performance criteria on automated measuring and electronic data evaluation systems for monitoring emissions - Digital interface“. These first two parts of the VDI 4201 series are providing now such a description of a digital interface based on PROFIBUS fieldbus. Part 3 and 4 are currently under development to provide solutions based on Modbus and OPC.
Picture 1 shows the limits of the AMS resp. DAHS and the function of the VDI 4201.
This paper explains the advantages of digital interfaces. It gives an introduction to both VDI guidelines and the solution based on PROFIBUS fieldbus. An example illustrates the implementation of the digital interface in a complete emission monitoring system and its appropriate type approval.



Picture 1: Function of the VDI 4201

Regulatory background for digital interfaces used in emission monitoring systems

Currently there is no EN Standard available providing a complete description for the data communication between AMS and DAHS at regulated sources. Only EN 15267 Part 3 “Air quality – Certification of automated measuring systems – Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources” [1] makes some general requirements for the output of AMS, e.g. requires a live zero to indicate also negative values. Working group 9 “Quality Assurance of Automated Measuring Systems” of CEN/TC 264 currently develops with working item “Stationary source emissions – Quality assurance of data obtained from automated measuring system” a standard which will cover also the data communication between AMS and DAHS, but for this standard there is still no publication date available.

The German regulation „Uniform Practice for monitoring emissions“ [2] allows in principal digital interfaces for the data communication between an AMS and the DAHS.
Under this regulation, a digital interface must fulfill following requirements:

- Transmission of measuring values and status signals
- Transmission of additional AMS data, e.g. measuring range, component name or unit
- Complete description of the digital interface in relevant standards and guidelines
- Evaluation of the digital interface during type approval of AMS or DAHS

The complete description of the digital interface in a standard or guideline and the type approval allows the seamless integration of AMS or DAHS from different manufacturers eliminates compatibility problems during installation and start-up and provides required quality levels. The VDI 4201 series was developed to fulfill these requirements.

Advantages of digital interfaces

Data transmission between AMS and DAHS at regulated sources usually uses today 4 … 20 mA-outputs for the measuring signal and digital contacts for the status signals. The analogue data transmission is simple, but has several drawbacks.

- Point to point wiring for each individual measuring value and status signal raises the overall installation cost
- Accuracy and resolution of analogue output may reduce the measurement performance of the AMS
- Transportation of additional information on the AMS is very limited
- Transmission of higher instantaneous measuring signals may require a second measuring range to provide the needed accuracy

To overcome the disadvantages, the development of digital interfaces was heavily promoted in the 1990s. In the meantime digital interfaces are used widespread in all industries. Especially for emission monitoring at regulated sources the digital interfaces have following advantages:

- Cover large measuring ranges at high accuracy
- Require less wiring at lower cost
- Access to additional information on the AMS like software version or serial number
- Provide easy access and control to QAL3 (Quality Assurance Level 3) data from the AMS
- Check sum algorithms result in higher data integrity

Introduction to the VDI 4201 series

The first two parts of the VDI 4201 series „Performance criteria on automated measuring and electronic data evaluation systems for monitoring emissions - Digital interface" are available since September 2010. Part 1 [3] covers the general requirements for such a digital interface; the following parts describe different possibilities for the technical implementation based on a standard protocol. Part 2 "Specific requirements for PROFIBUS" [4] is the first example for an implementation which was published together with the first part. Part 3 "Specific requirements for Modbus" and part 4 "Specific requirements for OPC" will provide solutions based on the Modbus or OPC protocol. Drafts for both guidelines [5,6] are already available, the final version is scheduled for end of 2011.
Emission monitoring systems with a digital interface according to VDI 4201 must provide at least the following functionality:

- Unique addressing of a measuring system within the complete emission monitoring system consisting of DAHS and several AMS
- Unique allocation of all measuring components and all status signals of the measuring system to the address of the measuring system
- Transmission of the description of the measuring system
    - software version
    - serial number
    - instrument name
    - names and output ranges of all measuring components
- Transmission of the measuring signals with associated status signal (validity, maintenance or malfunction of measuring system) at least once every second
- Control and / or feedback of applying zero and reference materials to the measuring system for QAL3 functionality
- Test procedure for testing during certification (QAL1), check of installation and calibration (QAL2) and annual surveillance test (AST)
- Export function for measuring and status signals for data acquisition during QAL1, QAL2 and AST

While many requirements like unique addressing of the AMS or transmission of the measuring signal are straight forward, some requirements are very specific for the emission monitoring. Especially the QAL 3 functionality, test procedures for quality assurance and export functions for measuring data need additional attendance and will be explained more detailed in the following parts.

Implementation of QAL3 functionality

EN 14181 [7] requires frequent checks of the AMS during continuous operation by applying zero and span reference materials. Initially, these checks have been done mainly manual by the operator, but in recent years, more and more AMS or DAHS can do these checks automatically by itself. This can reduce the AMS operating cost substantially. But a seamless integration of these automatic checks requires additional data exchange between AMS and DAHS. The DAHS must be capable to start the QAL3 check within the AMS and vice versa the AMS must be capable to send back the measured values back to the DAHS during the QAL3 checks. A digital interface based on VDI 4201 has these functionalities built-in and can be used without additional I/Os resp. wiring in the AMS and DAHS. In contrast, for an analogue solution based on 4 … 20 mA and digital outputs it will be very costly to integrate this functionality. It will need additional I/Os, wiring and software configuration of the AMS and DAHS.

Test procedure for QAL1, QAL2 and AST

A digital interface according to VDI 4201 must allow testing of the communication between the AMS and DAHS together with a verification of the configuration and math calculations in the DAHS. At first glance, this seems to be a major drawback, because it is very difficult to interact directly in a digital interface. To overcome with this problem, following simple procedure was developed for the VDI 4201. In a first step, it is tested if the measuring signals from the AMS are communicated to the DAHS without any alteration. For this purpose simulated data are sent from the AMS to the DAHS to be verified for consistency. In a second step, configuration and the math calculations are tested with these simulated data.

Both steps allow a very simple testing of the data communication by the test houses during QAL1 (type approval), QAL2 (calibration and validation) and AST (annual testing).

Export function for measuring and status signals

QAL2 (calibration and validation) and AST (annual testing) requires the collection of time stamped measuring data including status during parallel measurements with the standard reference method. The VDI 4201 provides for this purpose a standardized export function with a specified data format, which provides the measuring data including status as Excel or CSV file (comma separated value), independent from the used communication protocol. Knowhow on the used digital interface and / or additional hardware is not required. This facilitates for the test houses the data acquisition during the calibration.

Implementation based on the PROFIBUS profile

The requirements of VDI 4201 part 1 for digital interface can be fulfilled by the PROFIBUS PA protocol. PROFIBUS has become the world's most successful fieldbus with more than 35,000,000 installed nodes and global support. It is commonly used in different industries since more than 20 years. Basis for the implementation in VDI 4201 part 2 is the „Profile for Process Control Devices, V 3.01, December 2004“ [8] from the PROFIBUS user organization (PNO), especially the part for Conformance Class A – Parameters, Basic functions. Further development of the PROFIBUS PA Profile led to the actual profile version 3.02, which is fully backwards compatible to version 3.0.1. The PROFIBUS PA Profile is based on a function block model, which groups device functions together with appropriate parameters in several function blocks [9]. The VDI 4201 part 2 defines the minimum set of parameters from the PROFIBUS PA profile, which must be used to fulfill the requirements from VDI 4201 part 1. Additionally it specifies for some parameters default values, to minimize the effort during setup and installation. Table 1 gives a summary on used parameters and function blocks.

Functionality required by VDI 4201 Part1	**Suitable Parameter in the PROFIBUS PA Profile for VDI 4201 Part 2**	**Function Block used in the PROFIBUS PA Profile for VDI 4201 Part 2**	**Parameter settings**
Identification of the manufacturer	DEVICE_MAN_ID	Physical Block	Allocated by the PROFIBUS user organization
Identification of the measurement system	DEVICE_ID		Manufacturer specific
Serial number of measurement system	DEVICE_SER_NUM		Manufacturer specific
Software version of measurement system	SOFTWARE_REVISION		Manufacturer specific
Identification of measured component	COMPONENT_NAME	Analyzer Transducer Block	Manufacturer specific
Identification of unit of measured component	PV_UNIT		According to PROFIBUS PA specifications
Identification of measuring range	RANGE_1		Manufacturer specific, lower and upper limit of the measuring range
Transmission of measured signal and status	OUT	Analog Input Function Block	Mapped to scale according to VDI 4201 part 1
Transmission of simulated measured signal and status for testing	SIMULATE		Can be individually set by test house during QAL1, QAL2 and AST
Control of application of reference material for QAL3	SP_D	Discrete Output Function Block	Value = 0 → sample gas Value ≠ 0 → reference material

Table 1: Overview PROFIBUS PA parameters for VDI 4201 part 2

Implementation of the ABB solution

The main step to fulfill the requirements of the new guideline VDI4201 Part 2 is a PROFIBUS certification of the analyzers because the certification is one mandatory performance criteria of the standard. The certification is performed by an authorized test center. Currently there are 10 centers available across the major industrial countries. More information is available at http://www.profibus.org. The ABB analyzers of the Advance Optima and EasyLine series do have this certification since 2005 respectively 2008 and therefore are perfectly prepared for this solution.

The test procedures for QAL 1, QAL 2 and AST to send simulated data from the AMS to DAHS are integral part of the PROFIBUS specification. A built-in functionality of the PROFIBUS can be used by the DAHS to switch between normal and simulation mode and to set values to simulate the measured values and the status.

The implementation of the QAL3 functionality requires applying zero and span reference materials. For gas analyzers very often test gas bottles are used to fulfill this requirement. As an alternative the ABB NDIR photometer Uras26 can use gas filled calibration cells which are a cost efficient solution compared to test gas bottles. The PROFIBUS specification provides a built-in functionality which is used by the DAHS to switch between the reference materials. The mapping between the reference material and the discrete values is part of the AMS documentation.

For an analyzer built according to PROFIBUS PA specifications, the only necessary adaption of the analyzer software is the special scaling of the measured values which require a scale from -10000 to +10000 with zero point at 0 and upper limit of the output range at 10000.

Performance Test

A successful performance test is a basic requirement within the German regulation „Uniform Practice for monitoring emissions“ [2] for the acceptance of a digital interface in an emission monitoring system. For the ABB analyzers Advance Optima and EasyLine, the test was successfully performed on two independent and complete emission monitoring systems (AMS, DAHS) by TÜV Rheinland. This performance test for the digital interface is the basis for the extension of the already existing certification of the AMS according to EN 15267.

Table 2 and table 3 show the configuration of both ABB analyzers.

AO2000

Component	Range
CO	0 – 75 mg/m³
SO_2	0 – 75 mg/m³
NO	0 – 100 mg/m³
O_2	0 – 25 Vol%

Table 2: Configuration of Advance Optima analyzer

EL3000

Component	Range
N_20	0 – 100 mg/m³
CO_2	0 – 20 Vol%
NO	0 – 200 mg/m³
O_2	0 – 25 Vol%

Table 3: Configuration of EasyLine analyzer

In addition to the DAHS, there is no further test device necessary for the performance test. The DAHS provided the following functionality to test the AMS:

- PROFIBUS interface
- Reading of AMS description via the **Physical Block**
- Applying of zero and reference material via the **Discrete Output Function Block**
- Simulation of measured values and status signals via the **Analog Input Function Block**
- Data logging of measured and simulated data via the **Analog Input Function Block**
- Export function of historical data
- Status information

The test of the data transmission and the switching between zero and reference materials was performed close to real operation conditions with different test gas mixtures from test bottles and a sample switching unit. The test covered the broad range of normal operation, failure handling, test procedures for QAL1/QAL2/AST and the QAL3 functionality.

Summary and outlook

VDI 4201 series facilitates now the use of digital interfaces in emission monitoring systems for regulated sources. PROFIBUS PA as specified in Part 2 fulfills all requirements based on an internationally recognized communication protocol.

A digital interface between AMS and DAHS allows the transmission of detailed information on the AMS itself and an automated execution and documentation of the QAL3 procedure in addition to the measured value. Therefore it improves the quality of these cyclic tests during continuous operation. The export function for time stamped measured values of the AMS reduces the effort of test houses for data acquisition during parallel measurements with the standard reference method. Independent from the protocol used, these data are available in a standardized format.

Several AMS and DAHS have already been successfully tested according to the VDI 4201 by the TÜV Rheinland. First certified products are expected within the next months.

Acceptance of the digital interface for emission monitoring systems will be further increased by the VDI 4201 part 3 [5] and part 4 [6]. Part 3 specifies an implementation based on Modbus, part 4 based on OPC. This results in higher flexibility on the selection of a digital interface. Part 3 and 4 are currently under development and the final release is expected until the end of 2011.

Literature

[1] EN 15267 Part 3: 2008-03 Air quality – Certification of automated measuring systems – Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources

[2] Uniform Practice for monitoring emissions, RdSchr. des BMU from 13. Juni 2005 – IG I2 – 45053/5, GMBl (2005), S. 795

[3] VDI 4201 Part 1:2010-09 Performance criteria on automated measuring and electronic data evaluation systems for monitoring emissions - Digital interface - General requirements. Berlin: Beuth Verlag

[4] VDI 4201 Part 2:2010-09 Performance criteria on automated measuring and electronic data evaluation systems for monitoring emissions - Digital interface - Specific requirements PROFIBUS. Berlin: Beuth Verlag

[5] Draft VDI 4201 Part 3:2011-03 Performance criteria on automated measuring and electronic data evaluation systems for monitoring emissions - Digital interface - Specific requirements Modbus. Berlin: Beuth Verlag

[6] Draft VDI 4201 Part 4:2011-04 Performance criteria on automated measuring and electronic data evaluation systems for monitoring emissions - Digital interface - Specific requirements OPC. Berlin: Beuth Verlag

[7] EN 14181: 2004-09 Stationary source emissions - Quality assurance of automated measuring systems

[8] Profile for Process Control Devices, Version V 3.01 (December 2004), Conformance Class A plus Amendment 2 und 3. PROFIBUS User Organisation, Karlsruhe

[9] Diedrich, C; Bangemann, T: PROFIBUS PA, Instrumentation Technology for the Process Industry. München: Oldenbourg Industrieverlag 2007