The Benefits of Fieldbus Technology in Power Plants

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ABSTRACT

Fundamentally, energy in the form of electricity cannot be stored. The right amount of power must be generated at the right time. This is In-Market Availability and is crucial for power plants. Fieldbus technology can help increase In-Market Availability and reduce total cost of ownership. This paper discusses fieldbus technology and its benefits in power plants. Practical applications and considerations are also presented and discussed.

INTRODUCTION

Digital technology is increasingly driving changes in the power industry. Its pervasiveness is evident in all sectors of the power industry, including instrumentation. The communications capability of devices and continuous, transparent information flow are requisite components of cutting-edge automation concepts. Advances in fieldbus technology are characterized by similar trends. The introduction of fieldbus technology for instrumentation is closing the digital data communication gap between automation systems and field devices. The result is more accurate values and transmission of values, bi-directional communication, and flexible structures with fewer components.

The 4-20 mA signal is the standard used in the power industry today for the transmission of process values from the sensors to the control system and from positioners to actuators. The introduction of this standardized current signal resulted in a process automation revolution, saving users time and money with instrumentation. The 4-20 mA signal, however, has reached its transmission capacity limits. Process information is converted by the sensors into digital signals for the instrument microprocessor. After the signal is processed in the microprocessor, the signal is reconverted into analog for the
transmission. This inefficient conversion process costs money and reduces signal accuracy. By contrast, a pure digital signal transmission offers broader bandwidth for plausibility checks and status signals.

The digitization of process signals and the associated decentralization represents the most important development that paves the way for the application of a fieldbus system. The subsequent introduction of the fieldbus in power plants has changed the structure of control systems. Fieldbus technology allows shifting central functions into field devices and leads to decentralized structures in the automation systems. These decentralized structures reduce the costs for wiring and assembly and increase the availability. Availability is also increased by improved maintenance and diagnosis through smart instrumentation. Additional cost improvements can be achieved for installation, commissioning, operation, and also space requirements.

The introduction of the fieldbus technology for instrumentation is closing the gap of digital data communication between automation systems and field devices.

**FIELDBUS IN POWER PLANTS**

Distributed automation solutions based on open fieldbuses are the current standard for many sectors of the manufacturing industry and more recently, for process engineering. Fieldbus technology provides more information about the process and the field instrument itself. Only fieldbus permits full utilization of the functional advantages of digital communication such as improved resolution of measured values, diagnostic capabilities and remote operation. For the selection of a fieldbus system, not only are cost saving potentials important, but also selecting the "correct" system for your plant.

An important characteristic of networks is open communication. Open communication is typical for standardized networks where specifications are public. Interoperability of hardware and software components from different manufacturers is therefore guaranteed. Closed systems are manufacturer specific protocols for proprietary applications and products. The use of components from different manufacturers requires additional development for interfaces and drivers. Digital communication has been around for a long time but only as proprietary protocols. In the mid-1980’s several companies and universities started working on a standard protocol. The efforts resulted in two networks: PROFIBUS and Foundation Fieldbus. PROFIBUS is a standardized, open, digital communication system for all areas of applications in manufacturing and process automation. The PROFIBUS protocol is based in the international standards EN 50170 and IEC 61158. The technology is suitable for replacement of discrete and analog signals.

More than ever, systems are required to provide seamless communication from the actuator and sensor level all the way up to the management level. The communication capability of devices and subsystems and consistent information routes are indispensable components of cutting edge automation concepts.

Communication is increasingly taking place horizontally at the field level and at the same time vertically through several hierarchical levels. Coordinated industrial communication systems, such as PROFIBUS, with downward interfacing to AS-Interface and upward interfacing to Ethernet (over
PROFInet), offer the ideal preconditions for transparent networking in all areas of the production process.

PROFIBUS is a consistent, open, digital communication system with a wide range of applications, particularly in the fields of factory and process automation. PROFIBUS is suitable for fast (up to 12 Mbit/s), time-critical applications and complex communication tasks. PROFIBUS offers communication for all system hierarchy levels and buses with functionally graduated communication protocols (communication profiles). The main focus in power plant automation is set at the field level. This is where central programmable controllers, such as PLCs, PCs or process control systems, communicate with distributed field devices, such as distributed I/Os, drives and motors, valves, transducers or analysis devices, over a fast serial connection. Data exchange with the distributed devices is primarily cyclic, while additional information like alarms or diagnostic data are transmitted acyclically (on request).

The PROFIBUS solution for the field level consists of the H1 (PROFIBUS PA) and H2 (PROFIBUS DP) level. PROFIBUS DP (Decentralized Peripherals) is used for fast communication with distributed I/Os and other complex devices in production automation, while PROFIBUS PA (Process Automation) is used for communication tasks in process automation, such as transmitter and valves. It is the first fieldbus system, which covers the requirements of both sectors using identical communication services (Figure 1).

**Figure 1: PROFIBUS Overview**
PROFIBUS DP is the most frequently used communication fieldbus communication:

- It is optimized for speed, efficiency, and low connection costs and is designed especially for fast communication between automation systems and distributed peripherals.
- DP is a replacement for conventional, parallel signal transmission with 24 volts in manufacturing automation, as well as a seamless platform for analog signal-based transmission with 4-20 mA or HART in process automation.

It incorporates versatile network configurations (linear, star, ring) and optional redundancy with a fiber-optic double ring.

**BENEFITS OF FIELDBUS**

Fieldbus offers advantages in many areas. The standard has led to a variety of similar products from which customers can select the solution that best fits their needs.

As mentioned before, fieldbus has decentralized the structure of control systems. The control system consists of many control islands, sometimes with its distributed small controller. Single faults do not effect the entire system therefore also not effecting the plant availability. The higher the degree of automation, the higher the availability. In order to increase availability requirements, most components can optionally be redundantly structured. Redundancy can be provided in various stages, starting with partial redundancy up to a fully redundant structure including redundant modules.

Availability can also be achieved with diagnostic information from the smart devices. Fieldbus devices can provide more information than just the process value. Digital communication can also send diagnostic information like process temperature, electronic temperature, operating hours, status bytes or plausibility checks for the transmission. Other benefits of fieldbus devices include:

- Preventive maintenance of instruments
- Early prediction of sensor failures and damages to equipment
- Fast and precise error recognition of the field devices
- Predictable outages to increase In-Market Availability (IMA)

The improved availability increases the life cycle of the plant and is therefore important in reducing the total cost of ownership. Other factors that contribute to this reduction include increased performance and quality improvement. The benefits are achieved through configuration, cabling, engineering, documentation, assembly and commissioning, as well as through plant operation.
PRACTICAL APPLICATIONS

The I/O count for a power plant can range from 500 for a single turbine island to over 25,000 for a coal-fired power plant. The combined-cycle power plant is currently the most commonly built power plant. This standard design consists of about 4,000 I/Os (1,100 analog I/O) which are distributed to several Power Control Centers (PCCs - α in Figure 2) and remote field locations. Field locations can be the turbine hall (σ in Figure 2), the cooling fans (δ in Figure 2) or next to the Heat Recovery Steam Generator (HRSG - φ in Figure 2) at ground level and at the 100’ level next to the drums (γ in Figure 2). Field locations have the advantage of reducing the space requirements in the PCCs. In these cases, fiber optic cable is used for the redundant PROFIBUS for faster communication over the greater distance and avoids problems with lightning strikes. The field locations also help increase the availability due to the redundant PROFIBUS. Classic designs have I/O cabinets in the PCCs next to the controller with a non-redundant 4-20 mA communication out to field instruments. With this design most of the communication is redundant, while only a small communication path from the remote I/O to the instruments is non-redundant.

Figure 2: 2on1 Combined Cycle Power Plant
PROFIBUS is also being used to install small I/O clusters in operating equipment such as the turbine-generator (η in Figure 2) and the continuous emissions monitoring system. PROFIBUS has proven itself to be cost-effective and reliable in over 100 operating plants. Commissioning is performed in a timely manner due to the simplicity and the limited number of wires used in power plants. The reduced number of wires decreases erroneous connections and accelerates troubleshooting during commissioning.

Certain applications, like burner management systems or continuous emission monitoring systems, require separate controllers. PROFIBUS DP can integrate these applications for a fully integrated control system. HART can also be integrated into control systems by using HART-Multiplexers or HART capable distributed I/Os for applications where the 4-20 mA is a better fit.

The Siemens Westinghouse Power Corporation DCS, TXP™, is tailored for modern power plants using PROFIBUS as the backbone of the system TXP has rapidly gained acceptance in the U.S. power market, with more than 100 new operating units and many more under construction. The St. Francis plant located in Missouri is an excellent example of PROFIBUS being used in a combined-cycle plant. The plant is equipped with two units, each equipped with one gas turbine, one steam turbine, and one generator mounted on a single line shaft. This configuration features lower investment cost and high efficiency. PROFIBUS modules are used extensively in critical operations for this plant and feature high-speed communication of both analog and binary I/O over redundant communication paths. During the summer of 1999, a peak period for power consumption, St. Francis had 100% IMA.

**PROFIBUS PA**

The field level is fully integrated into the instrumentation and control (I&C) system through the use of PROFIBUS and intelligent field devices. The process control system penetrates all the way down to the field level for a bi-directional communication (Figure 3). Bi-directional communication is a requisite to meet the requirements for profitability and high flexibility demanded in plant automation.

![Figure 3: Penetration of PROFIBUS](image-url)

PROFIBUS is a reality in more than 100 power plants. So far only PROFIBUS DP has become a standard in power plant automation. In order to benefit completely from comprehensive digital communication it is time to open the doors to PROFIBUS PA (Process Automation). PROFIBUS PA...
has been tailored to meet the requirements of the process industry. It is used for networking transmitters, valves, and actuators in the process environment. The standardized communication services guarantee interoperability between field devices from different vendors and remote modification of field device parameters during operation. In other industries, like chemical, pharmaceutical or food and beverage, PROFIBUS PA has proven its reliability and efficiency.

PROFIBUS PA is the expansion of PROFIBUS DP using the same communications protocol as PROFIBUS DP. The RS 485 transmission system used for PROFIBUS DP has been replaced for PROFIBUS PA by the transmission system according to IEC 61158. This system is internationally standardized and can also be used for intrinsically-safe applications (not relevant in power plant automation). With PROFIBUS PA, information and power supply can be transmitted simultaneously at a slower speed (31.25kBit/s) on a two-wire cable. The uniform protocol of PROFIBUS DP and PROFIBUS PA permits simple combination of the two networks making it possible to also implement in large plants.

ADVANTAGES OF PROFIBUS PA

The introduction of PROFIBUS PA has closed the gap of digital data communication between automation systems and field devices. The improved functionality of PROFIBUS PA offers advantages through all stages of a project:

INSTALLATION PHASE
- Reduced wiring, and therefore, ease of engineering and installation
  - Faster assembly and reduced faults
  - Material saved for cabling
- Instruments can be installed in locations close to the process for direct measurement; information is accessible remotely, daily access is not necessary

COMMISSIONING PHASE
- More than 100 devices can be commissioned per day
- One person can complete commissioning; no need for a second person in the field to find and "activate" an instrument for the loop check
- Communication faults can be located from the control room
- No 4-20mA calibration is required since the digital device measures the full range of process values
- Instrument settings can be downloaded from the control room; no need to connect a handheld to each transmitter individually
- A calibration pressure source is not required

POWER GENERATION PHASE
- High resolution of the measured value
- The original signal is not altered by analog/digital conversion
- Higher transmission reliability
  - Digital communication is not subject to noise
  - Plausibility checks confirm the quality of the signal
- Communication of measurement value and device status from field instruments to DCS
- Fewer and predictable outages

**MAINTENANCE PHASE**
- Diagnostic information for predictive maintenance; maintenance is performed only when scheduled or required
- Determination of process or instrument faults
- Easy and fast troubleshooting from the control room
  - No need to find the instrument in the plant
  - Fewer trips to the field
- Self-test and corrective functions in the field device
- No periodic 4-20 mA calibration
- Plug and play by downloading replaced instrument settings to the new instrument

These benefits are available through various software packages. The display of the device parameters and functions has a common look and feel for all supported process devices and independent of their communications interface (e.g. via PROFIBUS-DP/PA and HART protocol).

**FIELDBUS APPLICATION CONSIDERATIONS**

Power plant operators have been hesitant to replace proven hardwired technology with the fieldbus. The application of fieldbus technology only makes sense if the efficiency of the entire system is increased and total cost of ownership can be reduced.

In order for customers to switch to the fieldbus, I&C vendors argue as follows: Advantages for the fieldbus technology in relation to conventional systems already occur due to the implementation of the system. The omission of I/O modules as well as racks and cabinets in the control systems reduce the hardware expenditure substantially. The associated savings balance additional expenditure for necessary components to operate a decentralized system.
The application of fieldbus devices avoids the use of a large number of cables, cable routes, terminal blocks, and marshalling racks as well as costs of laying of cables, cable connection, and checking. Reduced hardware needs result in easier project engineering, fewer engineering hours, and less documentation. Also, upgrades require no additional cables or cable routes and thereby become more economical.

CONCLUSION

Today, PROFIBUS is the fieldbus world market leader with more than a 20% share of the market in approximately 400,000 automation plants with more than 4 million nodes. There are of more than 2000 available PROFIBUS products from a wide range of manufacturers. Nobody argues the benefits of digital communication. Technology transition is always risky, especially for power plants where In-Market Availability is absolutely crucial. The first transition to the open and standardized PROFIBUS DP has clearly shown that it has improved IMA. The decentralized architecture and the diagnostic information especially are increasing availability of plants. Additional availability can be achieved by extending the digital communication to all field devices using PROFIBUS PA. The risks are limited because of the identical communication protocol. Foundation Fieldbus offers at the H1 level the same saving and availability potentials. For customers who are familiar with PROFIBUS DP it is logical to go with PROFIBUS PA to benefit from the seamless communication.

Often, low priority is given to plant controls and therefore the least costly control system or version of a control system is installed. PROFIBUS can be implemented in a control system with a high level of
redundancy. Redundancy and decentralization require a higher initial investment with cost saving during installation and commissioning.

If the saving still does not overcome the initial investment, imagine the following situation: Imagine losing two hours of power generation on a hot summer day between 3:00 and 5:00 pm. Now imagine losing an additional six hours due to a device failure. During those eight hours, thousands of dollars in opportunity costs are lost. Imagine this fault could have been recognized and diagnosed immediately with PROFIBUS technology. Quick fault recognition, for example, will turn opportunity costs into profit. Not hard to imagine.

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