Field Bus Technology in the 950-MW Unit K of the RWE Rheinbraun Lignite Power Station in Niederaußem

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1 Introduction

A lignite power unit with optimized plant technology is currently being erected at the Niederaußem plant of RWE Rheinbraun AG. The power unit with its gross output of 1012 MW during continuous operation (maximum possible gross continuous output: 1028 MW) and a power efficiency of 45% is due to go into service in the middle of 2002.

The power unit control system, which is being implemented by Siemens PG with the TELEPERM XP process control system, acquires approximately 4,000 analog measured variables and drives approximately 2,200 electric actuators.

Following a comparison of both the technical and economic aspects of conventional, electric actuators/sensors and field-bus-driven actuators/sensors, a decision was made as early as 1998 during the tendering phase of the project in favor of a hybrid concept based on proven solutions such as HART technology for the sensors and the more recent field-bus technology for the actuators. Important factors that contributed to this decision were reduced costs and enhanced functionality, while maintaining the existing control configuration of the power plant, in which great importance is attached to redundancy. Field bus technology was not, however, implemented across the board; instead, the most cost-effective solution was selected for the application in question. Alongside the costs for erecting the control system, the profitability analysis also considered service/maintenance costs and subsequent system/device availability, bearing in mind the long service life of the power plant and the ever shorter innovatory and product life cycles of the field devices, control systems and software.

Proprietary solutions were, therefore, rejected, and only field devices and bus concepts that conform to the Profibus standard DP-V1 were considered for the actuators. As no specific standards have yet been defined for time stamping and redundancy, Profibus PA technology was not implemented for the sensors.

Conventional interfacing between actuators is only used in exceptional cases if required by the prevailing technical circumstances (e.g. open-loop and closed-loop control actuators in the cooling tower, coal pulverizing mills or oil pumps for the main and feed pump drive turbine).

The 30 main actuators of the large generator sets, which maintain the availability of the power unit, are driven by the control system via interface relays by means of conventional wiring in the medium-voltage switchgear.

Fail-safe and normal solenoid valves are also driven for the most part via conventional interface relays.

The following sections provide a detailed description of the field bus concepts implemented in the 950-MW unit K of the Niederaußem plant.

2 HART Technology for Sensors

The decision made in 1998 in favor of HART technology was due to a number of reasons. As already mentioned, Profibus PA technology was not considered for this project due to the lack of authoritative standards for time stamping/synchronization and redundancy. In addition to this, no practical experience has yet been gained with regard to the dynamic behavior of analog signal processing based on Profibus PA in a complex, fully automatic power unit with one-man operation.

The HART technology used in this project supports most of the functions of Profibus PA while retaining the tried-and-tested analog signal processing functions of the TELEPERM XP control system. The important advantage of HART technology is that a digital signal is modulated upon the conventional 4-20 mA measuring signal. This enables digital communication and measured value processing to be handled simultaneously on one of the connecting leads of the sensor, without affecting the measuring signal.

Most of the sensors in unit K of the power plant are intelligent, analog measuring transducers based on HART technology, which are integrated in the Process Device Manager SIMATIC PDM (see Fig. 1).
The SIMATIC PDM is a parameterization tool that enables the basic functions of process devices (sensors and actuators) from different manufacturers to be used in one standardized operator control interface. The SIMATIC PDM supports functions for adjustment/modification, comparison, plausibility checks, simulation, management, documentation, as well as functions for commissioning process devices.

In the concept selected for unit K, HART-capable measuring transducers communicate with a server PC (Windows NT Terminal Server) via multiplexer modules on the basis of the HART protocol. The electrically isolated inputs of the multiplexer modules are routed in parallel to the inputs of the encoder conditioning in the analog signal processor of the control system for this purpose. The ELCON multiplexer modules are located in the automation cabinets close to the racks of the analog signal processor. Redundant measurements lead to symmetrical multiplexer assignments.

The software for controlling the multiplexer modules and the PDM software are installed on the server PC, which is connected to the central engineering system of the control system via the terminal bus of the control system. The PDM is operated and all of the HART-capable measuring transducers of the power unit are accessed centrally on the engineering system.

ELCON MUX modules enable 32 measuring transducers to be connected for each multiplexer. Up to 31 multiplexers can be combined in one RS485 network to be able to address all the measuring transducers individually. A total of four RS485 networks are implemented in unit K, which allow up to 4,000 process devices to be addressed and managed.

The main advantage of this concept is that most of the measuring transducers, which can be from different manufacturers and of different types, can be accessed centrally using one, standardized operator control interface and a shared database. The disadvantage, however, is that the engineering system and the HART server PC use different databases. Both of these subsystems therefore have to be reconfigured and modified. This problem can be avoided by using a Device Type Manager (DTM), which will be developed sometime in the future.

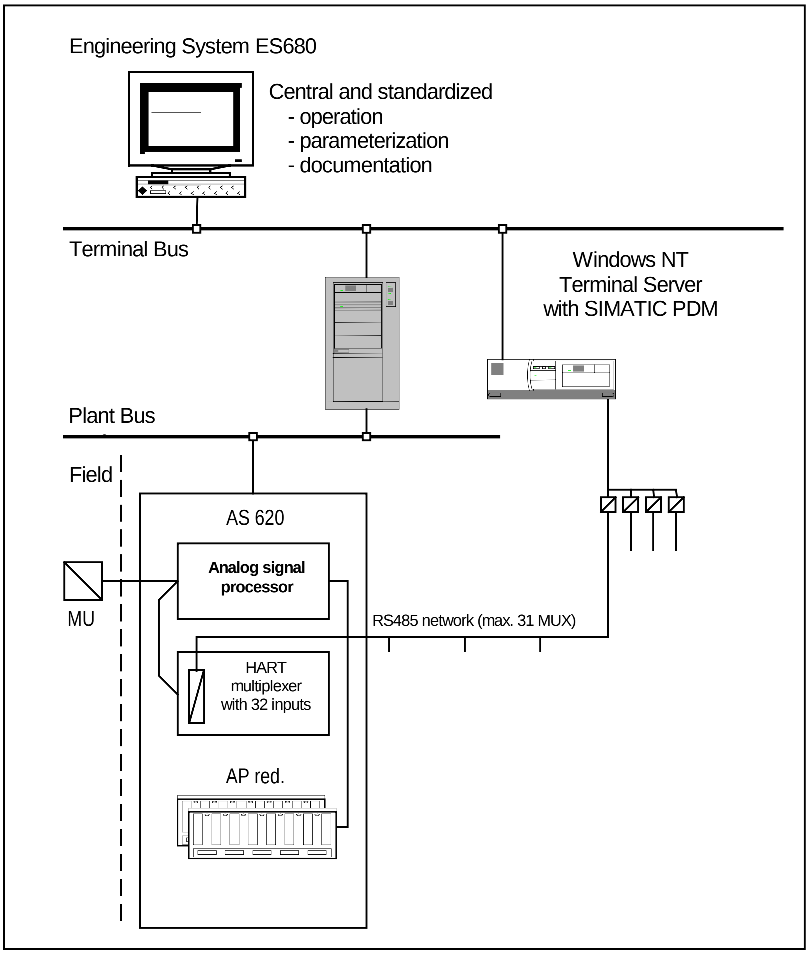

Fig. 1 HART Concept

3 Profibus DP V1 for Actuators

Profibus DP V1 was chosen for the actuators (closed-loop and open-loop control actuators, and the rotary actuators at the low-voltage level) on account of the many advantages that can be leveraged by power plants. These include:

- Its proven track record in power plants,
- Its relatively reliable data throughput, which ensures real-time responses,
- Flexible bus topology for reducing wiring costs,
- Mixed redundancy, integration of repeaters for network expansion, and couplers for interfacing to other bus systems
- Cyclical/acyclical data traffic and reliable diagnostics functions.

Profibus DP V1 technology also allows intelligent field devices with enhanced functionality (SIPOS actuators and SIMOCODE switching devices) to be used and integrated in the central engineering system (ES680) for parameterization and diagnostic purposes.

The SIMATIC PDM with its routing function is used again here. The PDM supports end-to-end communication from the engineering station to the control system through to the individual field and switching devices in the low-voltage switchgear.

The redundancy concepts aim to implement suitable redundancy measures for controlling the field devices, starting at the two automation processors (AP) in the electronics room, to the two interface modules/master redundancy (TXP/IM308C), field bus wiring/line redundancy, through to the Profibus input board/slave redundancy of the field devices. This system redundancy is transparent for the application in question.

This consistent, redundant, control structure is mirrored in the switchgear configurations for the process-oriented generator sets, with the aim of providing maximum power unit availability (see Fig. 2).

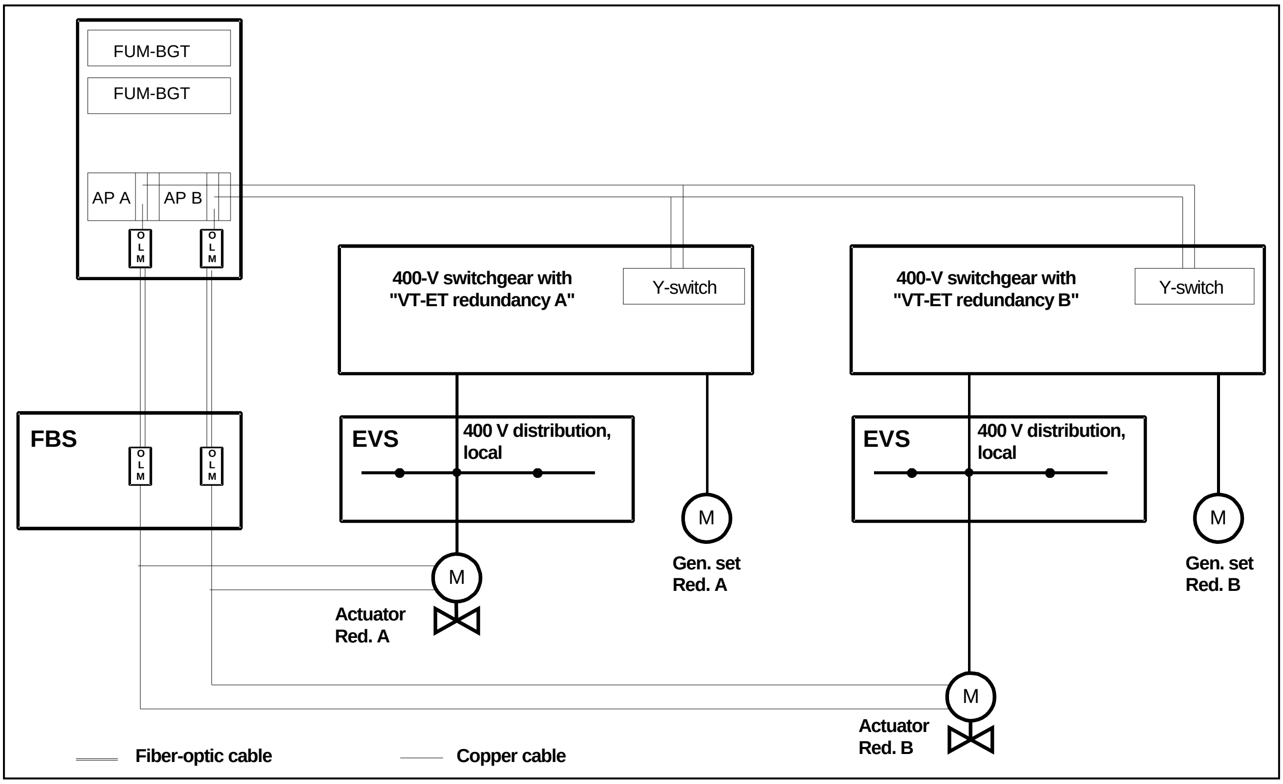

Fig. 2 Redundancy Concept

3.1 Open-Loop and Closed-Loop Control Actuators

Unit K uses intelligent actuators with redundant SIPOS 5 Flash Profitron Profibus connections. The SIPOS actuators are equipped with integrated power and communications electronics, which do away with the need for a controlled switchgear outgoing feeder and an actuator control module in the control system, and a power controller and control module for a closed-loop control actuator. These integrated communications and power electronics are installed separately from the electric actuator if ambient temperatures are particularly high or if the operating site is subject to severe vibration. Central actuator functions such as position detection and torque detection/cut-off are controlled by the integrated actuator electronics. The individual control level of the open-loop control actuator is handled as a function block in the automation processor, which sends the appropriate operating commands to the open-loop control actuator via the Profibus and evaluates the signals sent back. Open-loop control actuators are fitted with their own positioners with adaptive hysteresis, which are controlled by the process controller in the AP. "Outsourcing" this closed-loop control function to the local actuator reduces the signal traffic on the DP bus and ensures that the real-time-capable control response of the system is maintained. The frequency converters in the actuators support variable actuator speeds, end position soft starts and torque calculations. The actuator can also store three different torque/position curves, which are used for quality control purposes when the plant is being erected, and as a basis for a status-oriented maintenance concept.

The self-monitoring function for operating cycles, operating hours and torque-controlled cut-off in the intelligent actuator can trigger a maintenance request which, in conjunction with remote diagnosis via the PDM, supports a demand-oriented, preventive approach and opens up scope for reducing costs.

Other important actuator features include:

- Local operation
- Temperature measurement
- Analog position measurement
- Starting current suppression
- Direction of rotation does not need to be monitored
- No mechanical limit switches or torque limit switches
- Electronic torque limiting
- Electronic rating plate

3.1.1 Bus Concept

Open-loop and closed-loop control actuators are installed along common bus lines; mixed bus configurations are also possible by using repeaters. The selected transmission rate of 500 kbits/s restricts the copper bus segments to a length of 400 m. Repeaters can be used if greater distances have to covered. The number of electric actuators is limited to 64 stations by the TXP interface module IM308C. Two interface modules can be connected to one of the redundant APs (see Fig. 3).

Optical link modules (OLMs) are used in the bus wiring between the automation cabinets and field bus stations (FBS). An independent optical-fiber network is implemented here in line with the plant topology. In the FBS, which are installed as sub-distribution boards, the OLMs act as a transition point for the transmission medium from optical-fiber cables to Profibus copper cables. The copper bus branch lines can be arranged in a star configuration from the outgoing feeders of the OLMs. The bus ends are terminated with active bus terminators.

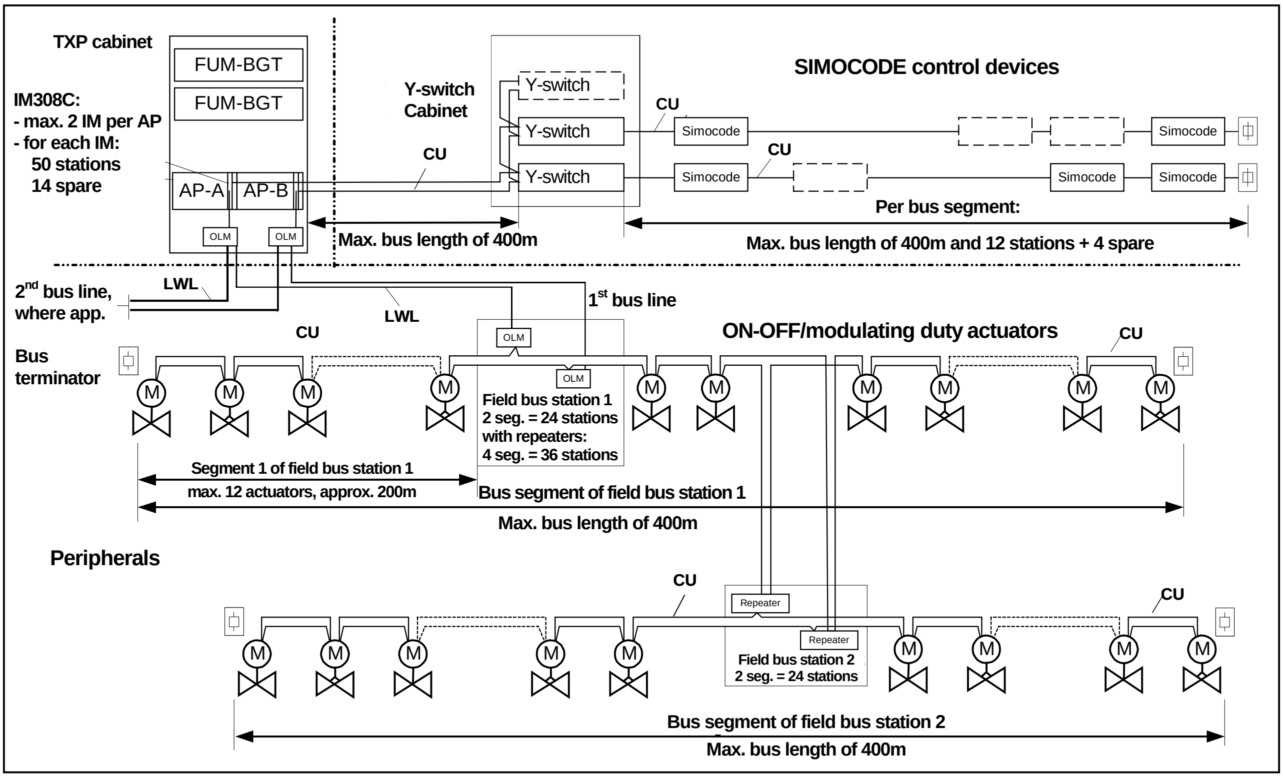

Fig. 3 Bus Concept

3.1.2 Power Supply Concept

The actuators are powered via distributed power distribution stations (PDS), which are mounted on a common rack with the FBS in the peripherals. These PDS are fed with a main incoming supply from the central 400-V switchgear stations and supply the actuators via individually-fused outgoing feeders either with 230 V AC (small actuators) or 400 V AC (larger actuators). This considerably reduces the wiring required. A "powerbus" is not used to supply the actuators due to the safety isolation problems involved. The power supply is monitored by the actuator electronics.

The 24-V DC supply voltage for the integrated power/communications electronics is derived from the actuator power supply. To ensure that bus communication with the control system is maintained if this internal 24-V supply fails, the actuators are provided with an additional external 24-V supply. Failures in individual actuators do not affect the availability of the power unit; bus switchovers in the auxiliaries, however, do. The brief interruption in communication that this would cause on the bus lines concerned could result in the power unit being shut down because no process checkback signals are received. The 24-V supply voltage is not buffered via energy-storage mechanisms in the actuator electronics due to the anticipated high level of maintenance involved.

The external 24-V supply voltage is formed via power supply units in the PDS, which are supplied by the 400-V UPS busbars, and is fed to the redundant diode-isolated incoming feeders of the FBS.

This redundant 24-V supply is fed to the actuators in a hybrid cable in order to reduce wiring. The shielded Profibus DP bus cable and a 24-V supply cable are integrated in the ECOFAST system hybrid cable. This redundant 24-V supply is connected physically as a ring feeder between the FBS and the actuators of the bus cable concerned, and forms a 24-V power bus.

The monitoring signals are sent from the FBS to the control system via binary contacts.

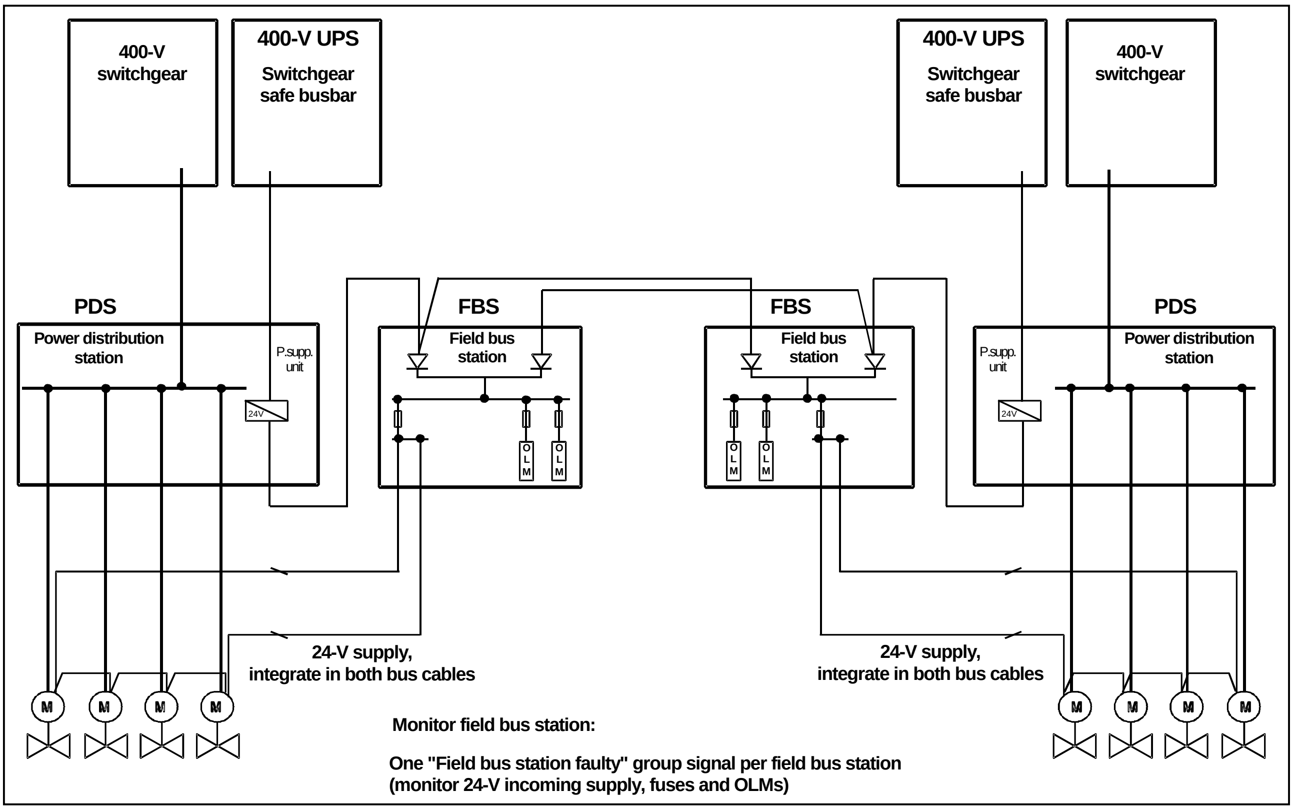

Fig. 4 Power Supply Concept

3.2 Continuous Actuators (Low-Voltage Level)

Intelligent SIMOCODE switching devices are used for the outgoing feeders in the SIVACON low-voltage switchgear station (MCC outgoing feeders), and communicate with the control system via a Profibus DP connection. The SIMOCODE switching devices are responsible for protecting and controlling the continuous actuators, and are fitted with a single Profibus DP port for communication purposes. The devices are also equipped with four binary inputs and outputs, which allow different switchgear feeder types to be implemented. The binary inputs can be used, for example, to activate the low-voltage function, which is then executed locally in the SIMOCODE switching device, and merely needs to be tracked in the control system to ensure that signaling is performed correctly.

The SIMOCODE switching devices are parameterized and serviced in the same way as the actuators via the standard operator control interface of the PDM and its routing function, right down to the individual switching devices in the switchgear. These activities are controlled from a workstation of the central ES680 engineering system of the control system. The parameters defined for the low-voltage switchgear are, therefore, an integral part of the database of the ES680 engineering system. Parameterization can also be carried out on the SIMOCODE operator display using a laptop.

Ranking between the control system and the switchgear is not possible because the actuators are assigned on field bus lines. Since the actuators were not allocated to the switchgear until a relatively late stage of the project, they had to be preassigned in the switchgear in accordance with the technological functional areas of the control system when the plant was being planned. Detailed assignments were then made later on.

One important feature of the SIMOCODE switching devices is that all actuators support a current measuring function, via which they are also monitored.

3.2.1 Bus Concept

The redundancy measures implemented in the bus concept for controlling the SIMOCODE switching devices are similar to those in the bus concept for the actuators (see Fig. 3). Starting from the redundant APs, redundant copper bus cables are routed to the switchgear via redundant IM308C interface modules (redundant bus masters). Since the SIMOCODE switching devices are linked by means of single Profibus connections, an interface is required to link the redundant buses to a single bus line. Y-switches, which are installed in separate cabinets in the switchgear stations, are used for this purpose. The Y-switches, which are supplied with redundant voltage, comprise two interface modules that terminate the two bus lines on the input side, and a Y-coupler which establishes the connection to a single bus line on the output side.

The bus lines here are configured in the same way as the actuator DP bus lines; in other words, two IM 308C interface modules per AP, and a maximum of 64 stations to one IM 308C. A maximum of 32 stations can be connected to the Y-coupler module on the output side. Only 50% (approx.) of this capacity is used in practice to ensure that sufficient reserves are available for retrofits.

3.2.2 Distributed Switchgear

Alongside the central switchgear stations of unit K, which are located in separate switchgear station buildings (SSB), the plant is also equipped with two distributed switchgear stations on two different levels of the boiler house. These distributed switchgear stations are housed in air-conditioned containers, and are responsible for controlling the 170 steam sootblowers and their auxiliary equipment (seal-air fans), which are used to clean the steam generators.

The significantly lower costs for the sootblower equipment wiring, which is controlled by the master control system, swayed the decision in favor of this distributed switchgear concept. The 24-V DC supply for the switchgear is generated on site in the distributed switchgear stations by means of power supply units.

The basic design of these distributed switchgear stations is in line with the Profibus DP concept of the central switchgear stations described in section 3.2.1. Fiber-optic cables and OLMs are used for the redundant field bus lines on account of the relatively large distances of 300 - 400 m between the switchgear station building and the distributed switchgear stations. The Y-switches establish the connection to the single Profibus DP, to which the SIMOCODE switching devices for controlling the sootblowers are connected.

Since the seal-air fans do not require a complex control system, AS-i modules (actuator-sensor interface) are used, which are connected to separate AS-i bus lines with a maximum of 31 stations/fan controllers. These AS-i bus lines are connected to the single Profibus lines by means of DP/AS-i links.

4 AS-i Bus for Controlling Pneumatic Valves

In non-time-critical process engineering systems that are not directly involved in the power conversion process, and which are relatively compact (such as the condensate polishing and ash handling plants), pneumatic valves are actuated by the control system by means of AS-i-bus-controlled pneumatic modules.

Process-related redundancy is also provided here by configuring the control system accordingly. The pneumatic AS-i modules replace the usual pilot solenoid valves for controlling pneumatic valves. They are also equipped with binary inputs, which receive the position checkback signals from the valves. The AS-i bus enables the electrical power for energizing the solenoid coils in the AS-I module and the checkback signals to be routed together along a two-wire line.

The mechanism for controlling the AS-i modules (from the redundant APs to the master modules) is, for the most part, identical to the mechanism for controlling redundant fiber-optic Profibus lines for electric actuators, as described in section 3.1 (see Fig. 5).

The redundant fiber-optic Profibus lines are routed from the redundant master modules to the field bus stations (FBS). Using OLMs, the redundant bus lines are routed to Y-switches, the outputs of which are connected to DP/AS-i links, which connect the Profibus DP and the AS-i bus.

The power distribution station is merely responsible for supplying the FBS with 24 V DC for powering the Profibus modules and 230 V AC for powering the AS-i power supply units. 31 stations/pneumatic AS-i modules can be connected to an AS-i bus line, which, without repeaters, can be up to 100 m long.

The AS-i modules are installed differently in the ash handling plant and condensate polishing plant (KRA). In the KRA, the pneumatic AS-i modules are concentrated in AS-i stations, whereas in the ash-handling plant, they are distributed and connected directly to the pneumatic valves.

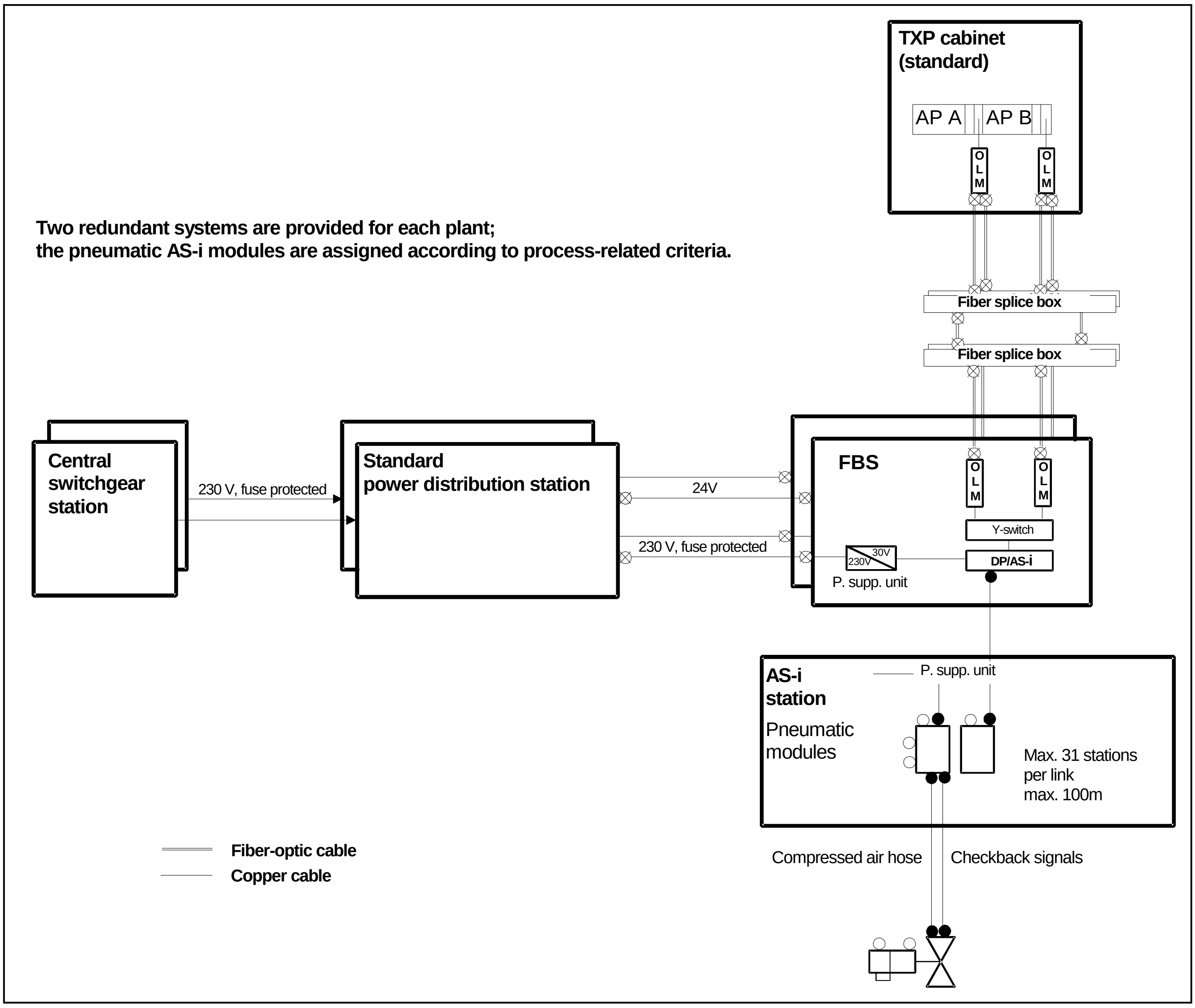

Fig. 5 AS-i Bus Concept

5 Connecting Intelligent Switchgear Control Systems to Master Control Systems

Up to now, controlling auxiliary switchgear has been the responsibility of master control systems (MCS). In unit K, this is carried out by a separate switchgear control system (SCS), which is essentially independent of the MCS.

The SICAM SAS, which is based on S7 hardware and the Profibus DP standard, is used here.
Each half-bus of the auxiliary switchgear is assigned a separate SCS control area (separate SICAM SAS). These are located in the appropriate switchgear buildings.

The master operator control level of the SCS is mapped by the Industrial Ethernet (H1) bus, which takes the form of a fiber-optic cable between the switchgear buildings.

The connection to the medium-voltage switchgear (SIPROTEC protective gear) is established by means of Profibus FMS, and to the low-voltage switchgear by means of Profibus DP.

The SCS in both SSBs are equipped with separate local operator terminals for commissioning and service purposes, and can be operated independently of the MCS.

Under normal operating conditions, the auxiliaries are operated by means of the SCS in the unit control room via the workstations of the operator control and monitoring system of the MCS. The video channels of the operator terminals are simply switched over for this purpose. The general SCS operation and visualization principles apply. Duplicating planning/configuration work and modifications in the SCS and MCS is thereby avoided. The control procedures are carried out by the electric personnel on a separate auxiliaries control station and not by the operating personnel of the power unit, which means that the philosophy of using a standardized operator control interface in a particular control area is upheld.

The status of the auxiliaries is also visualized in an overview display by means of the operator control and monitoring system of the MCS, thereby providing general information on the auxiliaries system of the power unit. Operator intervention is not possible in this mode. Since the auxiliaries control station in the power unit control room is not normally manned on a continuous basis, important group signals are also transmitted from the SCS to the MCS and reported simultaneously.

In order to transfer these group signals and visualize the auxiliaries overview display on the operator control and monitoring system of the MCS, appropriate signals have to exchanged between the SCS and MCS. A master PLC in each of the switchgear buildings is currently planned to handle this signal traffic.

6 Conclusion/Outlook

The extensive use of field bus technology in a large power unit, and the many new types of interface associated with this have so far required a great deal of coordination between the parties involved in the project. To minimize the risk involved in implementing the large number of field bus applications, a field bus model was created, which was used to test all the interfaces and field bus functions.

Deploying field bus technology has not only enhanced functionality, but has also provided a number of specific economic benefits during the course of the project. For example, the reduction in the amount of hardware required as a result of using field bus technology means that an entire storey in one of the switchgear buildings is no longer required. Further knowledge and information on implementing field bus technology in power plants will, no doubt, be gathered during the next project phase which involves commissioning the overall plant.

As the situation stands today, it can be assumed that power plant process control systems will, for the foreseeable future, continue to use conventional methods to link certain field bus devices. Process control systems will, therefore, be designed not just on the basis of field bus technology or conventional technology, but will combine the two to form a hybrid concept with a view to implementing a system that is both efficient and cost effective. In this respect, the control system of unit K in Niederaußem reflects the state of the art at the beginning of this decade.