Introduction

Backfitting measures in the plant C & I system may have their origin in
- changes or additional installation of process equipment (which may also affect the C & I system) or may be confined to
- the C & I system itself.

These changes arise while additional process variables might be monitored by new sensors, which must be installed at the interface between process and C & I system (see other paper) or new requirements concerning signal conditioning, control algorithms, failure of control system strategy need to be realized (see this paper).

A digital, decentralized C & I System with BUS-Transmission

Current NPP control equipment technology is essentially characterized by the transmission of information in parallel using individual cables, and utilizes hard-wired techniques for the processing of information, (see right-hand side of Figure 1).

Progress in the area of semiconductor development characterized by micro-processors and LSI-circuits, has opened up new possibilities for the solution of the control tasks. The new power station control system PROCONTROL P utilizes these possibilities - see left-hand side of Figure 1.

By the use of microprocessors and bus transmission methods, dedicated control subsystems, with digital stored program processing methods, can be designed decentrally and hierarchically. The digital techniques thereby used enable new service and diagnosis methods to be realized. Because of the dynamic method of operation, i.e. continuous monitoring, and automatic data validation conditions are created which enable disturbances in the whole plant to be identified according to location, type and time of occurrence by integrated diagnosis. This results in largely increased plant availability and improved overall plant operation.

Instead of allocating each measured signal and each instruction a separate wire, all signals and instructions are transmitted serially via a data bus, according to a time multiplexed procedure. By doing this, large quantities of cable are saved.

System Overview

The power station process control system PROCONTROL P covers all tasks, which are required for complete process control:
- signal conditioning
- transmission
- monitoring
- sequencing control
- analog control
- protection
- communication

PROCONTROL P features a decentralized hierarchical structure and has been designed around digital stored program techniques. The information exchange between the process control components is made via the bus oriented data transmission and distribution systems. All signals - measured values and instructions - are scanned and transmitted serially via a dual channel remote bus system.

Figure 2 shows the control system configuration. Each signal is connected from its originating location with a process station. Process stations can be mounted anywhere in the plant, so that only short cable runs are necessary between transmitter and station, or they can be mounted in a centralized location, such as the Electronics Room for example. The input signal is then converted into a digital signal and is passed to the bus.
Figure 3 shows a process station in a 800 MW plant. The blue cables come from the sensors, the yellow one is the bus.

The stations can contain input, output and processing devices in any mix. All stations are connected with each other by a remote or a local bus. All signals are transmitted via the remote bus to all stations which are connected to the bus. In each station the signals are distributed, if necessary, to all devices where they are required for processing or signalling or as instructions for example.

The remote bus coupler ensures that the stations are connected non-reactively to the bus. The distributor station coordinates the distribution of data. The remote bus consists of two independent channels. Each station is connected non-reactively to the two channels of a remote bus line - channel A and channel B. The principle of dual channelling is carried out consequently in the distributor stations. Each transmission channel has its own distributor station.

The transmission security of the PROCONTROL P remote bus system exceeds the maximum class according to IEC TC 57. A maximum of 8 remote bus lines can lead from the distributor station into the individual plant areas in a star configuration. Each remote bus line can be up to 1500 m long. The system is designed in such a way that the remote bus lines and the remote bus couplers can be planned, installed and commissioned without the exact position and layout of the individual stations being previously known. These stations can be subsequently connected to the remote bus coupler via direct connections up to 50 m long (see Fig. 3).

Figure 4 shows an application example of a 600 MW lignite power station. Four redundant remote bus lines lead (in separate channels each) from the electronics room into the field. Sensors and transducers comprise a total of approximately 2500.

The stations can be planned, installed and commissioned independently of one another and of the remote bus lines.

The data transmission system is event-oriented. Signal changes are transferred immediately. Even with a large number of events the reaction time is less than 10 ms.

In the hard wired programming technique the sequential control and analog control tasks are realised by hardware modules together with the associated project specific wiring. In the PROCONTROL P stored program technique the project specific wiring is replaced by a project specific structuring. The necessary functions for the process control tasks are available in the form of Standard Function Modules (Firmware). Proceeding from function plans these standard functions are structured by the means of the connection definitions and their parameters. The input of this data is in plain language statements which are familiar to engineers. Programming knowledge is not required.

The communication between the operators and the control system is designed as a system which is hierarchical with relation to its abilities and equipment. The principal item of this process-control communications system is a central operating desk. Via this desk it is possible to communicate with the whole of the process control system. All devices, structures, parameters etc. can be accessed from here, i.e. they can be displayed and modified with simultaneous automatic documentation. Among others, the following mode of operation are possible:

- simulation of signal statuses
- separation of defective signals
- remote adjustment of parameters
- signal tracing (including device internal signals)
- structuring of sequential control and analog control
- graphical display of process control functional details.

Communication with the process control system is very simple, being based on dialog techniques via the colour CRT units.

The capability to display disturbances which occur within the process control system (as opposed to process disturbances) is an additional important feature of the process control communication system. The basis for this is the centrally designed hierarchically structured diagnostic system of PROCONTROL P.
Addressing and Direction of Transmission

Each signal to be transmitted must be identified with an exclusive address. A signal can only have one point of origin; it can however be used at several locations. In PKOCONTROL P each signal to be transmitted is according to its originating location, i.e. its source (source location address).

Data sinks, like output or processing devices, keep an address list, in which the signals are delayed, which the device has to receive and evaluate. The signal connection is produced by inputting the required source address. The address list is stored in a programmable semiconductor memory (PROM) and thus easily amendable.

The data transmission with source addressing is, in principle, comparable with radio. The receiver is tuned on the transmitter; many receivers or data sinks can listen simultaneously. The system is simple and additional sinks may be added without repercussions on the data sources.

Example of a NPP

A typical example of backfitting C & I system in a nuclear power plant is the following:

In the 900 MW NPP Tihange 2 the central control room and the three independent emergency shut down rooms are linked together with three bus systems (see Fig.5). 870 criteria and 190 commands (all in a binary manner) are transmitted.

The bus system has the task,

- to transmit the positions of switchgear and valves of the safety system from the emergency shut down rooms to the control rooms and

- to give commands from the control room to the emergency rooms for safety-related and normal operational systems of the plant.

The application of the bus system allowed to fulfill the subsequent requirement of the licensing authority for linking the three emergency rooms between control room and safety related process systems in a non-reactively and redundant way. This could be realized very quick and without bigger contructions on site (no cabling!).

Galvanical separation between the safety process systems are realized in the emergency rooms and also between the control room and the safety process systems. IEEE-standards and NRC Regulatory Guides are satisfied (i.e. IEEE 308, 323, 344, US NRC 1.69 and 1.100).

Advantages in Backfitting Requirements

- New connections between the process and all monitoring, protection or control locations are made only by software modification. No cabling is needed. Each signal to be transmitted is identified by exclusive address and it can be used at several locations. Additional cabling or analog signal conditioning modules are not required and significant space is saved in already crowded control rooms.

- Maintenance and modification of existing systems is difficult because of the limitation on spare-parts. State of the art equipment is microprocessor based and more readily available and cost effective than outdated analog modules.

- The tasks of superordinated analog control or sequential control (which could be the sequential control of a function group) are carried out by micro-processor devices, which can communicate via the bus system. These devices receive input values, process them according to predefined programs and then output the resulting values and the positioning instructions to the bus system. Backfitting in the system can be considered in the user program memory at a later date. The number of devices is not affected and another device type is not required. Changes of algorithms in a control loop and of sequential control functions during backfitting, are realized by changing a PROM.

- Backfitting operations concerning damping and signal-to-noise ratio in the signal transmission path can be realized without expensive and time-consuming hardware operations by a non-linear adaptive filter.

- Process computer system together with the display system are used for high level information processing and display tasks. These systems allow the use of standard display formats as well as user tailored graphic display formats to aid in the
overall control of the process. All backfitting tasks concerning man/process communication can be realized therefore in a very simple manner only by changing software.

Error indicators from the C 4 I system, as measuring range overstep can be presented to the operator in an ergonomic optimal way. Backfitting, whose origin lays in changing ergonomical topics, can also be realized in a flexible way.

Fig. 1: Current equipment technology and digital, BUS transmitting technology

Fig. 2: System configuration of PROCONTROL P
Fig. 3: Cubicle with process station with cabling for transducers and transfer to the BUS-system

Fig. 4: Application example 700 MW Lignite power station Control system configuration
Fig. 6: Sequential control and analog control devices.
Figure 7: Central control room with main and auxiliary control consoles