Advanced control technology for power plant refurbishments

For economic reasons, many utilities prefer to refurbish or upgrade an existing power plant rather than build a new one. The lower capital investment that is needed, plus avoidance of the risks involved in obtaining approval for a new plant, are often the driving forces behind such decisions. Increasingly, refurbishment strategies have a total renewal of the plant control and instrumentation system tied into them. With the help of powerful software tools and modern project management, power plants can be refurbished today without causing more than a minimal loss of production.

The goal of power plant refurbishments is to secure reliable operation of the facilities for an additional 20 to 25 years whilst complying with the latest environmental standards. A major factor in every upgrade programme is the plant automation, in which state-of-the-art instrumentation and control technology plays a key role by helping to ensure that the objectives are met. These include:

- Plant operation within ranges that minimize equipment wear
- Extended lifetime
- Improved safety
- Enhanced plant availability
- Higher plant efficiency
- Optimized deployment of human resources
- Better economy
- Compliance with the requirements of DVG, the German authority that oversees the country's interconnected power systems

Utilities often specifiy an upgrade of the control system as part of the overall refurbishment strategy, which also covers the general plant services, rotating machines and power equipment. In many cases, the cost, quality and technical goals can be more easily achieved by completely renewing the control system (ie, from the control room to the field instrumentation) rather than replace the equipment step-by-step.

The typical examples given here illustrate the aims of control system upgrades, show the adopted procedures and describe the results obtained. Future-oriented hardware and software concepts as well as new strategies for operating and monitoring the power plant processes (eg, one-man operation) play a central role in such projects. With the help of powerful tools and modern project management, refurbishments of the kind described can be carried out with only very short unit downtimes.

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Reasons for installing advanced control systems

To perform the main control task, which is to systematically influence the power generation processes, modern-day systems have to meet new demands that go well beyond the capabilities of the older control equipment. This may be for a number of reasons, such as:

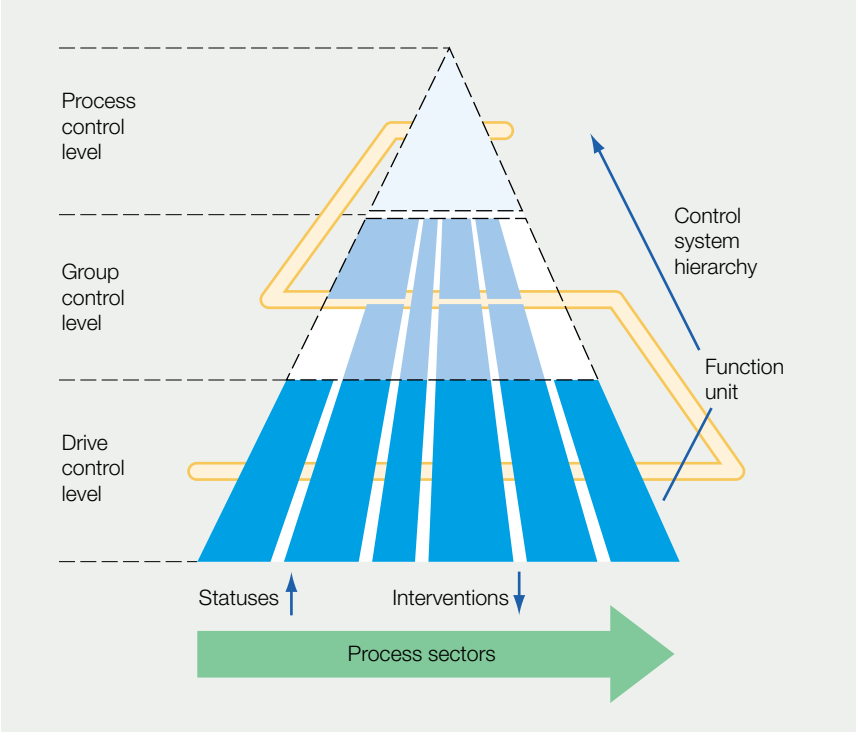
- Extensions are no longer possible as reserves have been used up.
- Spare parts can no longer be obtained, with the result that availability goals can only be achieved by investing more heavily in maintenance.
- Staffing problems are being caused by the changing work environment.
- Later additions to the system which are needed in order to comply with new regulations call for a level of automation that is not possible with the installed control equipment; harmonization of the different technology generations cannot be achieved at reasonable cost.
- The existing control system does not allow conformance with standards that are necessary to enable new economic goals to be met.

Also, since the innovation cycles for the control and instrumentation system are much shorter than for the process technology and electrical machines, the C&I system usually has to be renewed at some point during the lifetime of the plant. Early changeover to a more advanced technology pays as it allows maximum benefit to be obtained from the new system.

Investing in the future

Thanks to the distributed, hierarchical structure of ABB power plant control systems, the different availability requirements made on the various subprocesses can be met with centralized, semi-centralized or decentralized systems **1** .

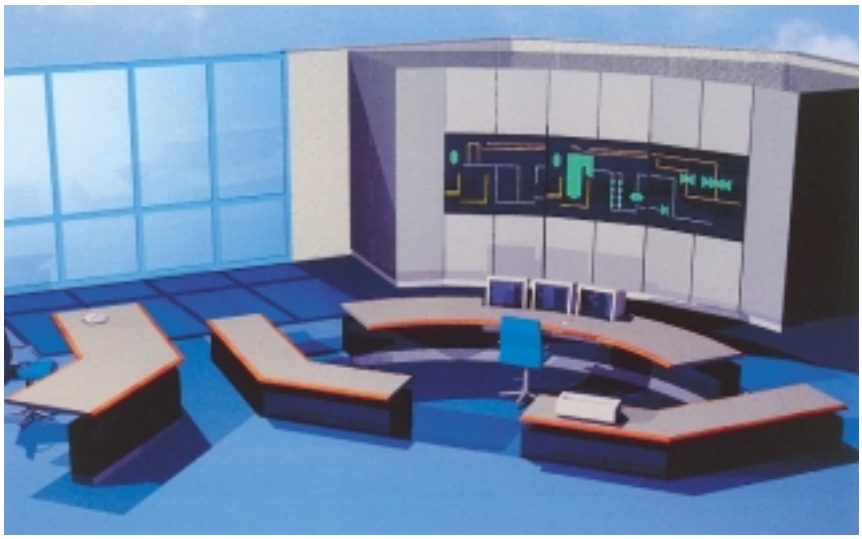
Besides satisfying present-day requirements, modern power plant control systems have features that will also meet operational demands in the foreseeable future.



Hierarchical structure of a distributed power plant control system **1**

Microprocessor-based control systems that make use of powerful computers and bus systems are capable of handling conditions that lie outside of normal power plant operation. For example, they make plant standby capacity (eg, thermal margins and flexibility in the generation schedule) transparent, and therefore immediately available. In addition, modern control technology supports the control room staff in carrying out their increasingly complex duties. The economy of the power plant as a whole is significantly improved.

User-friendly process control based on VDUs **2**



More efficient process management

Start-up of a power plant initially involves a large number of operations, thus increasing the risk of error. In theory, twelve operators are needed for the non-automated start-up of a 250-MW power plant, whereas during normal operation only two or three are needed. With automatic start-up and shut-down systems in place, the entire plant can be operated reliably by just one person.

VDU-based process operator systems **2** are one of the key factors in efficient process management. Mimic diagrams and standard displays provide the necessary overview of the plant. Other information is given, for example, by curves, trends and profiles, or by characteristics display fields in which the current working point is shown. Appropriately structured annunciation systems help to keep the operator informed at all times about incoming disturbance signals while allowing him to keep check on the overall situation. The VDU-based systems have been designed ergonomically to provide maximum support for the control room personnel. This is especially important in situations in which they not only need an overview of the plant conditions but also information about the momentary process status, plus possible corrective measures.

Faster unit control response

The relatively high cost of implementing and commissioning conventional wired control systems has meant that they usually have simple structures. Digital, programmable control systems, on the other hand, allow more complex structures to be installed without extra wiring and hardware. Systems automated in this way can improve the control of a unit's output and increase the controlled output range of, for example, a steam generator. Also, they allow shorter start-up and shut-down times, with optimum utilization of the rates of change permitted for temperature and load, plus an increase in the total efficiency.

Providing the other electrotechnical

requirements are met, plants upgraded in this way are able to provide standby power to the grid within just a few seconds, in compliance with the DVG agreement designed to prevent a system collapse. This task is performed by the proven ABB unit control system MODAKOND. The system regulates the turbine control valves, the fuel supply, and the amount of turbine condensate fed back to the low-pressure preheater. The method used to momentarily halt the flow of condensate is patented under the name ABB CONDSTOP.

Support for operational management

Some older power plants have already been operating for several years with process computers programmed to carry out plant management tasks; these include generating reports, calculating characteristic values, and off-line storage. However, modifications which become necessary when the computer-based process signal acquisition is changed are always accompanied by substantial costs for alterations to the wiring, hardware and software. In plants equipped with modern bus systems, such modifications can be carried out without these extra costs. All the process signals can be accessed on the system bus via standard interfaces. The cost of changing the signals is reduced to a simple program instruction which the user can easily enter himself with the help of menus.

Correction of control system disturbances

Modern-day control systems have diagnostic facilities integrated in them which provide the operators with very effective support in dealing with disturbances. Such facilities identify faults and disturbances the moment they occur, signal the event together with details of the location and possible causes, and suggest corrective measures that can be taken. Unlike the older control systems, modern systems tell the operator that a control function is disturbed before the function is actually required. Hence, the disturbance has no adverse effect on the plant availability.

Ease of extension – no operational downtime

Unlike the earlier wired systems, today's control systems offer a flexibility that allows extensions and modifications to be carried out even after initial commissioning of the plant. Control and instrumentation functions can be reprogrammed and tested on the respective modules before they go online. Operation is therefore not interrupted. A high-performance system bus allows all

Control room of an industrial power plant **3**

A refurbishment project – the 2 × 250-MW Staudinger coal-fired power plant in Germany 4

the process signals to be accessed anywhere in the plant in real time for further processing. Standardized interfaces allow additional components (eg, computers) to be connected. Bypass cables and signal routing systems are therefore unnecessary.

'Smart' data processing systems are available today for planning and implementing power plant control projects. These so-called planning computers have powerful software modules and databases for designing the user functions. The Engineering, Documentation and Service (EDS) system developed by ABB is an integral part of such power plant control equipment and covers all the user functions up to the actual planning stage. By simultaneously documenting the control functions, it also meets users' needs for EDP-supported paperless documentation. (All or part of the documentation can also be printed out whenever required.)

Before commissioning begins, the EDS system transfers all the data obtained during the planning phase to the control system and downloads the actual plant data into the system modules. Downloading avoids the discrepancies that can occur between the actual plant status and the information given in the documentation, especially during modifications and extensions. Information about modifications is transmitted exclusively over the EDS system.

Innovations in the maintenance area

The EDS system also extends powerful VDU-based technology into the areas of maintenance and service. EDS workstation computers are available for on-line diagnostics and plant optimization. These computers can access all the signals offered by the digital control system. Dynamic updating ensures that the latest measured values are shown on the screen displays used for function tests and disturbance analyses. Signals can also be simulated for test purposes. The service personnel can respond to new circumstances quickly and effectively, which has a positive effect on the plant availability.

Two types of module instead of ten

Control system advances have substantially reduced the different types of module required. For example, with the hard-wired programmed control systems up to 50 different types of module were required for the instrumentation and control functions. Considerable progress was made with the first digital, programmable power plant control systems, which managed with about ten different types of module. Today, the same tasks can be performed by just two types.

Step-by-step modernization of an industrial power plant

Generally speaking, it is more advantageous to completely renew a power plant control system than it is to progressively modernize it. However, as the following example shows, a step-by-step approach

also has major benefits. The case considered is a common-header industrial power plant in which the boilers, which burn oil and natural gas, and also the turbines had their conventional instrumentation and control systems upgraded to state-of-the-art systems over a period of several years. The main goals of the modernization programme were:

- Plant-wide automation
- Energy-saving within the process
- Improved dynamic control
- A wider useful load range

No plant-wide outage

To make sure that the steam supply would not have to be interrupted at any stage, it was decided to install the new control equipment one section at a time, based on the configuration of the process units. All of the operating and monitoring functions were transferred to VDU workstations. The result of the retrofit was to convert the plant, which had originally been operated mainly by hand, to a fully automatic facility **3**.

Total renewal in a coal-fired power plant

Two 250-MW units in a coal-fired plant had seen 25 years of operation and were scheduled to be converted from base-load operation to medium- and peak-load duty **4**. At the same time, a comprehensive upgrade was planned for the two units to secure their reliable operation for another 25 years. The conversion would have to take account of new conditions such as daily run-up and shut-down, frequent load-ramp operation with fast rates of change within the framework of the secondary load control, and primary frequency back-up control provided in the form of 5 percent standby capacity.

The utility had to choose between a step-by-step approach and a total renewal.

A new control system that simply replaced the old one was not the answer as it would not take proper account of the retrofit measures in the process engineering area. This fact alone precluded a step-by-step renewal. Besides this, there were some other convincing benefits that spoke in favour of a total renewal. For example, it would allow a thorough restructuring of the system, without compromises or any consideration having to be taken of the original plant, which was also suffering from a shortage of spare parts. Restructuring would enable cost-saving in the form of:

- No interfaces (old/new systems)
- Avoidance of weak points
- Easier disassembly
- Economic reconstruction

The advantages of a total renewal take effect immediately after commissioning and last over the full, extended service life. During this time it has a positive influence on the operational, economic and technical results. The staff are no longer preoccupied with system weaknesses that can appear anywhere and at any time, or with their immediate correction. It was therefore decided that the optimum strategy for this plant would be a total renewal, to be undertaken in a single step.

VDU-based process management

Each of the plant units is controlled from VDU-based workstations arranged in a redundant configuration. Back-up instrumentation has been almost completely eliminated, although some standby capac-

Process control in the coal-fired Staudinger power plant **5**

ity has been kept for unit 1. ABB process operator stations use easy-to-understand graphics to inform the staff of all operating statuses. Mimic diagrams are used to operate the main control and instrumentation circuits and to make them transparent. General equipment and systems not belonging to any particular unit are monitored and operated by means of two separate VDU-based workstations, in each case with back-up. These workstations are located in the ancillary consoles and feature draw-out operator keyboards 5.

The process computer system which monitors the variables for each unit processes 1,000 analog and 6,000 binary values in chronological order. Besides its other tasks, it determines the remaining lifetime for those plant components exposed to the highest stresses.

Computer-assisted process control has had a major effect on the manning of the control room. Whereas previously it took three operators to run the plant under normal service conditions, just one operator can now perform the same work 6.

Scope of automation has been significantly increased

The entire operating technology involved in start-up, load operation, shut-down and standstill, as well as the predicted effect of numerous potential operating disturbances, is embedded in the software for the new unit control level. It is this new automation concept which makes medium-load and peak-load operation of the units possible on a daily basis. The software ensures that during start-up and shut-down all the necessary procedures are executed smoothly and reliably, and that they make minimal demands on the plant and equipment. The interchange power is also computer-controlled at the unit control level, allowing automatic execution of the frequent and rapid load changes occurring between minimum and peak load during the secondary control. The 5 percent standby capacity for frequency back-up control is realized with the ABB unit power control system MODAN.

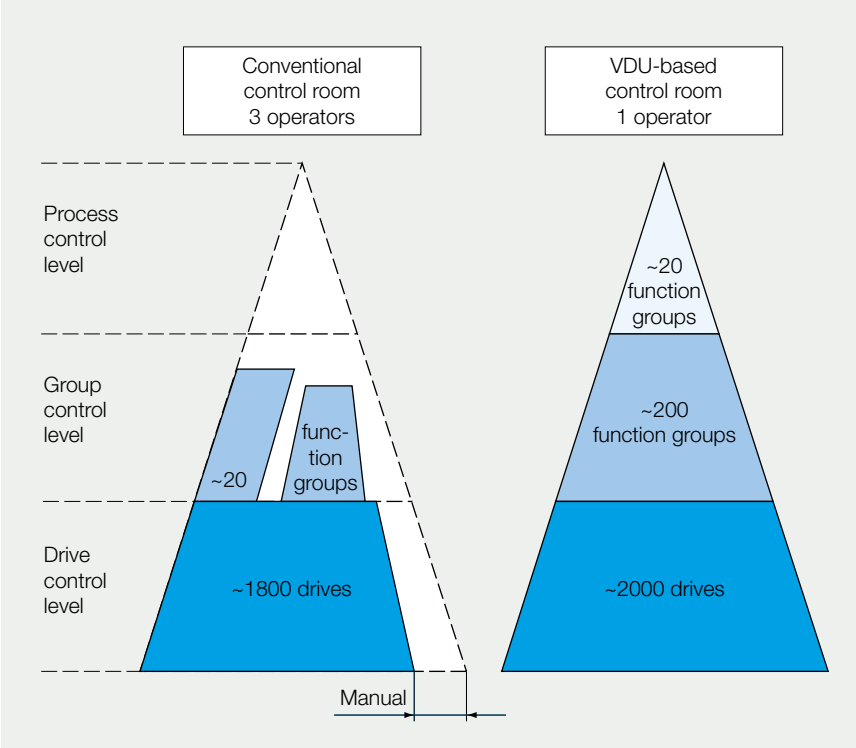
Space-saving hardware

All the monitoring and operating functions for the extensive ancillary equipment are located centrally in the control room. With very few exceptions, the local control rooms have therefore been eliminated. Due to modern control systems being extremely compact, the redesign of the control room layout to take account of a total system renewal was largely unproblematic. The scope of the functions relating to maintenance is, however, considerably larger than before. Nevertheless, by replacing conventional operator stations and indicators with VDU-based technology it was possible to reduce the floor space by about 30 percent. The rooms for the electronic equipment additionally accommodate the retrofit facilities for the flue-gas cleaning (FGD and DENOX).

Set objectives were reached

The defined goals were achieved and the results of the refurbishment met with the full satisfaction of the customer. In the case of unit 1, the downtime, from disassembly of the old plant to restarting, was nine months. In the case of unit 2, the same work took only 8 months.

Comparison of automation concepts before and after a control system upgrade 6



Total renewal in a lignite-fired power plant

The machines, electrical equipment and control systems in another power plant 7 which has two 500-MW units and burns lignite were upgraded to extend its lifetime by another 20 years, ensure compliance with environmental and DVG requirements, and improve the operating behaviour, availability and plant efficiency. To achieve these goals, it was necessary to retrofit a flue-gas desulphurization facility with low-NO_x burners and new low-pressure rotors.

The existing, outmoded control system, deliveries of which had stopped in 1980, was based on a non-uniform operating and monitoring concept and could not

Refurbishment project at Boxberg, Germany, where a 2 × 500-MW lignite-fired power plant was upgraded 7

keep pace with the increasing demands being made on it.

Large-scale automation relieves personnel of routine duties

Two possible ways of renewing the control technology were studied: adaptation of the control systems in the process areas on a case-to-case basis, involving major changes, and the complete replacement of the existing technology by a modern power plant control system. The decision was taken to totally renew the control technology with a new system as follows:

- Replacement of all of the control room equipment by a new twin-unit control room
- A new power plant control system for both units, with up-to-date systems for process operation, monitoring, diagnostics and maintenance
- Replacement of the boiler protection
- Renewal of the turboset control equipment
- Complete replacement of the cabling, sub-distribution boards and instrumentation
- Renewal of all field equipment
- Replacement of all control drives, plus some control valves
- Renewal of the electric actuators
- Elimination of the local control rooms

Operation and supervision are based on the ABB Process Operator Station. The stations in the central control room are linked to the process by the bus system, which extends into all sections of the plant. The process operator stations process all the operating data and present them on the mimic diagrams in a concise and appropriate form. With the help of these graphics, all the motors, actuators, control valves, controllers and function groups can be observed and operated. Besides being shown the plant disturbances, the operators are informed about how the disturbances could affect the process and how they can be corrected.

Single twin-unit control room

The flexibility and advanced capabilities of the new power plant control system enabled the two original control rooms to be replaced by a single twin-unit control room 8. Conventional back-up instrumentation could be eliminated in the majority of cases. All of the original, decentralized operating and supervisory stations (eg, the control rooms for the generators, feedwater, cooling water and condensate polishing) were concentrated in the central control room. The rooms for the switchgear and the coal handling were left unchanged. A new control room for overseeing the supply and treatment/disposal facilities was installed in the FGD building.

The design and functionality of the new control room incorporates the latest know-how in process management. The operators sit in front of their monitors in a sunken area. This allows them to concentrate fully on the process, as they are not distracted by what is happening elsewhere in the room. The plant overview dis-

play is positioned where it can be clearly seen by everyone in the room. By showing the main process information it keeps the operators informed of the overall plant status. Task-oriented monitors at the process control desks show the detailed information that is required.

A workstation with three display units is assigned to each of the main plant components (ie, the boilers and turbines). While this arrangement has ergonomic benefits, it also makes considerable demands on the system availability, display design and display selection. Process operator stations from ABB meet these demands, and the networked system structure (in redundant mode) allows all plant information and control functions to be accessed from every operator unit. If required, the universal scope of the system can be restricted, for example, to operation of just one plant component or to just monitoring, without the operator being able to give commands.

Extremely short unit downtime

The utility required the modernization to be carried out as quickly as possible in order to keep unit downtime to a minimum. It was possible to comply with this wish mainly as a result of the introduction of a new modular concept with just two 'universal' types of module for the measuring and control as well as a system-wide EDP network that links all of the departments participating in the project.

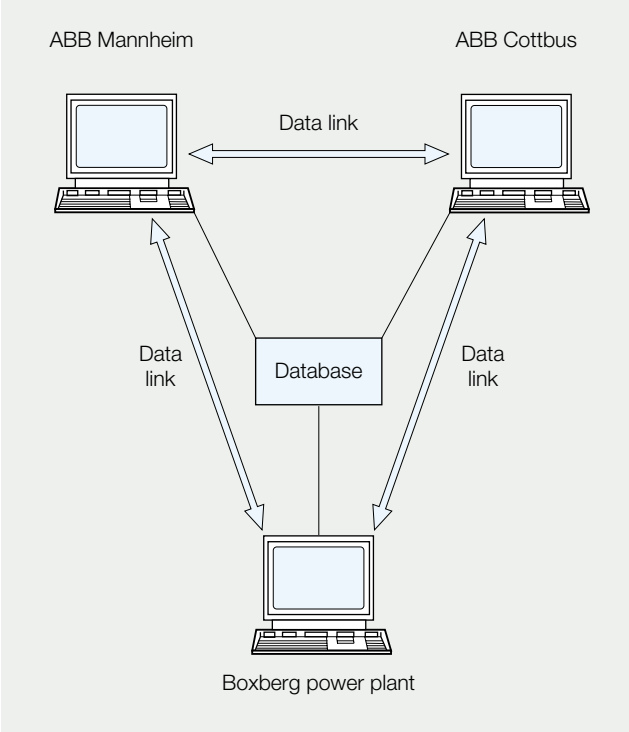
The networking of the project participants covered every office in every location on and off the site and during all stages of assembly and commissioning 9. Also linked up were the ABB planning engineers in Cottbus. The network allowed fast and flexible response to unexpected events or design changes at every stage of the project. It was also linked to the control system to allow planning data to be loaded into the instrumentation and control equipment direct, thereby saving considerable time.

One major challenge concerned the splitting up of the two units and the general plant in a way that would allow the first unit to be dismantled with the second still in operation. Each of the units was out of action for eight months as a result of the modernization.

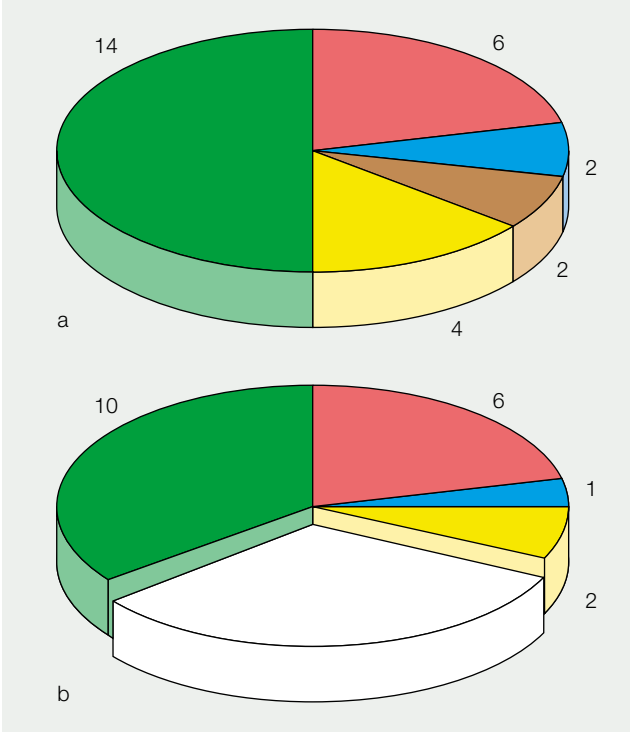
Manning – 'lean' shifts

A benefit of special interest to the plant owner was the difference in manning requirements 10: after modernization the power plant could be operated with a

Dual-unit control room after the total renewal of the control system. Conventional back-up instrumentation was reduced to an absolute minimum. All the original distributed control rooms are now concentrated in the new control room. 8



New software allows participants in a project to be easily networked. 9



Number of staff required before (a) and after refurbishment (b) of the Boxberg power plant 10

Red *Machine attendants*
Blue *Unit operators*
Brown *Coolant system supervisors*
Yellow *Foremen*
Green *Runners, local control rooms*

much smaller staff on each shift than before.

Successful conclusion of the retrofit

The utility has responded positively to the results of the retrofit and renewal of the control system. The advantages offered by modern power plant control technology were utilized to the full in achieving the set goals. Experience has shown that the link between the old and the new technology, which was installed to provide operational back-up, will not be needed in practice. VDU-based operation and monitoring was quickly accepted by the operators, who appreciated its many user-benefits.

Do refurbished plants perform as well as new plants?

A question that obviously interests the utilities is whether or not refurbished plants perform as well as new plants. New power plants which operate in the medium-load to peak-load range and have to fulfil DVG requirements, etc, are equipped with the same control functions as in the described refurbishments. Besides having to ensure optimum running of the process and main machines, the power plant control system often has to satisfy requirements in other areas:

- High-level automation to allow operation with a minimum number of staff
- Flexible unit operation
- Smart, 'predictive' control systems
- User-friendly man-machine communication
- Control rooms which are representative, compact and ergonomically designed
- Proven technology plus high availability
- Ease of maintenance, self-diagnostics

The extent to which these requirements can be met in older plants will obviously depend on the state of the process and plant machinery. A modern power plant control system satisfies the requirements in every case, whether the system is installed in an older or a new plant. Thus, although the scope of the general plant refurbishment remains a factor, the best results obtained in new plants can also be achieved by power plants which have been upgraded.

It goes without saying that when planning new plants, account has to be taken of the boundary constraints and the preconditions if an optimum overall result is to be achieved. This is exemplified by the upgrade of the 900-MW Schkopau power

Advanced twin-unit control room in the 900-MW Schkopau power plant **11**

plant in Germany, which has an advanced, future-oriented twin-unit control room **11**.

Economic operation after short downtimes

Any refurbishment of a power plant has to show a profit. Besides an extended lifetime and compliance with environmental standards, it has to ensure optimized and flexible operation of the plant, reduction of necessary staff to a minimum, and higher efficiencies. In short, economic operation. Advanced control technology is effective as a means of turning these requirements into reality. To obtain maximum benefit from the investment, the process and the control system must be properly linked together. Modern control systems with multi-purpose modules and powerful bus systems offer the required flexibility; even last-minute modifications in the final stages of a retrofit have no major impact on the completion dates.

As the examples show, the production downtime even for large-scale refurbishment projects can be kept to between five and eight months. This has been made possible by the availability of powerful planning tools, new technologies which have simplified assembly, and ABB know-how. In the meantime, downtimes of just two to three months are possible.

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