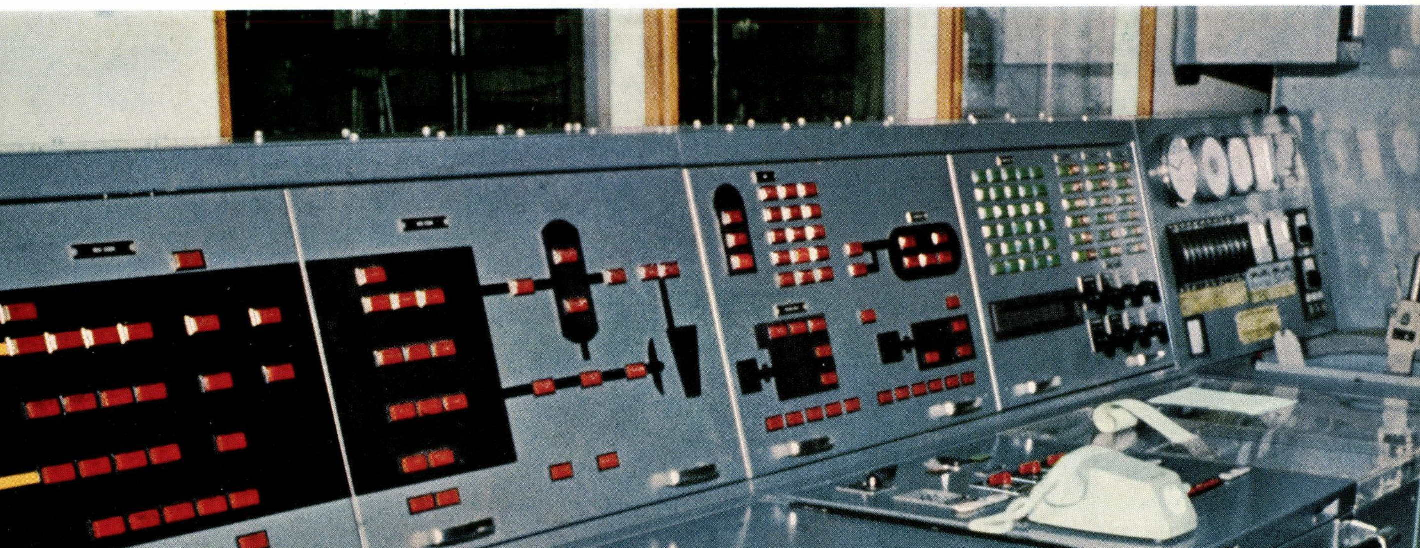
BROWN BOVERI REVIEW

Automatic Control Systems and Components



View of the control room in a refrigerated ship of 12 000 tons gross

The desk is part of a data logger installation with 460 analogue and digital measuring points

N BOVERI REV. VOL. 55 No. 9 p. 465–564 BADEN, SEPTEMBER 1968

Printed in Switzerland

THE BROWN BOVERI REVIEW

ISSUED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. 55 SEPTEMBER 1968 No. 9

CONTENTS

PREFACE

A SPECIAL issue of the Review was devoted to the Brown Boveri modular electronic system in April 1967, when the main theme was a new series of equipment employing integrated circuits. On that occasion it was stated that the new IC Series was to replace the earlier Series 2 (information handling). Now, over the past year we have also replaced the digital units of Series 1 (power applications), which appeared in 1960, by a range of equipment employing discrete components based on silicon devices.

As with the IC Series, which is now in use in many applications, the Si Series also employs the well established modular principle. The two series constitute a self-contained whole, both electrically and mechanically, and working as a single, integral system can provide the answer to virtually any problem likely to occur at present in the fields of industrial control, regulation and data processing.

As a result of the increasingly stringent requirements arising from the number and variety of the data concerned, the complexity of their interrelationships and the speed of processing, there has evolved a new system philosophy which differs in many respects from that relating to purely commercial data-processing systems. Whereas with this latter type of system the input and output units of the central computer have now largely been standardized, though the way to further development is still open, industrial systems require a far more complex and diverse arsenal of peripheral equipment which can be rigidly standardized to only a limited extent. The aim must be to ensure the greatest possible versatility, using a functionally structured system of equipment, without having to resort to one-off production in each specific case.

Such a compromise can, in turn, be attained only if one has a thorough knowledge of the process in the widest sense, whether this is a matter of power generation or the most varied industrial processes.

In the articles contained in this issue the emphasis is on the treatment of system problems and possible solutions over a wide range of industrial applications.

It is shown that a central computer, in so far as the use of one is justified at all, when viewed purely as hardware is in fact the least problematical part of the system. The difficulties lie far more in correctly defining and describing the process itself, deriving the overall structure from this and formulating the computer programmes.

A second theme of the present issue concerns the field of telecontrol, which is increasingly taking over the functions of data transmission in widely dispersed automatic control systems.

(DJS) A. DE QUERVAIN

THE NEW RANGES OF DIGITAL EQUIPMENT IN THE BROWN BOVERI ELECTRONIC SYSTEM

621.38.049.083.722

When the Brown Boveri electronic system was introduced in 1960 an electrically and constructionally unified modular system became available to industry. It employs analogue and digital devices for problems of control and supervision, telecontrol and data processing. While the original basic concept has remained the same, development of the system continually kept pace with advances in semiconductor techniques (silicon planar devices, monolithic integrated circuits) and in wiring systems (solderless and automatic wiring). This article discusses the present state of the Brown Boveri electronic system with its two complementary digital series; Si, which employs discrete silicon semiconductor devices (control, supervision and slow digital data processing) throughout, and the IC range using integrated circuits (high-speed digital data processing).

THE Company first introduced the self-contained modular Brown Boveri electronic system in 1960. This combines digital and analogue devices of the same general design [1, 2]. While the digital devices are built with germanium transistors, those operating on the analogue principle have, from the beginning, been fitted largely with silicon transistors. Hitherto, the Brown Boveri electronic system consisted essentially of Series 1, with digital and analogue devices for general industrial control engineering, and Series 2, with digital systems of higher maximum frequency for more rapid data processing. Examples of these are numerical control systems, process computers, data collection systems, etc. Both series have become well established over the years and continue to enjoy great success up to the present. Since their introduction, approximately 5500 large and small installations with about 900000 devices have been manufactured and delivered to customers. The basic concept was so well chosen that it has been possible to continue it practically unchanged over a period of eight years. On the other hand the individual devices have been improved continually. Since 1963 the alloy silicon transistors in the analogue systems have been replaced by improved and less expensive silicon planar transistors [3] which have been marketed more recently. In addition, further development in several areas has become necessary in the course of time. The general-purpose basic elements of the Brown Boveri electronic system are still used in constructing the majority of industrial installations, but for some types of installation, such as process control systems and the automation of power stations, advantages have been seen in developing additional, more highly organized special-purpose devices for those functional groups which are required in large numbers. At the same time these systems also fulfil the higher safety requirements normal for such installations [4, 5].

At first there were no serious reasons for replacing the germanium transistors in the digital series with silicon planar transistors. The temperature range of the germanium semiconductors employed was in the great majority of cases sufficient, while the higher limit frequency of modern silicon planar transistors, at least in Series 1, was even undesirable owing to the greater sensitivity to noise. Other factors had to be considered for Series 2, for rapid digital signal processing. Thus with the introduction about 1965 of monolithic integrated circuits a new system was developed with important advantages (high transmission speed, small size, small power loss, great reliability and low manufacturing costs due to mass production). Brown Boveri thus went ahead with devel-

Technical Data of the Digital Series in the Brown Boveri Electronic System

	Si Series	IC Series
Application	Control, supervision, data collection	High-speed data processing, for example; numerical control, process computers, time-multiplex remote control equipment, data collection, small self-contained measurement and information processing devices
Characteristic data:[1] Supply voltage	$U_s = +14$ V to $+31{\cdot}2$ V[2]	Signal devices: $U_s = +4{\cdot}5$ V to $+5{\cdot}5$ V Input and output devices: $U_s = +24\ \mathrm{V}\ {}^{+25\%}_{-15\%}$
Signal voltage	1-signal $U_{1A} \geqq 0{\cdot}8\ U_s$ 0-signal $U_{0A} \leqq 1{\cdot}35$ V	1-signal $U_{1A} \geqq 2{\cdot}4$ V 0-signal $U_{0A} \leqq 0{\cdot}4$ V
Static signal-to-noise ratio	typical 4 V at 0-signal 7·5 V–23 V at 1-signal	typical 1 V at both 0-signal and 1-signal
Response	Gate time-lag $t_d \approx 5$ to 20 μs Counter frequency limit $f \approx 10$ kHz	Gate time-lag $t_d \approx 10$ to 25 ns Counter frequency limit $f \approx 100$ Hz to 20 MHz
Power consumption	per gate function $P_v \approx 60$ mW	per gate function $P_v \approx 10$ mW
Temperature range	$\vartheta_u \approx -25$ °C to $+70$ °C temporarily $+85$ °C	Normal design $\vartheta_u =$ 0 °C to $+$ 70 °C Special design $\vartheta_u = -55$ °C to $+125$ °C

[1] Characteristic data pertaining to the special devices may vary on several points (supply voltage range, response); operation of basic and special devices in conjunction is, however, guaranteed in every case.

[2] Some special devices require a negative auxiliary voltage of $U_H \approx -14$ to $-31{\cdot}2$ V.

oping a new series with digital integrated circuits (the IC Series) to replace the old Series 2 [6, 7]. The basic components of the IC Series are now ready for use and the series has proved its suitability for industrial use under adverse climatic conditions and heavy electromagnetic interference [8, 9].

When development of this series had been completed, a new digital series was developed for industrial control and supervision (the Si Series). This new series with discrete components (silicon planar semiconductors, resistors, capacitors, etc.) has replaced the old Series 1. Characteristics include high interference thresholds and low interference sensitivity owing to a low limit frequency (counting rate ≤ 10 kHz). A number of special systems are available for problems of process control (Decontic) [4, 5] and of telecontrol (audio-frequency multiplex) [10], in addition to the basic systems generally employed, such as gates, stores, counters, timing elements and input and output devices, etc.

The New Digital Series in the Brown Boveri Electronic System

Under the general title Brown Boveri electronic system, the series (Fig. 1) are listed in the table with their main characteristics and ranges of application.

The Si Series

In its construction the Si Series corresponds to the old Series 1 and its characteristics are matched as closely as possible to the field of industrial control and supervision. The need for ease of planning and

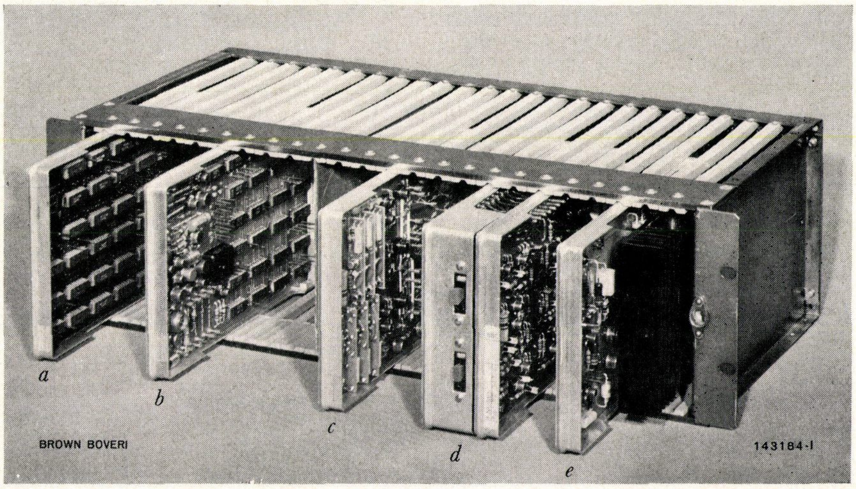


Fig. 1. – Devices of uniform design belonging to the various series in the Brown Boveri electronic system

a: Basic device of Series IC (for telecontrol system ZM 30)
b: Basic device of Series IC (analogue-digital converter UT 233a-E for three decimals)
c: Basic device of Series Si (signal range indicator UT 355a-E)
d: Special device of Series Si (control device VT 311a for motor contactors)
e: Voltage stabilizer for 15 to 27 V (At 010a-E)

insensitivity to noise are most significant here, while counting speed and power consumption are of secondary importance. In the Si Series, signal level and limit frequency have thus been left virtually unchanged from those in the established Series 1. The typical static signal-to-noise ratio has been markedly improved. For a 0-signal this amounts to about 3·5 V and for a l-signal about 7·5 to 20 V in the supply voltage range from 14 to 31·2 V.

By introducing an impedance transformer final stage, further improvements over Series 1 have been achieved. The development of the new system required that the outputs of the devices should deliver current (for a l-signal) as well as consume power (for a 0-signal). The importance of this requirement will be discussed later. Power loss should be as small as possible in the case of extremely variable, unstabilized supply voltages. A negative voltage bias should be avoided in the interests of simple system design. Rather than the usual switching transistor with a relatively low collector resistance, a circuit consisting of two transistors and one diode was chosen for this reason. The advantages offered by this system are discussed briefly below.

The power loss of the stage is very low over the total supply voltage range. For $U_s = 24$ V and a switching ratio of 50% it amounts to about 60 mW and is thus one fifth of that with the old Series 1. The output l-signal and thus the signal-to-noise ratio are significantly higher, even when heavily loaded by connected systems, than with Series 1. At full load it amounts to $U_A \geqq 0{\cdot}8\ U_s$.

With a 0-signal the stage can consume power at the output via a diode. In this way AND relations are formed with simple passive diode gates. The circuit design allows on the average a higher static noise threshold for both signal conditions than in Series 1. This is especially true in the case of l-signals and a 24-V supply. By including a capacitor in the circuit, the limit frequency of the final stage is reduced to approx. 10 kHz (counting rate). High static noise threshold and low limit frequency together produce the required insensitivity to electromagnetic interference. Compared with the simple stage in the form of a transistor and a collector resistor, the somewhat higher component requirements are compensated:

a. by smaller requirements for power supply units, fans and supervisory equipment resulting from the low power loss. In addition, the power supply units need not be stabilized,

b. by grouping the components into one structural unit which can be more economically manufactured as a result of higher production quantities.

The requirement that the final stage both deliver and consume current, as mentioned before, is based on the following considerations.

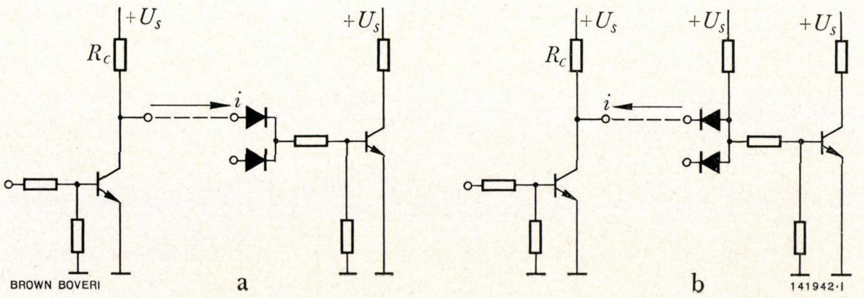


Fig. 2. – Various logic types

a: Current sourcing logic, R_c = low collector resistance. The input transistor is blocked.

b: Current sinking logic, R_c = high collector resistance. The input transistor is conducting.

Families of digital circuits which can be used generally, and which have to meet no particular security requirements are best designed as current sinking logic (Fig. 2). Among other advantages offered by this method is a smaller power loss which, however, applies only to the simple version with one switching transistor and one collector resistor. When current sourcing logic is employed, the collector resistance must be low, so that a sufficiently high l-signal is available for the highest permissible load by additional connected systems. For a 0-signal, i.e. for a conducting transistor, the power loss is relatively high. On the other hand, the collector resistor in the current sinking logic is connected to the inputs of the devices, whereas only one high-value resistor is fitted at the output, so that the connections to the inputs of the subsequent devices are fixed at a potential of $+U_s$ when a l-signal is given.

Thus with this method only as much power is required as is necessary for energizing the inputs actually connected. Since the number of devices controlled by a stage is generally smaller than the maximum permitted by the load limit, the average power loss is smaller when current sinking logic is used.

In many applications, process control for example, one requirement is that in the event of earth faults or interruptions of the signal line, no "dangerous" signals are emitted, i.e. signals that cause operations at the wrong moment. In both cases the affected stage should take up the "safe" condition. This requirement can be satisfied only by current sourcing logic (Fig. 3). As a safe condition, let us assume the 0-signal to be fixed at the stage input; as a "dangerous" signal, the l-signal at the stage input. With current sourcing logic (Fig. 3a), earth faults and interruption of the input connection are equivalent to a 0-signal at the input, while with current sinking logic (Fig. 3b) an earth fault does in fact result in a 0-signal, but conversely, interruption of the input connection corresponds to a l-signal (a "dangerous" signal).

In current sourcing logic we speak of an active-l system, which means first, that the l-signal is the dangerous one, and second, that for the l-signal, current flows from the controlling stage to the input of the controlled stage.

For current sourcing logic an odd number of signal changes on a printed circuit board must be avoided, as otherwise a 0-signal at the output would correspond to a "dangerous" l-signal at the input. In the case of an earth fault or a break in a connection from this output to the subsequent devices, a 0-signal, i.e. the "dangerous" condition, would be produced.

The method of circuit construction selected allows the security levels listed below to be realized with the new Si Series:

1. Normal security, meaning there is an even chance of earth faults or breaks in signal connections leading to either dangerous or safe switching conditions. Since experience has shown the probability of such faults within an electronic system to be extremely small, this degree of security is sufficient in most cases.
2. Improved security against earth faults and breaks in signal connections by using the active-l system.
3. High security through consistent two-channel design. In the event of antivalency due to interference on one of the two channels a special, inherently secure evaluation unit sets the affected control element to the safe condition.

The supply voltage range of the new Si Series was selected to enable operation with unstabilized power units rated at 24 V or stabilized units of 15 V rated voltage.

Through exclusive use of silicon planar semiconductors the temperature range in the immediate area of the devices has been extended to between —25 °C and +70 °C. The devices can be operated for short periods at +85 °C, in the case of heat accumulation resulting from a short breakdown of a fan on a traction vehicle, for example.

To summarize, the following improvements have been achieved using the new series:

- significantly lower power loss
- large supply voltage range, thus permitting feed from unstabilized power units
- no negative voltage bias required
- a larger temperature range through the use of silicon planar semiconductors
- various security levels are possible, thus allowing the best possible adaptation to the problem posed.

In addition to the basic systems [11, 12], special devices are available for certain applications, among which are three modular systems for the automation of power stations.

Decontic

This system is used for the construction of controls for functional groups for power station auxiliary operations (for example, condensing plant, cooling water, boiler draught) [4, 5].

Turbomatic

This system is employed as an automatic means of starting and supervising steam turbines and their steam generators [13].

Secontic

A remote control system derived from Turbomatic for processes using short starting and shutdown programmes as required for frequency converters, industrial turbines, gas turbines and drives in pumped-storage schemes.

Each of these three systems—they are almost always used in conjunction for power station control—contains basic logic systems and a few types of special devices.

Two requirements apply generally to power station control and lead inevitably to the development of specially designed devices within the scope of the Si Series:

a. certain self-contained functions of a power station have to be performed using one electronic device, especially when these functions occur in large numbers;

b. the security requirements of power station operation necessitate especially secure circuits at the command outputs of the electronic devices, which are designed so that the breakdown of a single element in the command circuit does not lead to an on/off command to the system.

These guiding principles have led to units for "valves", "drives" and "high voltage circuit breakers and isolators" in the Decontic system of power station

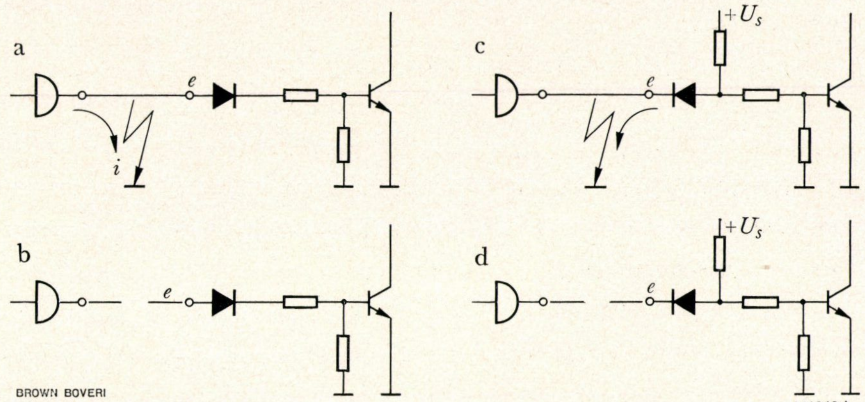


Fig. 3. – Interference caused by earth faults and interruption of signal connections

a, b: Current sourcing logic
c, d: Current sinking logic

a, c: Earth fault, $e = 0$, safe
b: Break, $e = 0$, safe
d: Break, $e = 1$, dangerous

control and, in Turbomatic and Secontic sequential control systems, to the programme stage modules in the logic of the individual steps of the programme.

The IC Series

The significant characteristics of the IC Series have been described earlier [6, 7]. Brown Boveri have since continued the development of signal processing equipment as well as that of input and output devices. A range of devices has been developed and tested in the laboratory as well as under practical operating conditions.

Items of the IC Series are employed in:

- NC 510, 560 digital systems for length measurement [15]
- NC 710, NC 720, NC 810 numerical control systems for machine tools [16, 17]
- programmed controls for cable cars [18]
- data collection and supervision equipment in DP 260 and DP 270 [19, 20]
- Indactic® ZM 30 and Indactic® DASA time-multiplex telemetry, telecontrol and data transmission systems [9]
- digital speed, extension and slip measuring devices [21]
- "Blendronic" proportioning devices for liquids
- marine manoeuvre recorders [8]
- control sets for separately controlled inverters.

Special attention has been paid to the problem of freedom from electromagnetic interference occurring in industrial plants. An excellent method of operation, also suitable for use in very noisy environments, was assured by taking the appropriate measures listed below, such as:

- complete environmental isolation of the signal processing part by electrical and constructional means
- combination of no-voltage and supply voltage connections into busbar systems with low characteristic impedance
- design of signal lines as point-to-point connections with low coupling capacitances and inductances
- use of high-frequency filters in the mains connections, etc.

Measures for interference suppression are described in more detail in [7] and [12]. The design chosen permitted on the one hand the attainment of the high level of interference suppression desired between the environment and the signal processing part, and on the other hand the solution of problems encountered in connecting numerous signal leads from the system into the processing part, which has now become very small. The effectiveness of the described measures for suppressing interference has been proved in comprehensive tests, and later under conditions of practical usage. Evaluation of the experience gained over the last few years with our own electronic control and data-processing equipment, and of the appropriate literature, has revealed that outside interference (i.e. via the supply network and the signal connections) covers a very wide frequency range. Thus its suppression generally requires the application of various measures in order to achieve the necessary bandwidth of the spectrum. Several types of interference simulators have been developed to produce these various kinds of interference in the laboratory.

a. Interference simulator for low frequencies

Voltage interruptions lasting from a few tens of ms to several seconds occur in industrial networks when high-power equipment is switched on. To reproduce this type of interference a network interruption generator has been developed and constructed. It consists primarily of a thyristorized correcting element which is controlled by an adjustable timing device. For an adjustable number of mains cycles the load receives a reduced mains voltage. The form of the curve remains sinusoidal; no phase intersection takes place. The amount of output voltage can be adjusted continuously between 100% and 50% of the rated value, and intermittently between 50% and zero. The duration of the break is evenly variable between 10 ms and 1 s.

b. Interference simulator for medium frequencies

Control systems, current supply systems, frequency converters, etc. with controlled valves (mercury-arc rectifiers, thyratrons, thyristors) are one of the main sources of interference in industrial networks. These types of devices produce interference voltages with frequencies ranging from about 100 Hz up into the megahertz range. In this case a thyristorized controlling element can be used as an interference simulator. It is connected in parallel to the load and works on a suitable network analyzer. Characteristic voltage interruptions and high-frequency transient phenomena originate in the network analyzer and thus also in the system (load) being tested. The generator can also be used for producing inductive interference. The load current of the thyristorized controlling element is fed to a wire loop which is fitted to any desired point of the system to be tested.

c. Interference simulator for very high frequencies

Investigation has shown [22] that, in industrial networks, pulses occur having voltages up to approximately 1 kV, rates of rise of 2 ns and repetition frequencies of up to 20 MHz. For simulating such interference pulses Tandon [22] suggested an interference generator consisting primarily of an adjustable d.c. supply, a mercury-wetted reed relay and a coaxial cable serving as an energy storage facility. The cable is connected to a voltage source and then switched by means of the reed relay to a 50 Ω terminal resistance and to the test object, which is connected to it in parallel. A pulse is thus produced which enters the cable and is reflected at the open end. During the entire time out and back there appears at the 50 Ω resistor an impulse with very high rate of rise, the voltage of which corresponds to half of the cable load voltage. The pulse travels via capacitors to the inputs, outputs and mains connections of the system under test.

An interference generator of this type has been developed and put into operation. The technical data are:

Pulse amplitude:	adjustable between 0 and 1·5 kW
Pulse flank:	1–2 ns
Duration of pulse:	adjustable in steps of 10, 40, 100, 200, 500 ns
Pulse recurrence frequency:	50 Hz, phase position uniformly adjustable with relation to mains voltage

All newly developed devices and systems based on integrated circuits are checked with regard to freedom from interference by means of the interference simulators described, two of which are shown in Fig. 4.

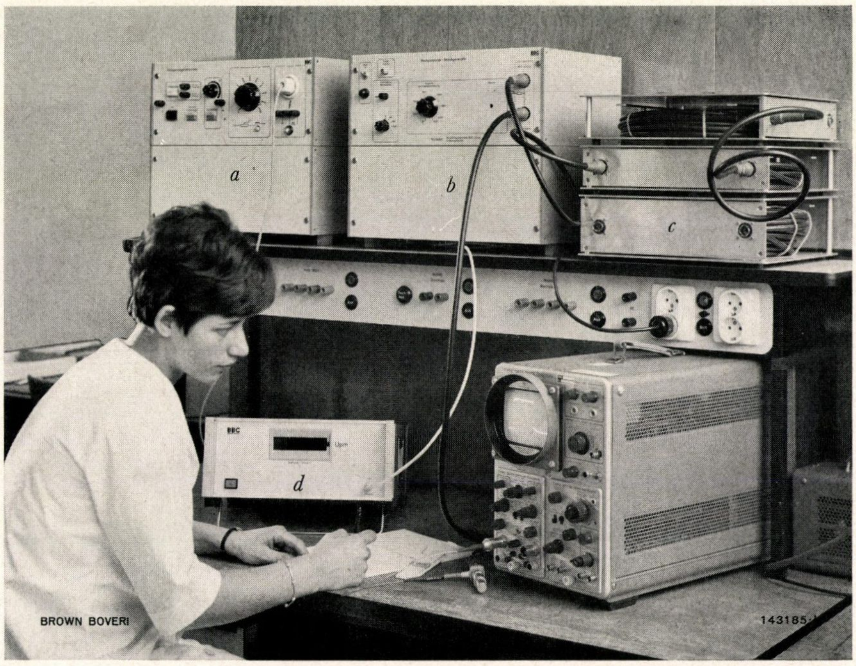


Fig. 4. – Testing the sensitivity to interference of a device with integrated circuits and interference simulators

a: Mains interruption simulator
b: Impulse interference simulator
c: Coaxial cable
d: Manoeuvre printer

Power Unit System

In addition to the compact power supply units already available in the Brown Boveri electronic system, a new modular system has been developed, offering various supply voltages and currents as they differ from one system to another. While the compact power supply units combine all functions (those of transformers, rectifiers, filter elements, stabilizers and supervisory equipment), these have been separated in the new power unit system. The units listed below are either being developed or are already available:

Various transformer units with rectifiers for connection to single-phase and three-phase networks. These units supply unstabilized d.c. voltage for direct feed to the electronic devices or for feeding the stabilizers.

Several different inverter units for connection to d.c. networks or to batteries.

A voltage stabilizer with a continuous controller (Fig. 1).

Version 1:	Voltage adjustable from	5–6 V
	Current intensity	2·3 A
Version 2:	Voltage adjustable from	15–27 V
	Current intensity	1·8–1·2 A

A voltage stabilizer with an intermittent controller.

Version 1:	Voltage adjustable from	5–6 V
	Current intensity	8 A
Version 2:	Voltage adjustable from	15–27 V
	Current intensity	5–4 A

All stabilizers are fitted with a current-limiting device having a falling characteristic which lowers the output voltage when overloaded, and also overvoltage protection which, when activated, shorts the output voltage.

A supervisory unit checks the various voltages and also shuts off the current in the event of under or overvoltages and failure of any phase in a three-phase supply.

This new power unit system is not intended to replace the power units now available, but rather to supplement them. It is principally used to supply power to larger electronic systems while compact supply units are used chiefly for smaller systems and devices. Advantages of the power supply system are found in its easy adaptability to the various requirements of different systems and also in that only one transformer is needed for each installation or each hinged frame. The transformer need not be mounted in the hinged frame, but in any suitable position within the housing. Using single components of the power unit system it is also possible to construct compact supply units which can be housed either in the tiers or in a convenient location within the cubicle.

Construction

The system with its basic units of the printed-circuit board, sub-assembly, tier and hinged frame, introduced in 1960, has thoroughly proved itself and has thus been continued in its essential form [12]. Adaptations have been made solely to allow the introduction of modern, solderless and automatically produced circuitry, and to fulfil the requirements of the IC series regarding screening, the number and length of connecting lines and the supply voltage connections. In addition, fitting the printed-circuit boards into the tiers has been improved through the use of tracks.

All series in the Brown Boveri electronic system, including the analogue series, are of similar construction (Fig. 1) and can be operated electrically in conjunction, via appropriate adapter units. Thus it is easily possible to use devices or groups of devices from all series with one another within one system. This principle enables the most suitable devices to be used in each case for the individual aspects of the problem. Because the lower and middle control levels in a power station control system have numerous connections to the surroundings, they are built up from the basic and special-purpose devices of the Si Series. On the other hand, the IC Series, with its larger signal-processing part, can be used to good effect at the topmost control level.

(SMW)

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THE SI SERIES, A SYSTEM OF CIRCUITS FOR INDUSTRIAL CONTROL

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The Si Series of silicon semiconductor devices is a system of electronic circuits of low threshold frequency. The system is largely unaffected by interference voltages and functions reliably over a wide range of voltages and temperatures. The organization of the system and the circuitry design make it especially suited to contactless control applications in automatically controlled industrial processes. The structure and properties of the system are described.

THE Si Series is a system of circuits for industrial control applications. This system has resulted from further development of the long established Series 1 of the Brown Boveri electronic system. Full use has been made of the experience gained with Series 1 and to a large extent it has been possible to retain the logic structure, organization of the various units and system of design. At the same time, the use of semiconductor devices and advanced circuitry techniques has led to greatly improved technical characteristics.

Continuous further development of the earlier system has meant that existing installations employing Series 1 can easily be extended with items from the Si range. The future prospects of the new system are also sound, as it can very simply be combined with the 15-V integrated circuit systems now becoming of increasing significance in industrial applications. The advantages of integrated circuits, which have hitherto been utilized almost exclusively in self-contained systems, such as data-processing devices, can now be extended to control problems in the industrial sphere.

System Structure

A new range of equipment must be:

economical
easily applied
versatile
extremely reliable
up-to-date with a guaranteed future.

The economic application of a system is determined not only by the price of the equipment but also to a very large extent by its performance, both at the planning, manufacturing and commissioning stages and also as regards maintenance. In a large installation as much as half the costs can be ascribed to these operations. An economically sound system thus incorporates the best possible solutions to the other four requirements mentioned.

A range of equipment can be applied easily, both by the manufacturer and the customer, if the various items of the range can be combined with each other in accordance with unified and straightforward rules. The signal levels for the inputs and outputs of the units are therefore standardized, and throughout the system the signals conform to the convention 0 = no voltage, 1 = voltage present, referred to the common neutral. Standardized input resistances and standardized output loadings contribute greatly to easy planning. This has been achieved by establishing a standard load for the input and a single minimum load capacity for the outputs. All the units have antivalent outputs. This means that one type of logic element is sufficient to link them, and in many cases circuit arrangements can be simplified.

With almost all the logic elements the number of inputs can be extended by means of diodes on one unit or the other. In this way the inputs can be matched ideally to the given number of input variables of one logic link.

An electronic installation can operate perfectly only so long as the functional sequence is not affected by electrical interference. The degree of protection against interference, for both the 1-signal and the 0-signal, has been set so high that even under unfavourable conditions, lengths of wiring such as may occur within a hinged frame or between two frames have no effect. Also there are numerous input and output units, available for various purposes, which ensure that interference coupled inductively or capacitively to the external lines is effectively kept away from the data-processing stages of the control system.

Great care has been taken to make the power supply as simple as possible. The equipment therefore requires only an unstabilized supply voltage. The voltage tolerance is such that, with mains voltage fluctuations of $\pm 20\%$ and using simple, unstabilized power packs, the system continues to function perfectly and all standard values are maintained. No special requirements were made of the wiring for the power supply equipment. As there is only one supply voltage, there is no need for any means of producing a bias voltage, or for the associated protective devices and interlocks. If necessary, items of the Si Series can work in conjunction with systems requiring several supply voltages, without forfeiting the advantages mentioned. Batteries working on the floating principle are often needed for supplying power to important control and indicator systems. One of the reasons for this is to bridge short-term mains interruptions so that operation of the installation is not affected. Direct battery supply is perfectly possible with the Si Series, owing to the wide range of supply voltage.

Ambient temperatures between —25 °C and +70 °C are permissible over unlimited periods without lowering performance. The power loss arising in an installation is determined principally by the type of circuitry chosen. The output stage selected for the impedance transformer has made it possible to keep the power loss very low [1]. As a result of these two facts the units of the Si Series can be packed tightly into cabinets having no additional ventilation with room temperatures up to about 40 °C. The Si Series is thus capable of providing the simplest and most economical solution for the great majority of applications.

These features of the Si Series make it easy to use without limiting its range of application. In practice, the user need only check the set standard loading of the outputs and can then concentrate on the logic system, and does not have to consider further regulations or restrictions.

The Si Series is based on a uniform system of circuits and has uniform characteristic data. It includes equipment for both general and specialized applications [2]. It can thus be used over a very wide field of application and can provide the best possible solution to the most varied problems and requirements, ranging from simple drive controls to process control systems and the iron and steel industry. The Si Series is especially suitable for collecting operating conditions, processing these conditions and intervening in the production process. It is therefore well fitted for automatic control of such processes. The items which can be used generally include those with several basic functions and also equipment with more highly organized logic, such as counters and registers. The reliability and security of electronic installations is of increasing importance to both manufacturer and user. Particular emphasis was therefore laid on these features when choosing the system for the Si range. The mean time between failures is often used as a criterion for assessing reliability. The dependability of an installation is determined by the choice of components, the specified dimensions, design, type of connections used, and so on.

The security of a system can be judged by whether internal faults give rise to dangerous outgoing signals. Measures to improve the security should be aimed at reducing the probability of externally dangerous signals or faults, irrespective of internal faults. Greater reliability and availability result in improved security of the overall system. When taking steps to improve the security, introduce redundancy or carry out specific modifications within the circuits, it is essential to strike a reasonable balance between the expense and the gain in security.

The degree of security can be characterized by the coefficient

$$S = 1 - \frac{\text{Frequency of dangerous faults}}{\text{Total frequency of faults}}$$

A range of equipment designed to deal with problems of control must be easily adaptable to different security requirements. Here we have a system which is able to comply with various degrees of security.

In a system with no redundance, a spurious 1-signal at the output indicates a dangerous operating condition. A spurious 0-signal, on the other hand, corresponds to a safe condition. If all the anticipated kinds of fault are examined: line breakage, earth faults, short circuits on the supply voltage, short circuits on the signal lines and component failure, it is found, on the basis of the system structure (each reversing stage negates the input signal), that a spurious 1-signal appears at the output in the case of about 50% of all conceivable single faults. Regarding reliability and security, non-redundant systems should be considered as circuits with all the components in series. With a system having no safeguards against single faults, S = 0·5.

If measures are taken to prevent certain single faults from causing dangerous faults, the result is a system with improved security ($0{\cdot}5 < S < 1$), but a reasonable economic relationship between expense and the gain in security is the decisive factor. Practical experience has shown that some 70% of all faults can be attributed to interruption of signal lines inside and outside the installation, due to breakage of the lines or poor connections. The remaining 30% are due to various causes inside and outside the equipment. If, by presenting the 1-signal in the form of current and voltage [1], one prevents a fault from occurring when a signal line breaks, a security factor of $S = 0{\cdot}85$ is obtained. As earth faults can be safeguarded against with this solution, and at no added expense, it is included. Improving the security by eliminating another dangerous fault, having a frequency of occurrence of about 5%, increases the security factor by only 0·025. It can be seen that security is significantly improved only when the frequency of a single fault is high.

Measures against further specified faults which have a low probability cannot be justified on economic grounds.

Security against all single faults in a system ($S = 1$) is achieved by employing a two-channel design, with a protected device for monitoring both channels. A security factor of $S = 0{\cdot}5$ for each channel is then sufficient.

The equipment of the Si series is so designed that installations with a security factor of 0·5 are obtained, using NOR elements, inverters and diode matrixes as logic elements. Installations with $S = 0{\cdot}85$ can be built by using an AND element in conjunction with a non-inverting amplifier.

Thus, with the items from one series of equipment it is possible to achieve three different degrees of security, and each step incurs a minimum of additional cost.

Components of the Si Series

The Si Series is a modular system. The basic mechanical unit consists of printed circuit boards or plug-in sub-assemblies. The units are combined in tiers to form electrical and mechanical functional groups. The smallest electronic unit is termed a functional unit. A mechanical unit can contain several, often identical functional units. Widely used circuits, such as inverters, are available as ready-made components.

With a modular system all kinds of applications can be catered for, using a small number of standard basic units. In many cases, however, this can mean appreciably higher costs than with devices especially adapted to a particular purpose. This drawback is avoided in the Si Series in that units more highly organized than the basic units are also available.

All signals in the Si Series conform to the positive logic convention, i.e. a 1-signal is created by a positive voltage, and a 0-signal corresponds to zero voltage. The reference point for all voltages is the neutral busbar common to the entire system. The signals at the outputs of almost all the units are antivalent to each other. The system is easy to use, as the output load capacity, input values and signal levels are all standardized. Table I summarizes the most important units for general applications. Fig. 1 shows some examples of these units.

Logic Elements

The basic unit selected for the logic elements is the NOR element, consisting of an OR element followed by an inverter. The NOR element can perform all logic operations which have no response time. Other logic elements may, however, be advisable for economic reasons. Inverters are used in almost all items of the series as input and output switching elements.

NOR Element DT 303

This unit contains seven NOR elements and two OR elements. The number of the inputs has been chosen so that the best possible arrangement is obtained for the more common applications. The number of inputs to each NOR element can be extended almost at will. The OR elements on the unit can also be used, as can externally connected diode gates.

Diode Matrix DD 317

Any desired diode arrangement can be assembled easily and clearly with this unit. The unit is in the form of a crossbar distributor with 16 × 20 "bars". A resistor can be fitted on any of the transverse bars, and a diode can be fitted to any of the 320 intersections. The connections and polarity can be arranged as required. It is thus easy to set up special-purpose circuits, such as passive AND elements, "AND before OR" combinations and pure OR elements with special allocation of the inputs. The possible applications are especially favourable for coding and decoding circuits employing decade counters. Despite its versatility, this unit is straightforward and easy to use. This is helped greatly by the clear descriptions and space allocation, and also by the carefully prepared connection diagram.

The double-clad circuit-board, with through-plated connection holes and solder points ensures that the unit continues to function reliably even after the soldered connections have been altered repeatedly.

Inverter DT 322

This is used for reversing and amplifying the signals. Together with the diode matrix it is thus possible to construct NOR or NAND elements in any way desired.

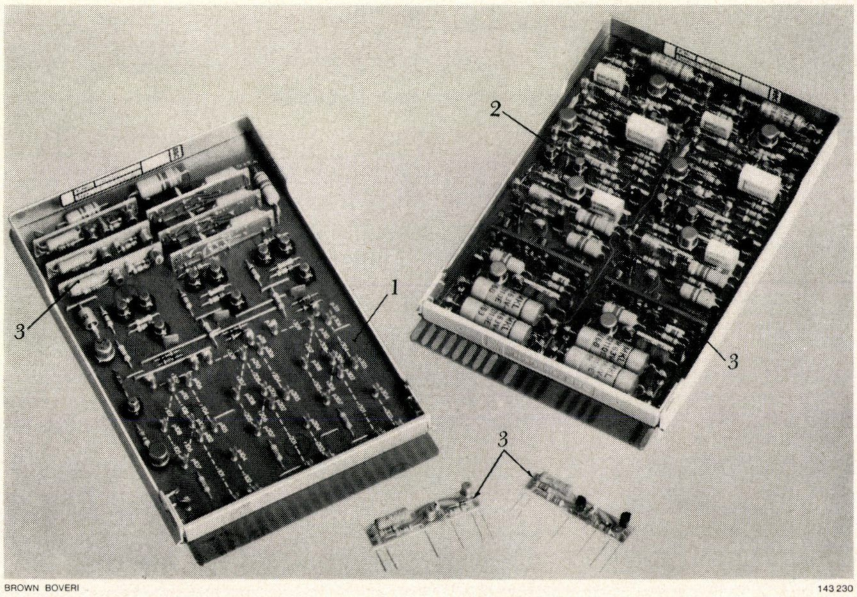


Fig. 1. – Units of the Si Series

1 = Signal range indicator UT 335
2 = Timing element ZT 320
3 = Final-stage element

TABLE I *The most important units for general applications*

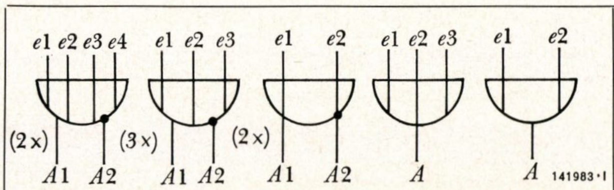
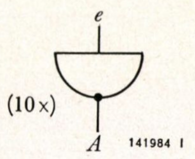
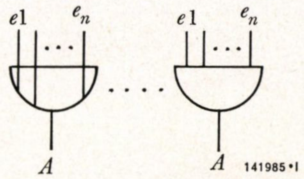
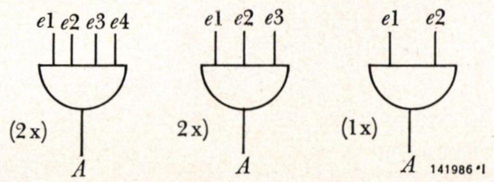
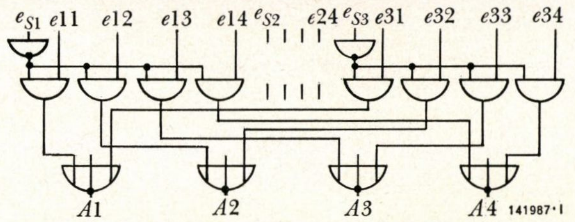
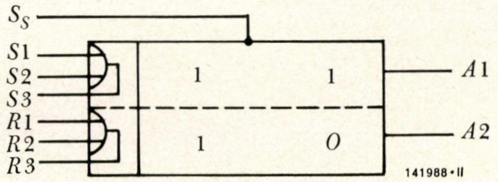
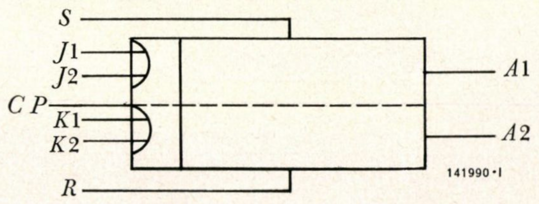
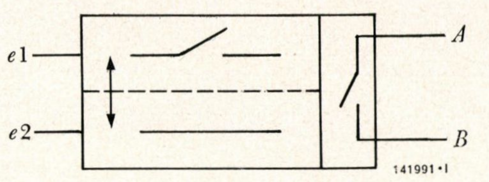
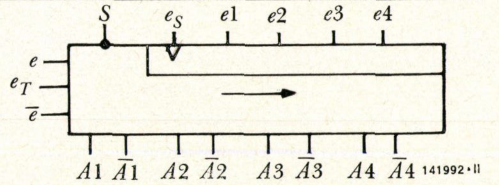
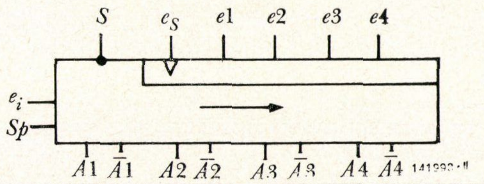
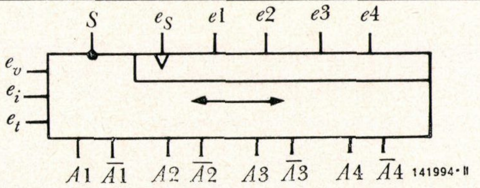
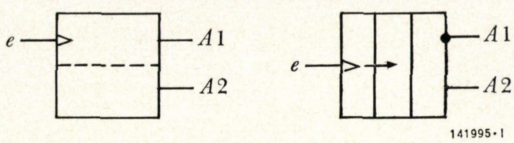
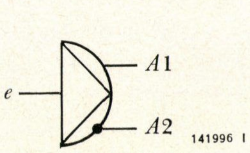
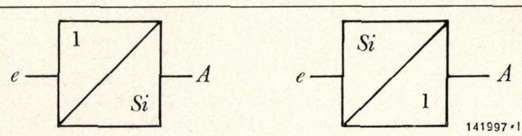
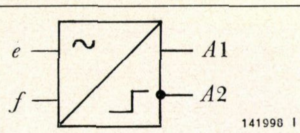
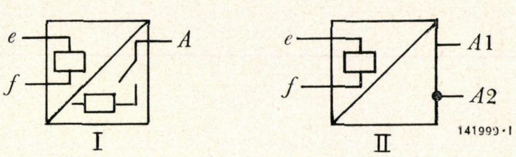
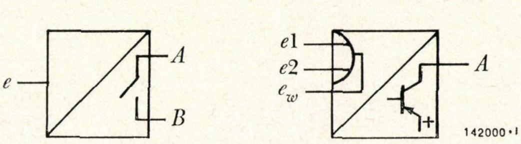
	*Logic elements* DT 303 NOR element
	DT 322 Inverter
	DD 317 Diode matrix for any OR elements up to max. 320 diodes or for max. 20 passive AND elements and in all combinations "AND before OR"
	DT 302 AND element especially for safety and interlock circuits
	DD 301 Static gate element for signal distribution especially for setting stores and counters
	CT 302 Store basic unit for mainly storing or mainly erasing
	*Stores and counters* UT 313 Store basic unit for building all kinds of counters or shift registers, can be used as *RS* or *JK* flipflop
	CR 307 Holding store with relay especially for holding output circuits if supply voltage is interrupted

TABLE I

The most important units for general applications
(in brackets, number of functional units for each device)

	CT 303 Shift register
	ZT 311 Counter for one direction
	ZT 312 Counter for two directions
	*Timing elements* for blocking or delaying ZT 319 Long-time element (1 ×) ZT 320 Long-time element (2 ×) ZT 321 Short-time element (4 ×)
	*Input and output units* UT 335 Signal range indicator (3 ×) for converting any voltages into standard signals Response threshold, hysteresis and frequency response variable by means of components on the unit
	UT 350 Signal converter l-Si (10 ×) UT 351 Signal converter Si-l (10 ×) for matching signals between Series 1 and Si Series
	UU 301 Input unit 220 V a.c.
	I UR 310 24 V relay input units (6 ×) UR 311 110 V with contact output (4 ×) UR 312 220 V for d.c. (4 ×) II UR 330 24 V relay input units (6 ×) UR 331 110 V with chatter-free (4 ×) UR 332 220 V output (4 ×)
	LR 311 Relay switching stage 1-pole (4 ×) LR 317 Relay switching stage 2-pole (3 ×) LT 305 Transistor switching stage 100 mA (3 ×) LT 307 Transistor switching stage 2·5 A (2 ×)

AND Element DT302

AND relationships often have to be formed by a 1-signal, particularly in the case of interlock and release circuits, so that no dangerous conditions can occur in the plant if a wire breaks or there is an earth fault. In other applications an AND relationship can generally be achieved more easily by a NOR element with inverted input signals.

Store CT302

The signal store consists of an *RS* flipflop. A 1-signal to the inputs *S* sets the corresponding output *A*1 also to 1, and output *A*2 to 0. This condition persists even if the input signal vanishes.

Only a 1-signal at input *R* can change the signal at the outputs. The store can be set to 0 at output *A*1 via setting input R_0.

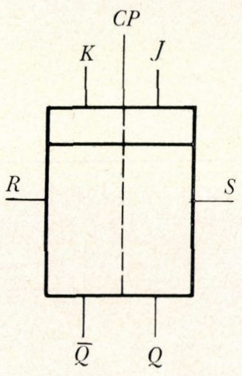
Static Gate Circuit DD301

Signals pertaining to decimal data from various channels often have to be selected and rearranged. This is particularly necessary when stores and counters are set. The gate circuit is designed for three input channels, each with four inputs. The four input signals of one channel can be switched through at any time to all four outputs by means of a switching signal. The outputs are matched to the setting inputs of the stores and counters so that these stages can be set to 0 or 1, according to the state of the signal. The number of outputs can be increased by connecting the outputs of several gate circuits in parallel.

Counter Units

The counter units are used to build up all kinds of counting and register circuits. The basic component is a static store with a time-pulse input. The manner in which it works can be seen from the circuit symbol and truth table in Fig. 2.

The store consists of two storage elements. The input data to *J* and *K* pass to the intermediate store when a 1-signal appears at the pulse input *CP*. When this signal changes back to 0 the data enter the output store, and the signals at outputs Q and $\bar{Q}$ change accordingly. A *JK* flipflop is thus obtained which, when triggered via *CP*, functions as a switching-frequency divider. The store can be set or erased, independent of the timing pulse, via inputs *R* and *S*. Synchronous and asynchronous circuits can therefore easily be set up. This store works only statically. It therefore avoids the difficulties associated with dynamic gates, particularly regarding interference signals and mains voltage fluctuations, and has the advantage that the inputs can be extended as desired by means of static logic. All counting devices are built on this basic unit. In addition to the versatile UT313 store there are a series of 4-bit devices with specialized setting and processing features. Decimal-coded data can be processed particularly conveniently.



J^n	K^n	Q^{n+1}
0	0	Q^n
1	0	1
0	1	0
1	1	$\bar{Q}_n$

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Fig. 2. – Symbol and truth table of store for counting purposes

Store UT313

This contains four mutually independent static stores which can be used generally as *RS* or *JK* flipflops. All kinds of counters and shift registers can thus be built up.

Shift Register CT303

This device is for series-parallel and parellel-series conversion of signals, and also for building ring counters. The unit can store four bits and shift in one direction.

The signals applied to inputs $e1-e4$ pass simultaneously to the four register stages when a signal edge 0–1 appears at setting input S. These signals are sent on to the next register stage by a timing pulse at input e_T. At the same time, the signals at inputs e and $\bar{e}$, which must be inverted relative to each other, are taken into the first stage. At outputs $A1-A4$ there are mutually antivalent signals which correspond to the position of the individual register stages. The register can be set to zero at any time by way of input S_0.

Counter for one Counting Direction ZT311

The counter can count in binary code from 0 to 15, or in Aiken or excess-three code from 0 to 9. These different types of operation can be set by means of a bridge inside the counter. As regards the outputs and setting inputs the device is essentially the same as the shift register. The counting process can be blocked via input *Sp*.

Counter for Two Counting Directions ZT312

The basic features of this device are the same as for the counter for one direction. The counting direction is defined by a 1-signal at input e_v or e_t.

Timing Elements

In a control system the timing elements ensure that the logic signals behave as required with respect to time. All eventualities can be catered for with two time functions: signal blocking and signal delay. Signal blocking is a basic function, and the signal blocker is often termed a monostable flipflop. It is actuated by a change in the signal of its input voltage and a command to block the signal for a specified, variable length of time appears at the output. Two modes of operation are possible: with the first the signal block is independent of the duration of the input signal, while with the second the signal block is interrupted if the input signal vanishes before the set blocking time has elapsed.

The signal delay unit is obtained by extending the blocker with logic elements. If the signal at its input changes, the output signal does not alter until after a certain adjustable time lag.

The timing elements of the Si Series can be used as either blocking or delaying devices. The mode of operation is fixed by means of soldered bridges on the unit. The set time is virtually independent of the supply voltage, and the units cannot be operated accidentally by fluctuations of the input signal within the level limits. They can therefore work reliably even with an unstabilized supply voltage. Two timing elements can be connected to one oscillator with an adjustable pulse/pause ratio.

Timing Element ZT319

This unit is intended as a general-purpose timing element for long time intervals. The circuit determining the time works on the principle of constant-current charging of a capacitor. Great accuracy can be achieved in this way, even with long operating periods, and the operating time can be adjusted instantaneously from outside by means of a time-control voltage.

Over the entire range of temperature and voltage the set operating time is maintained by the unit itself to an accuracy of about 2%, to which must be added the tolerance caused by the timing capacitor. With commercially available capacitors of metallized plastic foil it is possible to obtain specific operating times of about 5 s/μF, and the set value can be maintained within approximately 10%. Longer operating times or greater accuracy can be achieved with polyester capacitors. The unit includes places for 15 capacitors, which allows an operating time of roughly 8 minutes. Longer times are possible by using external capacitors.

Timing Element ZT320

This has the same function as the ZT319, but two independent functional units are mounted on the same circuit board.

Timing Element ZT 321

This simple element, for short times, works on the capacitor-charging principle and has a fixed operating time of 70 ms/μF. It has four functional units which can be used independently for creating various modes of operation. The accuracy of the device is approximately the same as for the ZT 319, but if the accuracy requirements are less stringent, electrolyte capacitors can be used. The spaces provided in the unit can accommodate static capacitors for times up to about 0·5 s and electrolyte capacitors for up to approximately 17 s. The time can be increased as necessary by adding external capacitors. The shortest time which can be set is about 100 μs.

Input and Output Units

In addition to preparing the signals and matching the logic to the controlled process, the peripherals of the system have the additional function of decoupling the electronics from the surroundings and suppressing electrical interference. The system therefore continues to work reliably in "noisy" environments and with long, unfavourably positioned input lines, with no need for expensive means of interference suppression.

Signal Range Indicator UT 335

With the signal range indicator it is possible to convert any voltages into standard signals. Its input circuit consists of a direct-voltage amplifier and associated circuitry. The signal range indicator is especially suitable as a "measuring trigger" for indicating limit values and for monitoring analogue signal voltages provided by transducers, contactless inductive position indicators and photoelectric devices. The response sensitivity is about 2 mV, and frequencies of approximately 10 kHz can be handled. The threshold values, hysteresis and frequency response can be varied within broad limits. Spaces are provided in the unit for the necessary circuit elements.

Input Unit UU 301 for 220 V a.c.

This unit is used to convert the mains voltage into standard signals. Owing to the high voltage the input channel can be made largely insensitive to dust and corrosive atmospheres, even with unprotected pick-up contacts. The unit is also insensitive to stray inductive and capacitive interference on its input lines. It continues to work reliably without added assistance with lines up to at least 300 m long and arranged in any way.

The input voltage of the unit is separated from the a.c. circuit by a transformer, then rectified and converted to standard signals by means of a flipflop. The switching delay is 15 ms.

Input Units for Direct Voltages 12 V, 24 V, 110 V, 220 V

These input units convert direct voltages into standard signals via a reed relay. The relay is linked through filters so that interference voltages cannot be transmitted. Units UR 310 to 312 have contact outputs, so chatter can occur. This is not usually a nuisance but otherwise it can be suppressed by stores or timing elements already present in the logic system. If this is not the case, input units UR 330 to 332 are used. These also contain reed relays for isolation. A flipflop is connected in series with the contact to suppress chatter.

Relay Switching Stages LR 311 and LR 317

With these output units, the output contact, which is at zero potential, closes when a 1-signal is applied to the input. The contacts are provided with *RC* elements, and so are suitable for inductive loads. As the contact circuitry can be removed, the unit can also be used as a zero-potential switch for signal voltages.

Switching Stages LT 305 and LT 307

These transistor switching stages are the standard output unit for 24 V d.c. They switch the positive supply voltage through to the load, one side of which is to neutral. The load cannot therefore be turned on accidentally by an earth fault. Both units may also be used in the logic system as non-inverting signal amplifier.

Features and Technical Data of the Si Series

The extent to which a project for an up-to-date modular system of controls for industrial applications can actually be put into practice is largely a question of the performance and economics of the components. The data of the Si Series are very much determined by the properties of the silicon semiconductor devices.

A depletion layer temperature of 125 °C to 200 °C is permitted. The equipment can thus be operated in high ambient temperatures. Since the transistors in digital devices serve only as switches, and so usually operate far below the maximum permissible temperature for the depletion layer, one can count on a long service life. Planar techniques and a protective layer of SiO_2 also contribute to this. Silicon transistors exhibit high current amplification values over a wide range of collector currents, whereas the collector-base cut-off current is negligible. Even with high ambient temperatures the transistors can be adequately blocked at a small positive base voltage and without reversal of polarity, so that the circuits can have a simple voltage supply with no need for a basis.

As planar techniques are particularly well suited to mass production of semiconductor devices, transistors can now be used more extensively than before, resulting in inexpensive circuits. Their advantages include freedom from interference, they are easy to use, and reliable over wide ranges of supply voltage and ambient temperature.

Power Supply

Units of the Si Series are supplied with a voltage of $U_s = +24$ V, which can vary by $\pm 30\%$. The equipment has been so designed that they continue to operate at $U_s = 14$ V, provided that a slight reduction of output load capacity is taken into account. No means of stabilization are necessary, even when allowance is made for internal voltage drops in the supply lines, transformers and rectifiers, as long as no voltage fluctuations greater than $\pm 20\%$ occur on the primary side of the transformers. The Si Series is also suitable for use with batteries, when the supply voltage can vary widely, in particular because no additional bias is necessary.

The systems employing integrated circuits can also be operated with a positive supply voltage of 5 V or 15 V, and so adapting or changing to the Si Series is a simple matter, to a certain degree even without additional equipment.

Temperature Range

The components used ensure that all logic elements will work faultlessly between temperatures of —25 °C and +70 °C (Table II). Operation up to +85 °C is possible for short periods, although continuous operation in the range +70 °C to +85 °C can reduce the life expectancy of certain devices. This temperature range is sufficient for all industrial applications.

Power Loss

The power loss incurred in a control installation is governed chiefly by the type of circuit chosen. For reasons of safeguarding against undesired output signals, the circuits are based on the NOR-principle, which in Series 1 resulted in a comparatively high power loss. By using an impedance-transformer output stage for the Si Series, on the other hand, it has been possible to reduce the power loss by a factor of 5. Natural ventilation is therefore sufficient.

Signal-to-Noise Ratios

Fig. 3 shows the typical transient behaviour of a switching stage (NOR gate). This provides information on the insensitivity to interference. From the distribution and ageing of the components, and taking into account changes over the entire temperature range from —25 °C to +85 °C, a scatter band is obtained which is bounded by the curves shown. Assuming the most unfavourable case we obtain the curves shown in Fig. 4 in relation to the supply voltage. Here, U_{ST0} is the interference voltage which, in the case of a 0-signal ($U_{0\,Amax}$), may be added to the greatest output voltage appearing at the output of a switching stage without bringing a stage of the same construction, and connected in series, into the triggering zone, even if this second stage is especially sensitive.

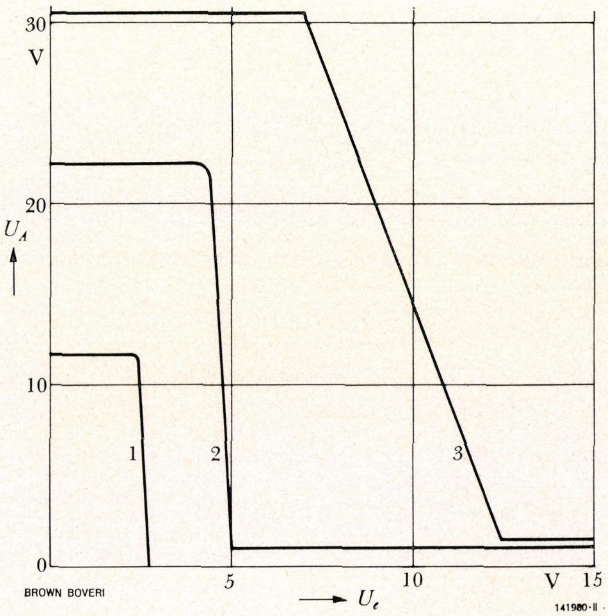

Fig. 3. – Transfer characteristic of basic circuit

Curves 1 and 3:

Limits of scatter band for the most unfavourable values of component scatter and ageing for T_u = —25 to +85 °C

Curve 2:

Typical curve at room temperature and U_s = 24 V

Fig. 4 shows an extract from the detailed data. Particularly simple design instructions apply for these voltage limit curves: each output may be loaded with eight input stages (8 NL_0) which represent a load (15 kΩ) relative to zero, and with three input stages (3 NL_u) representing a load (8·2 kΩ) relative to U_s. The permitted signal-to-noise ratios are also given.

In most cases, no loads relative to U_s are used, so that the input characteristics U_{Lemin} are lower if no AND elements are connected. Thus one can load the outputs more heavily with standard loads relative to zero, e.g. 16 NL_0, without reducing the signal-to-noise ratio. If the load capacity is not fully utilized, the signal-to-noise ratio will be higher. Much higher ratios are obtained in an application where neither the temperature range nor the supply voltage range are fully utilized. Moreover, it is unlikely that all components will reach their maximum data.

Typical values at U_s = 24 V and temperatures between 10 and 40 °C are

$$U_{st0} \approx 4\ \text{V}$$
$$U_{st1} \approx 12\ \text{V}$$

Circuit Configuration and Design

The technical data (Table II) of the Si Series are principally determined by the properties of the NOR element, an inversion stage with an impedance transformer in the output (Fig. 5).

The input data are dependent chiefly on the voltage divider at the input and base emitter voltage of *ps* 1.

A 1-signal at the input of the stage causes the transistor *ps* 1 to conduct. As a result, *ps* 2 is blocked and a 0-signal appears at the output of the element.

The 1-signal required to saturate the input transistor is determined by the criterion for the conducting condition:

$$U_{Le} = U_{BEsat}\left(1 + \frac{r_1}{r_2}\right) + r_1 \frac{U_s}{B \cdot r_c} + U_D$$

Here, U_{BEsat} is the transistor base emitter voltage required for saturation, B is the transistor's current gain and r_c its collector resistance, and U_D is the voltage drop at diode n_2 or n_3. With a load relative to zero (OR load) the collector resistance is formed only by resistance r_3, while in the case of load relative to U_3 (AND load) it is formed by the parallel connection of r_3 and by the load resistance.

A 0-signal at the input of the element blocks *ps* 1. Thus, *ps* 2 becomes conducting and a 1-signal appears at the output.

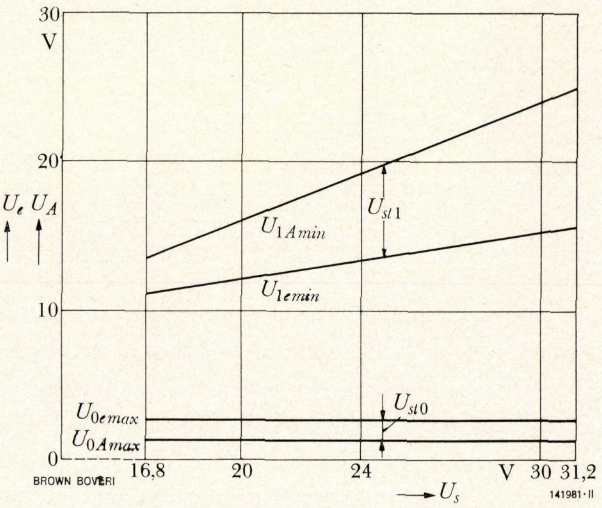

Fig. 4. – Signal voltages U_1 and signal-to-noise ratios U_{st} in relation to supply voltage U_s

TABLE II

Characteristic data of Si Series

Power supply	
Service voltage	
Rated	$U_s = 24$ V
Limit values	$U_s = 14$ V to 31·2 V
Power loss of a NOR element	
with 1-signal at output	$P \approx$ 25 mW
with 0-signal at output	$P \approx$ 110 mW
Signal levels	
0-signal	
permissible at unit input	$U_{0e} = 0$ to 2·7 V
present at unit output	$U_{0A} = 0$ to 1·3 V
1-signal	
required at unit input	$U_{1e} = 0{\cdot}31 \,.\, U_s + 6$ V
present at active output	$U_{1A} = 1{\cdot}0 \,.\, U_s$ to $0{\cdot}8 \,.\, U_s$
Signal time	
Pulse sequence frequency	$f \leqq 10$ kHz
Flank duration at unit output	$t_F \approx 10$ µs
Loads	
Input resistances	
with standard load rel. to zero (OR load)	$R_e = 15$ kΩ $\triangleq$ 1 NL_0
with standard load rel. to U_s (AND load)	$R_u = 8{\cdot}2$ kΩ = 1 NL_u
Number of standard loads possible at each output	
at $U_s = 24$ V ± 30%	
OR load	$F_o = 8$ NL_o
AND load	$F_u = 3$ NL_u
at $U_s = 14$ to 16·8 V	
OR load	$F_o = 5$ NL_o
AND load	$F_u = 2$ NL_u
Ambient values	
Ambient temperature	
limits all units serviceable	$T_u = -25$ to +85 °C
for data equipment permissible continuously	$T_u = -25$ to +70 °C
for power equipment rated load permissible	$T_u = -25$ to +40 °C
Classes of application (DIN 40040)	
humidity	*F*
mechanical stress	*M*
climatic conditions	*F, H*

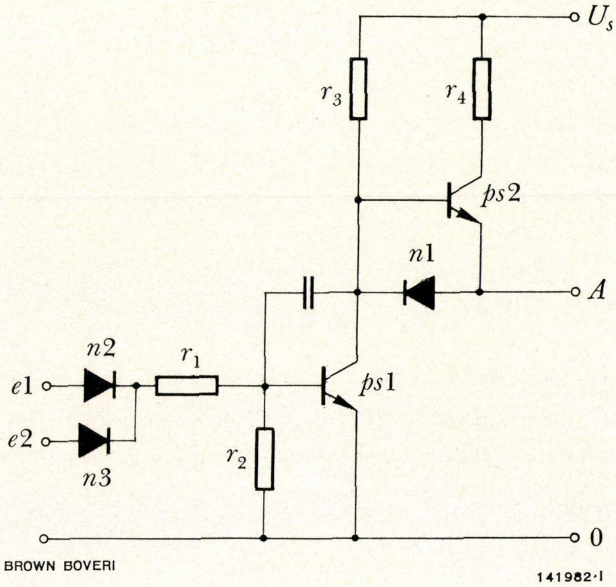

Fig. 5. – Basic circuit of the Si Series

The maximum permissible 0-signal when the transistor is blocked with base current zero can be found from the blocking condition:

$$U_{0e} = U_{BE\,block}\left(1 + \frac{r_1}{r_2}\right) + U_D$$

The 1-signal required at the input depends on the supply voltage. The influence is slight, however, so that the separation between 0 and 1-signals at the input is mainly determined by the difference between voltages U_{BEsat} and $U_{BE\,block}$. These voltages are dependent on temperature. The minimum value of U_{1e} given for the curves in Fig. 4 is thus obtained at an ambient temperature of —25 °C, and the maximum value of U_{0e} at +85 °C.

The 1-signal at the output of the inverter is determined by the impedance transformer *ps*2.

We have

$$U_{1A} = U_s - (U_{CEsat} + I_A\, r_4).$$

The residual voltage U_{CEsat} of the output transistor is about 100 mV. Output current I_A depends on the number of OR loads connected to the output. When loaded with 10 OR loads the smallest 1-signal occurs at 80% at least of the supply voltage.

The 0-signal at the output depends on the type of load. With a pure OR load it is 0 V. In the case of AND load it is formed by the residual voltage of transistor *ps* 1 and the forward voltage of diodes n_1. With a full AND load it is about 1 V.

The output is short-circuit-proof relative to zero, because the current is limited by r_4. Because of the consequent power loss, however, a short circuit must not be allowed to persist for any length of time. Under normal operating conditions the power loss is small.

The capacitor between base and collector of the input transistor forms a capacitive negative feedback. This increases the transit time of the signal flanks at the output to approximately 10 µs. This also creates a time threshold. Short-lived interference pulses which exceed the static signal-to-noise ratio are thus suppressed. The combination of a high signal-to-noise ratio and a time threshold makes the circuits largely insensitive to all kinds of interference.

(DJS)

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INDACTIC® DFM 10 CONTINUOUS TELEMETRY EQUIPMENT

621.398:621.317

Design features and operation of the DFM 10 telemetry device are described. It represents a further development of the type IFFM[1] equipment which has been in service for a considerable time. Its use as a telemetry channel for system control is discussed and the additional electronic circuits developed specially for this purpose are described.

General

INDACTIC® DFM 10, the new telemetry equipment, is used for continuous transmission of all forms of values which are present in the form of electric current or voltage. It is fully transistorized and the calibrated circuits employ silicon devices.

An accuracy class of 1% and a sufficiently small time constant enable this equipment to be used for transmitting controller outputs for regulating tasks. These may be in electricity supply services (interconnected operation, system control) or industrial automation as a consequence of progressive rationalization of technical processes. The Indactic DFM 10 telemetry equipment will find application in interconnected operation between electricity supply companies for transmitting the correcting value in the Y channel as well for transmitting the power value in the P channel where other equipment with greater time constants and bigger measuring errors is not suitable. As the device has a transmission channel bandwidth of 60 Hz on the CCITT 120 Hz standard mesh, starting at 1500 Hz $\pm$ 30 Hz up to and including the 3300 $\pm$ 30 Hz channel, it is very economical with respect to required bandwidth. When used with the PLC single sideband devices ETB or ETC these channels are usually subordinate as part of the modulation spectrum of overriding carrier frequency equipment. As the reflexion and symmetry damping of the transmitting and receiving filters conform to the requirements of postal authorities, the device can be operated along telephone cables. Both transmitter and receiver are built up of plug-in units and, together with the supply unit, are housed in standard Brown Boveri tiers.

As can be seen from the general arrangement the transmitter tiers can contain up to four complete transmitters and the receiver tiers can contain up to four complete receivers, including their respective supply and monitoring equipment. Space requirements are therefore very small.

The functional principles of transmitter and receiver are described as follows with reference to the block diagrams (Fig. 3 and 4).

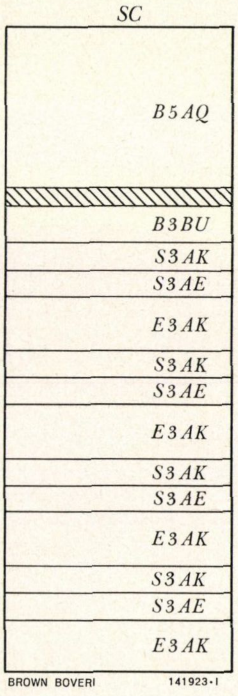


Fig. 1. – Transmitter tier SC

B5AQ = Supply unit
B3BU = Controller
S3AK = Transducer
S3AE = Converter
E3AK = Transmission filter

[1] B. GERNERT: IFFM Continuous-telemetering equipment. Brown Boveri Rev. 1966, Vol. 53, No. 4/5, p. 375.

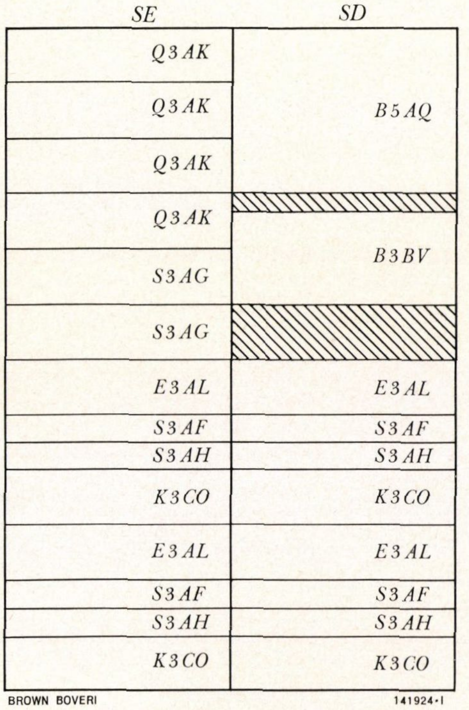


Fig. 2. – Receiver tiers SE and SD

B5AQ = Supply unit
B3BV = Controller
E3AL = Reception filter
S3AF = Multiplier
S3AH = Discriminator
K3CO = Isolating amplifier
Q3AK = Monitor 1
S3AG = Monitor 2

Transmitter

A direct current of between the standardized limits of 0 mA and 5 mA and equivalent to the electric or non-electric measured quantity is formed in an external measured value transducer. This current controls a current/frequency transformer (2 in Fig. 3) linearly from a frequency of $f_{min} = 1500$ Hz or 0 mA up to $f_{max} = 2100$ Hz or 5 mA.

The printed circuit board (3 to 7 in Fig. 3) converts the oscillator frequency into frequency $10 f_c$ with no loss of precision by means of mixing with a crystal frequency. This is divided in the ratio of 10:1 and results in the desired channel frequency and, at the same time, a reduction of the original frequency band from 600 to 60 Hz. As the final frequency is determined by the crystal frequency alone, the current/frequency transformers can all be the same as each other, which considerably simplifies assembly and setting of the components.

The transmitter filter output is symmetrical with characteristic values of $Z = 600\ \Omega$ and reflux attenuation $\geqq 11$ dB. The outputs of various channels can be connected in parallel without requiring any special measures. The current/frequency transformer is independent of the type of transducer, particularly of its internal resistance. For use in regulating channels it is fitted with input terminals which can be connected to any earth (type S3AK) as standard fitting in the transmitter tier.

Receiver

The signal arrives at a frequency multiplying circuit (1 to 4 in Fig. 4) in the connection to the receiver filter (E3AL) which has characteristic input values of $Z = 600\ \Omega$/symm. and reflux attenuation $\geqslant 11$ dB. Here the signal is mixed with the same crystal frequency as used for conversion in the transmitter. The mixed product is filtered through a low-pass filter and passed to a discriminator (5 in Fig. 4) in the frequency range 1500 Hz to 2100 Hz. Here the frequency is

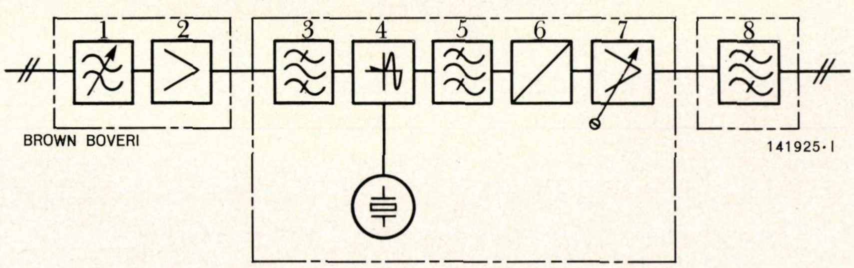


Fig. 3. – Block diagram of DFM 10 transmitter

1 = Voltage-controlled oscillator 1800 ± 300 Hz [S3AK]
2 = Isolating stage (galvanic insulation) [S3AK]
3 = Band-pass filter 1800 ± 300 Hz [S3AE]
4 = Frequency converter $f_0 = 10f + 1800$ Hz [S3AE]
5 = Band-pass filter $10f \pm 300$ Hz [S3AE]
6 = Frequency divider 10:1 [S3AE]
7 = Transmission amplifier [S3AE]
8 = Transmission filter [E3AK]

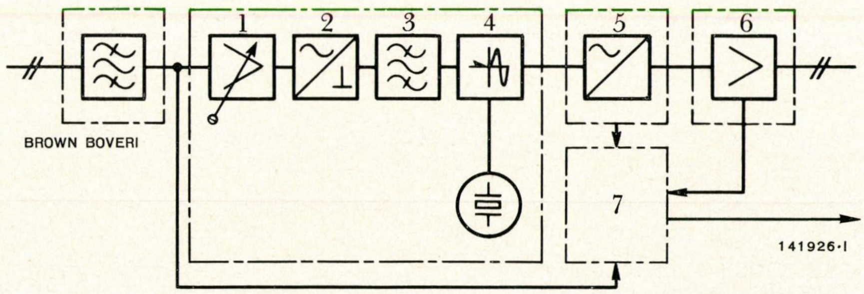


Fig. 4. – Block diagram of DFM 10 receiver

1 = Signal amplifier [S3AF]
2 = Frequency multiplier [S3AF]
3 = Band-pass filter $10f \pm 300$ Hz [S3AF]
4 = Frequency converter $f_0 = 10f + 1800$ Hz [S3AF]
5 = Frequency-voltage discriminator [S3AH]
6 = Isolating amplifier [K3CO]
7 = Monitor [Q3AK]

transformed back into a proportional direct current. As a result, a current of between 0 mA and 5 mA or $0 \pm 2{\cdot}5$ mA, which is largely independent of the burden, appears at the output of the series-connected d.c. amplifier (4 in Fig. 4) which attends to amplification and impedance transformation.

Crystals of appropriately high quality ensure frequency conversion in the transmitter and receiver without jeopardizing the precision of the current/frequency transformer in the transmitter or of the discriminator in the receiver. In addition to this, the reconversion of the frequency in the receiver also leads to advantageous simplification of the device, i.e. functional units which are identical for all channels, independent of the channel frequency.

The type Q3AK monitoring unit (7 in Fig. 4) evaluates several criteria. The signal level of the receiver with adjustable threshold is monitored in such a way that a drop in signal level below the threshold value causes an alarm signal to be given. In addition to this, the function of the discriminator with criterion signal/no signal and finally the measuring current circuit is monitored, this having adjustable criteria, e.g. $i_M = 5{\cdot}25$ mA and $i_M = -0{\cdot}25$ mA or $i_M = \pm 2{\cdot}75$ mA, and the alarm is given.

It is a very simple matter to change the current/frequency transformer in the transmitter and the discriminator in the receiver from unipolar (0 to 5 mA) to bipolar ($0 \pm 2{\cdot}5$ mA) operation. This is accomplished by merely interchanging two marked resistors.

The S3AG monitoring device can be used in cases where only simple functional monitoring is required. This device is designed for two receivers and contains two current limiters which prevent the measuring current from rising much above the standard value (5 mA) and causing damage to the instruments. Both monitoring units (Q3AK and S3AG) are provided with two interchange contacts.

The d.c. amplifier (4 in Fig. 4) can be either a chopper-amplifier (type S3AD), which supplies only a unipolar current (0 to 5 mA) across its non-galvanically insulated output terminals to the burden, or an isolating amplifier (type K3CO) which can supply a galvanically insulated bipolar current (0 ± 5 mA) to the burden.

The second type can therefore be used for forming the sum or the difference and will therefore find its main application in interconnected operation and system control, preferably in combination with the Q3AK monitoring unit. When adapted to local reception conditions (signal level, interference level) this can at the same time also monitor measuring current excess by means of adjustable positive and negative limiting values along an insulated path.

Additional Equipment for Using the DFM 10 as a Control Channel

As can be seen from the equipment plan (Fig. 5) the DFM 10 can be augmented by additional equipment for special applications. Using the DFM 10 as a control channel entails fitting the transmission-amplifying printed circuit boards Q3AH and the relay printed circuit boards Q3AG into a supplementary tier SF. An example is shown in the basic circuit diagram (Fig. 6) where the operating channels 1 or 3 are automatically switched over to the reserve channels 2 or 4 in the event of an alarm signal being

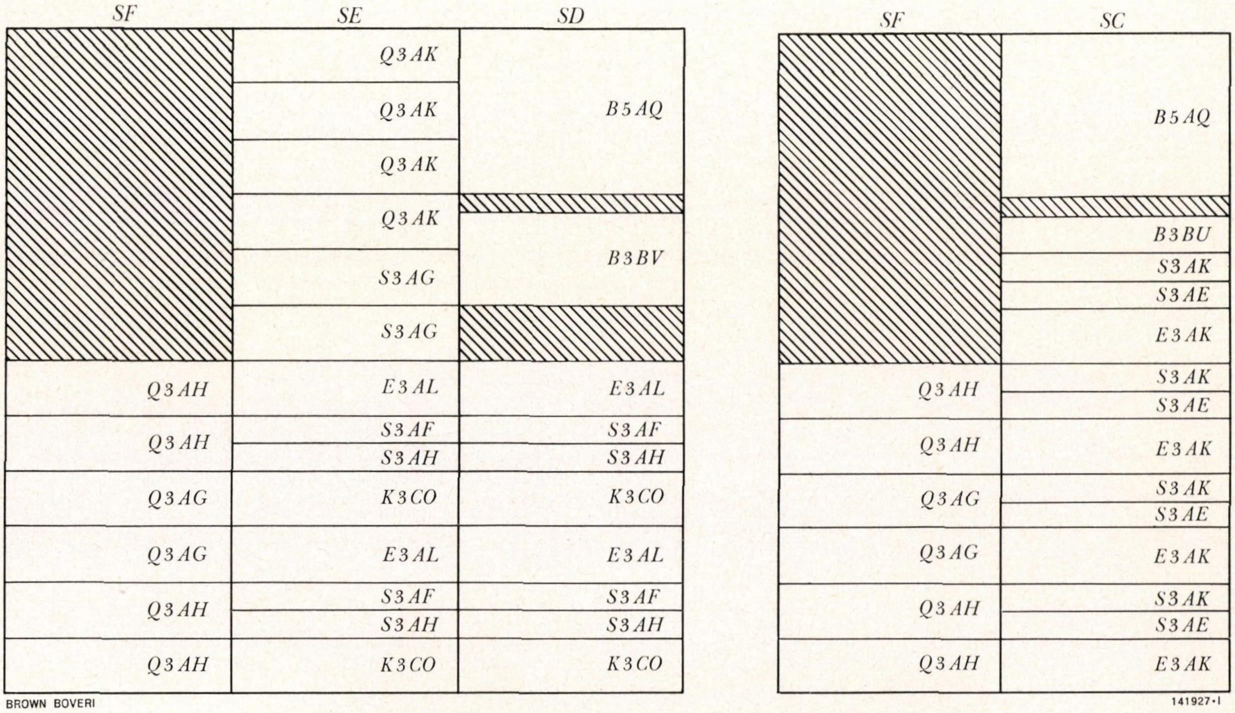


Fig. 5. – Diagram of augmented DFM 10 telemetry device for control channels

Receiver tier SD	Transmitter tier SC
Receiver tier SE	Basic equipment
Supplementary tier SF (equipped as required)	Supplementary tier SF (equipped as required)

Q3AH = Transmission or transit amplifier
Q3AG = Relay (printed circuit board)

given. Printed circuit board Q3AH in the receiver acts as a transit-amplifier and transmits the non-demodulated received signal at the standard signal level at the transit output (0·775 V) symm. to one or more other transmitters. In the event of an alarm signal being given, these units can automatically switch off the telemetry feeder and the transit feeder.

Current Supply

The current supply for the transmitter tiers (SC) and the receiver tiers (SD) uses plug-in units which permit operation from the a.c. mains (110 V or 220 V) or from batteries (48 V/110 V or 220 V) as desired.

Supply units B5AT (transmitter) and B5AU (receiver) are used for operating from the a.c. mains whereas units B5AG and B3BU (transmitter) and B5AQ and B3BV (receiver) are provided for operating from batteries.

Technical Data

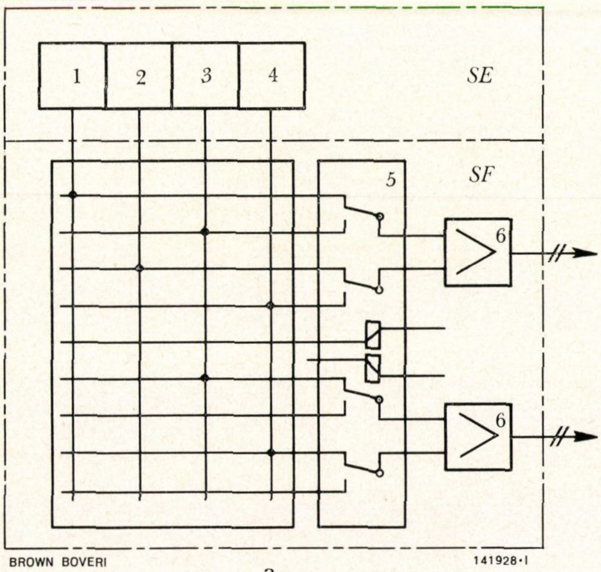
Measured value:

analogue input	
unipolar	0 to 5 mA
bipolar	0 to $\pm 2{\cdot}5$ mA
source resistance	arbitrary
analogue output	
unipolar	0 to 5 mA
bipolar	0 to $\pm 2{\cdot}5$ mA
burden	0 to 3 kΩ
accuracy class	1% between 5° and 45 °C
response time	200 ms

Transmission:

Audio-frequency in CCITT mesh at 120 Hz channel gap

frequency deviation	$\Delta f = 60$ Hz
channel-centre frequencies	1500 to 3300 Hz



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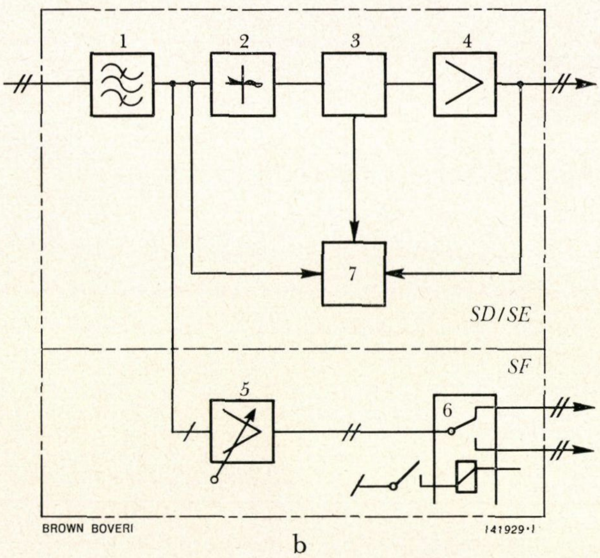


b

Fig. 6. – Block diagram of augmented DFM 10 telemetry device for control channels

a: Transmission end
Basic equipment (tiers SE and SF)
1 to 4 = Telemetry transmitter DFM 10
5 = Relay (printed circuit board) [Q3AG]
6 = Transmission amplifier [Q3AH]

b: Receiving end
Basic equipment (tiers SD/SE/SF)
1 = Reception filter [E3AL]
2 = Multiplier/converter [S3AF]
3 = Discriminator [S3AH]
4 = Isolating amplifier [K3CO]
5 = Transmitting amplifier [Q3AH]
6 = Relay (printed circuit board) [Q3AG]
7 = Monitor [Q3AK]

Transmitter:

symmetrical, unearthed	
adjustable transmission level	max. 0 dBm at 600 Ω
symmetry damping	≧ 45 dB
reflux damping	≧ 11 dB (600 Ω)
distortion damping	≧ 53 dB

Note: Transmitters for various frequencies can be connected in parallel as desired.

Receiver:

symmetrical, unearthed	
operating level	min. —34 dBm at 600 Ω
symmetry damping	≧ 45 dB
reflux damping	≧ 11 dB (600 Ω)

Note: Receivers for various frequencies can be connected in parallel as desired.

Current supply:

a.c./d.c. universal supply

battery voltage	48 V d.c. $^{+25}_{-10}$ %
mains voltage	110 or 220 V $^{+25}_{-10}$ %
	50 Hz

a.c. supply only

mains voltage	110 or 220 V $^{+10}_{-15}$ %
	45 to 65 Hz

Room temperature:

data assured between	+5 and +45 °C
operation assured between	—20 and +45 °C

Summary

The DFM 10 telemetry devices which have been in continuous service both in Switzerland and abroad have proved themselves even under the most difficult operating conditions. They have been in operation for a considerable time; mainly in power supply applications. The Indactic DFM 10 is a device which has been tested over a number of years and is characterized by its accuracy and reliability in transmitting measured values over long distances.

(AH) B. GERNERT

CENTRALIZED SUPERVISION OF TEMPERATURE

536.5

For continuous measurement, supervision and recording of many temperature measurements as they occur, for example, in the operation of a thermal power station, the use of a hand-operated measuring point selector switch is no longer sufficient. This article deals with a system, suited to automatic control, which continually compares all measured temperatures with pre-determined limits, indicates excesses and, in the case of important values, is also capable of directly influencing the plant.

The Problem

IN steam power plants there are generally a large number of points at which temperatures must be supervised, measured and recorded within the range of 0–300 °C.

As an example, the following table summarizes the 82 measuring points in a 250 MW plant:

	Lubricating and control oil	Bearings	Cooling water	Winding	Hydrogen	Sealing oil
Main Turbine	2	9 (Main Turbine and Generator)				
Generator			2	12	8	6
Feed Turbine	4	12				
Motor Pumps		10	3			
Motor Blowers		12				
Transformer				2		

Methods of Temperature Measurement

To convert temperatures into proportional direct voltages, the principal types of device are thermocouples and resistance elements.

With a thermocouple, a thermoelectric voltage is produced at the cold junction of two different metals when the opposite ends, which are welded together, are heated. The thermoelectric voltage depends upon the difference in temperature between the cold and hot junctions. For the measured value to remain independent of the ambient temperature, the temperature of the cold junction must either be held constant by means of a thermostat or the effect of the ambient temperature must be balanced by a compensating circuit. Since thermoelectric voltages amount to only a few mV per 100 deg C, precise and highly sensitive amplifiers are necessary for conversion.

Resistance elements are resistors which are mounted in probes and have a defined initial resistance at 0 °C and a defined dependence on temperature. If the element is fed with a constant direct current, the voltage drop at the element is a measure of its temperature. For absolute measurement of temperature a voltage corresponding to the voltage drop at the initial resistance must be subtracted. The simplest measuring arrangement is the two-wire circuit, with which the two conductors to the element are used simultaneously for both supply and measurement. In this case the resistance of the wires is contained in the initial resistance of the element. To ensure that measurement is independent of the wire resistances, with this method the loops to the elements are balanced accurately to a determined value by means of an additional resistance (circuit balance).

In the most accurate resistance elements the active part is composed of platinum wire. For standardized platinum elements with an initial resistance of 100 Ω (Pt 100), a tolerance of ±0·6% is allowed up to 300 °C according to DIN 43760. When the supply current for elements of this type is chosen so that the internal dissipation does not exceed 10 mW, the error resulting from self-heating is less than 1 deg C and the measuring voltage is approximately 0·25 V/100 deg C.

Because of this relatively high measuring voltage which permits the use of simple and sturdy evaluating devices, and the absence of any controlled-temperature device for the cold junction, resistance elements are preferred as pickups for the temperature range between 0° and 300 °C.

Design and Operating Characteristics

The ZETA centralized temperature supervision system serves to evaluate readings for which Pt 100 resistance elements are provided as sensors. It consists of an electronic part, housed in a cabinet or a hinged frame, and a control and display panel, which can be set up where desired. This is possible because, except for the lead for the central temperature indicator, it is connected to the electronic part only via pilot wires. The ZETA was designed on the modular principle, thus providing an economical way of supervising any number of readings. Each measuring point is permanently connected to its associated monitoring circuit. This principle was chosen for its high reliability and security for automated systems so that one fault cannot disrupt supervision of all temperatures.

The centralized temperature supervision system performs the functions listed below.

a. Temperature supervision with regard to exceeding individually chosen limits

Each temperature reading which exceeds its limit is indicated separately on the control panel. It is possible to programme a compilation of signals from any desired measuring points into a system of common alarms with a contact output. These common alarms can be used to control annunciators or as input signals for an automation system, such as the Turbomatic®.

b. Selective temperature measurement with programmed measurement range

With the aid of push-buttons on the control panel any reading may be switched to the central temperature indicator. Lights signal the readings indicated and which of the measurement ranges (150° or 300 °C) is being used. The selective switching facility is designed so that briefly pressing a button cancels the previous measured value from the display and then puts the selected reading through with a self-hold. A trend recorder can be connected in parallel to the indicator if required.

c. Simultaneous recording of arbitrary temperatures on a potentiometric recorder or point printer

For each value a recorded output of from 0 to 20 mV is provided. The circuit is selected so that even in the event of a short circuit in the recorder input, limit supervision of the measuring point is not influenced.

d. Built-in calibrator

This permits the resistances of the resistance element wires to be equated with the nominal value and also allows exact setting of the temperature limit.

Control Panel

On the control panel (see Fig. 1) a luminous push-button with two lamps is fitted for each measuring point. Values exceeding the prescribed limit are indicated by the lamps (L_1). Button (K) serves to set the value on the central indicator (I). The value just switched to the indicator is signalled with the appropriate lamp (L_1). The measurement range of the indicated temperature (150 °C and 300 °C) is signalled by the range lamps fixed near the instrument.

While the calibrator is functioning, lamp (E) lights to show that no real measured value is assigned to the display on the instrument. All lamps on the control panel can be checked with the lamp test button (K_L).

Components

The basic circuit diagrams of the components of the central temperature supervisory system and their interaction are shown in Fig. 1.

a. Evaluator module

An evaluator module (printed circuit board) $E1$ is allocated to each two measured values. For each value the circuit contains the supply (i) for the resistance element (ER), a potentiometer for balancing the lead resistance (R_1), the comparator (A/C) with adjustable threshold (R_2) and the measured value relay (M). This puts the value through to the central indicator via the amplifier (V).

Any influence on the threshold value of random voltages on the conductors to the resistance element is eliminated by the low pass filter (R_3, C).

For the potentiometric recorder (5) the voltage obtained from the resistance element is shifted and divided so that 0 V corresponds to 0 °C and 20 mV to 300 °C.

The signal emitted by the comparator (A) is passed to the lamp (L_1) on the appropriate illuminated push-button and also to the alarm matrix for the formation of common alarms.

b. Central unit

The central unit $E2$ contains the constant voltage sources (U_{k1} and U_{k2}) for supplying power to 20 evaluator modules, the automatic system for the measurand switching relays, the range switch and the amplifier (V) for matching the measurand level to the central display.

The automatic switching unit, consisting of the Schmitt trigger ($A/C1$) and the time one-shots ($ZK1$, $ZK2$), prevents the switching of more than one measurand to the amplifier when several buttons (K) are pressed simultaneously. The purpose of this is to exclude the possibility of false temperature limit signals due to coupling of measurands.

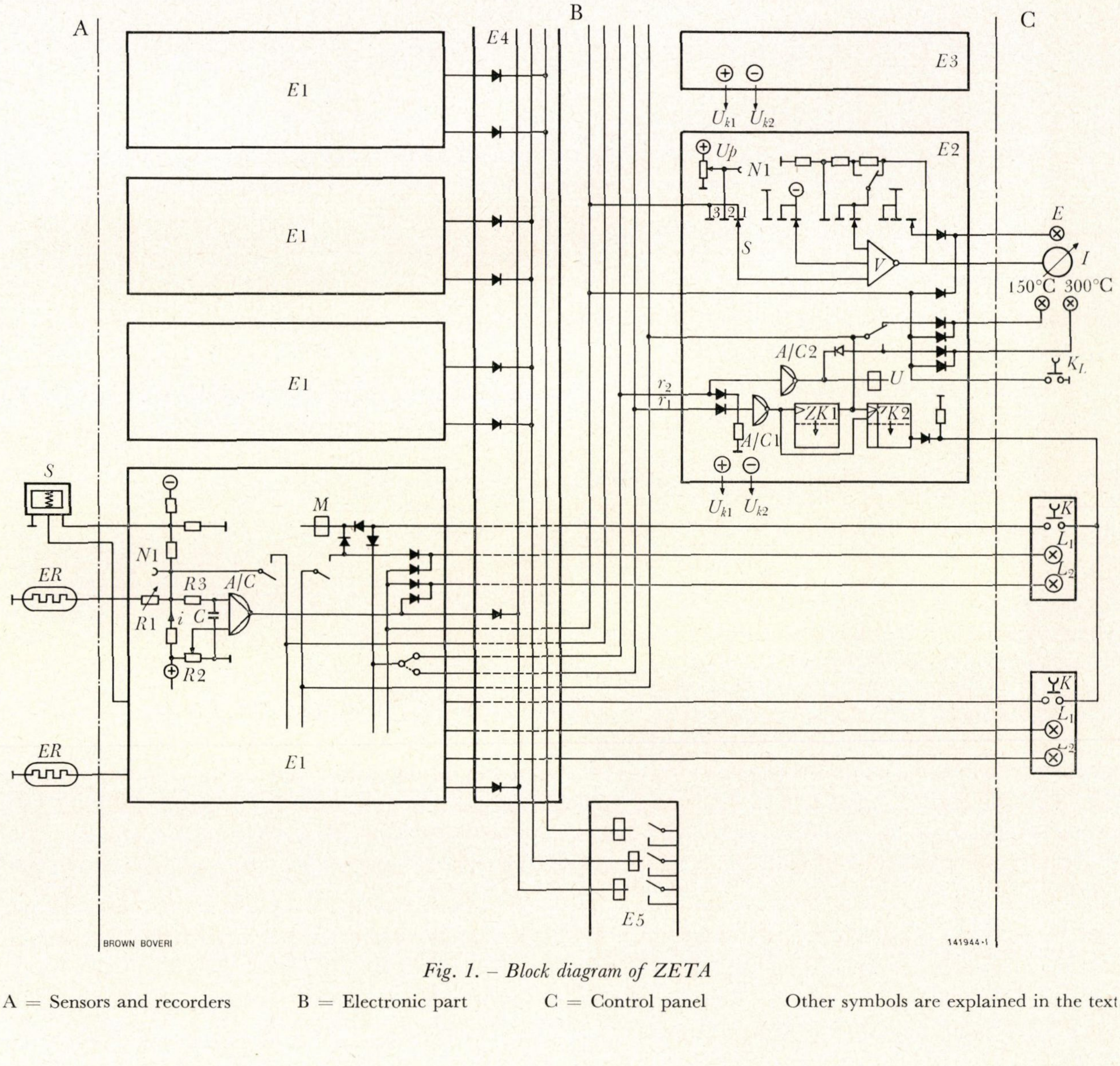
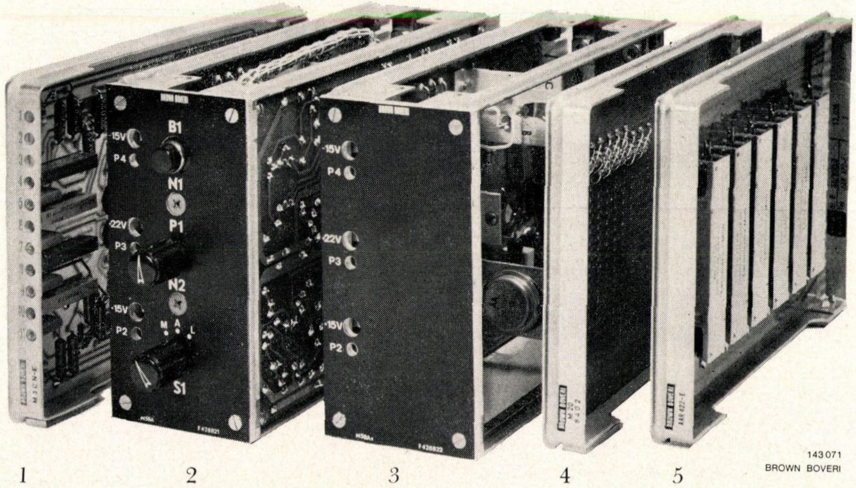


Fig. 1. – Block diagram of ZETA

A = Sensors and recorders B = Electronic part C = Control panel Other symbols are explained in the text.



1 2 3 4 5

Fig. 2. – Components of ZETA

1 = Evaluator module
2 = Central unit
3 = Constant voltage source
4 = Matrix module
5 = Relay module

The automatic switching unit is actuated by pressing a button (K) via the allocated evaluator module on one of the circuits r_1 or r_2. This causes first one one-shot ($ZK1$) to reset the relay (M) of the previously switched measurand, and then the other one-shot ($ZK2$) to set the relay (M) of the desired measuring point. If the control pulse comes in over circuit r_2 the relay (U) is simultaneously set via a further Schmitt trigger ($A/C2$) which switches on the range lamp for 300 °C and also changes the gain of the amplifier. The amplifier inputs are fed via the switch (S) which is shown in the operating position (1). A temperature value simulated by the test voltage source (U_p) can be read on the instrument (I) at position 2. By connecting the monitor jack (N_1) of the central unit with that of the evaluator module, the temperature corresponding to the threshold can be simulated. Position 3 serves to balance the lead resistances to the resistance elements.

c. Constant voltage source

For a system having more than 40 measuring points a constant voltage source $E3$ must be provided for each further group of 40 points. This contains the supplies (U_{k1} and U_{k2}) for 20 evaluation modules.

d. Matrix module

Common alarms for each group of 20 measuring points are formed using the matrix module $E4$. Programming is done by soldering diodes to the circuit.

e. Relay module

The relay module $E5$ is intended for the output of every set of six common alarms with shielded contacts.

Data

Sensor: resistance element Pt 100, two-wire circuit	
Max. resistance of wire loop between sensor and electronics part	10 Ω
Control resolution range of adjustment	—50 to +300 °C
Threshold hysteresis	1 deg C
Display output voltage	0–15 V
range ×1 corresponding to	0–150 °C
range ×2 corresponding to	0–300 °C
Potentiometric recorder output voltage	0–20 mV
corresponding to	0–300 °C
Max. error of measurement incl. linearity error of resistance element:	
range ×1	±2 deg C
range ×2	±5 deg C

(SMW) H. BLOCH

BROWN BOVERI TELECONTROL

621.398

The term "telecontrol" is used to denote the transmission and associated processing of technical data relating to a system, and which cannot therefore be changed arbitrarily, passing between a human operator and an installation, or between two installations.

Brown Boveri have been active in this field for nearly thirty years, the main emphasis having been on the power industry (electricity, water and, more recently, oil and gas).

The particular circumstances in the electricity industry, where long-distance telecontrol links are a characteristic feature of h.v. and e.h.v. networks, have meant that the appropriate data-transmission equipment is considered as an integral part of the system from the start of the project. The single-sideband carrier-frequency sets introduced some twenty years ago for transmitting data on high-voltage lines (power line carrier equipment), and also their successors, fitted throughout with semiconductor devices, have met with considerable success.

The aim of this article is to survey the telecontrol and data-transmission equipment in our present range of products.

Telecontrol Equipment

General

IN any telecontrol project one of the first problems is to determine the most suitable communications channel between the control centre and the installations to be remotely operated.

The nature of the project governs the volume of data and the time available for dealing with it.

The width of frequency band depends on the method of transmission chosen (when account must be taken of security requirements and the characteristics of the path available).

With the frequency-division multiplex system the communications channel consists of a number of smaller channels having staggered frequencies over which the separate signals are transmitted simultaneously (in parallel).

In the time-division multiplex system a single (faster) communications channel is sufficient, and the separate signals are sent staggered with respect to time, i.e. in series.

For short-range links (over distances of the order of 5 km) the most widely used means of transmission is the cable (either private pilot cables or rented pairs in public service systems), where bandwidth is available. Frequency-division systems are best used in such cases.

With long-range links, of 50 km or more, the available bandwidth has to be used more sparingly, for economic reasons. The time-division system is best suited for this.

Telemetering Equipment (Table I)

One of the functions of a telemetering system is to transmit a measured value, usually available in analogue form, from an outstation to a control centre, and then display it, again generally in analogue form.

Pulse-frequency or frequency-modulation methods, as employed in the Indactic FM 10 and DFM 10 [1, 2], are used to advantage when an accuracy of class 1·5 is specified.

Both systems require a gross bandwidth of only 120 Hz in the v.f. band. The frequency allocation schedule complies with CCITT recommendations. The Indactic DFM 10 is specially designed for use in large interconnected power systems, where it is employed in closed-loop power-frequency regulation systems for transmitting measurements and corrections.

The time-division multiplex system offers economic advantages when the number of measured values is more than 10. The Indactic DZF digital-cyclic tele-

TABLE I

Telecontrol Systems

Type: INDACTIC	FM 10	DFM 10	DZF	ZM 10	ZM 30	DUFA	DASA
Range of application	universal	Power industry (electricity, water, gas, oil)					
Purpose	remote control indication telemetry (analogue)	telemetry (analogue) correction trans- mission	telemetry/indication (digital)	remote control indication	remote control indication telemetry (digital) combined	remote control indication	remote control indication telemetry (digital) combined
Principle	electronic		electronic	electromechanical	electronic, integrated circuits	electronic	electronic, integrated circuits
System capacity							
Number of remote stations	1	1	1–8	1	1	1–10	1–16
Number of regulating commands[1]	in all 1–25	–	–	in all 100 or 441	14	(100)	none
Number of pulse commands[1]		–	–		588	1000	100 to all, and (100)
Number of indications[1]		–	32, in addition 8 each instead of one measurement	100 or 441	1176	1000	(192)
Number of measurements[1]		1 per channel	48	none	20	none	80 (16)
Transmission features							
Method	frequency-multiplex	frequency-multiplex	time-multiplex	time-multiplex	time-multiplex	time-multiplex	time-multiplex
Type of operation	one-way/duplex	single-sided	one-way	simplex	duplex	duplex	semi-duplex
Type of network	point-to-point	point-to-point	point-to-point/line	point-to-point	point-to-point	point-to-point/radial	point-to-point/ radial/line
Information security	$\binom{n}{m}$ code	–	parity check	$\binom{n}{m}$code acknowledgment	$\binom{n}{m}$code automatic repeat	$\binom{5}{2}$ code with echo automatic repeat	error-detection Hamming code automatic repeat
Modulation rate	30 Bd	–	50/100/200 Bd	10 Bd	50–600 Bd	50/100/200 Bd	200/600 Bd
Channel units	provided	provided	provided	required in addition	provided	provided	provided
Frequency range	420–3300 Hz, CCITT	1500–3300 Hz, CCITT	420–3420 Hz, CCITT				
Suitable transmission paths	cable circuits	cable, carrier, PLC	cable, carrier, PLC	cable, carrier, PLC	cable, carrier, PLC	cable, carrier, PLC	cable, carrier, PLC
Transmission time							
Commands	30 ms	–	–	3–4 s	980–82 ms	1080–420 ms	570/323 ms
Indications		–	cycle duration		1380–115 ms	1170–330 ms	320/107 ms
Measurements	continuous	continuous	9·00/4·50/2·25 s		cyclic	–	cyclic
Remarks	maximum 40 items if frequency range extended to 8000 Hz	response 0·2 s basic equipment provides space for 4 channels	transmission of meter readings with additional units	radial operation possible with con- stant system capac- ity			double capacity in substation possible by combining ad- dresses

[1] The first figure refers to the whole system, that in brackets to each substation.

metering system can transmit up to 48 readings in a cycle time of only 2·25 s and requires a gross band width of 360 Hz [3, 4, 5]. With the digital method the step allocated to an analogue measured value can be used to carry any kind of digital information (indications, meter readings, etc.). Also, several transmitters can be operated on a party line with the same receiver.

Remote Control Equipment

The purpose of a remote control system is to transmit commands from a master station to one or more remote stations, either manually or automatically, and transmit indications in the opposite direction with as small a delay as possible.

In contrast to telemetering, where an occasional loss of information is unimportant because of continuous, or at least cyclic updating, remote control imposes very stringent requirements as regards the security of transmission.

Simple, short-range remote control tasks can be performed without great expense by the components of the Indactic FM 10 system. With this system the data can be encoded by using suitable combinations of frequencies (multi-frequency coding) [1].

Classical remote control techniques have for many years made use of the time-division principle, which is particularly well suited to large installations (with large numbers of commands and signals). These relay or uniselector-type remote control systems employ electromechanical components and are distinguished by their low maintenance requirements and excellent reliability if a reasonable balance is struck between the frequency of operation and service life of the parts used. An example of a successful, purely electromechanical relay-type remote control system is the Indactic ZM 10.

With modern semiconductor devices using discrete components the problem of the central part of a remote control system can be solved fully electronically, very effectively and ensure even greater reliability and less maintenance. The use of electromechanical relays is then restricted to the periphery of the network, with few logic functions besides their main purpose as an interposing element between the controlled installation and the telecontrol equipment. An example of this technique, using discrete component circuits, is the Indactic DUFA telecontrol system [6].

Combined Telemetering and Remote Control Systems (see Table I)

Many of the applications of modern telecontrol techniques require both telemetering and remote control functions, thus providing grounds for a combined system. The Indactic ZM 30 and DASA are two fully electronic telemetering and remote control systems, both incorporating integrated circuits [7, 8]. Electromechanical relays perform limited logic functions and act as interposing elements.

Whereas the Indactic ZM 30 is designed for heavy-duty point-to-point service, the Indactic DASA is especially suitable for highly dispersed networks, one master station being able to serve up to 16 remote stations.

With both systems the information is encoded by the latest techniques. The modulation rate can be chosen to suit the particular task and communications channel. Both systems can be used for PLC transmission.

Telecontrol Transmission Systems

General

Telecontrol is not only concerned with the exchange of information between operator and installation; there is still a need for versatile voice links. With these, particularly in the event of faults, it is possible to put into effect measures which go beyond the scope of the telecontrol link itself.

One special group of transmission equipment is the protection signalling equipment used for line and station protection in high-voltage networks.

Unlike telecontrol systems in which the transmission equipment is separate from the data-processing unit, in protection signalling equipment the transmission channel is combined with the data-processing unit to form a single entity.

TABLE II

FM V.F. Telegraph Channel Equipment

	NSK 2/50 Bd	NSK 2/100 Bd	NSK 2/200 Bd
Application	general for v.f. telegraph purposes		
Frequency range	420–3420 Hz	480–3360 Hz	900–3420 Hz
Channel spacing	120 Hz	240 Hz	360 Hz
Step rate	50 Bd	100 Bd	200 Bd
Transit time	25 ms	18 ms	14 ms
Transmit level	0 dBm in 600 Ω		
Receive level[1]	—45 to +10 dBm in 600 Ω		
Dynamic signal distortion	≤7%		
Input/output circuits		electronic (with intermediate relay if desired)	
Power supply	24 V d.c.	24 V d.c.	24 V d.c.

[1] Operating level, guide value for normal line condition.

V.F. Telegraph Equipment (Table II)

The classical Brown Boveri technique employs a frequency-shift v.f. telegraphy channel, as in the well-established plug-in basic units of the NSK 2 range [9]. These are available for modulation rates of 50, 100 and 200 Bd.

The units can either be combined with the telecontrol equipment or be built into self-contained telegraph terminals.

The equipment is of the frequency-division type, and extras such as transmitting amplifiers, high impedance amplifiers and hybrid circuits are available for use in cable or power-line carrier links.

PLC Systems (Table III)

The standard Brown Boveri PLC system is a single-channel multi-purpose SSB terminal with a gross bandwidth of 4 kHz capable of adjacent-channel operation. This provides either a full voice channel

TABLE III

PLC Equipment

	ETBA	ETCA	ZTA
Application	Multi-purpose single sideband PLC system		single-purpose double sideband tributary links
Frequency range	36–460 kHz		40–460 kHz
Gross bandwidth	4 kHz[2]		3 kHz
Transmit level (PEP)	15 W	80 W	+32 dBm (carrier level)
Receive level[1]	+3 dBm		+3 dBm
transmitted v.f. band	300–3400 Hz or 300–2000 Hz		
superimposed v.f. telegraph channels	up to 10		none
Power supply	48 V d.c. (other battery voltages on request)		
	110/220 V a.c. 45–65 Hz		

[1] Planning level
[2] 2·5 kHz spacing on request

with a bandwidth of 3·1 kHz or, by cutting to 2 or 2·4 kHz, a band of 1·25 or 0·80 kHz is obtained with an acceptable loss of readability when the frequency-division system is used [10–13].

In most cases the sets are of the single-channel duplex type with outband pilot regulation, but a twin-channel duplex version with independent sidebands is also available.

Sets with a gross bandwidth of 2·5 kHz can also be supplied on request, but their versatility is then severely limited.

The ETB single-sideband set, fitted throughout with semiconductors, has an effective sideband output of 15 W PEP.

The high-power ETC set, also with semiconductors throughout, uses the same components as the ETB for the small-signal stages, but has an effective sideband power of 80 W PEP.

The power amplifiers of both sets are safeguarded against no-load and short circuits and special protective measures make them safe from interference voltages originating from the h.v. line. The intermodulation damping of the sets is very good.

Double-sideband equipment is now scarcely used any more for long-range links because the frequency bands are so crowded. Owing to their modest technical requirements they are of some interest for short-range service, either for pure voice links in stationary or semi-mobile systems, or for tributary telecontrol links.

The ZTA range, a miniature double-sideband system with a carrier power of 1·5 W, has therefore been developed, and is in considerable demand.

Protection Signalling Equipment (Table IV)

Protection of modern h.v. and e.h.v. networks would be inconceivable without protection signalling equipment for transmitting tripping commands.

The recently introduced NSD range of v.f. equipment takes into account the need for greater security of transmission and more effective safeguards against maloperation under adverse noise conditions [4].

The NSD 10 set makes use of a v.f. frequency-shift channel, the required transmission security being brought about by an outband noise detector which blocks the command output of the receiver if the noise level exceeds a preset level.

The system can be used for acceleration (intertripping) in conjunction with distance relays on all kinds of transmission channel, and for direct tripping on cable and PLC circuits.

TABLE IV

Remote Tripping Systems for Power Line Protection

	NSD 10	NSD 10	HSA
Application	v.f. acceleration and direct tripping		PLC remote tripping system
System	v.f. frequency shift keying with external outband noise detector	v.f. frequency shift keying with pulse-coded command transmission	v.f. frequency exchange keying (duplicated for direct tripping)
Frequency range	v.f. band	v.f. band	36–480 kHz
Channel spacing	120/240/360 Hz	120/240/360/480/560 Hz	2 kHz
Command transmission time	30/20/15 ms	105/60/35/20/14 ms	14 ms
Transmit level	0 dBm in 600 Ω		+13 dBm in 125 Ω
Receive level[1]	—45 to +10 dBm on 600 Ω		0 dBm
Keying circuit (input)	dry reed relay		dry reed relay
Trip loop (output)	thyristor circuit or mercury-wetted reed relay (command transmission time 50% greater than stated)		high-speed contactor
Power supply	48/60/110/125/220/250 V d.c.		24/48/110/250 V d.c. 110/220 V 45–60 Hz

[1] Operating level, guide value for normal line condition.

The NSD 20 set also uses a v.f. frequency-shift channel, but increased security is obtained by means of pulse coded transmission. Evaluation takes place only when the code pattern received agrees with a reference pattern generated in the receiver.

This equipment can be used for limited and direct remote tripping on any kind of transmission channel.

The HSA range of PLC protection signalling equipment is made up of single-purpose PLC sets using frequency exchange keying directly in the IF band. A gross bandwidth of 2 kHz is required per one-way channel.

The equipment is available in acceleration and direct tripping versions, the command transit time being of the order of 14 ms.

Data Logging and Processing

The purpose of the Indactic ZFM sequential time recorder is to record and log spontaneous bivalent changes of state in the correct chronological sequence. It enables up to 1200 criteria to be recorded with a resolution of 1 ms.

A line printer is employed as a local output unit. Supplementary peripherals are available for transmitting the output data over telemetry or telecontrol channels of the Indactic DZF or DUFA systems.

Electrical readout of electricity meters (kWh meters) is at present only possible with an increment pulse device fitted to the meter system.

In order to allow an absolute transmission of a meter reading a reliable electromechanical register Type PCB has been developed. This counting register accumulates the incoming increment pulses, displays the contents visually in decimal form and allows electrical readout for teletransmission or data processing purposes.

(DJS) R. J. Ritter

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INDACTIC® ZM 30
A TELECONTROL SYSTEM USING INTEGRATED CIRCUITS

621.398:621.38.049

The ZM 30 considerably increases the scope of the Indactic range of telecontrol systems. It is designed primarily for use in the field of power utilities and is essentially for point-to-point applications. Information input and output is electromechanical whereas information processing is electronic. The telecontrol equipment comprises plug-in units resulting in simple arrangements and great versatility, enabling the system to be used in point-to-point and radial traffic.

The Problem

THE telecontrol equipment in the Indactic range covers all possible applications of any telecontrol system presently available. The Indactic ZM 30 electronic system is part of this range and is used mainly for combined telemetering and remote control tasks. It is at its best in point-to-point operation and is therefore eminently suitable for use in the field of electricity supply. The range of applications includes remote control of

hydro-electric plant,
transformer stations and switchyards,
rectifier installations and
pumping stations.

The system can, however, also be used in traffic control, industrial and gas, water and oil distribution applications.

All the usual transmission paths may be employed in transmitting the information for this system, including power line carrier systems, communication cables and radio links. Duplex operation is preferred.

In order to ensure that the equipment is economical and in no danger of becoming dated in the near future, integrated solid-state circuitry is employed in the electronic part of the equipment. The commands and indications are given by up-to-date electromechanical devices which ensure particularly efficient separation of electric potential. The measured values are, however, fed in and out by means of electronic devices.

The use of integrated circuits, together with special screening measures and appropriate circuitry techniques, have given the system a high degree of immunity against external sources of interference. Test circuits incorporated in the device ensure that interference along the communication line or a defective component in the telecontrol equipment cannot lead to incorrect information being given (fail-safe system).

Principle

An overall picture of the principle of the system can be gained from Fig. 1. A command given in the control room is stored in the transmitting device S_B and converted into a coded d.c. pulse telegram. The channel device (7a) uses this telegram to modulate an audio frequency which the receiver (7b) converts back into a d.c. signal. The telecontrol receiver 11 evaluates the signal, carries out a check on its correctness, covering transmission and equipment faults, and if the test result is positive, gives the appropriate command. In addition to pulse commands which are transmitted from the input side for a constant time regardless of the operating time, it is also possible to transmit continuous commands whose output time corresponds to the duration of the input time.

The transmission process for indications is virtually the same but the input and output are different. All signals are fed in through interposing potential isolating relays which serve as storage elements where necessary. This makes "floating" signal contacts essential. Any change of signal condition causes a supply criterion in the input units which causes the actuation of the indication transmitter 6, through-connection and transmission of the new signal condition.

After the indication has been received and checked for transmission or equipment faults by receiver 10, it is stored and at the same time displayed to the operator. If required, an acoustic signal can also be given in conjunction with this process.

A peculiarity is represented by the transmission of coded numbers (signalling the tapping position of a transformer). The Indactic ZM30 enables digital measured values to be transmitted but additional peripheral equipment is required.

The measured values are transmitted in a continuous cycle in one-way operation. On the other hand, sudden new information is given priority and introduced into the transmission cycle. The additional measured value device 14 for the signal generator contains the analogue-to-digital converter and an electronic device which introduces the analogue measured values into the analogue-to-digital converter, one at a time. The additional measured value device 14 for the signal receiver 10 allocates the measured values arriving in digital form to stores. Each signal is allocated a separate store.

It is possible to take a digital display direct from the store. If the value is to be displayed by analogue measuring instruments, a digital-to-analogue converter is connected after each digital store. The measured values can be encoded in two different ways to suit the accuracy of transmission and the display. For a digital display and an accuracy of 0·5%, the 12-bit BCD code is used. This means that a signal telegram can contain only one measured value. Two measured values can be contained in a telegram only if the accuracy may be 1% and the display is in analogue form. If this is the case, the measured values are transmitted in a binary code of eight bits each.

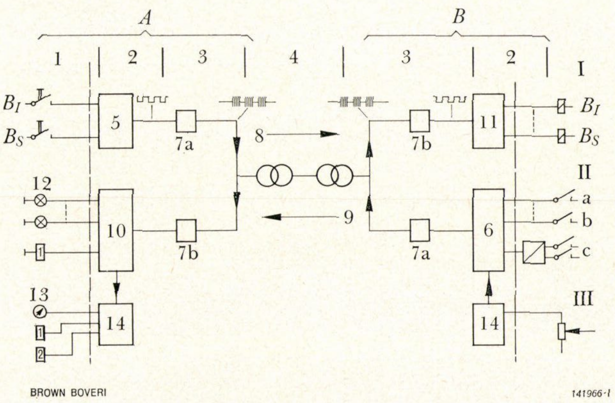


Fig. 1. – Block diagram of ZM 30 telecontrol system

A = Central control
B = Substation
1 = Command input
2 = Telecontrol unit
3 = Channel devices
4 = Pair = 2 Channels
5 = Command transmitter
6 = Indication transmitter
7a = } Channel devices
7b = }
8 = Command direction
9 = Indication direction
10 = Direction of indication reception
11 = Direction of command reception
12 = Indication display
13 = Measured value display
14 = Supplementary devices
B_I = Pulse command
B_S = Setting command
I = Commands
II = Indications
III = Measured values

Signals from *a:* Switches
b: Transformer steps
c: Counted values

Transmission Characteristics

Telegram Structure and System Capacity

Command direction

In the command direction, a telegram comprises 16 information bits and 9 bits for security. The information characters are divided into groups and individual characters and always in the $\binom{n}{m}$ code. A command telegram is shown in Fig. 2a. The standard version has 588 commands and a special sign in the command direction and, extended to the maximum, has up to 1176 commands. The number of commands quoted refers to so-called pulse commands whose output time is predetermined by two timing elements fitted in the receiver.

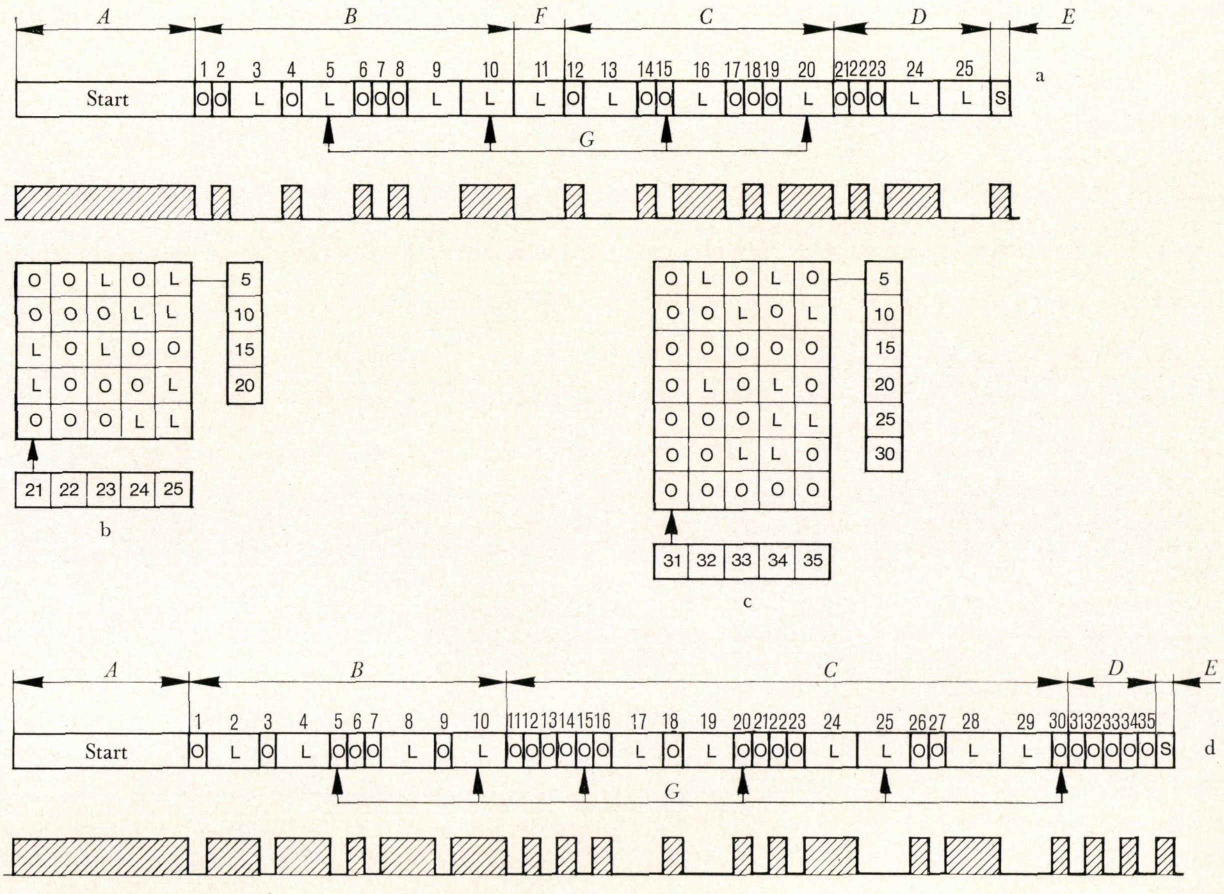


Fig. 2. – Telegrams and check signals

a: Command telegram
b: Test matrix for command telegram
c: Test matrix for indications telegram
d: Indications telegram

A = Start signal
B = Group signal
C = Individual signal
D = Column check signal

E = End signal
F = Special signal
G = Line check signal

It is also possible to transmit continuous commands for control purposes. In this case the signal is emitted for as long as the command is applied at the input end. By employing the special sign, up to seven independent commands can be included in a telegram.

Indication direction

The telegrams in the indication direction are basically the same as those in the command direction. A distinction is made between the following telegram contents: 16 indications or one 12-bit measured value in BCD code or two 8-bit measured values in binary code (Fig. 2d).

Characterization of transmitted information

Information characterization is achieved by length modulation, where binary 1 is characterized by a long pulse or a long pause and binary 0 is characterized by a short pulse or short pause (Fig. 2). The ratio *V* between binary 1 and binary 0 can be selected between 2:1 and 4:1. Selection of the ratio depends on the requisite security of transmission, the transmission time and also on the quality of the transmission line.

Forming the check character

Each telegram to be transmitted is divided into four blocks of four characters. The number of "binary one" characters is supplemented in each column and on each line of the matrix by parity check characters. The nine check characters 5, 10, 15, 20 and 21 to 25 resulting from the sixteen information characters are all included in the telegram.

Transmission Security

The measures taken to ensure adequate transmission security in the Indactic ZM 30 remote control system are based on the following considerations.

Security against spurious transmissions due to equipment defects or due to interference on the transmission channel.

After a fault has been identified the transmitted sequence must not be carried out and the fault must be indicated either visually or acoustically. The system is secure against equipment defects. An additional check is provided by selecting an $\binom{n}{m}$ code which will identify a fault in the device or on the line. In the command direction, a telegram which is incorrectly formulated cannot enter the transmission path. Further circuitry measures ensure that operating faults (multiple operation) and faulty input equipment (keyboards, control acknowledgement switches) cannot lead to faulty switching at the controlled position. An additional test circuit provides security against equipment defects. This is situated at the output of the command receiver 11 (Fig. 1) before the final command output. A check is thus made in the output circuit whether only one piece of equipment is to be operated. Additional security against equipment defects and interference on the transmission path is provided by the "synchronous end check". This determines whether a constant number of telegraphy steps is contained in a telegram. The code check and the check for redundant check characters in the matrix of the receiver form the basic security against interference. The selection ratio of the length of pulse or pause

$$V = \frac{\text{long pulse}}{\text{short pulse}}$$

determines the Hamming distance d.

The principle used here is based on evaluation of characters in the receiver by an integrating character modulator and helps to increase the security of transmission.

Fig. 3 shows the relationship between the bit-fault probability P_E which represents a measure of interference on the transmission paths, and a block-fault probability P'_B for the Indactic ZM 30 system. P'_B represents the probability of spurious evaluation of a telegram. The diagram commences with a telegram with a specific information content and the pulse ratio V and thus the Hamming distance d serves as a parameter. The relationship between the two values is shown in Fig. 3. At a bit-fault probability of $P_E = 0{\cdot}02$ and a Hamming distance of $d = 4$, the resultant block-fault probability $P'_B = 10^{-7}$, i.e. on a transmission path with any amount of interference, a maximum of one spurious signal can occur in 10^7 telegrams. All other faulty telegrams are identified as incorrect and indicated.

Permissible character distortion

The permissible character distortion for a pulse ratio of 1 : 3 is theoretically 50% and for a ratio of 1 : 4 approximately 60% relative to a short character. Characters with a distortion of up to 20% are evaluated as correctly transmitted characters in the demodulator.

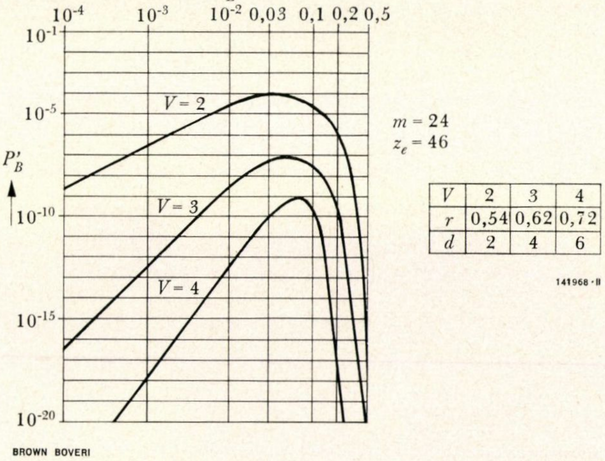


Fig. 3. – Block-fault probability P'_B and bit-fault probability P_E in a step-synchronized telecontrol system with matrix check

The step-length ratio V is the parameter

V	2	3	4
d	2	4	6

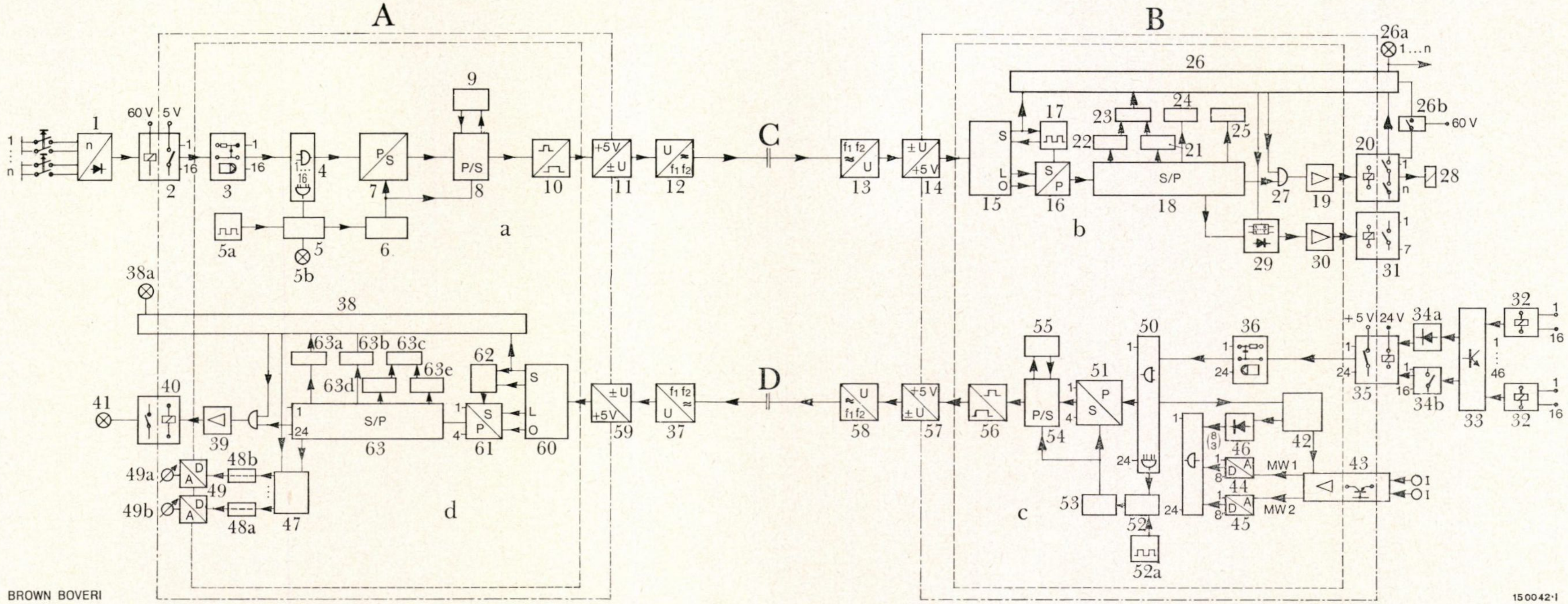


Fig. 4. – The principle of information transmission in the ZM 30 telecontrol system

A = Central control
B = Substation
C = Command direction
D = Indication direction

a = Command transmitter
b = Command receiver
c = Indication transmitter
d = Indication receiver

Items 1 to 49a and b are described in the text, the rest are:

50 = Input logic
51 = Line formation (6×4 bits)
52 = Group for $\binom{8}{3}$ check
52a = Timing pulse
53 = Start check
54 = Control unit (information and data security)
55 = Data security (line and column)
56 = Signal modulation
57 = Channel matching
58 = WT transmitter
58a = WT receiver
59 = Channel matching
60 = Signal demodulator
S = Start signal
0, 1 = Binary signs
61 = Series/parallel converter (4 bits)
62 = Timing pulse
63 = Control unit (line and column)
63a = Synchronous end
63b = $\binom{n}{m}$ check
63c = *pc* comparison
63d = *pc* formation
63e = *pc* reception

Modulation rate and transmission times

The modulation rate of the Indactic ZM 30 system can be selected between 50 and 600 Bd (1 Baud = the unit of modulation rate). The transmission time depends on the selected code, the ratio V, the modulation rate and therefore also on the bandwidth of the available or required transmission channel. The average transmission time for one command telegram at 200 Bd modulation rate and a ratio of $V = 3$ is 300 ms. The corresponding value for transmitting an indication or measured-value telegram is about 370 ms.

Error correction

Transmission errors in the Indactic ZM 30 system can be corrected by one or more repetitions of the transmission sequence. This is, of course, assuming that the receiver indicates a fault after recognizing it and requests a repetition of the defective transmission process by means of an acknowledgement signal. The repetition can be initiated manually. Simple additional equipment, however, enables a predetermined number of repetitions to be carried out automatically. With automatic repetition, a visual or acoustic warning is not given until the full sequence of repetitions has been carried out and this has not led to a successful transmission.

Information Conversion

Command direction

The principle of information conversion for both indication and command directions is shown in Fig. 4. The commands fed in through a double-contact keyboard are encoded in matrixes 1 $\binom{8}{2}$ and $\binom{7}{2}$ and fed into the relay store z. This is where the potential isolation between the current supply equipment of the external plant and the system voltage for the electronic equipment is carried out. The information (16 bits) present in parallel is fed into the electronic part of the remote control system by means of the potential-free contacts of the intermediate relay store through suppression filters and signal forming stages 3. A static energizing circuit 4 starts the code tester 5 which checks the group code $\binom{8}{2}$ and individual character code $\binom{7}{2}$.

If the test result is correct, the starting check 6 is initiated and the conversion of the 16 characters present in parallel into four groups of four in the line former 7 is carried out. The data are secured 9 and the parallel/series conversion is carried out in the control unit and parallel/series converter 8, respectively, according to Fig. 2b. The check character is stored in between, along the line as far as the end of the telegram and attached to the 16 information bits in the form of a block. The information is in the form of a series of bits at the input of the character modulator 10 and is converted into length-modulated characters. The length-modulated pulse telegram arrives at the a.c. telegraphy channel through the stage "channel matching 11". The channel matching is designed for all standard channel inputs with single and two-current control.

The use of an a.c. telegraphy channel according to the frequency-keying principle enables the length modulated pulse telegram to be frequency-modulated in the a.c. telegraphy transmitter 12 and transmitted along the transmission path to the substation. On arrival the frequency-modulated telegram is converted into a pulse telegram by the a.c. telegraphy receiver 13. The channel adaptation 14 with potential isolation converts the pulse telegram into the system voltage of the electronic part at the receiving end. A digital character demodulator 15 employing IC evaluates the short pulses and short pauses as binary 0 and the long pulses and long pauses as binary 1 after the start signal has been received. Superposed interference can only cause a wrong character 5 to be received if the energy content of the fault equals 27% of the energy content of an unaltered character.

The adjacent series/parallel converter 16 converts the information in blocks of four bits each. The timer, running at 80 times the transmission frequency, provides the timing pulses which are synchronized with the reference character changes in the character demodulator and the parallel/series converter. The information contained in the groups of four is converted into 16 bits in parallel in the subsequent control unit 18 and passed through the amplifier 19 to the relay output store 20. In the same manner as at the transmission end, the matrix check characters for line and column are formed for the information arriving and stored in between while the information is being converted. These newly formed check characters 21 can now be compared in the coincidence circuit 23 to the check characters 26 transmitted with the telegram. At the same time a dynamic check is made in the code checker 24, to establish whether the $\binom{n}{m}$ code $\binom{8}{2}$ + $\binom{7}{2}$ and the synchronous end check 25 (number of characters) are complied with in the telegram. All told, the following check conditions: start, matrix comparison, $\binom{n}{m}$ check and synchronous running must be complied with. If any one of these conditions is not fulfilled the information is prevented (27) from being passed on to the relay store. In this case a fault is indicated and transmitted to the central control as "telegram fault".

The relay and output store 20 ensures potential isolation and carries out storage and decoding of the information. An output relay 28 is tripped only if the $\binom{n}{1}$ check has established that a single output relay shall be switched in the switching circuit. This check prevents any faults occurring in the relay output section or in the circuitry from passing on a fault.

The relay output time can be selected in the short time range of 0·1 to 1 s or in the long time range of 1 to 10 s, which enables free choice of connection of each output relay to one of these two time tracks. Additional timing elements enable the pulse times of the command issue to be suited to the characteristic operating times of the controlled equipment in addition to the selected time range. Continuous command issue is an exception to the above. Each $\binom{8}{2}$ group enables seven continuous commands to be transmitted independently of each other in a telegram. In this case, the push-button input time corresponds to the relay output time because the telegram sequence is issued by the command generator. The receiver recognizes these by the special sign (bit 11, Fig. 2a) and switches the individual electronic store 29 to the appropriate group decoder. The continuous commands are issued to the continuous command relay through amplifier 30.

Indication direction

In principle, the indication direction operates in the same fashion as the command direction. The differences are in the length of the transmitted telegrams, the group coding $\binom{8}{3}$, the individual character code (as desired) and the type of information transmitted, i.e. instantaneous indications and measured values.

The indications are in groups of 16 in the $\binom{8}{3}$ group code. An electronic priority component is allocated to each group of relays for each group of indications. If all priority components 33 are interconnected in a circuit, the priority for several indications arriving simultaneously is determined by the nature of the circuit. On instantaneous arrival of indications, the indication groups are notified and the indication pick-ups are stored according to the group. After priority has been established, the group with the highest priority is switched through the group code 34 together with the 16 individual characters to the intermediate indication store 35, where the potential isolation is carried out. A total of 24 information bits are passed in parallel through the suppression filter and signal forming stage 36 into the electronic equipment, the data checked and converted into a length-modulated pulse telegram which is transmitted along the channel in the direction of the receiver. At the receiver end starting signal, matrix, $\binom{n}{m}$ and synchronous checks are carried out and they are passed to the switching amplifier 39 and thence to the signal output relay with decoder 40. The measured values are transmitted in a cycle which is subordinate to the indication process. On the arrival of indications, the measured value cycle is interrupted for the duration of the indication transmission. At a command from the central control, a measured value can be selected, i.e. a selective transmission of two measured values can be transmitted independently of the cycle.

Two measured values of eight bits each are contained in a binary code telegram. The corresponding measured value group 42 is switched on by the electronic equipment and the measured values are passed to a matching amplifier 43 through a fully electric measuring position selector switch to the two converters 44 and 45 and are to be encoded at a maximum of 40 ms after the up/down integration process.

The 16 bits of the two measured values, present in parallel, are transmitted to the control centre together with the corresponding group of measured

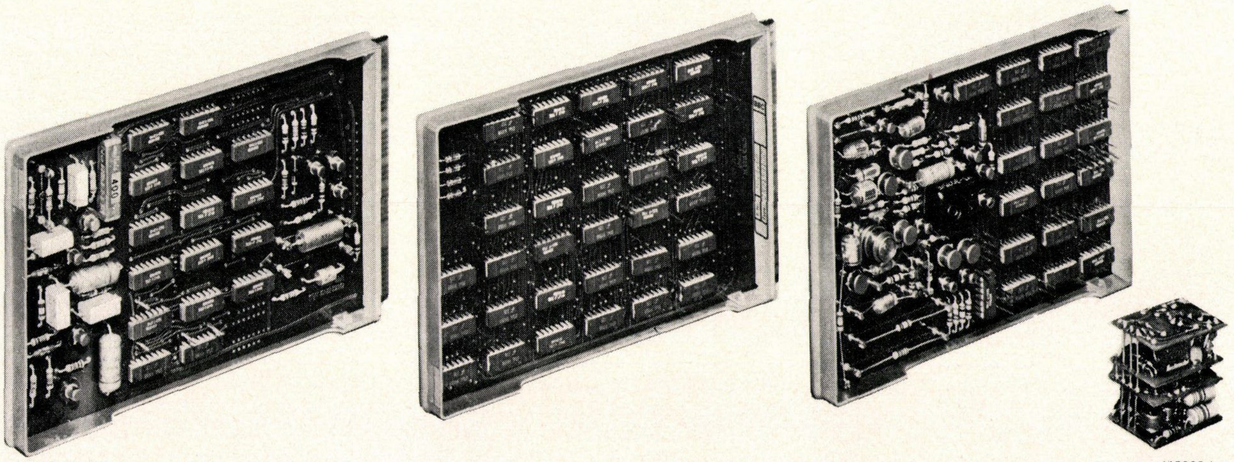


Fig. 5. – Electronic equipment of the ZM30 telecontrol system with integrated digital and analogue circuits, priority component and analogue-to-digital converter

values 46 in a telegram. They are passed to the measured value group decoder 47, thence to the intermediate measured value store 48 and digital-to-analogue converter 49 and displayed in the form of analogue values on the display instruments 49a and b. Either digital or analogue measured value stores can be employed at the receiving end.

Design Features

The Indactic ZM30 remote control system has an electronic part for information processing and checking. A primarily electro-mechanical supplementary section contains functional groups which are essential for matching the remote control system to the equipment to be controlled. A high degree of adaptability has been achieved because the electronics require no modification.

The components were selected with regard to technical suitability and with an eye to the future. Telecommunication relays are employed for input and storage of individual indications and these also provide potential isolation. They also enable the pick-up criteria to be determined, they are seldom tripped and operate slowly. The function conversion part (rapid switching, high accuracy, no wear and tear) uses semiconductors exclusively. This electronic equipment comprises essentially integrated circuits in the form of diode and transistor logic circuits. Integrated circuit techniques, where several transistors, diodes and resistors are combined to form a complex circuit, have the advantages of being very reliable, occupying minimum space, consuming very little power, being unaffected by temperature fluctuations and are not likely to be superseded for some considerable time to come.

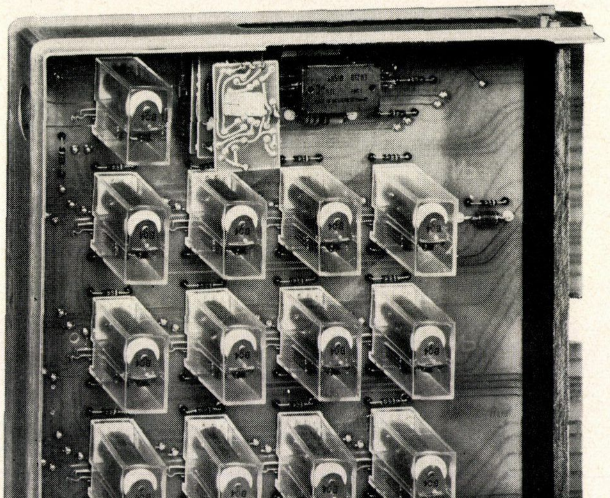
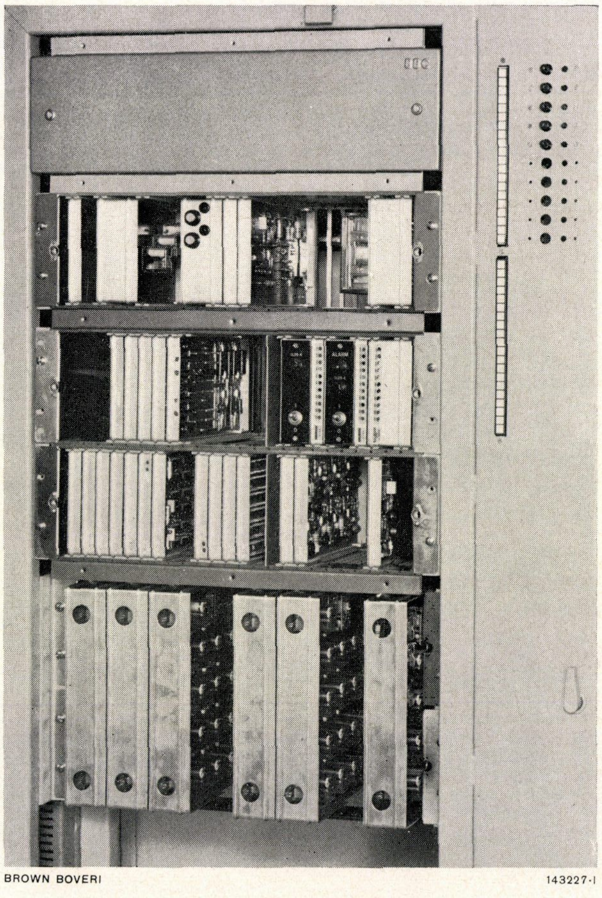


Fig. 6. – Plug-in relays with electronic priority component

The circuits, together with the electronic components, are mounted on printed circuit boards and arranged according to their functional group. The analogue part of the measured value transmission is equipped with integrated analogue amplifiers. In the analogue-to-digital converter in Fig. 5, one printed circuit board contains the analogue part with integrated analogue amplifiers and also the digital part with integrated circuits.

The Indactic ZM 30 is in two separate parts. The information processing part is separated from the input and output section in such a manner that the screening, bushing capacitors and input filters eliminate any inductive or capacitive interference to the electronics. A total interference suppression of up to 80 dB at 50 MHz has been attained between the site of interference and the information processing part of the equipment. This renders even pulse-type interference with rates of rise in the nanosecond range and voltage peaks of 1·5 kV ineffective. A particularly low-resistance busbar system guarantees the necessary interference immunity for the signal processing part.

The plug-in relays for input and storage of signals are also based on the printed circuit board principle (Fig. 6). These components are mounted on a telecommunication rack or hinged-frame cabinet together with the electronic components and the a.c. telegraphy channel (Fig. 7).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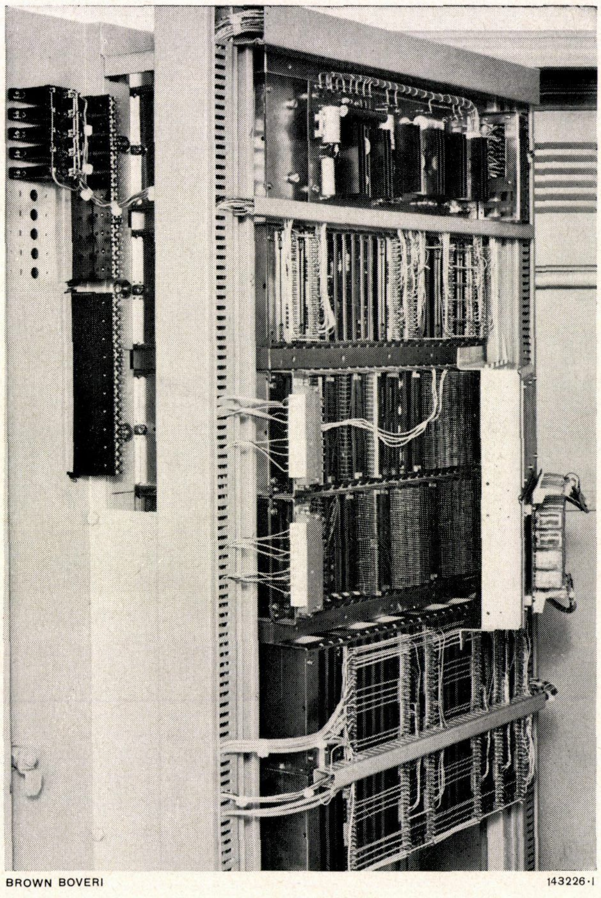
BROWN BOVERI 143226-I

Fig. 7. – Central control of ZM 30 fitted in a cubicle with built-in a.c. telegraphy channel

Left: Front view

Right: Rear view with screening for electronics opened

Current Supply and Supplementary Equipment

The Indactic ZM 30 telecontrol system is designed for battery operation with a voltage tolerance of +10 and —15% at 12, 24, 48, 60 or 110 V. The static d.c. converter is suppressed to VDE 0875.

Cables, power line carrier and radio can all be used as means of communication. The transmission channel of the NSK 2 system with frequency modulation for modulation rates of 50, 100, 200 and 600 Bd is used in several frequency grids. Line and bridging amplifiers and low-frequency hybrids with balancing network are available for realizing all types of transmission networks for point-to-point, line and radial operation.

Portable test transmitters and receivers with adjustable telegram combinations are used for simplifying commissioning and interference elimination.

The most important test signals for limiting faults are connected to a terminal strip for printed circuit boards and indicated with the aid of a tester.

(AH)

G. GERNER
M. VON ROON

NEW COMPONENTS FOR INDACTIC® FREQUENCY AND FREQUENCY/TIME MULTIPLEX TELECONTROL SYSTEMS

621.398:621.38.049

New components have been produced for the Indactic® series of frequency and frequency/time multiplex telecontrol systems. They are essentially intended for use in the power distribution field and for remote control tasks in industrial applications. The basic systems are described in detail and the equipment for information collection, processing and transmission is illustrated.

Basic Systems

INFORMATION can be transmitted for remote control purposes by means of frequency multiplex, time multiplex and mixed systems. They enable central control of widely dispersed points of operation in power distribution systems and remote control of production operations and sequences. Frequency multiplex systems are used mainly in small remote control installations whereas frequency/time systems are usually employed in medium sized plant. Time multiplex systems, on the other hand, are nearly always used in medium and large remote control applications. The information to be transmitted comprises commands, signals or measured or counted values which are characteristic of power supply, traffic and industrial remote control systems as well as in the distribution of gas, oil and water. In order to accomplish this, the transmission equipment must be augmented by a series of devices for collecting and processing the information. These must be capable of operating in analogue, digital or mixed fashion, regardless of the manner in which the information is transmitted.

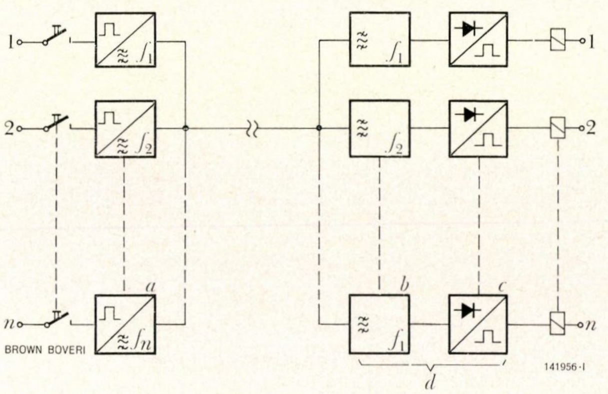

Fig. 1. – Simple transmission of n information signals with a to n audio frequencies along a line

Explanation in text.

Non-Coded Transmission

The simplest version of a frequency multiplex system is shown in Fig. 1. In this case a push-button controlled audio-frequency generator 1 is used for allocating a specific frequency to each binary character (1 to *n*).

All audio frequencies are transmitted along a line to the receiver end where they are received by selective audio-frequency receivers *d* and converted back into binary characters.

The audio-frequency receivers comprise the filters *b* which are tuned to the appropriate frequency, the general section for rectifying the audio-frequency voltages and the flip-flop unit with the switching amplifier *c* for energizing relays. In this non-coded parallel transmission, the command issuing time corresponds to the input time (push-button selection), delayed by the filter action time and by the relay tripping time. The information can be transmitted in a relatively short time but a large bandwidth is required. The system is designed for 25 transmission channels on the CCITT frequency grid with 120 Hz between each channel commencing at 420 Hz and with a modulation rate of 30 Baud. It can be used on all the usual transmission paths with a channel bandwidth of 300 Hz to 3·4 kHz.

Coded Transmission

In this type of transmission (Fig. 2), each binary signal is allocated a combination of audio frequencies which correspond to the code in use. The information (1 to *n*) is coded in encoder *b*, the corresponding code combination is switched to the audio-frequency generator *c*, transmitted to the receivers *d* at the receiving end and passed through decoder *e* to the output relays *f*. This method of transmission permits only one set of information to be transmitted at a time. It is a typical frequency/time multiplex system. The most common codes used in this system are the checkable $\binom{n}{m}$ code or the uncheckable binary code (1, 2, 4, 8).

Security of Transmission

Transmission security is ensured in these systems by employing either checkable codes $\binom{n}{m}$ or binary codes with a check character (in addition to using even numbers). Other possibilities include dual transmission (true and inverse) or time tolerance detectors for analogue purposes. The original information content can therefore not be corrupted due to faulty conversion or faulty transmission.

A Hamming distance of $d = 2$ is adequate for many applications. This means that only after a double fault can false information be passed on by a new meaningful code combination. The Hamming distance of an $\binom{n}{m}$ code can be increased from $d = 2$ to $d = 4$, etc., by selecting some of the possible code combinations.

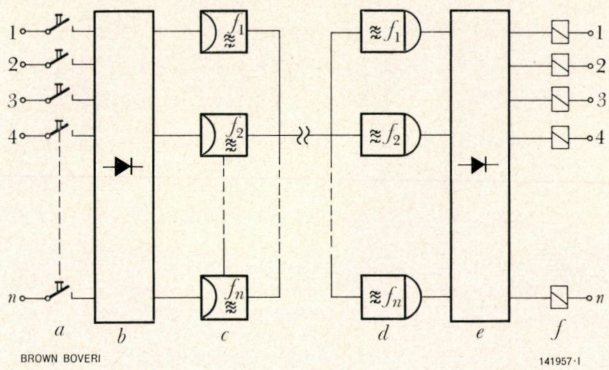

Fig. 2. – Coded information transmission with n audio frequencies along a line

Explanation in text.

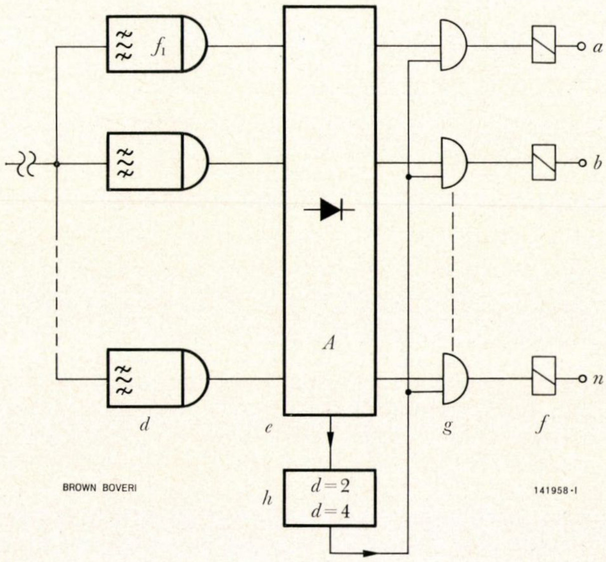

Fig. 3. – Principle of code checking with frequency multiplex and frequency/time multiplex systems

Explanation in text.

In this security process which operates on the digital principle (Fig. 3) a code checker *h* is connected to the receiver end of the decoder *e*. The information is checked (within the selected Hamming distance) and released through output *g* to the output circuit *f*. In addition to this data security system, each audio-frequency receiver can be fitted with a time delay (0 to 1 s) which allows short-time interferences, which can be caused by external effects on the transmission lines, to be separated from the information and rendered harmless.

Transmitting Measured Values

Measured values can be transmitted by analogue or digital means. The analogue process is less costly although the accuracy class is limited to about 2%. For this reason it is usually used in small and medium sized systems. In this case the transmission is carried out on the pulse frequency principle where each measured value is allocated a transmission channel.

The principle of the pulse frequency process is illustrated in Fig. 4. The output signals of units *b* to *e* are shown beneath.

Source *a* provides a measuring voltage or an impressed measuring current. A voltage/frequency or current/frequency converter *b* makes an analogue conversion of the current into a pulse frequency so that 0% of the measured value corresponds to 5 Hz and 100% corresponds to 15 Hz. This pulse frequency is scanned by the audio-frequency generator *c* whose shrouding transmission signal corresponds to the pulse frequency. The audio-frequency receiver *d* emits the pulse frequency in the form of a binary signal and the frequency/voltage or frequency/current converter *e* converts the pulse frequency back into an analogue measured value; *f* is the indicator instrument.

Additional Components for Audio-Frequency Transmission

In order to exchange information in both directions between the control room and the substations of a remote control network, certain additional equipment is required apart from the actual channel equipment, including:

- damping elements at the transmission end for setting the permissible total level which is dependent upon the transmission path
- matched transformers with balancing network for two-line operation
- bridging amplifiers for high impedance branching of stations operating on a party line system
- final and intermediate amplifiers in high-attenuation transmission paths.

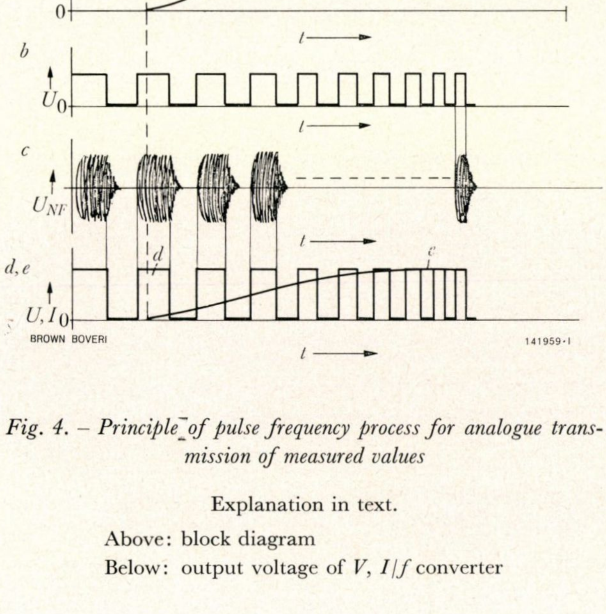

Fig. 4. – Principle of pulse frequency process for analogue transmission of measured values

Explanation in text.

Above: block diagram

Below: output voltage of *V, I/f* converter

Components Available

Particular attention was given to versatility during the development of the components.

All components are designed for a supply voltage range of 11·4 to 31·2 V and are available for positive or negative supply. Their electrical design is such that they are compatible with all other devices in the Brown Boveri electronic system. The frequency-dependent devices are interchangeable and permit free selection and planning of frequencies independent of the devices within the CCITT grid.

The design principles of the Brown Boveri electronic system have been applied here. The basic modules are 3E printed circuit boards which are two divisions wide.

Audio-frequency Generator XT 343

The XT 343 is an amplitude-scanned (AM-WT) transmitter (Fig. 5) and comprises an oscillator, output circuit and switching stage. If a 1-signal is fed into input *e*, the oscillator emits an audio-frequency signal from the output. Appropriate selection of components which determine the frequency ensures that the frequency deviation due to temperature change and ageing can be disregarded. The audio-frequency voltage is decoupled by a series resonant circuit which is tuned to the operating frequency. This enables all generators to be operated in parallel on one line at the output end.

Setting the operating point of the oscillator with a Zener diode gives an almost constant output level

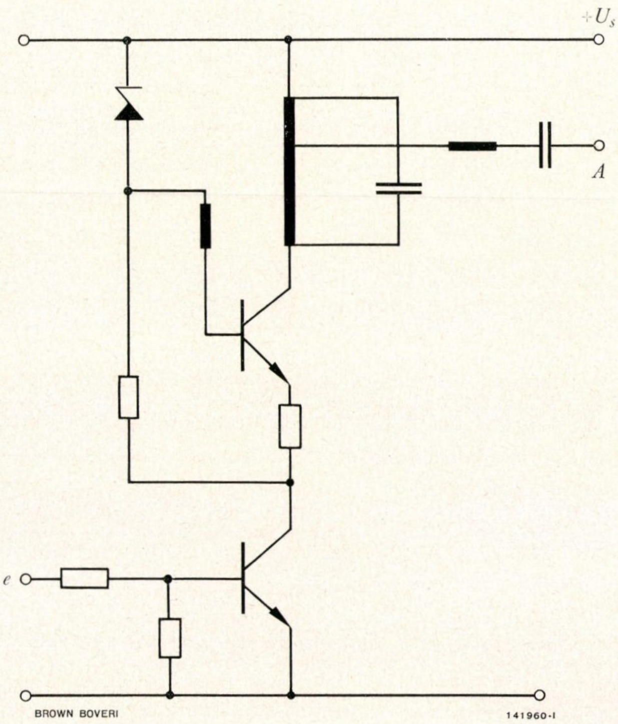

Fig. 5. – Audio-frequency transmitter XT 343 basic circuit diagram

(0 N corresponds to 775 mV at 600 Ω) over the whole supply voltage range.

The transmitter arrangement is shown in Fig. 6. The chassis can accommodate equipment for three generator functions so that generators can be assembled as desired for the available frequencies. A device for a single generator function is shown in the foreground of Fig. 6.

When operating on public telecommunication lines the total level on entering the line must not exceed a predetermined limit. An attenuator is fitted between the generators and the line and its circuitry is appropriate for the number of generators in use.

Audio-frequency Evaluator XT 344

The evaluator is an AM-WT receiver. Its principle is shown in Fig. 7. Basically it comprises an input filter 1, preamplifier 2, demodulator 3 and two final stages 5.

The audio-frequency input filter 1, which is tuned to the appropriate rated frequency, selectively receives the signal voltage from the mixture of frequencies transmitted. The receiver filter is designed for an input resistance of 600 Ω and arranged in such a manner that it is possible to connect it in parallel for all rated frequencies.

The audio-frequency amplifier 2 allows a lower receiver input level ($U_{e\,max} = 25$ mV) for a signal change at the output of the device. Under normal operating circumstances the pick-up threshold of the receiver is set at 250 mV with secure issue of a binary 1-signal at output A. The subsequent rectifier stage 3 develops a direct voltage from the low-frequency signal and this voltage triggers the standard final stage 5 of the Si series of the Brown Boveri electronic system. This final stage is part of the basic equipment of the receiver.

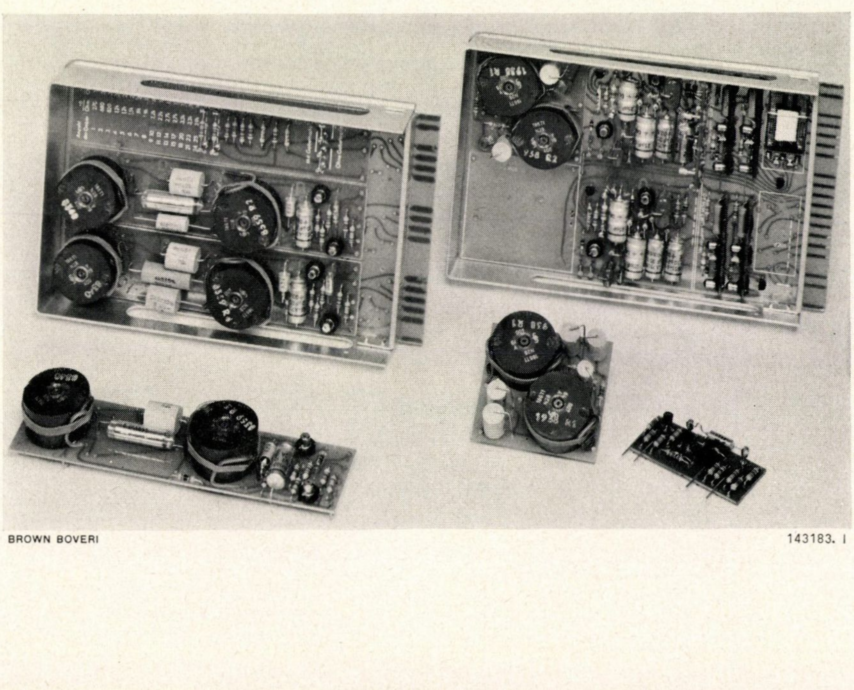

Fig. 6. – Audio-frequency transmitter XT 343 (left), audio-frequency evaluator XT 344 (right) of Indactic FM 10 and FZM 10 remote control systems

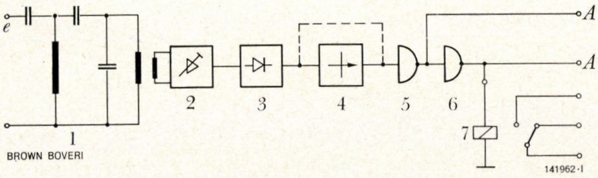

Fig. 7. – Audio-frequency evaluator XT 344 block diagram

Explanation in text.

A time-delay circuit and a relay can be fitted to complement the basic equipment. The delay circuit permits operation with a great deal of interference on the line. The delay can be set at up to 1 s. The contact end of the relay is designed for triggering contactors with voltages up to 200 V.

Voltage (Current)/Frequency Converter UT 399
Frequency/Voltage (Current) Converter UT 340

The *V/f* converter makes analogue conversion of the measuring voltage into a pulse frequency. An impressed current, which is proportional to the voltages to be measured, is fed to the converter and charges a capacitor. If the voltage at the capacitor reaches a preset limit, a transistor is switched in parallel and discharges the capacitor. The short signal thus created is converted by a bistable stage into rectangular pulses which usually trigger a transmitter.

As the rectangular pulses pass through zero at the reception end, rectangular signals of constant length are formed at the output of the evaluator. The output voltage or the impressed output current is derived from the formation of average values of the blocks with an integrated direct-voltage amplifier. Taking into account all sources of distortion on the line the transmission error is smaller than 2%.

Audio-frequency Amplifier UT 346

Transmission over very long distances very often requires intermediate and final amplification of the signal. The low-frequency amplifier can amplify by up to 100 times and the amplification can be adjusted by an input divider and a fine-adjustment potentiometer. The output resistance is 600 Ω and is suited to the audio-frequency evaluators XT 344.

Bridging amplifiers are an exception to this. When used along a line, audio-frequency signals are coupled in and out at high resistance at several points along the line without noticeably affecting the impedance conditions. The amplifier has an input resistance of 10 kΩ. An output resistance of 10 kΩ can be attained by fitting an additional resistor.

Hybrid Circuit with Balancing Network Q3AE

The hybrid circuit enables decoupling of transmission and reception in two-wire systems. There is space available for a balancing network which simulates the line according to Hoyt.

Attenuation Equalizer

The attenuation equalizer equalizes the attenuation in the transmission line. It is only necessary if the adjustment of the evaluator is not adequate.

Special Accessories

Standard equipment is available for encoding, decoding, $\binom{n}{m}$ code checking and binary code. Other encoding and decoding can be achieved by means of printed circuit boards.

(AH)

G. Gerner
L. Schollenberger

DATA LOGGING IN SHIPS

681.3.07: 629.12

Three items of the Brown Boveri electronic system are discussed in relation to the requirements of merchant shipping. In addition to the widely used central alarm system, particular attention is paid to the data logger and manoeuvre-recording system, their planning, system structure and performance in service.

Introduction

FOR several years, Brown Boveri have been engaged in developing equipment for logging, transmitting and processing data. The nature of the incentives to employ such equipment in ships may be sociological, legal, technical and, particularly, economic. One factor or another takes precedence, depending on the country of origin.

Because of the many months at a time which have to be spent tied to one's job, it is becoming increasingly difficult to find qualified officers and crew. The rules of the merchant seamen's unions and the legal requirements of many countries contribute to the fact that shipowners are transferring more and more duties on their ships to automatic data-logging and supervisory systems.

The basic requirements spring from the fact that marine installations are exposed to much more arduous conditions, the chief ones being vibration, shock and the climate. As well as being extremely reliable and simple to operate, the equipment must require the minimum of maintenance, and in most cases one cannot assume the presence of trained personnel.

In solving these problems, Brown Boveri have been able to make use of many years' experience in the fields of marine generators, switchgear, various auxiliary equipment and the turbocharger.

The more specific requirements are discussed briefly below.

If the machinery and equipment in ships are still to be functioning reliably after several years' continuous operation under extreme conditions, they must be monitored. Alarm signals must be given optically and acoustically at some central point. The alarm devices must also allow connections to be made to secondary points, such as the bridge, the galley and various cabins. Local sensors are in the form of limit monitors, usually thermostats and rheostats [1]. The sensors at the point of measurements are generally accompanied by direct indicating instruments.

Central supervision by means of limit monitor switches is frequently no longer sufficient to ensure optimum control of the larger systems. The value of the measured quantity must also be displayed centrally in analogue or digital form, particularly in order to recognize possible failures as early as possible. These values are detected by continuous signal transducers, e.g. thermocouples, resistance elements, strain gauges, and others. In these cases there is no need for local instruments, except at a few essential points. A printer which logs abnormal values can be used here, both to identify the source of the alarm and to help in later reconstructing a fault.

An average of between 50 and 100 measurements need to be taken in the engine room for the main and auxiliary drives (e.g. ship's generators, refrigeration compressors, pumps, etc.). The number will be greater in the case of ships with partly unmanned engine rooms. As well as monitoring of the engines and other machinery, some kinds of freight, too, need to be checked continuously. In medium to large refrigerated ships, for example, a hundred or more values for temperatures, humidity, gas content of the atmosphere, etc. have to be measured, recorded and monitored for the refrigerated cargo alone.

All ship-borne measuring and monitoring devices must meet the requirements of the classification societies. Some countries also require that an engine log should be kept in which between 20 and 40 entries have to be made each shift. These are principally data on the main propulsion unit, whether diesel engine or steam turbine.

The shipping authorities require that a manoeuvre book should be kept (in addition to the engine-room logs) in which the telegraph commands from the bridge to the engine room have to be recorded, together with the date and time. The introduction of means of automatically recording manoeuvres presented the opportunity of extending the number of items of information to the strip chart records which are replacing the handwritten manoeuvre book.

Consequently, in many cases the propeller speed is recorded, and in some instances the issuing of commands and their acknowledgment and execution are also registered.

Planning and System Structure

In addition to the alarm system referred to earlier [1], Brown Boveri have developed a versatile data-logging and monitoring system for marine use, known as the DP 260, which employs integrated circuits. This is accompanied by a manoeuvre-recording system, also built with integrated circuits.

To draw the full benefit of a data-logging and monitoring system it is essential that, right from the planning stage, there is close collaboration between the ship-owner, the shipbuilder and the suppliers of the main propulsion unit and the automatic equipment. The use of data loggers not only leads to better working conditions but also allows a reduction in the ship's complement. It is not unusual for a charter to be won on the strength of the technical and operational gear on board.

The essential parts of a data-logging and monitoring system are:

- transducers
- wiring and cable installation
- the central data logger
- operating controls, and
- output units

The transducers must be chosen according to the permitted error of measurement, their location and the ambient conditions. All kinds of sensors with an electrical output signal and suitable for marine service can be connected direct to the data logger, without the need for external adapter elements. Power for passive transducers is supplied from the data logger. The amount of wiring and cables depends on the number and location of measuring points throughout the ship. In many cases a neatly laid out and inexpensive installation can be achieved by fitting separate connection boxes in appropriate places. All the cables used are of marine quality or equivalent. The connections are unaffected by vibration and corrosion.

The DP 260 Data Logger and its Operating Controls

The purpose of the data logger is to gather readings from a large number of widely distributed transducers to a central point. The measured values are converted to numerical form, in some cases checked to ensure that set tolerances have not been exceeded, and then recorded and displayed.

System Structure

As can be seen from Fig. 1, the DP 260 system consists of a multiplexer (2), a central unit with control panel (3) and the output channels (4). The latter form the link between the recording and display instruments (5) and the central unit (3).

The multiplexer is in principle a multi-stage selector switch which connects the lines from the analogue measuring devices (1) to the measuring amplifier (*C*). The measurements gathered in this way are either direct currents or direct voltages generated by appropriate measuring elements or signal converters outside the data logger. An analogue-digital converter (*D*) converts the analogue signal to a digital value which is then passed to the central unit for further processing. Digital readings, arriving on a multiplicity of lines in the form of yes/no signals, are fed direct to the central unit via electronic gate circuits (*B*) and a selector switch (*E*).

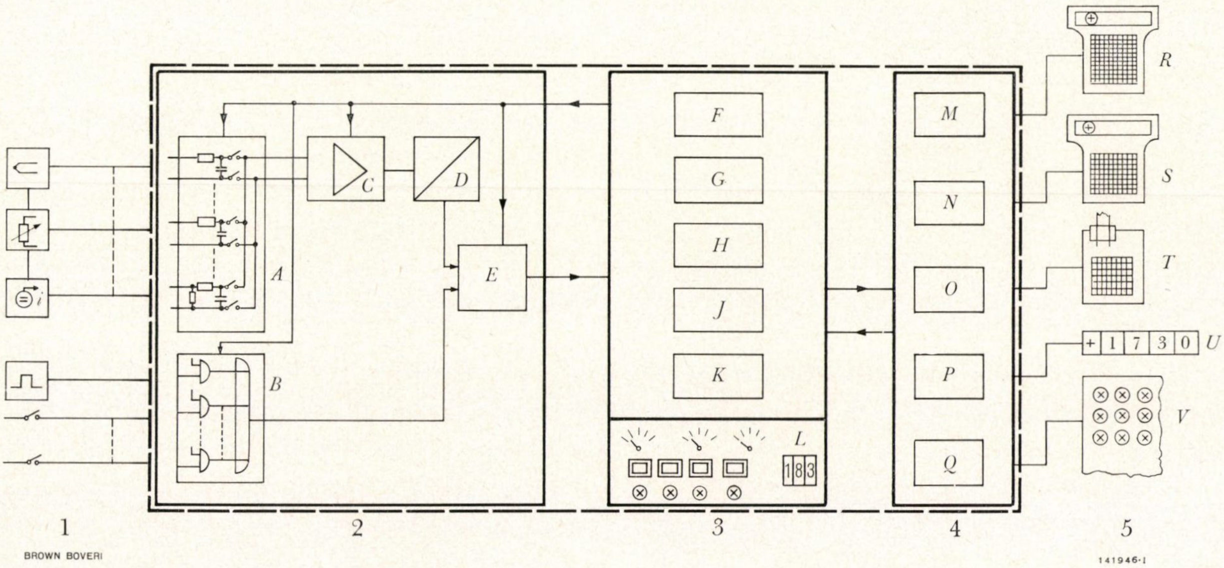

Fig. 1. – Block diagram of the DP 260 data logger

1 = Measuring pick-up
2 = Multiplexer
3 = Central unit and control panel
4 = Output channels
5 = Output units
A = Input filter and scanning relay
B = Digital scanning
C = Measuring amplifier
D = Analogue-digital converter
E = Selector switch
F = Electronic clock
G = Control unit and address counter
H = Programme store
J = Limit-value store
K = Limit-value comparison
L = Control panel
M–Q = Output channels
R, S = Typewriters
T = Printer
U = Digital display
V = Alarm indication

The central unit contains the central electronic control system. This controls the sequence and timing with which the readings are scanned, amplified and converted to digital form. It also generates the operating commands for the indicating and recording instruments.

The central unit also includes the limit-value comparison unit (*K*) and an electronic clock (*F*) which supplies the time and date and also initiates the scanning cycles at regular intervals.

Finally, the central unit contains permanent stores (*H* and *J*) which provide the data for scanning, processing and monitoring the measured values.

The control panel (*L*) has various operating controls and displays for the data logger.

In a fully extended system, the output units (5) together with their associated output channels (4) might include two logging typewriters (*R*, *S*), a fault-value printer or typewriter (*T*), digital display units (*U*) for the number of the measuring point and its reading, and a display panel (*V*) for alarm signals.

The size of the multiplexer depends on the number of connected measuring points. Output channels are provided to suit the number of output units.

The central unit and control panel constitute the basic part of the data logger. The control panel can be installed away from the logger, on a console, for example.

Measurement Input Multiplexer

The DP 260 data logger can interrogate up to 1000 digital or analogue measuring points. Suitable transducers must be provided to ensure that the analogue measured values are available as voltages, impressed currents or resistances. Small direct voltages, especially from thermocouples, resistance elements and resistance bridges, have to be considerably amplified. The multiplexer therefore contains a highly sensitive measuring amplifier with automatically compensated drift.

To interrogate a measuring point, the appropriate number or address of the point is fed from the central unit to the multiplexer.

In the case of analogue signals the address is used to energize a two-pole relay with sealed contacts which is allocated to the measuring point. The relay constitutes part of a relay matrix built up of groups, each with 15 relays.

Fig. 2 shows three of these groups. The two above consist of relays with dry reed contacts, while the bottom one has sealed mercury-wetted contacts for very accurate measurement of small signals. The simple and hermetically sealed construction of sealed dry-reed relays ensures highly reliable interrogation, even with high numbers of operations and under unfavourable ambient conditions.

The groups in Fig. 2 also contain the input circuits *A* indicated in Fig. 1. The purpose of these is to filter the measured signals. They can also match the measured quantities and convert impressed currents into voltages via measuring resistances.

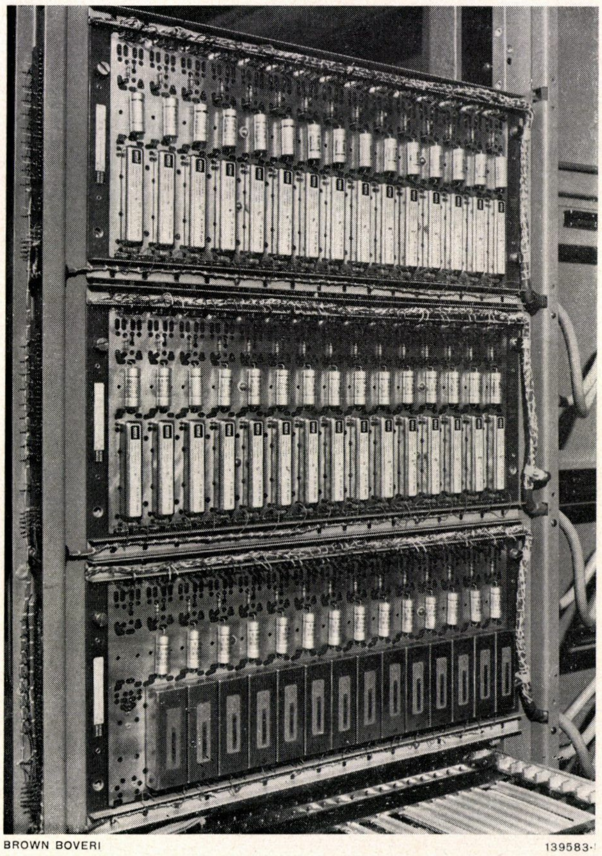

Fig. 2. – DP 260 data logger. Measuring point selector switch

Above: Dry reed relays
Below: Mercury-wetted relays

Having been scanned and prepared, the measured voltages must be brought to a standard level for further processing. This is done in amplifier *C* (Fig. 1), the gain of which is changed according to the input signal and the measuring point. The gain is usually chosen such that the reading is presented in the units of the measured quantity, degrees, for instance. The amplifier and analogue-digital converter are automatically compensated for drift so that even very small voltages of only a few mV can be processed with no zero error.

Once amplified to the standard level, the measured signal is passed to analogue-digital converter *D* (Fig. 1), where it is converted into a four-digit decimal number. The conversion process is in the nature of integration over one cycle of the mains frequency. Interference voltages and short-lived interference pulses are effectively suppressed. The resolution of the measured signal is 1 : 2000.

The relay switching time, the response time of the amplifier, drift compensation and the time required for conversion are such that, with analogue signals, 16–20 points can be interrogated per second. Digital values can be scanned much more quickly, since they can be selected almost instantaneously via electronic gate circuits *B* in Fig. 1. They are fed direct to the central unit via electronic selector switch *E* (Fig. 1), bypassing amplifier *C* and converter *D*.

Central Unit, Programming, Operation

As mentioned above, the central unit either specifies or receives the address of whichever measuring point is being interrogated. It thus controls the scanning cycles and, working on the basis of a priority system, ensures that the cycles are carried out in the desired sequence.

The central unit receives the selected reading from the multiplexer, compares it with the set limits and sends it on, together with an alarm signal if necessary, to the appropriate output unit. These control operations are carried out on the basis of data from a programme store.

As can be seen from Fig. 3, the store is of the permanent type, in the form of a crossbar distributor. It is selected by the control system for a group of

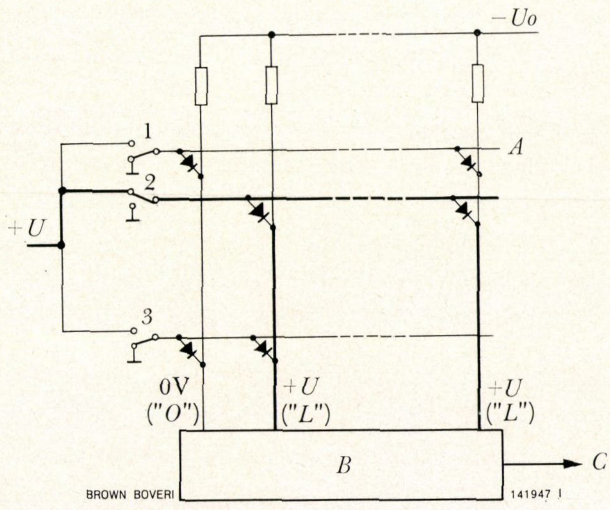

Fig. 3. – Basic circuit of crossbar distributor

A = Plug-in or soldered diodes
B = Evaluation unit
C = Programme instructions
1–3 = Transistor switches for measuring point groups 1–3
"O" = Binary 0
"L" = Binary 1

measuring points processed in the same manner, group 2 in the example of Fig. 3. Line 2 thus contains the instructions for evaluating group 2. These are then passed on in the form of "0" and "1" signals via the vertical column wires to evaluator unit *B*. This unit then forms the appropriate programme commands from the combinations of signals. The signal combination is fixed on the lines by plugging in or soldering diodes. The instructions can be closely matched to the requirements of the installation. The tolerance limits of the measuring points are stored in the same manner.

Fig. 4 shows plug-in storage units with soldered diodes (A) and plug-in diodes (B). Type B is intended principally for storing the tolerance limits, which can easily be adapted to suit the operating conditions. The stores can be extended to accommodate the number of measuring points and their associated limit values. Any application can easily be catered for with the plug-in units shown in Fig. 4. Fig. 5 shows an example of programming for measuring point groups 205–209, which belong to plant section 3. By identifying the part of the installation it is possible to divide the measuring points into groups for forming mea-

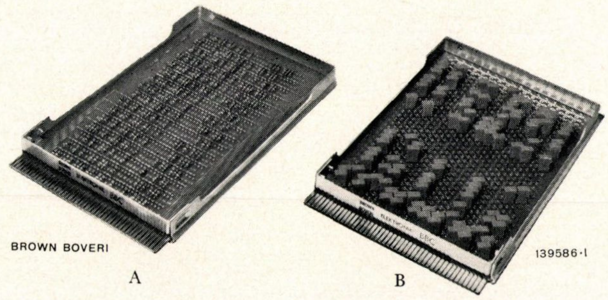

Fig. 4. – Plug-in store units (crossbar distributor)

A = Programme store unit (soldered diodes)
B = Limit-value store unit (plug-in diodes)

suring and recording cycles for which the alarm condition of the measured quantity can be used as an additional criterion. The cycles are started by an electronic clock, because an alarm condition has been established, or manually with push buttons.

It is possible to select each measuring point individually and show the value on the control panel.

The cycles consist of two monitoring cycles which at regular, and short, intervals serve to check that the values from two measuring point groups are within the set limits. An entry is made on the alarm printer when a limit is found to have been exceeded, and also when the value returns within the specified tolerance.

Two other cycles are provided for two output channels, typewriters for example.

Finally, the alarm printer can be used to record the measured values of a system group, the set limit values and those measuring points which are in an alarm condition.

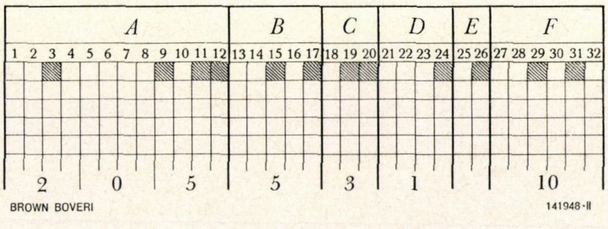

Fig. 5. – Example of programming

A = Number of first measuring point within a block (205)
B = Length of block (5)
C = System groups (3)
D = Measuring-amplifier range (1)
E = Typewriter switching command (line ends)
F = Limit-value address (10)

▧ = Diode present
□ = Diode absent

The central unit includes control devices which monitor operation of the data logger. Reference quantities are used to check the analogue part, and the control sequence is monitored automatically by digital means at regular short intervals. Errors are shown by lights on the control panel.

Output Channels, Output Units

The output units can be used to suit the particular application as shown in the basic circuit diagram (Fig. 1). With the system fully extended there are:

- 2 data output channels with typewriters or tape punches
- 1 alarm printer or typewriter
- digital displays for measured values and limits
- alarms (visual, acoustic and relay contacts)

The output channels are allotted to the appropriate output unit. They take over direct control of the output units by means of electronic control and storage devices.

The typewriters used for logging are of the golf-ball type with a speed of about 15 characters per second. The routine log is usually typed on pre-printed forms.

The alarm printer performs all the recording functions not undertaken by typewriters or tape punches. This is mainly a question of noting alarm signals, in which case the address, measured value, unit and limit value are printed in red. An entry is made when

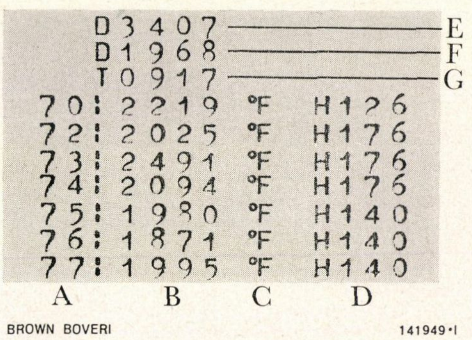

Fig. 6. – Extract from "alarm summary"

A = Measuring point number
B = Measured value
C = Unit
D = Lower limit value
E = Date (day, month)
F = Year
G = Time (hours, minutes)

(The decimal point in the readings is not printed)

the value returns to within its set limits. Other entries are the "alarm summary" (Fig. 6), when all the measuring points in an alarm condition are printed, the "limit setting summary", which is for recording all the specified limits, and the "measured value summary", in which case all the measured values for a plant section are logged.

The numerical displays have already been mentioned in connection with the single-point selection facility. The mimic diagram includes lights corresponding to the monitored measuring points. Detection of an alarm condition is indicated by the appropriate light flashing. Having been acknowledged, the light continues to burn steadily until the alarm condition is cured. Beyond the multiplexer any indication of an alarm condition is available only briefly, namely during interrogation, and the signal therefore has to be retained in "alarm stores" in the interim. These stores form part of the output channels, the quantity provided depending on the number of alarms to be indicated.

Manoeuvre Recorder

As a result of many years' experience of building individually designed manoeuvre-recording systems Brown Boveri have developed a standard unit which, by employing integrated circuits, is inexpensive and takes up little space, and yet contains the optimum amount of information on its log. The equipment consists of a control unit and the manoeuvre printer itself. The engine-room telegraph signals are fed in by a cam-operated switch coupled to the telegraph. The speed transmitter, which functions without contacts and consists of a slotted disc and two pick-up heads, is driven by the propeller shaft or by a control shaft on the propulsion unit, whether diesel engine or turbine. The control unit is connected as a slave clock to the ship's main clock. If the main propulsion unit is operated remotely from the bridge, an auxiliary contact is required on the manual/automatic switch and the emergency manoeuvre switch. Installation is largely a matter of prefabricated, plug-in cable links, and is simple enough for the system to be fitted in ships already in service.

Principle of Operation

The manoeuvre recorder employs a digital printer to provide a clearly arranged log of the telegraph commands and propeller speed, together with the date and time. The time is given in hours and minutes. In addition to the nine telegraph commands (FAh, HAh, SAh, DAh, ST, DAs, SAs, HAs, FAs) other letters indicate whether the propulsion unit was under automatic or manual control, the fact that an emergency manoeuvre had been called for and that a check print-out had been initiated by hand (Fig. 7).

Print-out takes place under the following circumstances.

a. When the telegraph order changes (order print-out) provided that the new order persists for more than 1·5 s. Intermediate settings through which the telegraph passes when the order changes, are disregarded. Order print-outs are in black and have priority. Orders for emergency manoeuvres are printed in red.

b. When the propeller speed changes (acknowledgment print-out). Here one can choose between two possibilities by throwing a toggle switch on the control unit.

   In the "revolutions" position, acknowledgment print-out takes place when the propeller reaches the desired speed as set on decade selector switches. This type of acknowledgment print-out is particularly suitable when cruising.

Date	Time	Order	Speed
20 5 '68	M751	M D Ah	+000
20 5 '68	M752	M D Ah	+032
20 5 '68	M754	M S Ah	+036
20 5 '68	M754	M S Ah	+051
20 5 '68	M755	M H Ah	+055
20 5 '68	M755	M H Ah	+071
20 5 '68	M801	M F Ah	+071
20 5 '68	M802	M F Ah	+100
20 5 '68	M802	R T F Ah	+099
20 5 '68	M802	R D Ah	+106
20 5 '68	M803	R D Ah	+039
20 5 '68	M806	R S Ah	+038
20 5 '68	M806	R S Ah	+050
20 5 '68	M806	R H Ah	+050
20 5 '68	M806	R H Ah	+072
20 5 '68	M817	R F Ah	+074
20 5 '68	M817	R F Ah	+100
20 5 '68	M818	R S T	+102
20 5 '68	M818	R S T	+000
20 5 '68	M818	R H As	+000
20 5 '68	M819	R H As	−070
20 5 '68	M820	R F As	−066
20 5 '68	M821	R F As	−100
20 5 '68	M821	R S T	−092
20 5 '68	M822	R S T	−000
20 5 '68	M822	R E F Ah	−000
20 5 '68	M823	R E F Ah	+102
20 5 '68	A139	R T S T	+000
20 5 '68	A140	R D Ah	+000
20 5 '68	A140	R D Ah	+010
20 5 '68	A140	R D Ah	+021
20 5 '68	A140	R D Ah	+030
20 5 '68	A143	R S Ah	+030
20 5 '68	A143	R S Ah	+040
20 5 '68	A143	R S Ah	+050
20 5 '68	A145	R H Ah	+050
20 5 '68	A145	R H Ah	+061
20 5 '68	A145	R H Ah	+070
20 5 '68	A156	R F Ah	+070
20 5 '68	A156	R F Ah	+080
20 5 '68	A157	R F Ah	+090
20 5 '68	A157	R F Ah	+103
20 5 '68	A158	R S Ah	+097
20 5 '68	A158	R S Ah	+089
20 5 '68	A158	R S Ah	+069
20 5 '68	A158	R S Ah	+070
20 5 '68	A158	R S Ah	+059
20 5 '68	A158	R S Ah	+060
20 5 '68	A158	R H Ah	+059
20 5 '68	A158	R H Ah	+070
20 5 '68	A203	R D Ah	+073
20 5 '68	A203	R D Ah	+058
20 5 '68	A203	R D Ah	+039
20 5 '68	A203	R D Ah	+041

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Fig. 7. – Key to record strip

Date: 20th May 1968
Time: 0751 to 1403 h

M = a.m.
A = p.m.

Type of control: R = Remote control
M = Manual control
T = Check print-out (Test)
E = Emergency manoeuvre
FAh, HAh, SAh, DAh, ST, DAs, SAs, HAs, FAs correspond to telegraph commands

Speed: + = Ahead
— = Astern

At the "10 rpm" position an acknowledgment print-out takes place whenever the "tens" digit of the propeller speed changes. By suitably choosing the switching hysteresis it is possible to prevent speed fluctuations of ± 10 rev/min due to the motion of the sea from causing repeated recordings. This type of acknowledgment print-out is intended particularly for manoeuvring, when a new telegraph order is often given before the speed corresponding to the previous order has been reached.

The propeller speed is recorded exactly to the nearest ± 1 rev/min. The maximum speed which can be handled is 199 rev/min. Acknowledgment print-outs are in red.

c. Manual start (check print-out)

A check print-out, in black and identified by the letter T (test), is started by pressing the check button on the printer. The current telegraph order and propeller speed at that moment are printed together with the date and time.

Each print-out includes the date and time in hours and minutes. The date is moved on each day by hand.

Function of Control System (Fig. 8)

To ensure effective suppression of interference, the control unit, printer and speed transmitter are connected via the armour of the marine cables to a single Faraday cage which is earthed only to the control unit. The contact inputs of the emergency and manual/auto switches and the speed transmitter are decoupled via relays. These are outside the Faraday cage. The input signal lines are led to the input units via bushing-type capacitors. The input units consist of a signal-range indicator (Schmitt trigger) and a filter.

The speed of the propeller shaft is measured by means of a slotted disc and two initiators. The rotation discriminator derives the sense of rotation of the shaft from the transmitter pulses, which are shifted by 90° el. The direction is recorded on the log sheet as "+" for ahead and "—" for astern. During measurement the pulses, the frequency of which is proportional to the propeller speed, are counted into the rev. counter connected in series with the direction discriminator. The meter employs Aiken code and can register up to 199 (rev/min).

The signal for starting an acknowledgment print-out can be obtained either from the comparison between actual speed and desired speed, which can be set for each speed by means of decade switches, or from a change in the "tens" of the actual speed. In the first case each request for more or less speed is acknowledged only once, when the desired speed appropriate to the order is attained, or exceeded. In the second case, changes in propeller speed can be read off at shorter intervals from the repeated print-outs.

Telegraph orders are given by the speed transmitter, and a change of order is derived from the brief overlap of the transmitter contacts when a change of speed is made.

The purpose of the control unit is to process the input signals logically. It consists of a shift register which obtains its timing pulse from a 1 kHz crystal-stabilized oscillator. The first of the five control commands sets the rev. counter and time counter to zero, so as to obtain defined initial conditions. The second control command releases the rev. counter. The length of time for which it is released is determined by the measuring time. This is specified by the time counter, which is similarly controlled by the oscillator. The timing pulse of the control unit is blocked during the measuring period, so that control command 3 is not given until the actual speed is stored in the rev. counter. Control commands 3, 4 and 5 initiate the possible ways of starting a print-out. A scan is first made to establish whether a check print-out has been started by operation of the relevant button on the printer. Control command 4 then initiates a print-out if the telegraph order has changed and the delay time of 1·5 s has elapsed. The last control command starts the acknowledgment print-out.

The sequence of control commands 3, 4 and 5 also determines the priorities for starting a print-out. If a print-out is initiated by control command 3 (check print-out), for example, the timing pulse is blocked, so that another command to start cannot be given until the print-out is finished and the control unit has been reset to its initial condition.

Construction of our Marine Electronic Equipment

Both the DP 260 data logger and the manoeuvre recorder are built up from elements of the Brown Boveri electronic system, in which the design and voltage and current levels are standardized. The components are of the plug-in type, and so can easily be checked or replaced. Apart from the power amplifiers, the digital circuitry is composed throughout of monolithic integrated circuits, which ensure exceptional reliability.

As mentioned earlier, the DP 260 data logger is assembled on the modular principle, and can thus

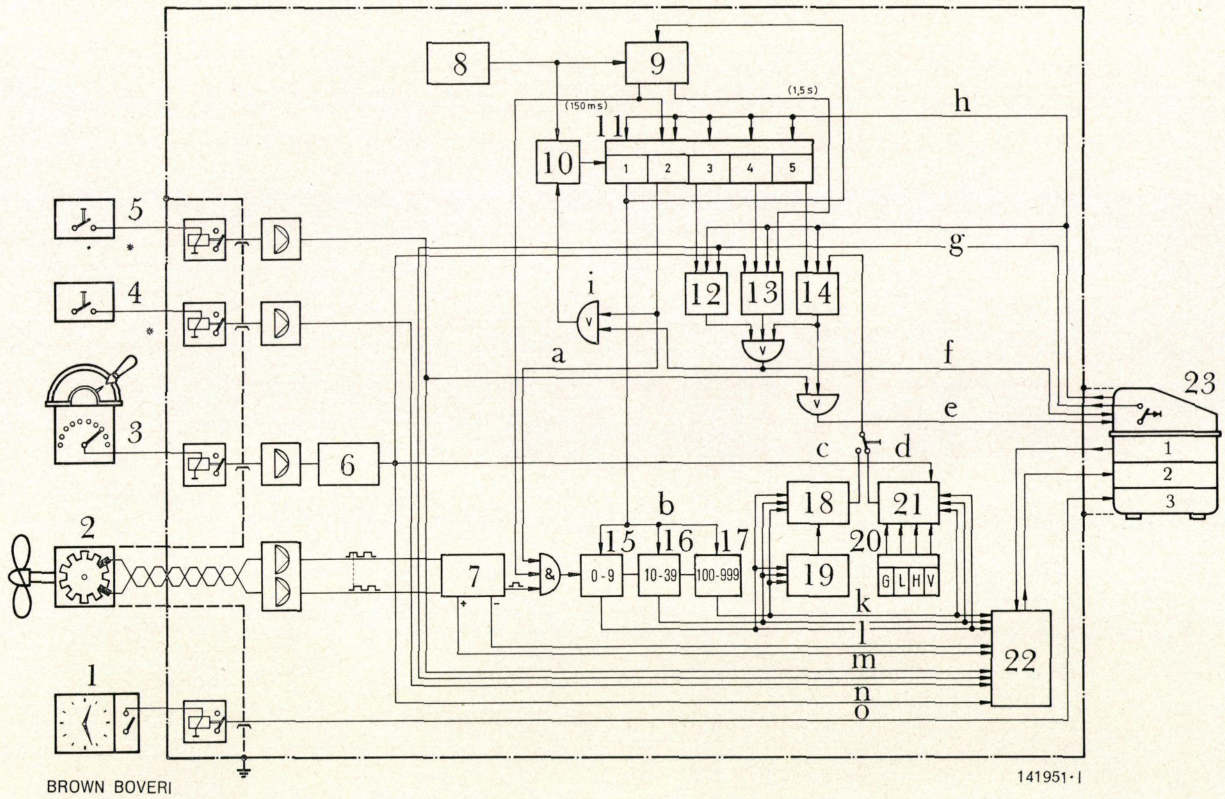

Fig. 8. – Block diagram of ship's manoeuvre recorder

1 = Ship's clock
2 = Shaft speed transmitter
3 = Telegraph command transmitter
4 = Manual/auto } only when main engine
5 = Emergency manoeuvre } is remote controlled
6 = Telegraph command decoder
7 = Direction discriminator
8 = Crystal oscillator
9 = Time counter
10 = Timing pulse release
11 = Shift register, control commands
12 = Check print-out
13 = Order print-out
14 = Acknowledgment print-out
15 =
16 = } Counters
17 =
18 = } Comparator
21 =
19 = Buffer store
20 = Decade switches
22 = Printer: triggering and output amplifier
23 = Printer
 1 Step pulses
 2 Blocking magnets
 3 Date attachment

a = Measurement
b = Zero set
c = Every 10 rev/min
d = Set revolutions
e = Red/black select
f = Print/start
g = Check print-out
h = Print/end
i = Block timing pulse
k = Revolutions
l = Direction
m = Identification letters
n = Telegraph orders
o = Clock time
p = Reset
q = Delay
r = Zero set
t = Measuring time (150 ms)

be built up to suit the type and number of measuring points. The individual plug-in units are mounted in 19″ tiers which are in turn combined into complete frames and fitted in cabinets. All important parts are easily accessible, as the frames are hinged and can be swung out. Fig. 9 shows the central unit with its plug-in units.

The manoeuvre recorder, also built up from the same components, is self-contained and is fitted in a good-looking and conveniently arranged standard housing, as shown in Fig. 10.

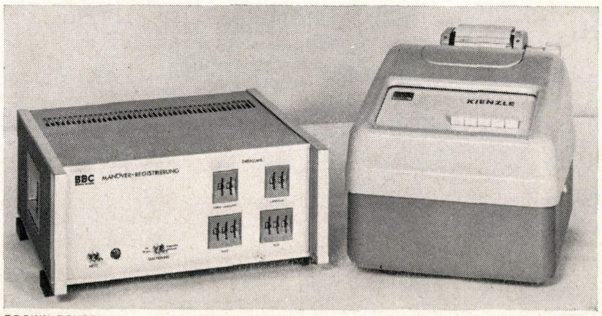

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Fig. 10. – Ship's manoeuvre recorder

The evaluation and adjustment unit is on the left, the associated printer on the right.

Particular emphasis has been laid on means of suppressing mechanical and electrical interference. Vibration, shock, corrosion and climatic conditions were taken into account when selecting the components, the construction and the types of connections used.

The measuring system of the DP 260 ensures effective suppression of common-mode and series-mode interference. A high signal-to-noise ratio is achieved by separating electrically noisy and noise-free functional units, and by screening and twisting sensitive lines. The measures taken to ensure effective suppression of interference in the manoeuvre recording system have already been discussed.

The different pieces of equipment are tested continuously for several days under various ambient conditions. Fluctuations of the supply voltage and interruptions and noise on the measuring and supply lines are simulated during the test.

All systems have a monitoring unit which carries out checks at fixed intervals and indicates localized faults.

An emergency power supply with battery, charger and inverter is recommended if the ship's power system is prone to failure.

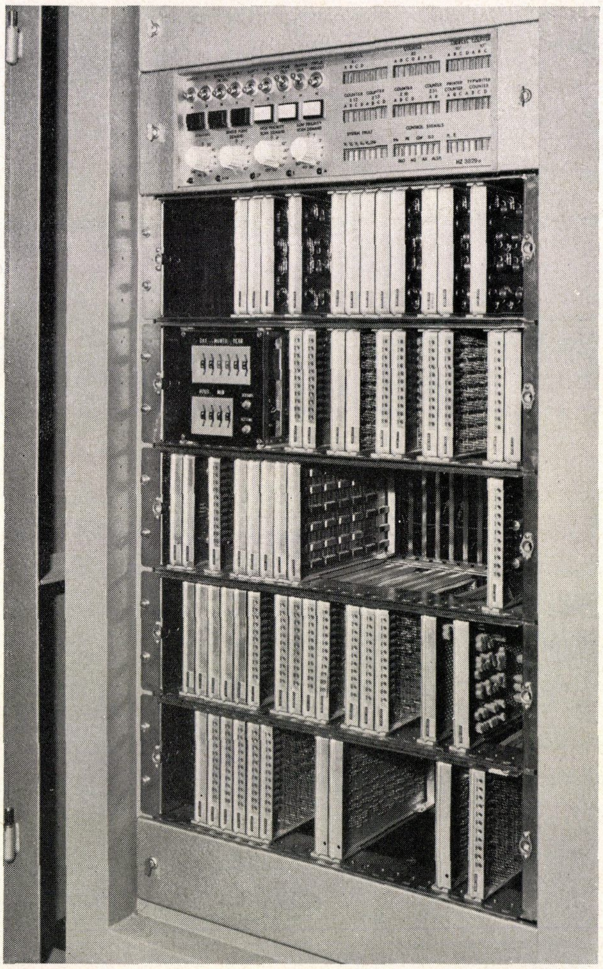

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Fig. 9. – DP 260 data logger. Central unit

A = Check and display panel
B = Output amplifier
C = Clock, output channels
D = Alarm store, measuring-point selector circuits
E = Central control unit
F = Plug-in unit with digital integrated circuits

Experience in Service

Alarm systems [1] and manoeuvre recorders [4] are in service in several ships and are performing well. Already they can largely be considered as standard equipment.

Fig. 11 shows a typical data logger cabinet for a medium-size installation with an integral synoptic display. This provides a good solution when the available space in the control room is suitable. The picture on the front cover shows a rather more extensive, but very good and clearly laid out arrangement. All the operating controls, indicating devices and output units are contained in the desk, from which the engine room and all the cargo rooms can be supervised. Connections for alarms can be made to the bridge, the measuring room and various cabins.

Training, mainly for the chief engineer, first engineer and electrician, has been completed in one to two weeks following commissioning, either in the shipyard or during the first trip. It includes all kinds of operation, including programming and simple fault-finding, especially of the measuring pick-ups and the peripherals. Faults in the electronics have been largely eliminated through using integrated circuits and thoroughly testing the equipment. A built-in test chart aids the operators in indicating the condition of the equipment and in locating faults.

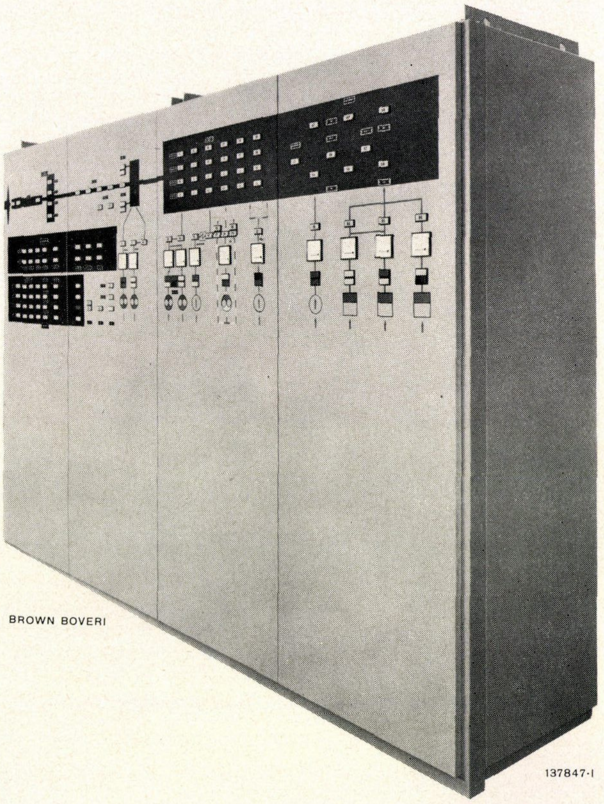

Fig. 11. – Data logger for factory trawler

with 170 measuring points, limit-value supervision and indication, alarm printer, log typewriter, single-point first-priority selection and manoeuvre recording.

Maintenance is restricted to the output units. On average these require servicing every 6 months and overhaul once a year. This is done by the manufacturer.

The equipment discussed in this article has been developed with regard to the arduous conditions encountered at sea, and has been proved in numerous installations. It meets the requirements of the classification societies. All the systems in service have been approved both by the societies and by the relevant national authorities.

The construction and the use of silicon semiconductor devices with monolithic circuits have resulted in reliable, well proven systems suitable for marine applications.

The transition is complete, and the data logger and manoeuvre recording system are now generally accepted in shipping circles [5]. They will find even wider application as the trend towards partly unmanned engine rooms continues.

(DJS)

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PROCESS COMPUTERS IN STEAM POWER STATIONS

681.31: 621.311.22

Following a brief survey of the increasing use of process computers in steam power stations, their possible applications are indicated and discussed. A completed installation in a brown-coal-fired station is then described, together with the experience gained.

THE possible use of process computers in steam power stations was first studied in the USA rather more than ten years ago. The first stations equipped with computers went into service in the early sixties, and various power companies in Europe soon followed the American example. Despite early difficulties and mishaps, some of them serious, the use of computers has continued to increase. At present there are approaching 100 stations either planned or in service in the USA which employ computers for various functions, and about 25 each in Japan and Europe.

The trend in America is towards equipping new power stations with computers which can handle up to 1000 measuring points and 500 contact positions.[1] In most instances a log is printed out and performance calculations are carried out. More than half the existing installations also indicate trends. Closed loop systems are used in about 25% of the cases for controlling the turbine, and in some 10% for presetting reference values and controlling combustion, too.

Now that experience has been gained from a few pioneer installations the use of computers in steam power stations is also increasing in Europe.

Possible Applications

Before examining the case of a completed installation, let us consider in general terms the many possible uses for computers in steam power stations.

A computer in a power station can carry out a great many functions, chiefly because of its ability to perform calculations, make decisions and by establishing priorities it can be made available to the peripheral equipment serving a large number of inputs and outputs. Apart from the economic and technical aspects, which will be discussed later, process computers can take over the following tasks:

measurement collection and supervision
performance calculations
sequential recording
logging
statistics and accounting
optimization
economic distribution of load
measurement and evaluation during acceptance and control tests
monitoring serviceability of the plant components
adjusting controller parameters
communication with higher-order computers
off-line calculations

In addition to these open loop functions there are also the following closed loop applications:

starting, shutting down and supervision of the unit
regulating tasks.

[1] 1966 Energy systems design survey. Power 1966, Vol. 110, No. 10.

The Process Computer in Frimmersdorf Power Station of the RWE

In May 1965 the Rheinisch-Westfälisches Elektrizitätswerk (RWE) awarded Brown Boveri of Mannheim the contract to supply a process computer for unit P in Frimmersdorf power station. The unit, of the single-boiler type, is rated 300 MW, burns brown coal and has single reheat.

As a result of careful preparatory work by the customer the system was test run in December 1966 and commissioned in March 1967. The time taken to fulfil the contract was governed by the fact that there was no basic software, as this was the first time Brown Boveri had installed a computer in a thermal power station.

The Problem

When the order was placed the station management specified the technological problem and the main administrative body presented concrete ideas on the way the measured values should be collected and the manner in which the data should be treated by the output programmes. The individual tasks to be performed were as follows:

- scanning of 200 analogue and 30 digital measurements
- checking of measured values with summation to total values
- issuing of incorrect values in the event of false measurements
- averaging of total values when collection is completed
- examination of behaviour with time of averaged values (gradient check) over two data-collection cycles
- facilities for access to all measured performance values and process constants via a page printer
- calculation of the following performance values, among others:
  effective heat output of boiler—boiler efficiency (by an indirect method)—boiler furnace output—stack losses—flue gas temperatures (and their distribution in the boiler)—specific heat rate of turbine—heat rate (gross and net) of unit—correction of heat rates—correction of various flow rates in relation to pressure and temperature—comparison of corrected heat rate with the nominal heat rate—terminal temperature difference of condenser—percentage station service requirement and make-up water requirement—cooling water flow rate (determined from the condenser heat balance)—daily statistics, compiled from values such as: generator output, station service requirements, effective boiler heat output, corrected live steam rate, feedwater rate, and others—starting and shutdown losses—fouling of boiler heating surfaces.
- issuing of process characteristics
- issuing of daily statistics at the end of each day
- issuing of averaged measurements (temperatures) for calculating temperature-hour records.

Totalled measurements, excess gradients, values for the temperature-hour records and changes in process constants are punched out on paper tape for statistical and technological evaluation on another computer.

Configuration of the Process Computer (Hardware)

This is explained with reference to the basic circuit diagram in Fig. 1.

Data collection

Interrogation of a measuring point is initiated by a selector word transmitted via the output register (2) of the process computer (1). This word contains such parameters as number of measuring point, indication of block length, measuring range of amplifier, speed of interrogation and the form of input and output. At the same time the selector word, with its data for controlling the data-collection sequence, is fed into the input unit (3). Analogue values are fed to the input register of the central unit via relay multiplexer (6), amplifier (5), analogue-digital converter (4) and a buffer (3).

The amplifier, the amplification factors of which are determined by the selector word, raises the measuring voltage to the input voltage (0–5 V) of the

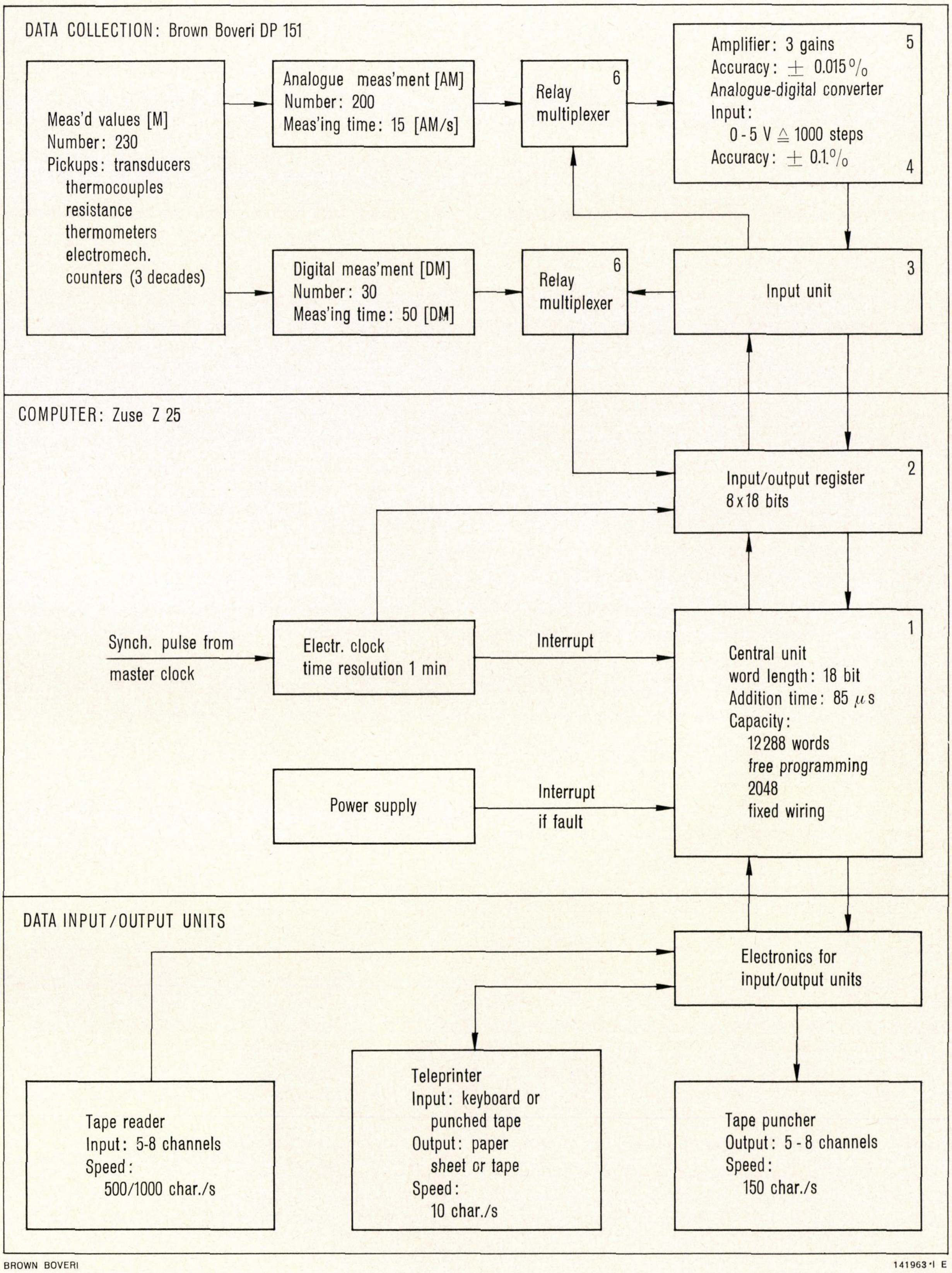

Fig. 1. – Configuration of the process computer

analogue-digital converter. The measuring voltages are different because of the various measuring arrangements used for the different types of measuring element (thermocouples, resistance thermometers and transducers), see Fig. 2.

The analogue-digital converter is pulsed at a frequency of 20 kHz, and attains a maximum of 999 steps in 50 ms. It can follow a change in the input signal at a rate of $S = 100$ V/s.

Owing to the inertia of the amplifier and the analogue-digital converter the scanning rate is 15 readings per second.

Having been selected, digital values (meter readings) are fed direct into the input register (2) of central unit (1) via relay multiplexer (6).

The Zuse Z 25 computer

The central unit is a fully transistorized, programme controlled, electronic computer. It can perform arithmetic and logic operations with numbers, commands and also letter symbols. The data are processed in binary code.

The unit of information with the Zuse Z 25 is a word consisting of 18 binary digits (bits). The words are processed in series. One "elementary operation" (addition, subtraction, etc.) is performed in a "word time" of 85 μs. The stock of commands amounts to 38, some of which can be combined with each other. Reading and writing of the store are carried out in parallel.

The central unit comprises:

programme store (2048 words permanently wired)
working store (12288 words)
computation unit
control unit
control desk
4 interrupt levels

The input and output units are:

teleprinter
tape punch
punched tape reader
pulse counter input
pulse counter output

The system is so designed that other equipment can be connected. Coupling to other Z 25 central units is also possible. A view of the computer room is shown in Fig. 3.

Programme Sequence (Fig. 4)

The organization programme is responsible for the time division into 6-minute cycles, synchronizing the programme start with the elapsed time when the process computer starts, and calling up the sub-rou-

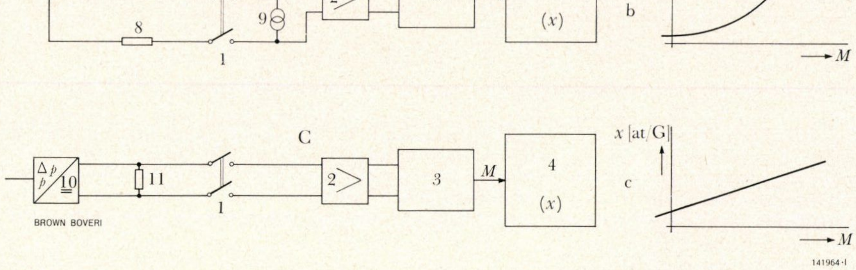

Fig. 2. – Principle of the measuring circuit

A = Thermocouple
B = Resistance thermometer
C = Transducer (e.g. pressure)
a, b, c = Corresponding characteristics: measured quantity x as a function of sensor voltage M
1 = Relay multiplexer
2 = Amplifier
3 = Analogue-digital converter
4 = Computer
5 = Thermocouple
6 = Thermostat with cold junction
7 = Resistance thermometer
8 = Comparison resistance
9 = Constant-current sources
10 = Transducer
11 = Burden

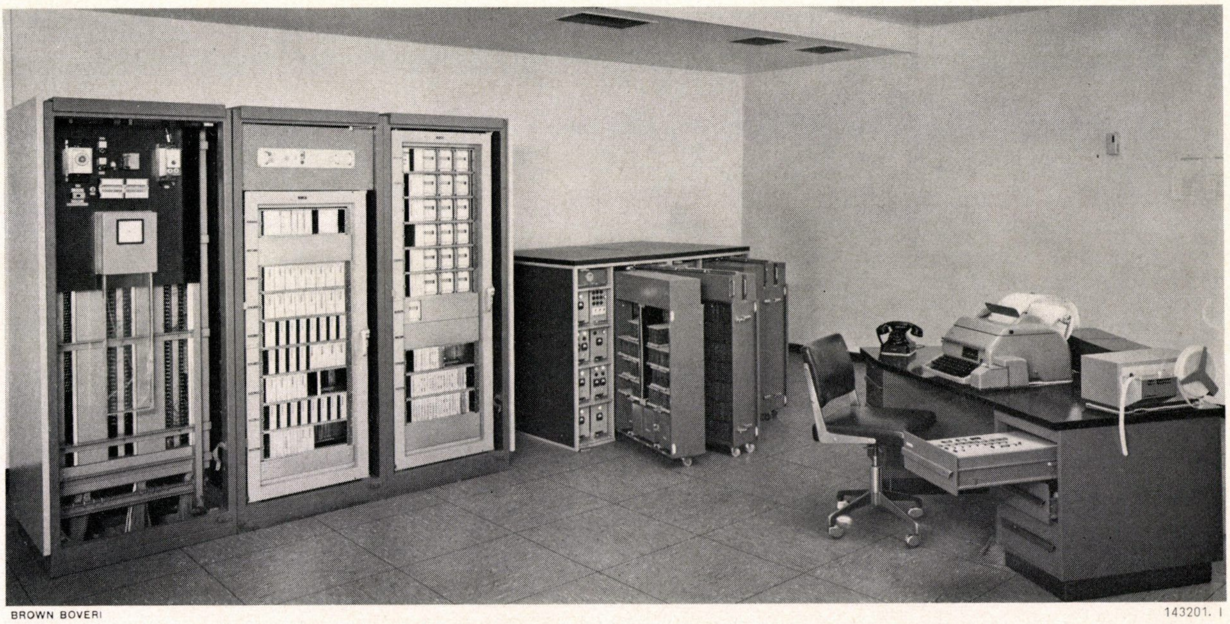

Fig. 3. – The computer. The doors have been removed and the circuit modules withdrawn

tines. The programme is so constructed that it is still fully operational even when the number of incorrect measurements reaches the theoretical maximum.

A 6-minute cycle begins with collecting the meter readings (1) and determining the differences between meter readings from the values measured in two consecutive cycles. Conversion of the meter-reading differential, with allowance for the pulse weighting factors, yields values for the power generated, that required for station services, and that drawn from outside.

The performance calculations (3) then run as basic programmes, together with their output programmes.

The scanning programmes (2) interrupt the basic programmes while the measured values are being transferred to the computer and processed.

The scanning programme is called up several times during each 6-minute cycle. Collection is complete when faults in the event of incorrect measurements have been determined and printed out (4).

The subsequent gradient check compares mean measured values with the corresponding values of the preceding 6-minute cycle. If a gradient has been exceeded, the fault output is triggered, together with the output for the previously totalled mean measured values obtained from earlier 6-minute cycles. Under fault-free conditions the hourly totals (sums of all mean measured values in one hour) are printed out every hour.

Each mean measured value is allotted a value for its sensor characteristic (Fig. 2) by means of a conversion programme (5), whereupon the characteristic is replaced by a polynomial.

The value on the characteristic has the form of a numerical value multiplied by the physical dimensions.

The time remaining to the end of a 6-minute cycle is taken up by the traffic programme (6). With this it is possible to obtain measured values, mean measured values, formal results of performance calculations, measured-value limits and gradient limits by means of a keyboard and the teleprinter punched tape. The traffic programme is terminated by the organization programme at the end of the 6-minute cycle.

By imposing a condition the traffic programme can be extended by a further 6-minute cycle.

The fact that operations instructions are received and analysed in character form ensures that the traffic programme is extremely reliable.

Daily records are printed out at the end of each day.

The changes from one day, month or year to the next are controlled by a calendar programme (part of the organization programme).

Operational Experience

The process computer is used to supervise the thermal performance of unit P. It is also intended to check the accuracy and reliability of the data-collection systems.

It was found from earlier measurements that serious interference voltages occur with conventional wires and cables for measuring purposes. This interference has been largely eliminated by using special cables (screened individual cables, screened main cables and star-connected earthing of the screening at the crossbar distributor).

As a result of these measures it has been possible to dispense with filtering for almost all measured values. The pick-up wires for measurement, regulation and data processing are combined into common main cables. The transducers of the measuring and regulation systems are also used to provide the data for the computer. The burden loops of the transducers are not screened. Despite these methods of cabling, symmetrical interference voltages were observed having amplitudes of $V_s < 5$ mV and frequency in the kilohertz range.

The inertia of the amplifier and analogue-digital converter eliminate interference voltages with frequencies above 300 Hz, except for a residual error of less than 0·1% of the measuring range.

Most of the transducers used have an output signal which is free from harmonics. In the case of four transducers an interference voltage of 100 Hz had to be smoothed with filters. The effect of this is that the measurement monitoring system goes into action comparatively rarely under normal operating conditions.

To gain some idea of the accuracy of the measured values and performance values calculated by the computer, tolerances were determined for each individual value during the planning stage. To establish the most probable error the errors of the transducers, the transmitters, the measuring amplifier and the analogue-digital converter were added together geometrically. The number of values included in this calculation is sufficiently large to justify the procedure. As a check, the maximum possible error was also determined by adding the individual errors arithmetically.

This calculation yielded a probable overall tolerance for the heat rate of the turbines, for example, of 1·7%. Computation of this value is particularly critical, because it can be determined only by the

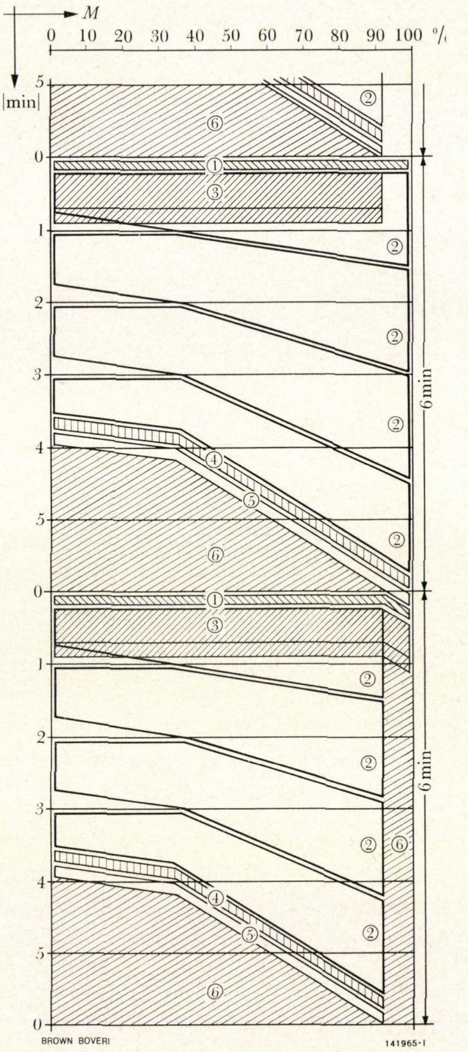

Fig. 4. – Programme sequence in relation to input measurements M (number of measured values with error)

1 = Scanning of meter readings
2 = Scanning of measured values
3 = Performance calculation
4 = Measured-value output
5 = Linearizing programme
6 = Traffic programme

direct method. The accuracy is appreciably higher in the case of boiler efficiency as here it is acceptable to employ the indirect method.

This tolerance calculation does not include the error due to fluctuating measured values. To obtain a general indication of the influence of this, during the early days of operation various measuring points were interrogated at short intervals up to as many as 384 times, and the values were put on a punched tape. The mean of all the readings was taken to be the correct value. The deviation found from various scanning combinations was then referred to this value.

It was found from this evaluation that the error is dependent on fluctuations caused by operating conditions and on the frequency of interrogation within one computation cycle. The effective scanning speed is of no influence. What error is acceptable for a given measuring point depends on the significance of the measured value to the result of calculation.

In general it can be said that flow rates need to be measured most frequently. To achieve an error of less than 0·1%, 40–50 interrogations per cycle are necessary for normal flow rates, and up to 100 per cycle for flow rates which fluctuate widely (water for spray desuperheaters or for flushing the Sulzer water separator). With pressure measurements 20–25 interrogations are sufficient. Temperatures are the most sluggish, requiring only 15–20 interrogations.

It is a feature of the method of calculation that the closest attention as regards accuracy must be paid to the measurement of the live steam flow rate and the power at the generator terminals.

For a data-collection system a permissible error of 0·1% represents a very high degree of accuracy. Further increasing the frequency of interrogation is of no advantage. A higher scanning speed, on the other hand, is essential for control functions.

On comparison with acceptance tests it was found that the accuracy of the values determined by the computer are within the predetermined tolerance. The largest discrepancies occurred with measurements of flow rate.

The daily log supplied by the computer not only gives the operating staff an immediate indication of the state of the plant, but also provides the station supervisor with a quick picture of the situation the next morning. With the daily logs in their usual form, a certain amount of time is required to prepare the values. The daily record is also of value as regards the thermal statistics. To check the belt weigher, for example, the quantity of heat determined by the computer and brought into the station need only be divided by the calorific value.

The boiler of unit P has no marked tendency towards fouling. Long-term evaluation of the fouling programme has therefore only yielded the fact that the heat absorption of the heating surfaces has not significantly changed.

The traffic programme has proved to be very valuable. It was surprising how quickly the operating staff made use of the facility for calling up readings and formula values.

The process computer has not led to a reduction in the scope of the display on the control desk. There are a few measurements, however, which normally are registered only by counters. These quantities can be obtained more quickly from the computer than by forming meter-reading differences. There is added advantage in being able to cross-check measured values. In special tests the computer was instructed by punched tape to print out up to 150 measured vulues.

No statement is possible on unit optimization tests, as they have not yet been fully evaluated.

The temperatures of various superheater headers are punched on tape. These values are sorted and classified in a second data-processing system. Evaluation is not yet complete, but it is already clear that the classification previously done by hand can safely and reliably be taken over by the computer.

System availability was initially less good than expected. To improve the situation a second teleprinter and a second tape puncher were installed as standby equipment. The teleprinter is connected via an electronic switching system so that the motor is running only while the machine is printing.

The air conditioning system was troublesome. The guaranteed values for air temperature and humidity could not be maintained. Even more disturbing was the fact that the necessary freedom from dust could not be achieved. Impurities settled on the conductors of the pulse counters for measuring electrical output. The counters therefore had to be enclosed in a dustproof housing. The relays of the data-collection system had to be replaced by relays with mercury-wetted contacts, particularly in the case of measuring points with resistance thermometers. These changes led to a considerable improvement in the availability. It has been decided to provide the computer with its own air conditioning plant when the station is extended with unit Q. It is hoped that the availability will then be further improved.

Conclusion

Brown Boveri have gained valuable experience from installing this process computer. In particular, solutions have been found to the hardware and software problems which arise from real-time operation of a computer and its peripherals.

The cost of a process computer, the measuring sensors and the associated wiring and cabling is very high, but such equipment brings a great many advantages as regards operation of the plant. Not all of these can be expressed in financial terms, but consist in more detailed and, to a great extent, ready-prepared data.

For a computer to be an economic proposition, it must first be as fully occupied as possible, and secondly, the costs of hardware and software must be lowered. The first condition is met by handing over to the computer all those tasks for which it is suitable. There is no fundamental reason why a computer should not serve several units. To meet the second point Brown Boveri are building a new system. The hardware for this is based on integrated-circuit techniques, and problem-orientated languages are employed for the software.

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AUTOMATION OF ARC FURNACE OPERATION

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By automating arc furnaces a higher level of steel production can be achieved while production costs are reduced. In this article two methods of automation are described, the first of which employs programme control to predetermine and supervise the energy required for melting. The second method uses a process computer which, in addition to presetting the necessary melting energy, also logs the most important melting data, calculates the required oxygen and alloy corrections, and monitors the power consumption.

IN present arc furnace practice, control of the process is generally limited to periodic chemical analysis of the melt, measuring the temperature of the melt in the furnace and ladle, determining the slag composition, measuring certain electrical parameters of the furnace and measuring the energy consumption.

The various production phases of steel in an arc furnace are determined by a large number of variables which influence the material, the process, the product and the general economics of production. The operator tries to assess the complex interrelations empirically, basing his decisions on the results of analysis of the melt and repeated temperature measurements, and on his visual observation of conditions within the bath and of the slag and furnace walls.

Keeping in mind the need to rationalize production and the frequent lack of qualified personnel, automation of the process becomes necessary here, too. Two methods of automatically controlling arc furnaces are described below.

The first method is programme control. Primarily, the energy required for the various melting phases is determined and supervised. In the second method a computer is used as what is termed an operators guide system. The tasks to be carried out are extended from logging the process data to supervision and control of the entire melting operation, including additional orders such as maximum demand control.

Programme Control for Presetting Energy Requirements

The working cycle of an arc furnace begins with the melting-down phase. Two or three charges of scrap iron are successively placed in the furnace and melted, after which they are decarburized and refined.

The programme control system determines the amount of energy in kWh required to melt each charge introduced. In order to achieve an economical furnace operation with regard to moderate energy use, short melting time and protection of the furnace walls, each successive charge must be placed in the furnace at the proper moment and the optimum current and voltage steps for starting up, shutting down and during melting of the charges must be set. The Brown Boveri programme control system has been developed especially to perform these tasks [1].

A short description of the melting-down procedure will serve to illustrate the purpose and functions of the apparatus:

- the first charge of scrap is introduced into the furnace;
- the weight of the charge in tons is set on decade switches;
- the specific energy required per ton of scrap introduced (kWh/t) is set:

- the additional specific energy in kWh/t required for complete liquefaction is then set. This energy is added to the energy for melting down the last charge;

- a digital multiplier determines the energy for melting down the first charge by multiplying the weight of scrap by the specific melting energy;

- the amount of energy determined for the first charge is shown on a decimal display. During the melting-down process this value is continually reduced according to the energy consumed;

- pulses can be emitted for initiating commands described below, in accordance with the kWh-meter reading:

  a first set of pulses serves to control the furnace voltage and current during conveyance of a charge to the furnace;
  a second set serves to trip optical and accoustic signals to the furnace operating crew, for example "prepare second charge", "introduce second charge", etc.;

- current and voltage settings which are of special significance for optimum furnace operation can be pre-programmed separately. Once set, an optimum programme can be repeated. Limits in the logic system prevent settings which could lead to overloading of the furnace transformer;

- optical signals inform the crew continuously of the present phase of operation.

The operating sequence for further charges is as described for the first charge.

The settings to be recorded by the operators are:

- specific melting energy consumption up to introduction of the next charge;

- the additional specific energy consumption necessary for complete melting after introduction of the last charge;

- correction factors influencing the melting energy requirements.

Construction of the Programme Control Unit

The control logic is made up of electronic modules and operates on the digital principle. With the exception of the kWh pulse meter all instruments are housed in a cabinet.

The necessary control and decade switches for the data inputs and the visual displays are installed on the front of the panel. Separate decade switches are available for each charge. A kWh pulse meter emits signals to the control logic to measure the melting energy consumed, for each 5 kWh for example.

Automation by Process Computer

Let us first consider the basic phases of the melting process in an arc furnace (Fig. 1).

- The scrap is selected according to size and alloy content and is introduced into the arc furnace in one to three charges. The next charge is introduced shortly before the scrap is completely melted.

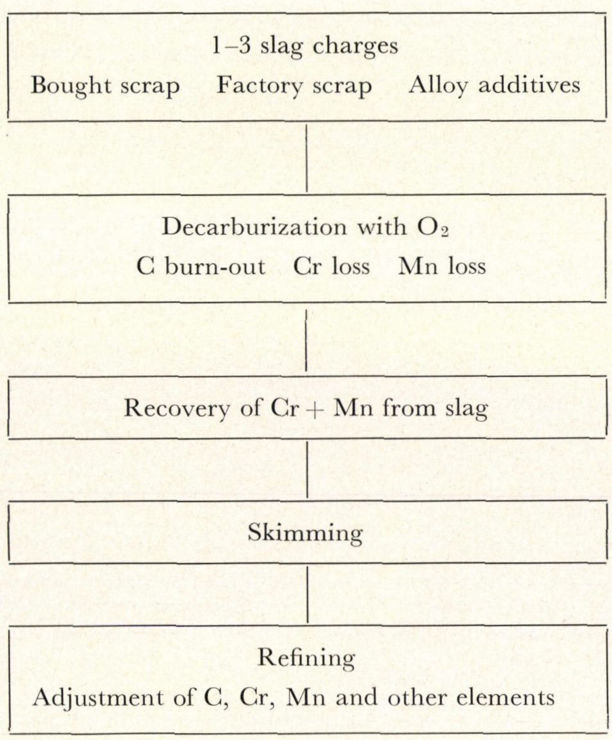

Fig. 1. – Principal stages of the melting process (flow diagram)

- Toward the end of the melting-down operation, oxygen is introduced into the metal bath by means of a lance, in order to reduce the carbon content to the desired proportion ("decarburization"). An unwelcome effect is that, in addition to impurities in the melt, desirable metals such as manganese and chromium are oxidized and absorbed in the slag.
- With the manufacture of most qualities of steel a large part of the metals oxidized in the slag are recovered by adding silicon.
- The first slag produced is then often drawn off, after which the steel is refined. A second slag is formed in order to reduce the reaction of the melt to the air, thus making the alloy corrections more effective.
- By adding alloy metals at exactly the right moment and in exactly the right quantity the melt is brought to the desired final specifications. The molten steel is then poured into the ladle.

Tasks of an Automatic Control System

A process automation system is generally developed in several stages. For practical reasons, the first step is to use the computer as a data logger for recording significant melting data. Basic data for further process automation are collected and evaluated.

The functions of a process computer in a steelworks equipped with arc furnaces can include:

- recording all significant melting data;
- pre-determining and supervising the energy for the melting, decarburization and refining stages;
- determining the start and duration of oxygen introduction;
- calculating the alloy additives and time of introduction in accordance with spectral analysis of the melt, in order to achieve the required final specifications;
- extrapolation of the energy consumption over extended periods, and maximum demand control [2, 3, 4].

The Process Computer as an "Operators Guide System"

The furnace crew begin to load the first charge bucket with scrap. The bucket number, with scrap content noted separately by type and weight, is fed into the computer by means of buttons on the control panel. The computer stores these data until they are required according to the programme.

Following introduction of the first charge and closing of the furnace cover the computer begins its function as an "operators guide" and "data logger". It determines the kWh for melting the first scrap charge, displays this value on an indicator near the furnace, and also prints it out on a typewriter on the furnace control unit. Further, the voltage and current levels for starting are determined, and an indication is given as to when these are to be switched on and off. The process is repeated for charging the next bucket, and also for decarburizing and refining. The voltage and current levels actually obtaining are automatically registered and printed by the typewriter.

When the process computer has reported completion of the melting process, instructions are given to measure the bath temperature. This is fed to the computer via a keyboard. If the prescribed value has been attained, an order is given to take a sample of the bath for analysis. The results are fed into the computer, which immediately calculates the amount of oxygen and alloy additives and the required final specifications. These are then shown on the printer on the control unit. The oxygen introduced is supervised and recorded, and the end of injection is indicated.

For each further input of the bath-analysis value the computer calculates the necessary alloy additives and their time of introduction, and prints these results.

During the entire melting process the computer receives information from the operator and the automatic systems inputs. These are checked, processed and stored, and the computer transmits suitable instructions to the operator via the typewriter or possibly also over an illuminated diagram.

The primary advantage of the system is the capacity to determine alloy additives to achieve the required final specification. A further area of use consists in monitoring and controlling factory-wide energy consumption, a possibility which becomes especially advantageous in steel plants operating more than one arc furnace.

The basic operation of the process computer in the pre-determination of the melting energy, supervision and control of plant energy consumption and calculation of alloy additives is described in further detail below.

Pre-Determination and Supervision of Energy Consumption

Figure 2 shows the general energy supply pattern during the melting operation.

Tests and experience with existing installations show that the electrical energy consumed is the most suitable criterion for calculating melting time, and indirectly, for the development of heat in the electric arc furnace.

Measurable data on the physical and chemical conditions of the melt have until now given no useful basis for calculating the optimum operating procedure and necessary actions during the melting process.

Computation of the melting energy is based on statistical data determined from several melting operations. Specific melting energy in kWh per ton of scrap is given for the various types of scrap. These energy values are multiplied by the weight of each grade of scrap and, when added together, give the mean energy requirement for each charge. For more exact calculation several factors must be considered:

- The number of melting operations performed between renovations of furnace hatch and walls;
- the proportion of heavy scrap in each charge;
- the material weight of each charge and total weight as a percentage of furnace capacity;
- total time for which cover and doors are open;
- cooling water and radiation losses;
- unproductive time, for example, for major and minor repairs, and furnace shutdown over weekends.

Each of these parameters must be determined and accounted for individually. If the scrap is composed of large pieces, for example, the energy requirement is greater for the same weight of the charge than if the pieces are small. The thickness of the lining of the furnace walls and cover has a strong influence on convective and radiant heat losses.

The energy required for the first charge differs greatly, depending on whether the furnace has been shut down for a few minutes since the last melt, or over the weekend.

All of these parameters are recognized by the computer and are superimposed on the calculated mean energy requirement for each charge. A kWh meter in the furnace power supply system emits a pulse for each 10 kWh. These pulses are counted by the computer and give the energy consumed, which is then compared with the predetermined rate. The difference, i.e. the melting energy yet to be supplied, is shown on a digital display. When the actual energy consumed equals the prescribed amount, an appropriate signal is emitted, or the power supply is changed automatically.

Calculation of Alloy Additives

The achievement of a specified alloy combination from the alloy composition of the scrap following liquefaction requires the introduction of various additives. Determining these additives is extremely

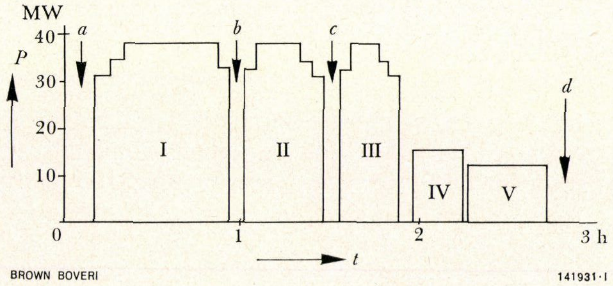

Fig. 2. – Power consumption of an arc furnace during a melt cycle

P = Furnace power
t = Time
a, b, c = Charging
d = Casting, patching
I, II, III = 1st, 2nd, 3rd charge
IV = Decarburization
V = Refining

complex, and the development of the alloy depends, among other factors, on:

- the time the additives are introduced;
- the temperature of the melt;
- carbon content;
- the proportion of other elements present in the melt;
- the basicity of the slag;
- the time at which the sample is taken.

A mathematical means of describing these relationships is linear programming.

A linear programming model of a melting operation is a mathematical representation of all known and estimated values significant to the production of a specified grade of steel in the form of a linear equation matrix. The variables are the molten elements and the alloy additives. Restrictions are imposed by chemical specifications, operating and metallurgical requirements, and possibly also by the availability of various materials. The aim is to produce the required steel grade at minimum cost and within the shortest possible time.

The method of linear programming is explained in rather more detail by the table below. Normally one must consider many more factors which mainly increase the size of the mathematical model, without, however, making it more complex.

Rows 1 to 10 can be expressed in the form of linear equations or inequalities. Row 1, for example, contains on the left the weight in kilos of phosphorus in the melt, the weights of phosphorus which are brought in with the alloy additives, as well as reduction factors which describe the removal of phosphorus during the melting process. The right side shows that the total weight of phosphorus contained in the melt must remain within specified limits.

1	Phosphorus from all materials	$\leqslant$	Phosphorus specification [kg]
2	Silicon from all materials	$=$	Silicon specification [kg]
3	Carbon after decarburization + carbon from all additives — reduction during refining	$\leqslant$	Carbon specification [kg]
4	Chromium after decarburization	$=$	Reduction factor $\times$ Cr (from analysis)
5	Chromium after decarburization + chromium from slag + chromium from additives	$\geqslant$	Chromium specification [kg]
6–10	Alloy additives (01, 02, 03, 04, 05)	$\leqslant$	Alloy additives available [kg]

The equations relating to rows 6–10, for example, limit the use of alloy additives to the amounts directly available from storage. Each of these equations relates to a scrap type 01 to 05. Similar restrictions can be imposed for metallurgical reasons. Final chemical specifications, factors for recovery of elements from the slag, chemical reactions and operating factors are contained in equations 1 to 5. As can be seen, consideration is given to both minimum and maximum conditions, ranging from a specified minimum chromium content to maximum phosphorus content of the steel in Eq. (1).

Extrapolation of the Energy Consumption over Measured Periods and Maximum Power Demand Control

The most complete utilization possible of the energy agreed upon contractually with the power suppliers is a decisive cost factor for a steel plant. The power supply contract generally specifies a price per kWh consumed, plus an added cost per kWh over a certain limit. This power is calculated from the kWh consumed during measured periods, usually of 15 or 30 minutes' duration. In most instances the cost is calculated on the basis of the measured time with the highest recorded kWh consumption during one month. The object is to remain below the power limit agreed upon for the month, but on the other hand to use all the power possible that has been agreed upon within each time period. In this way it is possible to obtain electrical energy more cheaply.

In steel plants operating several arc furnaces the control of energy consumption by means of control computers is especially advantageous. The total factory load is supervised, and the power consumption of the arc furnaces, i.e. the largest and most easily regulated loads, are controlled on this basis.

The basic requirements of a power supervision system of this type are as follows:

- The highest possible energy consumption during a measured period should be reached, while remaining within contractual limits.
- The computer must select the arc furnace to be regulated. The furnace with the smallest energy consumption per melting cycle in proportion to its normal output is always regulated, that is, the furnace whose melting operation procedure is least advanced. The furnace power must not be altered during the refining process.
- The computer controls the load tap changer and the main furnace switch automatically, and shows the settings of the switches on an illuminated display.
- The control system must be arranged so that the furnace can be shut down by it via the computer and re-started at the beginning of the next cycle.
- For purposes of determining the time of the measured period the computer must use the same control impulses as those employed by the power supplier.

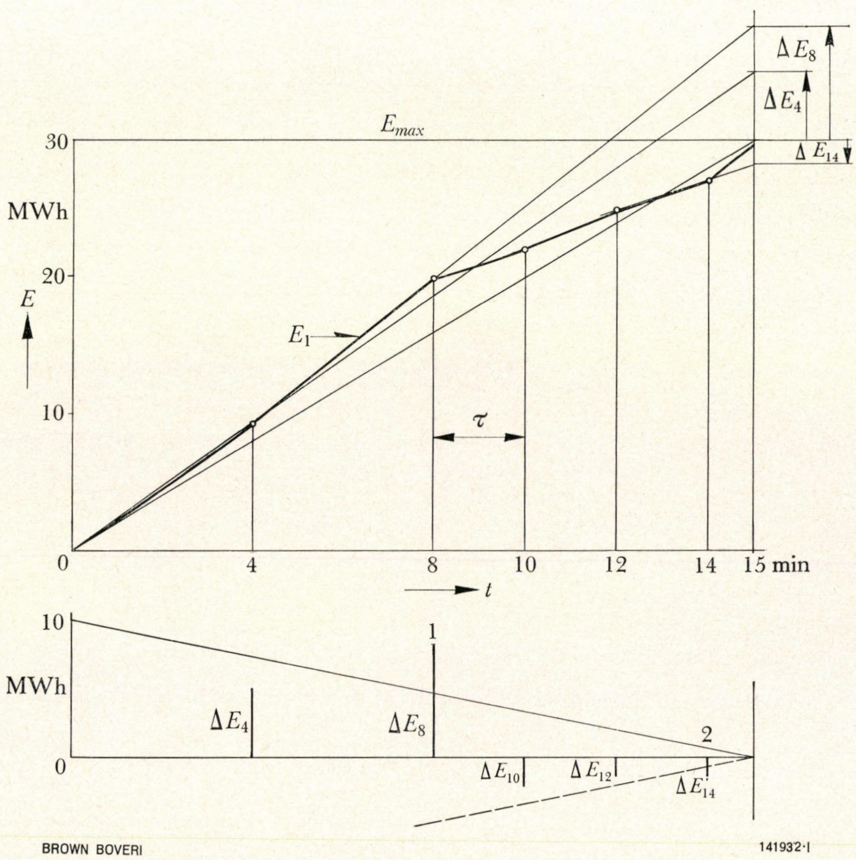

Fig. 3. – Assumed power consumption in a foundry during a measured period of 15 minutes

To maintain the energy limit an arc furnace of 40 MW capacity is controlled

E = Energy
E_{max} = Energy limit
E_1 = Total plant energy
ΔE = Amount above or below the energy limit
t = Time
τ = Measurement interval
1 = Furnace shutdown
2 = Furnace start-up

– The same furnace whose power was previously reduced to balance peak energy periods must have its power increased to counter slack power consumption periods.

Principle of Operation

The factory power can change unpredictably within certain limits during a measured period. Energy consumption during a period is supervised, but in order not to limit unnecessarily the production of the arc furnaces to be controlled, and to avoid too-frequent operation of the main furnace switch, steps to limit the power should be taken at the latest possible stage.

In Fig. 3 the full curve shows total plant energy consumption over a span of 15 minutes. An energy limit of 30 kWh is prescribed for the period. As a simplified explanation of the example in Fig. 3, an arc furnace is switched on or off in order to approach the limit as exactly as possible at the end of the time period. If we assume the furnace to have a power consumption of 40 MW it thus uses a maximum of 10 MWh during one measured period.

The following procedure is recommended. The time span is divided into intervals which become shorter towards the end of the period: 4-4-2-2-2-1 minutes in the figure. At the end of each interval the consumed energy is measured. In addition, by means of linear extrapolation the total consumption to the end of the measured period is determined from the usage during the interval. A check is made to see if the extrapolated value does or does not exceed the energy limit. In the example in Fig. 3, the values $\Delta E\,4$ and $\Delta E\,8$ represent excesses of the energy limit, $\Delta E\,14$ signifies that the limit has not been reached. One excess alone is insufficient reason to shut down the furnace by which the energy consumption is controlled. A shutdown is ordered only when the excess is larger than the pre-calculated consumption of the control furnace up to the end of the time period (see $\Delta E\,8$ in Fig. 3). Conversely, the furnace is switched on again when a deficit has been determined which is greater than the energy consumption of the furnace to the end of the time period (see $\Delta E\,14$ in Fig. 3).

The decreasing time intervals during the measured period were chosen because extrapolation of the total energy consumption becomes consistently more accurate and a more rapid response to power deviations becomes necessary.

Through this procedure a maximum of energy can be drawn and the previously defined energy limit is maintained very accurately in spite of load deviations.

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DEPODAT, A SYSTEM FOR AUTOMATING STORAGE

658.78-52

Industrial rationalization has caused not only production processes but also the flow of materials and storage systems to be automated. The Brown Boveri Depodat is based on the modular principle and makes functional groups available for solving the multifarious problems associated with automated storage. Various stages of automation are provided and can be augmented in a stage-by-stage expansion programme. The extent to which the available equipment can be efficiently employed is determined by an investigation of the economics involved in each individual case.

Purpose

STORES cost money. They occupy valuable space, incur expense for equipment and staff and tie up capital in the form of goods. For these reasons it is essential that they be kept as small as possible. On the other hand, a store is the only means of covering differences between output and sales requirements. Stores also allow purchasing in sufficient quantities when prices are favourable and finished products to be held in stock to cover market fluctuations. In addition they are used for holding stocks of production materials. Intermediate stores cope with the different cycles of the various production processes.

There are a number of reasons for the development of fully automated stores during the last few years.

- The structural changes of organizations caused by production agreements and mergers have led to the formation of large marketing organizations which carry large central stores. Although deliveries are still guaranteed, the amalgamation of several stores into one large one means smaller stocks are necessary and therefore less capital is tied up, ground rent is saved and financial risks are reduced.
- The contradictory requirements for rational, i.e. inflexible production and a high degree of adaptability to the market demand an excellent overall picture of stock movements to enable timely action to be taken to compensate for market fluctuations.
- Increasing costs for responsible stores personnel influence the economic analysis in favour of the fully automated store.
- The development of mechanical handling equipment and conveying techniques in connection with electronic controls, data processing and data transmission has enabled fully automated central stores to be designed.
- Shortage of floor space can often lead to the building of high-stock stores or pallet silos. These are predestined for full automation because the use of mechanical handling equipment is unavoidable.

Storage Problems

Goods arriving at the store, possibly on pallets, are identified and directed to a vacant space. Factors affecting the choice of location can include the compatibility of different articles and their rates of replenishment.

The goods are then conveyed to their designated position and the arrangement of goods and location are registered in the card index. The registration can contain other information apart from the article designation and location, such as the date of arrival and value, both of which are important economic considerations.

When an order is received, the card index determines the location of the corresponding item which is then conveyed to the outlet point. In many cases the consignment may consist not only of complete units (pallets), but also of portions of the number of items on one or more pallets.

The purpose of the storage system is to automate these processes as far as possible in order to reduce storage costs by saving space, increasing turnover and reducing staff.

A distinction must be made between automating mechanical handling and conveying and automating routine control and the allocation of space.

Movement of Stock Within the Store

A store comprises essentially the goods acceptance, the actual store room and the dispatch departments as well as a consignment section which is often in the store room. These various sections are connected by a conveyance system which is of either the continuous (moving belt or chain) type or suitable vehicles. Figure 1 shows a general plan of stock movement within the store.

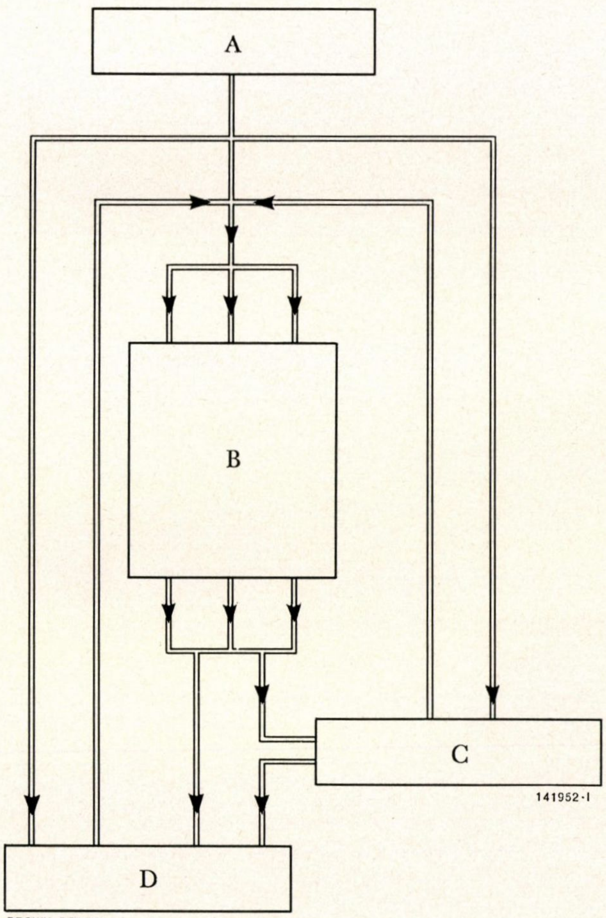

Fig. 1. – Possible material flow arrangements in the store

A = Goods inwards   C = Commissioning store
B = Store room   D = Goods dispatch

Depodat System

Brown Boveri Depodat equipment is based on the modular principle and contains all necessary components for automating storage including connections to electric drives with conventional and electronic controls, data transmission equipment and process computers, and has connection channels for commercial data processing equipment. Special problems and customers' requirements can be easily accommodated and high flexibility is assured by extensive division of the equipment into functional groups which can be augmented by units specially tailored to suit specific applications.

Automating conveyance means that the goods can only be transported along predetermined paths. Starting from the consideration that in an automated store the conveyance is provided by tracked equipment (Fig. 1) for stacking, etc., whereas the supply and distribution is carried out by continuous conveyors with junctions, the components of the Depodat system can be classified as

drives
controls for the stacking equipment
data transmission
central electronic equipment
materials flow monitoring and
data processing

as shown in Fig. 2.

During the design stages of this equipment, particular emphasis was placed on enabling the automation process to be carried out in stages. It is quite feasible to begin with semi-automatic operation and increase through further stages until computer-controlled operation is attained.

Drives

As the drives for the conveyor systems generally operate on the ON/OFF principle they are not required to fulfil any extraordinary demands. Three-phase squirrel-cage motors are used in the majority of these applications.

On the other hand, the demands made of the drives for the mechanical handling equipment are considerably more stringent. The stacking equipment in a pallet-rack store must be able to position the pallets quickly and accurately in order to maintain a high turnover with the minimum of equipment. The maximum speed and rate of acceleration are limited by the stability of the goods loaded on the pallets. For the same reason, the acceleration and travel must not be jerky. To ensure that zero speed coincides with the target, the motor speed must be infinitely variable.

The above reasons have contributed to the increasing popularity of thyristor-fed d.c. motors for traversing and lifting mechanical stacking equipment. In addition to this, the three-phase motor with induction regulator has also gained importance. This is a three-phase motor with resistance rotor whose speed is infinitely variable through a thyristor phase-angle controller [1, 2].

On the other hand, however, the platform or fork drives for the stacking equipment are nearly always simple three-phase motors.

Mechanical Handling Controls

The task of the controls of the mechanical handling equipment is to determine the commands and desired values for the drives so that the position can be arrived at with minimum delay and also to give the follow-up control commands for the platform or fork action. It determines all this from the input data, comprising the location, goods in or out and on which side of the gangway this shall take place.

Optimum speed control can be achieved only if the distance yet to be travelled is accurately known at every point along the journey, in other words an accurate measurement of the distance from the equipment to the target location. Three principles are available for this: analogue-absolute, digital-incremental and digital-absolute.

In the analogue-absolute system, the actual location is in the form of a continuous function which is liable, however, to be inaccurate due to unavoidable non-linearities in the electro-mechanical converter. The incremental system is based on the counting of marks so that the measurement of location is carried out at intervals. Interference pulses can falsify the result. With digital-absolute position measurement, each location is unmistakably designated by code carriers. This system is certainly the most reliable but supplies the actual position only at certain intervals.

In a large automatic store with several thousand pallet spaces, the required location must be approached with maximum accuracy to ensure that the goods are in the right place. This is particularly important in cases where the "chaotic" storage system

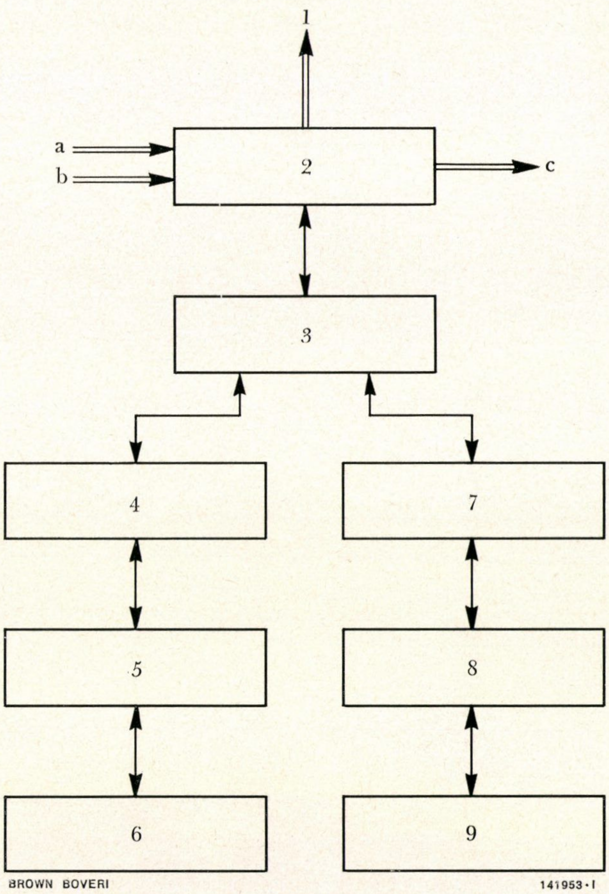

Fig. 2. – Control and data processing in storage systems

1 = Commercial data processing
2 = Data processing equipment
a: goods in
b: goods out
c: goods in stock
3 = Central electronic system
4 = Materials flow monitoring
5 = Control of continuous conveyor
6, 9 = Conventional controls
7 = Data transmission
8 = Control of mechanical handling equipment (positioning)

is used, i.e. a freely selectable arrangement of goods and locations in order to save space. In such cases it is imperative that a digital-absolute designation of the goods and location be carried out before the actual stacking or removal of the goods.

Maximum accuracy and speed is attained by using the following location process:

Before travelling commences, the actual location is measured by digital-absolute means and the total travel can be determined by comparing this result with the destination. Starting from this initial value, the remaining distance is evaluated incrementally during the journey. In addition to counting, the speed between two marks is integrated for interpolation purposes. This provides a continuous and very accurate value of the distance of the remainder of the journey. This value is fed into function generators which prescribe the desired rate of travel. At the end of the journey a digital-absolute comparison of the desired and actual positions is carried out and, if necessary, a correction is made to the travel programme.

If the deviation from the actual location can be only a few millimeters, a metal strip is scanned by two inductive position indicators whose response ranges overlap only within the permissible deviation from the stopping point. The identification array with the small metal plates and the corresponding scanning device with inductive position indicators for the three positioning phases are shown in Fig. 3.

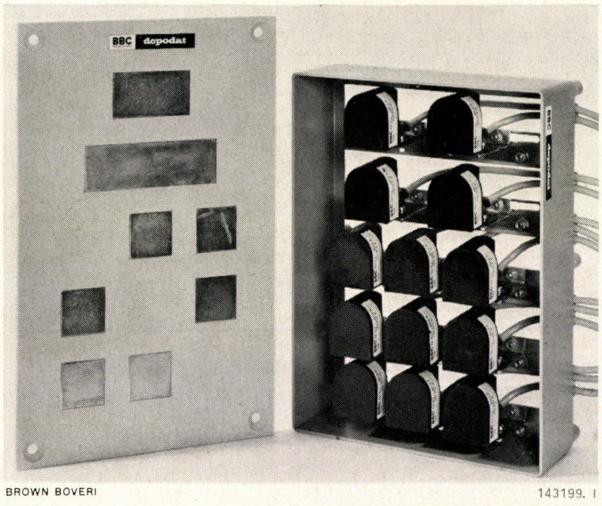

Fig. 3. – Identification array and position indicator for digital-absolute position measurement, incremental positioning and fine positioning

Transmitting Data to the Mechanical Handling Equipment

In semi-automatic systems the commands are given by an operator travelling with the handling equipment, through a decade selector switch (Fig. 3) or through a punched card or punched tape reader. In this case, only the movement sequence of the handling equipment is automated.

Fully automated storage, i.e. controlling the handling of goods by a data processing installation in on-line operation,[1] is possible only if the data can be transmitted from a central control to the handling equipment.

Various processes can be used for data transmission. If the system is limited to the issuing of commands to a few fixed points along the journey, the data can be transmitted through contacts into which the handling device engages or through inductive coupling of transmission and reception coils. This method is only profitable if a stacking and a removal command can be given at the same time and the information stored in memories, because otherwise the handling device would need to return empty to collect new information and therefore the turnover capacity would drop.

Considerably more flexibility can be gained, however, if data can be transmitted at every point along the journey. This may be by means of a trailing cable or by scanning the magnetic field of a strip conductor (inductive strip or line conductor) parallel to the direction of travel with the aid of a ferrite rod antenna. In principle, the trailing cable method is the simpler of the two but the cable and its track waste a certain amount of space. On the other hand, the second method, for which Brown Boveri developed the Indactic LFM 25 telecontrol system [3], can be used universally.

[1] On-line operation denotes that a direct connection exists between the data processing equipment and the process being monitored by it, enabling immediate exchange of relevant data. If, on the other hand, the relevant data is collected and exchanged at predetermined times by means of punched cards etc., the process is referred to as off-line operation.

Central Electronic System

If the store is to be controlled from a central point by means of commands to all handling equipment, an electronic system becomes essential for issuing the necessary command for moving goods. To a certain extent the input data can be processed on a permanently wired programme. For this reason the design of the central electronic system is most influenced by the nature of the store. The commands are fed in by means of punched card readers, punched tape readers, decade selector switches or a keyboard.

If data processing equipment is used for controlling the stores, the central electronic system forms the connection between it and the other control components.

Monitoring the Material Flow

Automating the goods inwards or goods outwards to or from the store room using continuous conveyor systems demands that the destination of the goods is indicated at every junction to ensure that the goods are transported in the correct direction. The essence of the problem here is to provide the information in parallel with the goods.

The process of labelling the goods with the necessary information by mechanical, magnetic or visual means is difficult because of the limited space available and because very close mechanical tolerances have to be kept at the read-in and scanning positions.

These limitations no longer exist if the information is transported with the aid of a materials flow monitoring system based on stationary stores. A replica of the conveyance system is formed by using electronic shift stores or a core store. As the information is transported in parallel with the goods, virtually any quantity of information can be used for controlling the path taken [4].

Data Processing in the Store

The use of data processing equipment for controlling the movement of goods within the store permits an integrated storage system to be realized, in which the conveyance is automated and also the economics

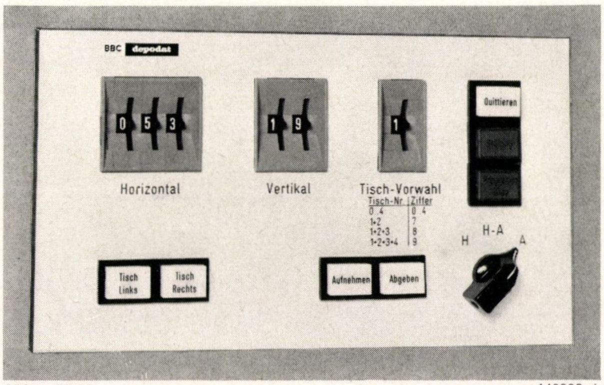

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Fig. 4. – Input panel of control set for semi-automatic operation with change-over for manual, semi-automatic and automatic control

involved in operating the store are taken into consideration, including running costs, available stocks and keeping a perpetual inventory. The basic arrangement of such a storage system is shown in Fig. 2.

The data processing equipment runs the card index and allocates storage locations according to predetermined criteria. The relevant data of the item recorded on the replica in the data processing equipment can be supplemented by various characteristics, e.g. value and date of arrival, which are important for determining the economics involved. This also enables an order to be placed automatically if the stock of a certain item drops below a specified minimum and the value of goods in stock can be monitored constantly.

In fully automated operation the target for the conveyance system is transmitted along a channel to the central electronic system. The only way to remove goods from the store without incurring too much expense is to remove complete units, e.g. pallets. In those cases where only part of the load on one pallet is withdrawn, it is best achieved by semi-automated means on the basis of a commissioning list issued by the data processing equipment in accordance with certain predetermined optimization data.

The use of data processing equipment has the following advantages over previous storage methods:

rapid and accurate location of goods in spite of large and diversified stocks,

space saving due to arbitrary selection of storage spaces (chaotic storage), fewer staff and lower administration costs due to direct control of the conveyance system,

daily account of stocks and items which are moving.

The optimum method of controlling a store is by means of a computer in on-line operation. On the other hand, however, to avoid continuously occupying a commercial data processing system with controlling stock movements, off-line operation is often employed.

There is, however, the alternative of decentralizing the data processing and to provide a separate, on-line process computer for running the stores inventory and controlling stock movement. It can then prepare the data for processing in a commercial data processing installation.

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DIGITAL COMPUTERS FOR HYDROELECTRIC POWER STATIONS

681.32:621.311.21

As the use of automatic control becomes more widespread and interconnected groups of power stations and distribution networks become more extensive, so the need for measuring and regulating equipment becomes progressively greater. Central digital computers are required to collect the various data and measurements and, depending on the degree of automation, intervene in the control processes. The article deals with the functions of data-processing systems in the automatic operation of hydroelectric power stations.

ALL steps taken towards applying automatic control more extensively in power supply systems are aimed at improving the cost effectiveness and reliability of ever larger and more complex installations, and also at relieving qualified staff from monotonous jobs. In the event of faults, especially, the limited capabilities of a human operator can have serious consequences in a large installation if there is no suitable automatic control system to initiate the necessary measures quickly enough to protect the plant.

Aids to Automation

Programme Control

Comprehensive logic links, as required in high-speed programme-control devices or for lower-order individual controls in modern power stations, for example, can be built up in a very straightforward manner with the aid of highly reliable electronic components.

Data Processing

As automatic control becomes more widespread and modern groups of power stations and their associated networks become more extensive, so there is a substantial increase in the number of plant components to be supervised, and in the amount of measuring and control equipment. Whereas in the early days of automation the emphasis was on data collection and logging, in the future increasing use will be made of central digital computers, not only for overall tasks but also for functions previously reserved for permanently wired, special-purpose programme-controlled devices associated with individual generating sets and plant components.

Since they can be programmed as desired, data-processing systems and digital computers used in conjunction with a wide variety of peripherals (including external high-capacity stores), can be matched to operating requirements, even when these vary.

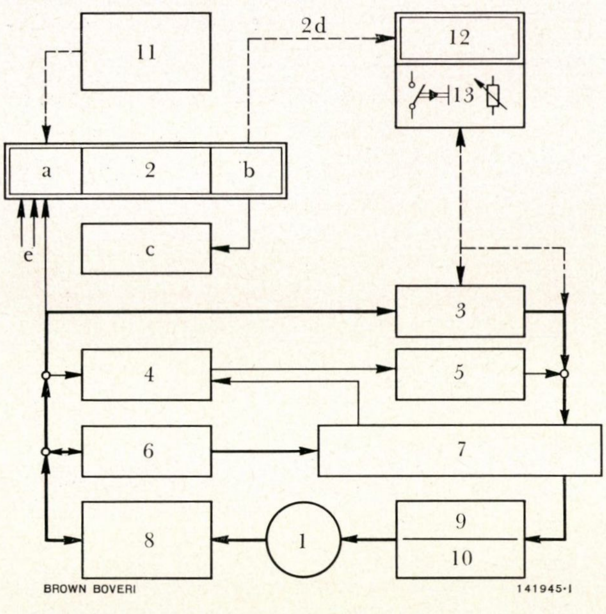
The possible ways of using a digital computer can be summarized as follows:

- collection of data and measured values and data processing in accordance with input provided by data-transport media, punched tape for example (off-line operation);
- as above, but the data-processing system is connected direct to the analogue and binary detecting elements, dispensing with data-transport media (on-line operation);
- indication of real-time results of data processing for operating instructions (open-loop operation);
- as above, but with automatic issuing of control commands within a closed circuit, even over appreciable distances, without active intervention by the operator (closed-loop operation).

Data Transmission

Central control of hydroelectric power stations, transformers and switchgear installations, together with the increasingly complex ties between transmission systems, requires an ever more extensive exchange of information.

For progressively extending telecontrol systems, Brown Boveri have developed versatile data-transmission and telecontrol systems which are extremely reliable (error-detecting transmission techniques), fast and can handle large volumes of data, making the utmost use of the limited frequency bands available.



Block diagram of a remote-controlled hydroelectric generating set

1 = Generating set
2 = Digital computer
a: input
b: output
c: logs
d: meter-reading log
3 = Programme control
4 = Measurement, alarms
5 = Single-item or manual control
6 = Criterion link
7 = Partial automatic controls, protective devices, regulators
8 = Analogue and binary detecting elements
9 = Auxiliary power
10 = Operating controls
11 = Subsidiary power stations
12 = Load dispatching station
13 = Central control point

The techniques briefly outlined above have already been applied in a number of large, new hydroelectric stations.

Functions of Data-Processing Systems in Hydroelectric Plant

The functions required of a data-processing system for a hydroelectric power station arises from the need to rationalize station operation and overall direction of the system by the load dispatcher, whose digital computer must work in more or less close conjunction with the data-processing system of the station.

As an illustration, the figure shows the connection between a central data-collection system for several generating sets of a large hydro station and the decentralized control system of one generating set.

In the block diagram, heavier lines have been used to emphasize the two control loops least dependent on one another, for the protective devices and for the programme-control system.

The data paths shown with thinner lines lead to the manual controls and the station data-processing system.

General Functions

Measurement logging

Regular scanning

of important values (e.g. every 30 minutes) presented in analogue form by transducers, which have to be converted accordingly and printed out on the measurement log. The values of chief interest in a hydroelectric station are: voltages, currents, power, temperatures, acid densities in batteries, water levels, pressures and flow rates.

Checking

whether a measured value is valid. When a reading has been obtained the data-processing system can be used to check that it is correct. Also, a reading just received is compared with the previous value from the same detecting element and shown as wrong in the print-out if the change in the value is impossible.

Automatic checking of limit values:

If a measured value exceeds the programmed limit value, this can be printed in red. Programming can be done in such a way that the limit values can easily be changed at any time by the operator.

Data processing:

The water levels and flow rates can be used to determine the power and water supply available at any time, and also the amount of water lost, if necessary. These can then be recorded.

The data-processing system can be made to store certain values and make them available to the load dispatcher on punched tape, for further evaluation perhaps.

Daily log

At the end of the day the measurement log can be completed with a daily balance which includes the number of types of operation (generator, phase advancer, etc.), hours of operation and the actuation of important electrical and hydraulic components. These data are based on the processed signals obtained from the detecting elements and provide valuable information regarding maintenance. They also form a basis for statistical investigations.

Event log

The event log contains the important commands, switching operations and changes in state of the plant occurring during service, together with the time and date.

If a group of power stations is controlled from one station, the central data-processing equipment is installed in the command station. Changes of state in the remote-controlled stations must then be transmitted to the command station via telecontrol links. Date and time can be provided by a sequential time recorder.

Fault log

Indicated faults are recorded clearly and in their correct sequence, logging having priority over all other operations.

a. Indicated faults are printed in red to distinguish the indicated settings, which are in black. Faults are recorded in the correct sequence, together with the time, both when they are first indicated and when they disappear.

Tripping of a differential protection system and turbine overspeed, for example, may be printed out in clear, as in the following table:

h	min	s	Nature of fault
02	30	00·1	Generator I Differential protection energized
02	30	00·2	Generator I Differential protection tripped
02	30	05·4	Turbine I Overspeed 720 rev/min

The time is printed out in hours, minutes and tenths of a second.

b. If fault indications are to be collected in sequence in the outstations, transmitted to the central station and there fed to the digital computer for logging in clear, a sequential time recorder is required in each outstation. These recorders, the simplest being of the permanently wired type, can also be provided with a tape printer to print out fault indications in coded form on the spot. The recorders in the outstations can also be used to collect data on settings and switching operations, and pass them on to the central data-processing system together with the time.

c. The central data-processing system can be programmed to scan and log in clear all existing fault indications, if necessary (when the shifts change, for instance). Scanning is initiated by pressing a push-button.

Collection of meter readings

Automatic collection, transmission and evaluation of electric and hydraulic meter readings by the central data processing system, and printing out meter records, makes accounting simpler. Also, suitable processing of the meter readings and of the mean powers sent out during one scanning cycle opens up a variety of opportunities for automatic control and management of the power supply network.

The functions which could thus be carried out include:

- optimum utilization of the power generated within the network;
- gathering of data and statistics for making economical use of the available water supply;
- supervision of an exchange of power, defined by contract, through feeding in the mean powers within the scanning periods and issuing commands through the data-processing system, thus eliminating the cost of exceeding the maximum values.

The times of operation, with the corresponding meter-reading differences, are printed on the meter-reading log when one type of operation (generating, pumping, etc.) ceases or when the type of operation changes. Daily balances with the output totals stored in the course of one year can be written out automatically. Intermediate logs can be obtained by pressing an interrogation button. Large hydro stations or stations controlling a group of stations have their own data-processing systems, with the corresponding degree of automation. The typewriter for the meter-reading log may be installed in the load dispatching station and controlled by the computer via a telecontrol system. With the aid of a tape puncher in the power station, and connected to the data-processing system, the meter-reading log can also be used for securing the data and for further evaluation.

Automatically Controlled Management of Water Supply for Groups of Power Stations

Pondage operation of a chain of run-of-river stations

At times of peak load, the predetermined flow rate of a chain of run-of-river stations is supplemented above and beyond the normal flow by releasing water stored in the headwater of the top station. Depending on the daily active-load programme, the time between peaks is used to fill the upper reservoir by feeding in part of the natural flow. A reservoir must be provided before the bottom station. Having been emptied beforehand, this receives the water from the headwater when operating on the pondage principle. The bottom station of the chain can then be operated in such a way that its tailwater level remains within the prescribed limits.

A group of medium-sized or small run-of-river stations can be controlled by means of one central remote control system. No particular requirements are imposed as regards the speed of regulation or transmission of commands, but great reliability is essential.

A central digital computer installed in a command station (usually the topmost station) can take over the functions described briefly below.

a. Regulation of the water supply, with both run-of-river and pondage operation, between the headwater reservoir and the buffer reservoir before the bottom station. Water levels at the headwater end should then be kept as high as possible, owing to the effects of level on the attainable power output. Account can also be taken of flow conditions within the chain of stations. The local headwater-level regulators are also required for local emergency control, and during automatic operation serve as means of monitoring storage levels in the separate stages.

b. Automatic starting and stopping of the generating sets in the individual stations in accordance with a daily active-load programme. The automatic command to start is transmitted to a generating set with account taken of the most efficient mode of operation, and the moment of issuing the command is matched to the transit time of surges caused by sets started previously in the next highest station.

c. Uniform distribution of active load between the stations by means of a central preset desired value which, with run-of-river operation, is determined from the headwater level of the topmost station, and with pondage operation from the daily operating programme.

The equipment for automatically starting and stopping the sets is best installed on the spot in the appropriate stations.

Should a fault occur either in the telecontrol system or in the central programme-control equipment, local control takes over. The latest effective desired values remain valid after the change. Failure of a generating set is detected by monitoring the total output of the chain in both run-of-river and pondage operation, and the loss is automatically compensated by sets or stations which are not working to capacity. In a case of emergency, however, the sluices must be operated as necessary in order to maintain the supply of water to the other stations.

d. The programme control system for pondage operation has to perform the following functions:

- store the daily active-load programme;
- automatically check and indicate through the computer if the daily programme, as based on the measured values collected by the computer, cannot be fulfilled, and then process corrected input data;
- compare the measured output gradient at set intervals with the desired value given in the daily active-load programme, and automatically make the necessary adjustments to stabilize water levels in the individual reservoir stages;
- maintain the current preset desired value if the programme is interrupted as the result of a fault, etc.;
- incorporate the sluices into the superior-level programme control to maintain the preset water supply if a generating set is suddenly shut down while under load because of a fault.

For automatic control of this kind it is essential that all safety devices (surge control to protect boats, for example) should be completely reliable. Generally the safety devices are installed locally and are made as autonomous as possible.

Joint operation of pumped-storage station and a medium-head station

The considered system of power stations consists of a high-capacity medium-head plant and a smaller pumped-storage plant which is used for regulating the water supply. The main station obtains its water from an equalizing basin via a pressure tunnel. This basin is filled by river water fed through a system of tunnels, and by streams flowing direct into the basin. The basin is also connected via a pressure tunnel and a pumped-storage station to a large, somewhat higher reservoir.

The pumped-storage station and the main station are remotely operated from a central point. Extensive telecontrol systems [1, 2] ensure that the data and control commands are accurately transmitted between the various parts of the system. All the necessary data are collected and processed by a data collection system at the central control point. Switching operations and fault indications are printed out in chronological order in clear to form an "operations sequence log". Meter readings (water flow rate, power output) are processed to obtain balances which are also printed out. Certain values, such as contents of the reservoirs as a function of head, power generated per m^3 of water consumed, total water supply, etc. are calculated from measured values and similarly printed out.

In addition to collecting data, the automation system has another function to perform which is discussed in rather more detail below. The structure of the system of stations is such that, by dividing power production between the main station and the pumped-storage plant, the water available (depending on weather conditions) can be allocated so that only the amount of water needed to generate the required power has to be used. The system as a whole thus combines the features of a run-of-river plant and a pumped-storage station. The purpose of the automatic control system is then to divide power production between the two stations so that the following conditions are satisfied:

- the total power generated must agree with the value stated in a power supply contract;
- the resultant total flow into the equalizing basin (inflow minus measured outflow) must fill or empty the basin, or keep the level constant, in accordance with a predetermined time function;
- the total flow into the main reservoir (natural run-off, pumped water, used water) must also fill or empty the reservoir in accordance with a predetermined time function.

Allowance must be made for the fact that the capacity of the pumped-storage station is limited and the pump output can be preset in only two stages. Pump capacity is also very much dependent on the fall between the main reservoir and the equalizing basin.

For the control system to perform this function the flows into the two storage basins must be known as accurately as possible. Since they cannot be measured, they have to be calculated from changes in the contents of the reservoirs. For this one must know the reservoir contents as a function of the levels. Flow into the equalizing basin is found by calculating the change in content from the change in level and adding the measured flows to the main reservoir and to the main station.

This quantity of water is then divided between the two stations in accordance with the specific outputs (output referred to discharge) and the following conditions:

$$P_T = P_H + P_S$$

or

$$P_H = P_T - P_S \qquad (1)$$

P = Output
T = Total
H = Main station
S = Pumped-storage station

Assuming a constant level in the equalizing basin:

$$W_Z = W_H - W_S \qquad (2)$$

W = Water discharge rate [m³/s]
Z = Total of supply flows still not yet utilized in equalizing basin

$$W_H = \frac{P_H}{L_H} \qquad (3)$$

L = Specific output $\left[\frac{\text{kW}}{\text{m}^3/\text{s}}\right]$

$$W_S = \frac{P_S}{L_S} \qquad (4)$$

Substituting expressions (1), (3) and (4) in (2) yields

$$W_Z = \frac{P_T - P_S}{L_H} - \frac{P_S}{L_S}$$

whence we obtain P_S (output of the pumped-storage station):

$$P_S = \frac{P_T - W_Z L_H}{1 + \dfrac{L_H}{L_S}} \qquad (5)$$

Let us consider the individual terms of Eq. (5).

The term $W_Z \cdot L_H$ represents the power which could be generated in the main station with water flow W_Z. The required output P_T may be greater or less, the difference in the numerator being positive or negative accordingly. The factor $1 + L_H/L_S$ in the denominator takes account of the fact that the output difference is produced jointly by the two stations. (The water supplied to or removed from the equalizing basin by the pumped-storage station is either available in the main station, or not.) In this way a much greater difference between water supply and consumption can be compensated with the small capacity of the pumped-storage station.

Eq. (5) therefore shows what power must be generated (or consumed) in the pumped-storage station to keep the level of the equalizing basin constant. If the power is found to be negative, this power must be used for pumping. As the pump capacity can be preset only in two stages, the required power is consumed by regulating the times for which the pumps are on or off. Here, particular attention is paid to seeing that the pumping periods are as long as possible, and occur at times of low power demand (usually at night). Calculation of the pumping periods is based on the maximum permissible fluctuation of the level of the equalizing basin.

If the power in Eq. (5) is positive, the pumped-storage station must generate power in order to keep the water level in the equalizing basin constant. In this case, too, allowance is made for the fact that power is generated only if the equalizing basin would otherwise be emptied too quickly.

Filling of the main reservoir is controlled by regulating the amount of power drawn from the system. If there is found to be a significant deviation from the desired filling curve, which is monitored at regular intervals, a calculation is made to determine by how much the average withdrawal of power has to be altered in order to maintain the filling curve.

To accomplish the tasks mentioned above a process control system has to be supplemented by data-collection systems [1, 2] and telecontrol facilities [3, 4]. These are used to gather measurements, meter readings, and contact settings, etc. Control commands are given via telecontrol systems or direct by means of contacts. A punched tape reader is used to feed in the power supply programme. Logs of measured readings and the state of the plant are provided by electric typewriters.

Conclusion

The control of modern power stations poses an increasing number of problems which can no longer be resolved with the traditional means of automation. Digital computers must therefore be employed. The problems involved are usually associated with optimization. The general requirements when a computer is used to direct the supply of water to groups of power stations are discussed with the aid of two examples.

(DJS)

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BRIEF BUT INTERESTING

Four-System Dining Cars of Swiss Federal Railways for International Traffic

625.232.3 (494)

IN 1965 Swiss Federal Railways decided to order ten dining cars for international traffic. The coachwork was entrusted to the Waggon- und Maschinenbau GmbH, Donauwörth, Germany, and the Swiss Car and Elevator Manufacturing Corp. Ltd., Zürich, provided the bogies. Brown, Boveri & Co., Ltd., Baden, were responsible for the complete electrical equipment and the air conditioning plant.

Mechanical Part

The coach body is of type X according to UIC (Union Internationale des Chemins de Fer) standards and is a lightweight construction throughout. The shell weighs only 4315 kg but in its fully-equipped condition with full water tanks it weighs 39 tonnes and is therefore about the same weight as an ordinary passenger coach for international traffic [1].

Electrical Part

The vehicle has an all-electric kitchen, air conditioning and fluorescent lighting and can be used on all the permissible power systems in RIC (Regolamento Internazionale Carrozze) Regulations, with supply from a heating line or contact wire. Table I shows the power systems used in some European countries.

TABLE I

	Contact wire	Heating line
Switzerland Germany Austria Sweden Norway	15 kV, $16\frac{2}{3}$ Hz	1 kV, $16\frac{2}{3}$ Hz
France	25 kV, 50 Hz	1·5 kV, 50 Hz
France Netherlands	1·5 kV d.c.	1·5 kV d.c.
Italy Belgium	3 kV d.c.	3 kV d.c.

The complexity of these systems demands a power supply for kitchen and air conditioning plant with comprehensive technical equipment [2].

The consumers are divided into the following groups relative to their supply systems:

TABLE II

Supply	Consumer
a. 36 V d.c. from coach batteries	Control current Air conditioning fans Air compressor Refrigerator compressor Public address system Fluorescent lighting
b. 220/380 V, 60 to 100 Hz	Kitchen equipment Battery charger (36 V d.c.) Rectifier-fed compressor motor for air conditioning plant
c. 1000 V, $16\frac{2}{3}$ Hz d. 1500 V, 50 Hz e. 1500 V, d.c. f. 3000 V, d.c.	Electric air heater for air conditioning plant

A three-machine converter set on flexible mountings beneath the floor of the coach supplies low-voltage power to the consumer groups listed under b in Table II. This totally enclosed machine comprises a three-phase synchronous generator with a power output of 39 kVA at a controlled voltage of 380 V and two pulsating-current motors for 1500 V each, flanged onto the sides. For 3000 V d.c. these are connected in series but for all other systems they are in parallel. Additional transformers, high-voltage rectifiers and a smoothing choke for smoothing current surges are essential for single-phase a.c. operation at $16\frac{2}{3}$ Hz and 50 Hz.

A fully automatic voltage and system selection device transmits the control commands to the grouping contactors for any type of supply regardless of whether it is from the heating line or from the contact wire. The converter set is started up and the generator voltage controlled and switched to the consumer fully automatically by the closure of one of the control current switches which are labelled "kitchen master switch" or "air conditioning". When no power is being supplied for heating, i.e. when the vehicle is standing, a single-arm current collector mounted on the vehicle can be raised by compressed air. As already mentioned, the rest of the switching sequence is fully automatic. Comprehensive safety and monitoring equipment protect the electrical equipment in the event of a fault.

Air Conditioning Plant

This comprises an electric fresh-air heater, a compressor/condenser set, an air conditioning unit with evaporator, fans, filters, air ducting and a control device.

A centrifugal fan mounted beneath the car draws in about 1200 m^3 of fresh air per hour through an intake between two of the windows. This air is forced through a filter system and the electric air heater. Some of it passes into the warm air ducts along the floor of the coach and the rest goes into the air conditioning unit. This part is then mixed with return air extracted from under the seats, cooled if necessary and fed back into the dining car through the perforated ceiling. All air conditioning equipment is under the floor of the coach.

When heating, the air conditioning equipment is regulated on the "air modulé" principle [3], i.e. the temperature of the fresh air drawn in is controlled in relation to the conditions prevailing in the coach and the ambient temperature. There are three cooling stages; two are by different speeds of the cooling compressor and one by reducing the condenser area in the air conditioning unit. Regulation is by a four-stage thermostat with a sensor in the return air. The reference value can be varied by $\pm 2{\cdot}5$ deg C by the passengers.

When heating, the plant can produce 34400 kcal/h, while maximum cooling is about 20000 kcal/h. This corresponds to a constant temperature of +20 °C at ambient temperatures between —30 °C and +44 °C.

Auxiliaries

The refrigeration plant is a compressor/condenser set similar to that of the air conditioning plant and serves the refrigerators in the kitchen and pantry for meat, vegetables, beverages and deep-frozen goods. The set is suspended beneath the floor of the coach and driven by a d.c. motor which draws its supply from the batteries. The compressed air supply with its own compressor serves the current collector, air-break circuit-breaker, roof and earthing isolators and closes the doors automatically.

The public address system enables the staff to communicate with the passengers throughout the train.

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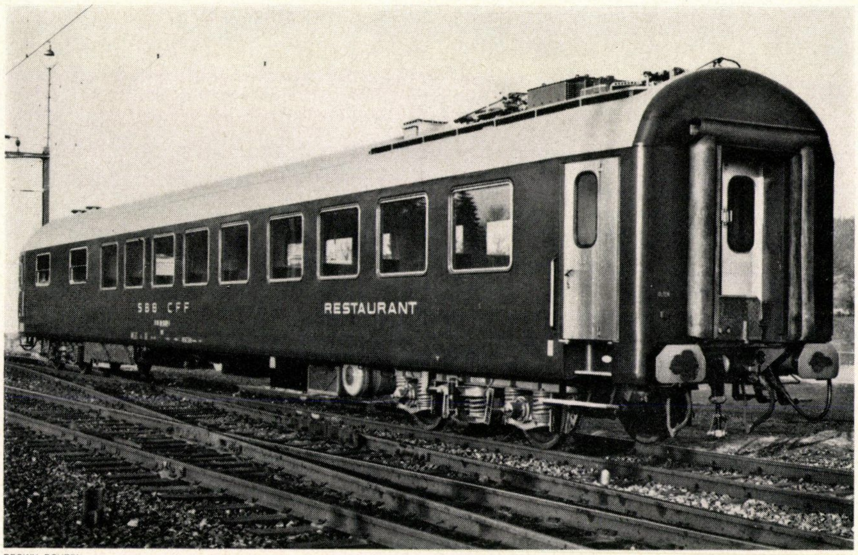

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Restaurant car of Swiss Federal Railways for international passenger traffic, conforming to all current systems permitted by RIC specifications. These are 15 kV at $16\frac{2}{3}$ Hz, 25 kV at 50 Hz and 1·5 kV or 3 kV d.c. (Photo by courtesy of Swiss Federal Railways)

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Published by Brown, Boveri & Company, Limited, Baden, Switzerland. Printed by Berichthaus Zurich, Switzerland.

Obtainable direct from the publishers