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Cover:
Schellenacker control room of the St. Gallen Municipal Gas and Water Service
Left, the control desk and IBM 1800 process computer; right, the mimic display. The telecontrol equipment is in a room behind the mimic panel.

Contents

ED 1000 — A Family of Modular Equipment for Telecontrol and Industrial Data Handling Applications

F. Tisi

Developments in semiconductor technology and process computers have enabled telecontrol and industrial data handling operations, which were previously performed by various purpose-built systems and equipment, to be covered to a large extent by a single family of equipment. Modular compatibility of hardware and software enables economical solutions to be found for a wide range of tasks in both large and small installations. The demands made in respect of test facilities, ease of service and possible future expansion, and also with regard to security and reliability, are becoming even more stringent and these can be complied with by a modular system concept.

The Brown Boveri ED 1000 module family, discussed in general terms in the following, is the direct result of consistent further development of the Indactic telecontrol systems and the DP 700 and DP 1000 process automation systems.

Introduction and Objectives

The tasks of telecontrol and industrial data handling include data collection, transmission, processing, presentation and logging in addition to control. However, present-day development in various fields of application is earmarked by similar trends and requirements:

– modular hardware to enable installations of various sizes to be economically built-up, and extended, using common modules,
– programmability, i.e. replacing the hard-wired control logic by a programmed central processing unit,
– upward compatibility of family of central processing units from the mini-computer with fixed programme (ROM) to the larger process computers with facilities for on-line programme development,
– modular software with a high proportion of standard software,
– uniform interfaces and common data exchange between central processing unit and peripherals,
– high security, reliability and availability,
– simple checking, servicing and expandability.

These were the objectives in developing the ED 1000 module family. Fulfilling them was made possible by up-to-date semiconductor technology and an absolute modular system structure is essential. It is of fundamental significance, however, that the following common demands are made in the most diverse applications from the event recorder to a telecontrol system and on to load dispatching equipment, up to process monitoring and process control systems: – input and output of analogue and digital signals in parallel or series form, data processing and logging and so on.

The tasks are to be performed by the same hardware in the same system structure and, largely, the same software modules. This knowledge is, of course, by no means new but it has led to the development of the process computer. Consequently, the ED 1000 module family is the result of consistent further development and enlargement of the Indactic telecontrol systems [1, 2]. It forms the basis for primarily those tasks associated with process computer systems for network control, but is equally suitable for solving general tasks in industrial data handling.

Fig. 1 – Basic structure of ED 1000

CPU = Central processing unit
M = Memory
I/O = Input/output peripherals
I = System bus interface

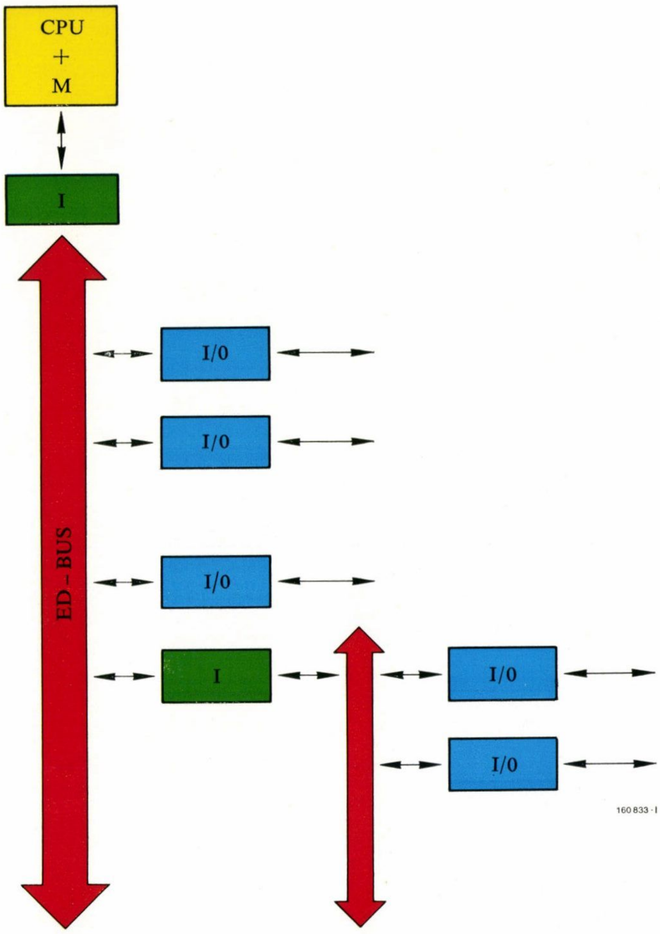
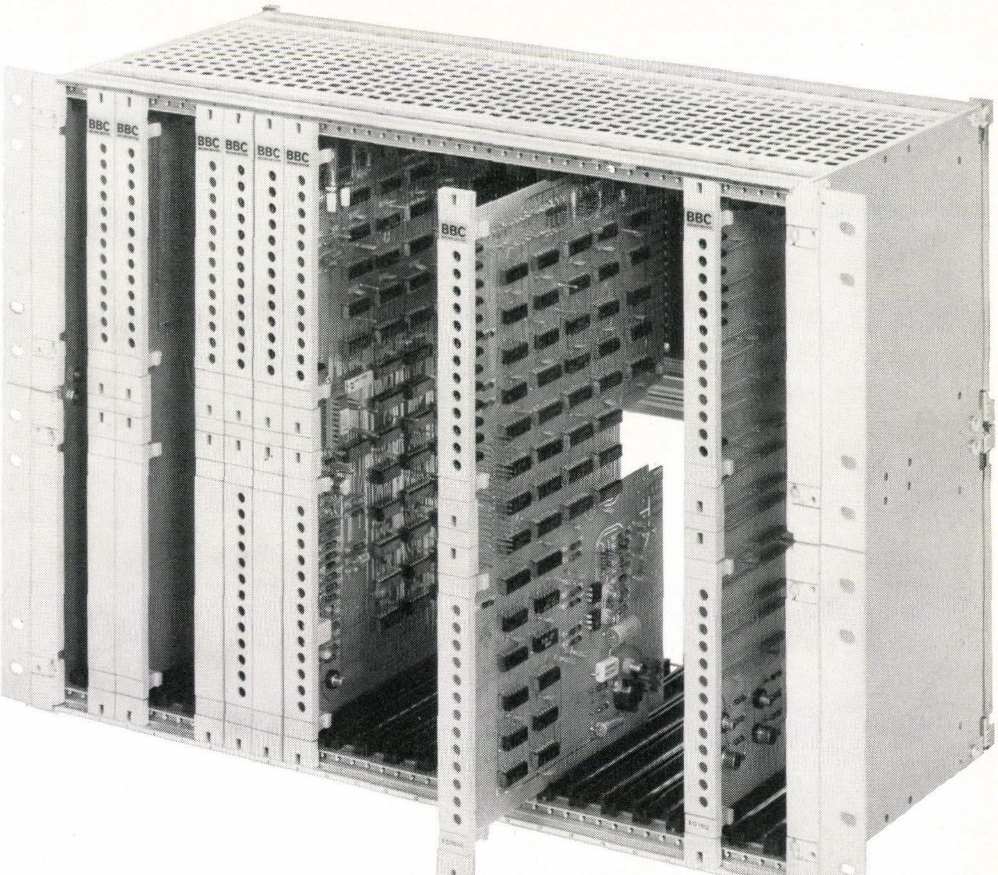


Fig. 2 – Tier arrangement

a: Front view
b: Rear view showing system bus



a

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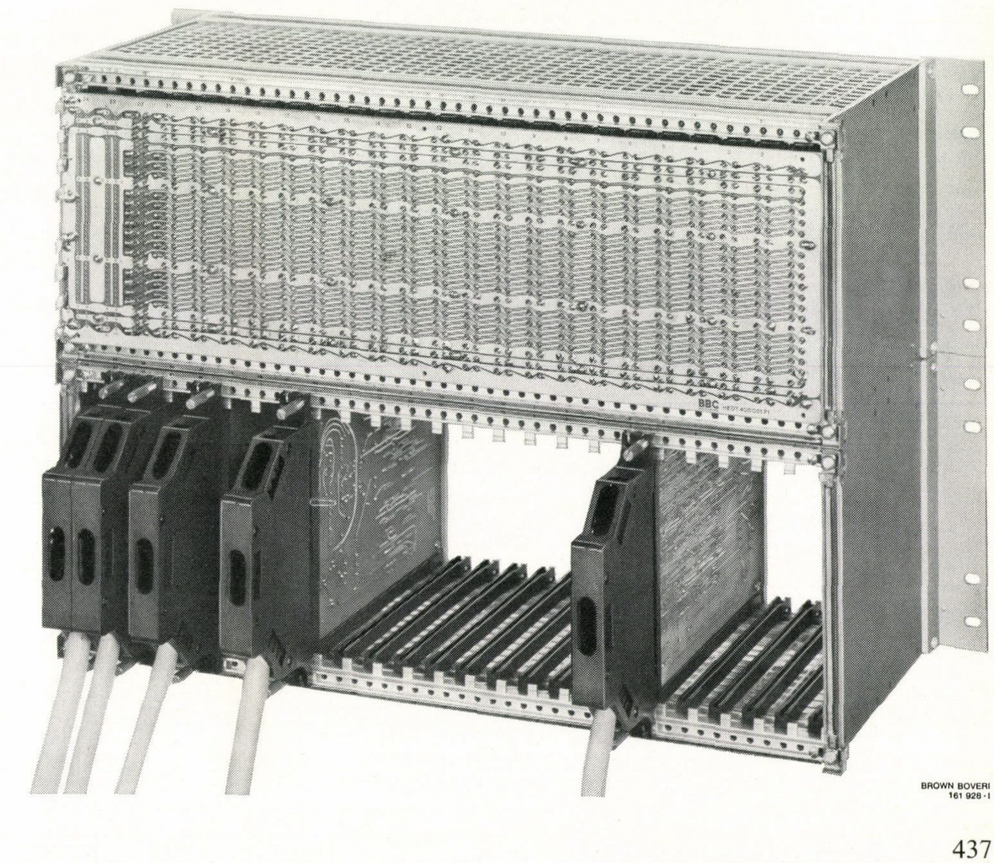

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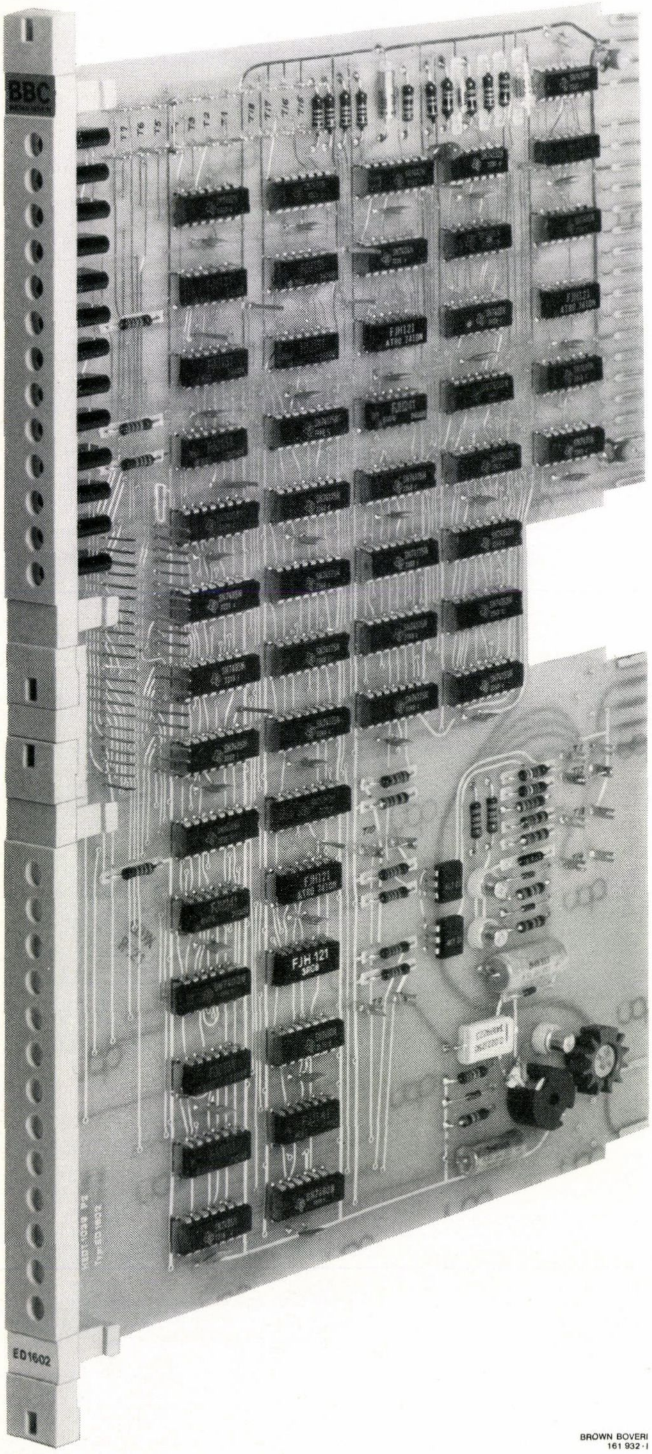


Fig. 3 – Peripheral unit module

Basic Structure of Hardware

The basis of the hardware structure for all the equipment is an identical *system bus* (Fig. 1). It forms the backbone from both electrical and design aspects. Data is exchanged between the peripherals and central processing unit along the system bus on a uniform basis. The data controlled by the central processing unit are transmitted in parallel and asynchronously. The interfaces of all peripheral units are standardized. Each unit can be located in any position or allocated to any address. System modularity is thus achieved in conjunction with a family of central processing units.

From the design point of view the central tier forms the basis of a system. All racks are twice the standard height (Fig. 2a and b). The upper section of the module contains the printed circuit system bus; the lower section has the system plugs with connecting cables to the process or to other parts of the equipment. The central tier can take up to 16 peripheral devices or other modules such as a simple power supply, microcomputer or interfaces for the process computer. Consequently, a small system may comprise merely the central tier.

Peripherals

It is important to devise two types of peripherals. The first type is installed in the central rack. The buses can be extended to form connection to input and output units and contain peripherals of the second type. This arrangement permits both large and small plants to be built up economically because certain functions can be grouped together in the peripherals of the input and output racks. As shown in Fig. 3 all peripherals are in the form of plug-in modules. One set of connections plugs straight into the system bus and the cables connecting it to the process are plugged into the other set.

CPU's

In order to perform the various tasks, central processing units of various sizes and capacities are essential and the obvious solution is to use a family of CPU's. In this particular case the optimum choice was the PDP11 series of the Digital Equipment Corporation. All units of this family are compatible in respect of connection to the system bus. Also, the programmes of each computer operate on the larger computers of this series.

The ED 1800 CPU was developed to augment this series at the bottom end of the scale. It is actually in the form of a micro computer based on integrated circuits. It is used primarily where standard programmes can be used, i.e. in substations of telecontrol systems. The programmes are stored in ROM's so that they are not destroyed even if the supply fails or in the event of extreme external interference.

Major modules of the ED 1000 series

Designation	Type	Model	Remarks
Module tier	ED 100	–	CPU
	ED 111	–	Rack for digital input type 2
	ED 121	–	Rack for digital output type 2
	ED 141	–	Rack for analogue output type 2
Digital inputs	ED 1101	1	With galv. separation, with interrupt
	ED 1102	1	With galv. separation, without interrupt
	ED 1105	1	Connection for sequential event recorder
	ED 1121	2	Without galv. sep., without interrupt
	ED 1122	2	With galv. separation, without interrupt
Digital outputs	ED 1201	1	With galv. separation
	ED 1205	1	Without galv. separation
	ED 1221	2	With galv. separation
	ED 1222	2	With galv. separation, acknowledgement display
	ED 1223	2	With galv. separation, warning signal output
	ED 1224	2	With galv. separation, control acknow. switch
	ED 1225	2	With galv. separation, pulse output
Analogue inputs	ED 1301	1	Without galv. separation
Analogue outputs	ED 1401	1	Without galv. separation
	ED 1421	2	With galv. separation
Digital in and outputs	ED 1501	1	With galv. separation
Special functions	ED 1601	1	Channel transmitter
	ED 1602	1	Channel receiver
	ED 1611	1	Series input/output
	ED 1615	1	Data bank
	ED 1617	1	Electronic clock
	ED 1620	1	Counter reading
	ED 1630	1	Incremental input
Functions within system	ED 1780	1	System bus amplifier
	ED 1781	1	System bus interface
	ED 1790	1	Screening board
CPU's	ED 1800	1	Microcomputer
	ED 1810	1	ROM/RAM
	ED 1841	1	Interface PDP 11/ED bus
	ED 1842	–	
	PDP 11	–	Process computer family
Power supplies	ED 185	–	
	ED 1861	1	

Including the memory, the ED 1800 comprises two printed circuit boards which take the place of a computer interface in the central rack.
The more significant modules available in the ED 1000 series are compiled in the Table.

Data Exchange

In order to complete the picture, data exchange through the ED system bus is described briefly in the following. The CPU writes a data word in a peripheral unit by

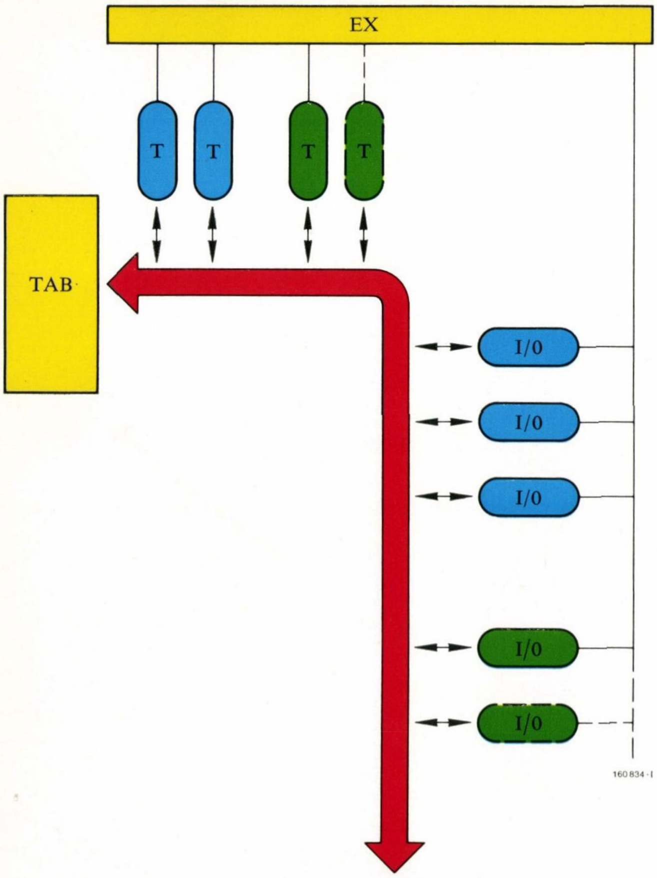


Fig. 4 – Basic structure of software

Yellow = Basic programmes
Blue = Standard programmes
Green = User programmes
EX = Real time mode
TAB = Tables
T = Processing programmes
I/O = Input/output programmes

supplying the address of the peripheral unit, the address of the operation register (each peripheral normally has one status and up to three information registers) together with the data, to the system bus. It then transmits the accept statement. The peripheral unit checks the addresses and writes the information in the addressed information register. Following this it feeds the acknowledgement signal back to the CPU which then resets the accept statement. This cancels the acknowledgement feedback and the bus is then clear for the next operation.
The CPU reads the data words from the peripherals in similar asynchronous fashion. In the case of certain types of information, such as alarms, the peripheral takes the initiative and spontaneously issues an interrupt command to the CPU.

Basic Structure of Software

A distinction is made between basic, standard and user programmes (Fig. 4). User programmes vary from one application to another. The objectives in developing the software were firstly to keep the proportion of user programmes for known, recurrent applications to a minimum, and secondly to establish a modular structure for the basic and standard programmes. As a result, only those components necessary for the given functions need be used for each application (memory capacity) and the user programmes are easily adapted to the basic and standard programmes.
The following deals with on-line software only; off-line software depends on the series of computers used.
The newly developed *basic on-line software* is used mainly in the small to medium-sized installations. Its main components are the real-time operating system and tabular organization. The operating system controls and coordinates all programmes. It ensures correct programme sequence with respect to time and priority and monitors the programmes.

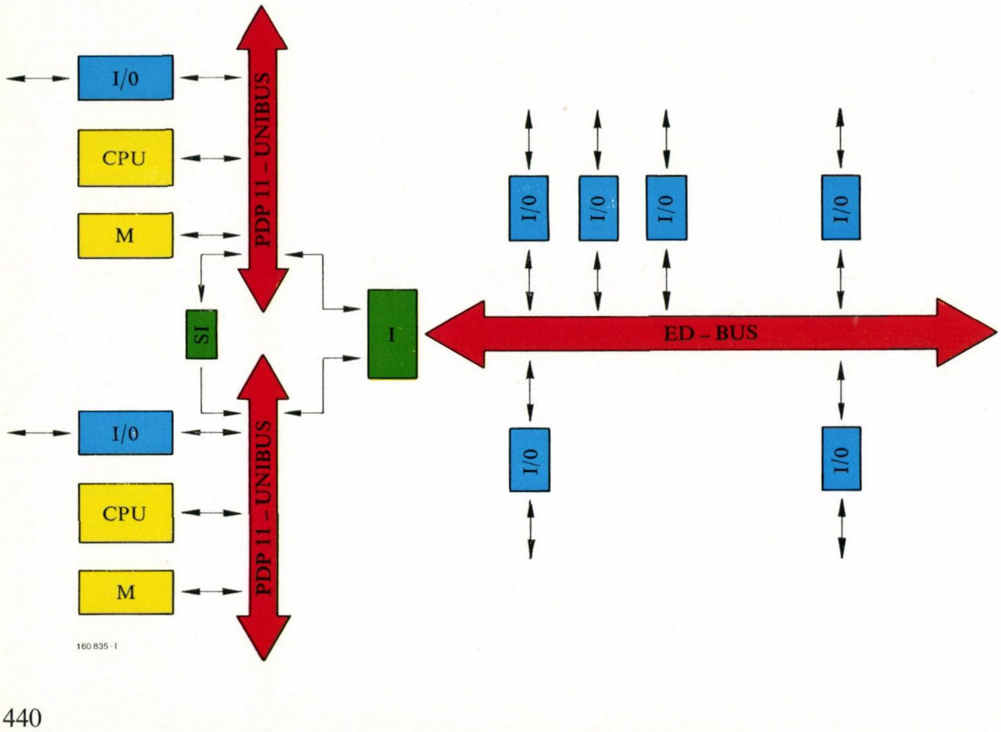
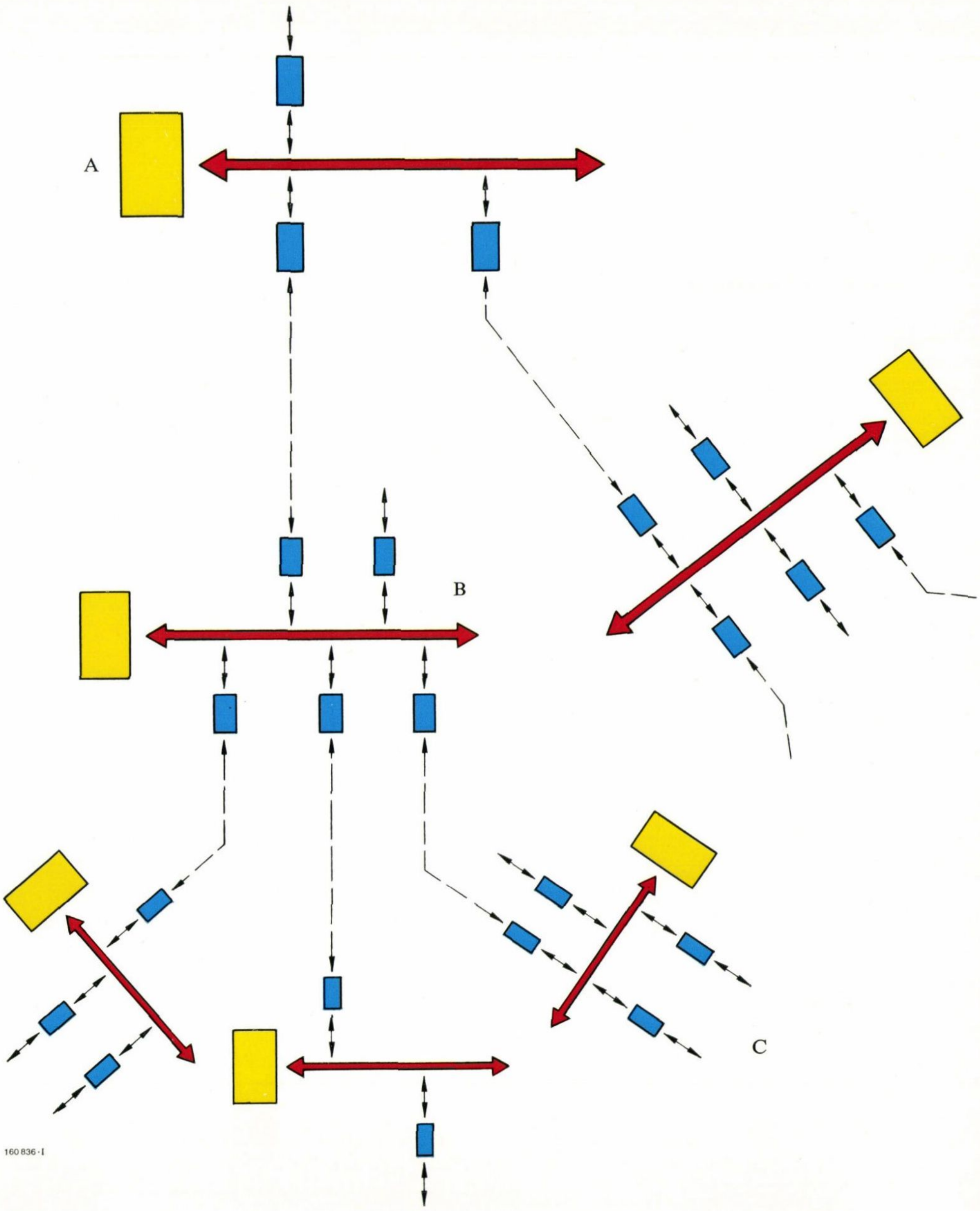


Fig. 5 – Dual computer systems

CPU = Central processing unit
M = Memory
I = Interface PDP 11 unibus/ ED system bus
SI = Interface between CPU's
I/O = Input/output peripherals

Fig. 6 – Hierarchical system

A = Supraregional control centre
B = Regional dispatching centre
C = Substations



Call-up and organization of the data tables are standardized within the basic software for simple co-ordination with standard and user programmes.

Standard Programmes

are used for solving problems which recur in many applications. The peripherals control the input/output programmes. Telecontrol programmes are of particular significance in the ED 1000 system. Measured data processing with limit checking is a typical example of a processing programme.

User Programmes

are developed for solving special problems.
The above mentioned programmes are complemented by *check routines* and a *system generation routine* which selects and coordinates the necessary programmes for a given user configuration.

Applications: Standard Systems and Purpose-Oriented Configurations

The modular structure of hardware and software allows the most diverse configurations for solving a wide range of problems. Efficient project planning and simple service and maintenance are given by the definition of

Standard Systems

The configuration of these standard systems is already decided. The system parameters can be selected only within certain limits. At present the Indactic system family ZM 15, ZM 20 and ZM 20 S [2] is augmented by the following standard systems:

Indactic 13 is a simplex telesignalling and telemetering system for point-to-point or communal traffic (party line, radial or radial/party line) used with the ED 1800 central processing unit in transmitting, transit or receiving stations.
Indactic 33 is a duplex, combined telecontrol system for transmitting all information for network control in the various kinds of traffic, used with ED 1800 central processing unit in the substation and the PDP 11 computer in the control centre.
Indactic 41 as a sequential event recorder with the ED 1800 central processing unit; can be integrated in the substations of the Indactic 13 and Indactic 33 systems.
Indactic 42 as a sequential event recorder with the PDP 11 central processing unit with a wide selection of clear text logging of messages; or as a purpose-oriented application integrated in the remote station or master station of the Indactic 13 and 33 systems.

Purpose-Oriented Configurations

The following are but two examples of special applications taken from the broad spectrum of possible configurations:
Redundant systems which have certain components duplicated to increase their availability. The dual computer system shown in Fig. 5 represents an important case encountered in practice. The arrangement of the computer interface to the ED system bus permits selective control through either of two central processing units. These communicate with each other through a special link.
Hierarchical systems. Network control systems are often arranged on more than two hierarchical levels (substations, regional dispatching centres, supraregional dispatching centres). The structure of such a system is shown diagrammatically in Fig. 6. At the central level the information is issued not only locally, but part of it is passed on to the upper level. The geographical distance between the two levels is of secondary importance.

Conclusion

The ED 1000 modular family is an up-to-date range of equipment based on the latest engineering principles, developed for diverse applications in telecontrol and industrial data handling on a uniform basis. The modular structure is its main feature, simplifying service, maintenance and expansion. Appropriate basic software and defined standard systems reduce project planning costs. Special problems can be solved with very little engineering.

Bibliography

[1] *G. Gerner, F. Tisi:* Brown Boveri Indactic telecontrol equipment. Brown Boveri Rev. *59* 1972 (7) 318–323.

[2] *W. Bizer, K. Demmelmair, G. Gerner, F. Tisi:* Indactic ZM 15, ZM 20 and ZM 20S – a modular system family for telecontrol applications. Brown Boveri Rev. *60* 1973 (2/3) 56–64.

A Dispatching Centre for Gas and Water Supply in St. Gallen

P. Nemetz

A process control system has been supplied by Brown Boveri for centralized monitoring and control of gas and water services in the town of St. Gallen. This system allows the water supply to be controlled fully automatically for the first time, and also monitors the gas supply plant. In normal operation the process is controlled by a computer, the control room being manned only intermittently. System analysis and programming were carried out under the guidance of the firm of H. Grombach, consulting engineers, Zurich, and in close cooperation with the customer. This article describes the nature of the task and reviews the equipment and process software employed.

Introduction

The problem of providing a domestic water supply has many similarities with that of distributing electricity. The requirements regarding continuity and security of supply are of roughly the same order in both cases. On the other hand, there is a fundamental difference in that water can be stored in reservoirs, and therefore faults in the treatment plant or distribution network need not immediately endanger the supply. Consequently time is a much less vital factor than with the distribution of electricity and this fact influences both the data transmission systems (telecontrol) and the systems processing the data (process computer).

In many instances the task of system control can today still be performed simply and economically with conventional equipment. With supplies of drinking water, however, the very important quality checks give rise to many items of information which must be monitored continuously. As consumption figures rise, not only does improved plant utilization become increasingly important but also up-to-date means of system control are needed to process the ever larger volume of information [1].

St. Gallen's Water Supply

St. Gallen's public water system serves a population of roughly 100 000 with a maximum demand of 50 000 m^3/day [2]. Although these figures are not particularly high, the water supply is complicated by the following factors:

- The total volume is provided from three sources having quite different characteristics: spring water (amount small, heavily dependent on weather conditions, cheap), well water (amount small but suitable for peak coverage) and lake water (Lake Constance, covers the total demand, expensive).
- The area supplied includes a total difference in altitude of 450 m, so that four pressure zones are necessary within the town alone, and two more for the surrounding district.
- The densely built-up part of the town extends along a steep-sided valley 10 km long and 1 km wide, requiring a further division into storage zones.
- During prolonged dry spells, certain neighbouring areas have to be supplied when their springs are no longer adequate, thus imposing an additional load on the system as a whole.

At present there are two waterworks and two spring areas to be tended, together with ten pumping stations and twelve reservoirs to be monitored and controlled. Owing to the high wages factor and lack of personnel, the plant of the water supply system has for many years been extensively automated. At the time of changing over to centralized control, virtually all the various installations were equipped with local control facilities, which greatly simplified the planning of the overall system. The map in Fig. 1 gives an indication of the geographical situation.

The Major Functions

The facilities to be provided by the project can be split into the following five categories:

Alarm processing: Faults are registered, identified with the time of their occurrence and recorded in an alarm log (Fig. 2). When the control room is unmanned, urgent alarms are passed by telephone to a picket.

Control: Under normal operating conditions the pumping stations are controlled automatically by the process computer, with account taken of reservoir levels, tariff periods, anticipated total demand, etc. In abnormal circumstances (faults, maintenance work, and so on), commands can also be given manually by means of the typewriter keyboard, and these are then carried out with the aid of appropriate programme control (Fig. 3).

Recording: A large part of the operating data are not needed under normal conditions, but access to the information before, during and after faults is most important. Reliable and accurate reconstruction of faults and abnormal operating conditions is essential to good management of the system. By using a process computer, data can be held for a considerable time (36 hours, a week) without unnecessary printouts, and the required information can then be presented in a concentrated and clearly arranged form (tables and plotter diagrams).

Statistics: The temporarily held data are periodically evaluated and compressed and transferred to a magnetic disc. These values can provide important information on the long-term performance of the system, providing a basis both for improving the programmes and also for planning extensions to the water supply.

Background tasks: When the process computer is not engaged in the tasks described above, computer time is made available by the operating system for nonprocess jobs. One important use lies in developing, checking and implementing new, improved versions of existing programmes [3].

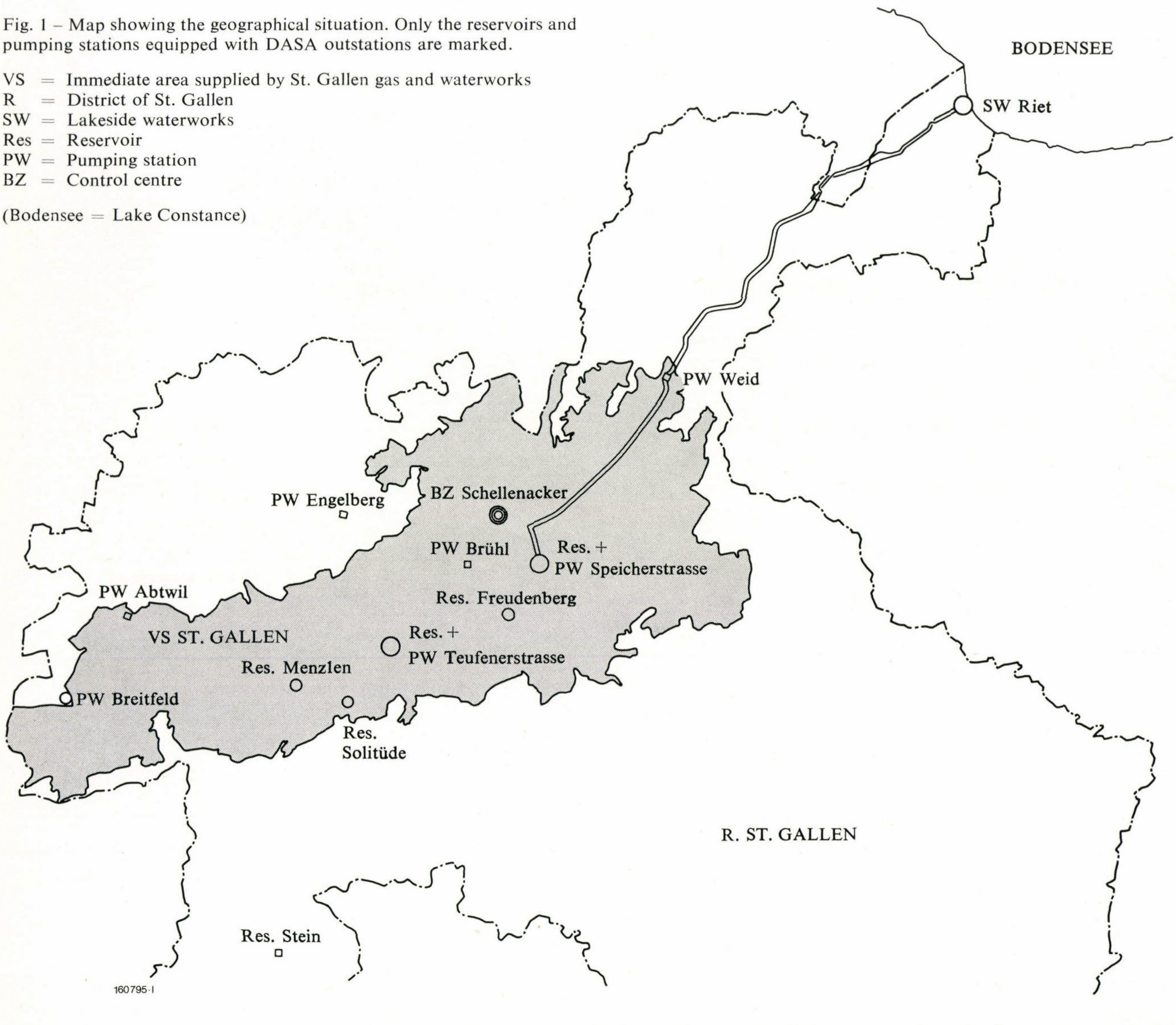


Fig. 1 – Map showing the geographical situation. Only the reservoirs and pumping stations equipped with DASA outstations are marked.

VS = Immediate area supplied by St. Gallen gas and waterworks
R = District of St. Gallen
SW = Lakeside waterworks
Res = Reservoir
PW = Pumping station
BZ = Control centre

(Bodensee = Lake Constance)

System Concept

Hardware: Telecontrol System and Process Computer

The Brown Boveri Indactic® DASA Combined Telemetering and Telecontrol System

The exchange of information between the dispatching centre at Schellenacker and the outstations is handled by the powerful, combined Indactic DASA telecontrol system. This is capable of meeting all requirements regarding transmission capacity and security, scope for expansion and operating in conjunction with a process computer [4]. Although in a water supply system a large part of the volume of data to be processed comes from relatively small substations, so that the complex telecontrol gear constitutes a significant proportion of the equipment in the outstations, this solution has advantages in both technical and operational respects (uniformity in system structure and handling of the data, service, stocking of spares, etc.).
An economical concept has been achieved with this system in that the information required from very small substations is transmitted over multiwire lines to neighbouring stations in which DASA equipment is installed. The telecontrol and computer system is shown schematically in Fig. 4. Some 30% of the transmitted data volume is presented on the mimic diagram. This is operated direct by the telecontrol system so that in the event of computer failure the engineer still has a good general picture of the state of the system. The quantities of data to be transmitted and processed are summarized in the Table.

The IBM 1800 Process Computer

The IBM 1800 system employed [5] meets the particular requirements to a large extent, as the scheduling system allows the use of a relatively small main store together with a large auxiliary store. All non-critical routines as regards time are held on the discs, and when needed are read into an area in a variable core provided for this purpose, and run through. Normally system control (controlling the pumping stations) is in the on-line closed-loop mode, i. e. without intervention by the personnel.

Central Control Room

The control room is laid out in accordance with the needs of modern system control (see cover picture). The large, passive mimic diagram provides a clear overall picture of

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STOERUNGS-MELDUNGEN        VOM      4.    12.  1972
*******************

15.48   SEEWASSERWERK   RIET             FEUERMELDEANLAGE     STOERUNG
15.49   SEEWASSERWERK   RIET             FEUERMELDEANLAGE     STOERUNG
15.49   SEEWASSERWERK   RIET             FEUERMELDEANLAGE     STOERUNG
15.51   FILE 1 IST AUFGEFUELLT
16.45   UNTER-STATION   ENGELBURG        BLOCKIERT MANUELL
16.45   UNTER-STATION   ENGELBURG        BLOCKIERT DURCH RECHNER
16.51   PUMPWERK        ROTMONTEN        PUMPE 2 STOERUNG
17. 0   PUMPWERK        ROTMONTEN        PUMPE 2 STOERUNG
17.20   PUMPWERK        ABTWIL           VORDRUCK
        UGR    8.18  MW    9.52  OGR    9.38   KP/CM2
17.25   PUMPWERK        ABTWIL           VORDRUCK
        UGR    8.18  MW    8.84  OGR    9.38   KP/CM2
20.31   UNTER-STATION   TREUACKER        BLOCKIERT MANUELL
20.31   UNTER-STATION   TREUACKER        BLOCKIERT DURCH RECHNER
21.25   KOMMANDOSTAT 1  1. PARITY-FEHLER
21.55   KOMMANDOSTAT 1   1  PARITY-FEHLER
22. 7   FILE 1 IST AUFGEFUELLT
```

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Fig. 2 – An alarm log

New alarms are printed in red (lines with screen), cancelled alarms in black, using the same text. The text library is contained in tabular form on the disc. Changes are made simply by reading in new text punched on cards with the aid of an auxiliary routine. Time is always stated in hours and minutes.

Fig. 3 – Examples of manual instruction input and interrogation of system states

Lines 1–4: manual input. The command code (*BEEW) is typed in. This command, together with the time and date, is then printed out in clear for checking. The operator now decides whether the instruction is to be carried out (J) or not (N).
Lines 5 and 6: interrogation of a measured value by entering the appropriate code (*MW 01).
Lines 7–19: interrogation of the system state in the form of a dialogue with the computer. On entering the code (*MA) the computer gives the various input possibilities in clear, together with the input format. When the desired information has been selected (AL 99), this is printed out. The input codes are always available from a list near the operator's typewriter.

```
*BEEW
    9. 12.  10.40   SEEWASSERWERK  RIET            BELUEFTUNGSANLAGE    EIN
     BEFEHL ABGEBEN    JA / NEIN  (EOF)
N
*MW01
 9.12.1972  10.41 UHR  RESERVOIR       SOLITUEDE       RESERVOIRSTAND          3.58  METER
*MA
SCHREIBEN DES ALARM-UND/ODER MELDUNGS-ZUSTANDES
EINER ODER ALLER UNTERSTATIONEN
XX YY      XX = AL  FUER ALARM-ZUSTAND
           XX = ME  FUER MELDUNGS-ZUSTAND
           XX = MA  FUER ALARM- UND MELDUNGS-ZUSTAND
           YY = MODIFIZIERTE US-ADRESSE FUER EINE US
           YY = 99  FUER ALLE US
AL 99
          IST-ZUSTAND DER FOLGENDEN ANLAGEN AM   9.12.1972  10.42 UHR
          **********************************
          GRUNDWASSER-PW  BREITFELD      SPANNUNGSAUSFALL
          ENDE DER ALARM- UND / ODER STELLUNGS-MELDUNGEN
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Summary of transmitted data

Outstation	Plant	Criteria				
		AV	DV	IN	PS	AL
Solitüde	Solitüde reservoir (res.)	2	2	3	2	5
Teufenerstrasse	Nest reservoir, Teufenerstrasse reservoir and pumping station	7	7	15	13	15
Treuacker	Pumping station Treuacker	2	1	5	4	4
Menzlen	Menzlen reservoir	2	2	3	2	5
Geissberg	Pumping stations Geissberg, Breitfeld, Herisau; Nordhalde reservoir (Bruggen h.p. gas p.s.)	17	8	35	32	38
Abtwil	Abtwil pumping station	4	2	7	5	5
Hättern	Hättern pumping station	3	1	7	5	5
Schellenacker	Peter und Paul reservoir, Rotmonten pumping station (Schellenacker transfer station), Wittenbach pressure reduction station, Gais h.p. gas p.s.)	11	3	6	8	25
Riet	Riet lakeside waterworks, Goldach pumping station (Riet transfer station)	32	3	90	108	110
Weid	Weid pumping station, Mörschwil supply station	6	2	5	15	10
Grütli	Grütli compressor station	2		7	3	5
Brühl	Brühl pumping station	2	1	7	6	6
Speicherstrasse	Speicherstrasse reservoir and pumping station, Scheitlinsbüchel reservoir	11	11	23	22	21
Freudenberg	Freudenberg reservoir	2	2	3	2	5
Total		103	46	216	227	259

Key:
AV analogue values
DV digital (quantized) values
IN instruction
PS position signal
AS alarm signal

Note:
Installations in parantheses belong to the gas supply network, which is covered by the monitoring system.

the state of the system without creating confusion through showing too many details. Detailed information can be called up easily by means of sophisticated dialogue routines. In normal operation the system is controlled by the process software, and so the manual input of commands could be made very simple, using the typewriter keyboard (see Fig. 3).

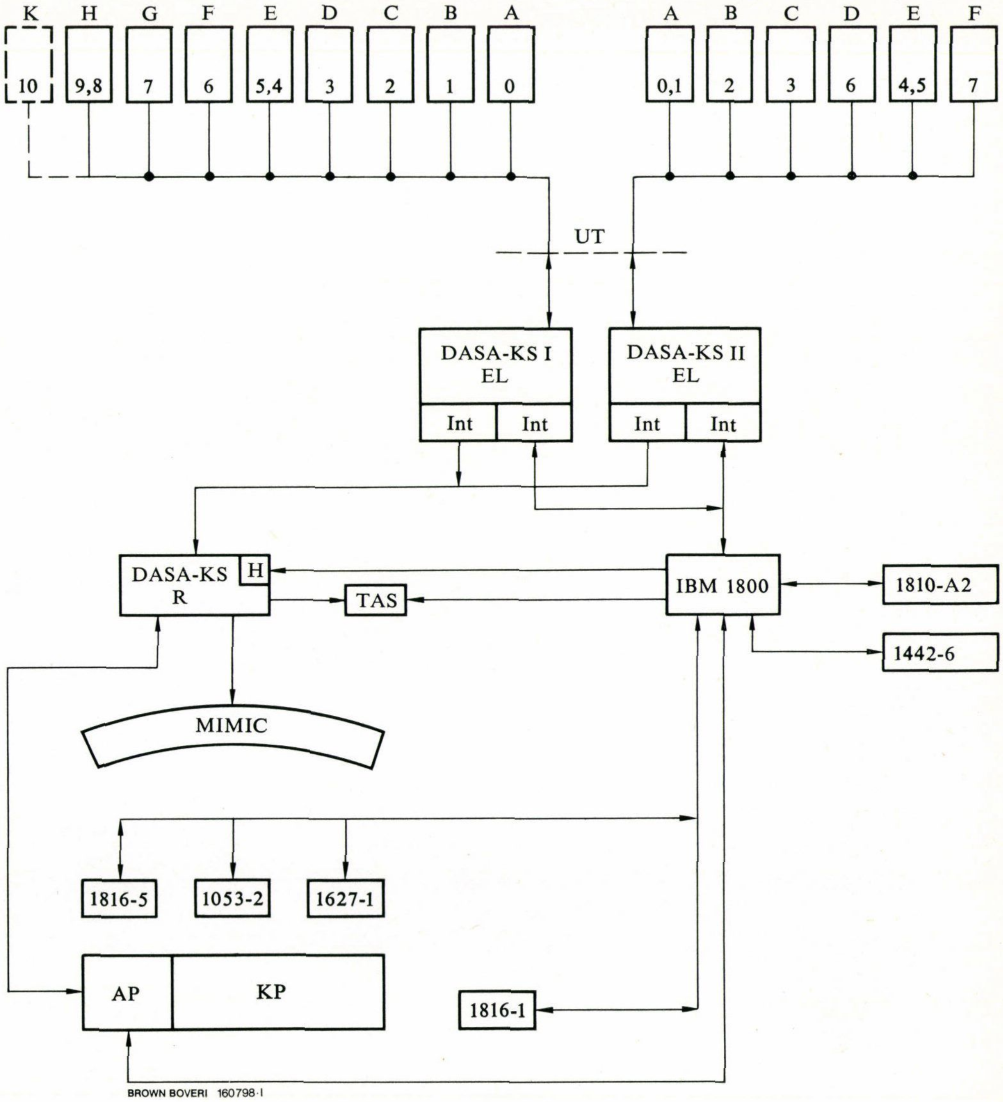
The control desk is divided into a place for the programmer and a place for the operator. The programmers use mainly the console typewriter for writing and testing programmes and the card reader and punch for feeding in programmes. The operator works chiefly with the alarm printer, the operator's typewriter, and the plotter. The output of the alarm printer consists of alarms as they occur and disappear. This is the only information which is always printed out (see Fig. 2). Access to all other information is possible only by manual request; the plotter (Fig. 5) and the operator's typewriter being available for this purpose. The moving head disc is at present equipped with two units (storage capacity 512 K each) containing the operating system, process programmes, auxiliary and check routines and the subroutine library.

System Control: The Software

Software Development

In order that the great flexibility of the computer system as regards software development can also be made use of, three members of the gas and waterworks personnel underwent suitable basic training and then joined the software development group. The resulting collaboration between customer and supplier has been very successful.

Fig. 4 – Block diagram of the complete control system



DASA-KS = DASA control station
EL = Electronics
R = Relay periphery

Outstations for DASA-KS I (the numbers are the substation addresses):
A = Stein reservoir (res.)
B = Teufenerstrasse res. and pumping station (p.s.), Nest res.
C = Treuacker p.s.
D = Menzlen res.
E = Nordhalde res., Herisau p.s., Breitfeld p.s., Bruggen h.p. gas station (HPG), Geissberg p.s.
F = Abtwil p.s.
G = Hättern p.s.
H = Gais HPG, Wittenbach pressure-reducing station, Rotmonten p.s., Peter und Paul res., Schellenacker transfer station
K = Stein res. (not yet installed)

Outstations for DASA-KS II:
A = Riet waterworks, Goldach p.s., Riet transfer station
B = Weid p.s., Mörschwil supply station
C = Grütli compressor station
D = Brühl p.s.
E = Speicherstrasse res. and p.s., Scheitlinsbüchel res.
F = Freudenberg res.
UT = Transmission equipment
Int = Interface
H = Horn
TAS = Telephone alarm system
MIMIC = Mimic diagram
AP = Alarm panel
KP = Control desk
IBM 1800 = Process computer, core storage capacity 16 K
1810-A 2 = Disc storage with two discs, storage capacity 512 K each
1442-6 = Card reader and punch
1816-1 = Console typewriter
1816-5 = Operators typewriter
1053-2 = Alarm printer
1627-1 = Plotter

A few specially noteworthy points may be mentioned in this connection:

– A process computer offers great advantages as regards optimum system management if programme modifications and extensions can be made largely without taking the computer off line.

– Training the customer's engineers through appropriate programming courses and calling them in to help on the project is sufficient to ensure that the software is kept up to date by the customer.

– A large proportion of the possible applications of a process computer do not come to light until it is in service, and are hard to predict in the planning stage.

– The participation of the customer's engineers should be aimed at as standard procedure, and is helped by choosing a larger computer which allows the use of higher-level programming languages, such as FORTRAN.

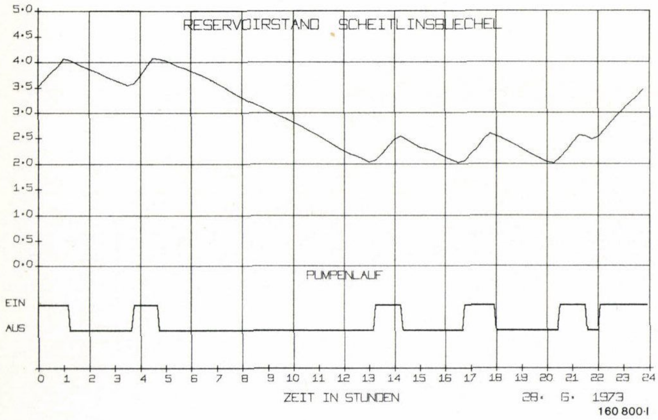
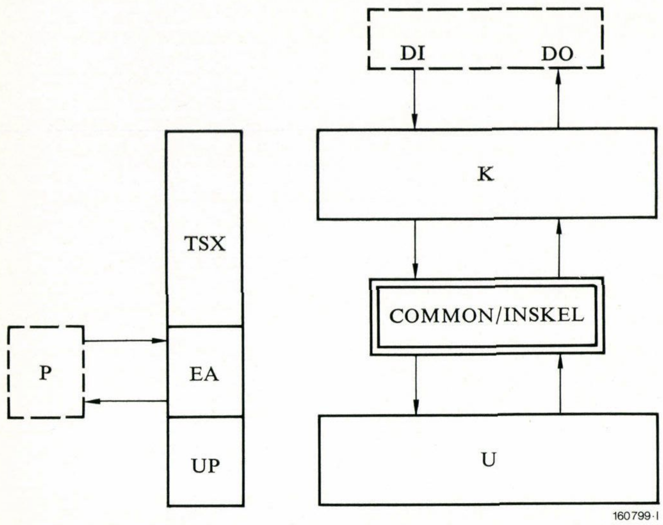


Fig. 5 – Example of a plotter diagram. The bottom half of the diagram shows the running times throughout a day of a pump filling the reservoir indicated in the upper part of the diagram, together with its level.

Fig. 6 – Composition of software

Data exchange with the process is by means of a programme package in assembler language. The COMMON/INSKEL tables decouple these programmes from the software controlling the system which is dependent on the application.

DI, DO = Digital input/output to telecontrol equipment and alarm panel
K = Dialogue routines
COMMON/INSKEL = Tables permanently in main store (buffer tables for data exchange between programmes, system status, measured-value tables, etc.)
U = Monitoring and control programmes
TSX = Scheduling system (Time Sharing Executive)
EA = Input/Output routines (Standard)
P = Peripherals
UP = General subroutine library



Composition of the Software

The basic composition of the software and its interrelations are shown in Fig. 6. The operating system used is the Time Sharing Executive system (TSX) [3]. The dialogue routines for the telecontrol systems are essentially for purposes of data exchange with the DASA stations and for storing the transmitted data in various tables (COMMON/INSKEL tables) from where they are withdrawn and further processed by the process programmes. This part of the software is largely independent of the actual process functions, and is decoupled from these by the COMMON/INSKEL tables. Since the programmes are run through very frequently (some ten times per second), they have to be permanently in the main store. They have therefore been programmed in Assembler language.

The process programmes, which deal specifically with controlling the process, are contained entirely on the two discs and are written almost exclusively in FORTRAN. The greater part was developed by the gas and waterworks personnel themselves. In this way it was possible to incorporate direct all the customer's ideas and also the wishes of the operating staff. Together with the test routines for checking out the process programmes, the data tables and the auxiliary routines they occupy a disc area, making it necessary to employ a two-disc system. Long-term storage of data is effected by replacing the second disc with the archive disc and transferring the data to be stored. The process programmes have therefore been divided between the two discs in such a way that the second system disc can be exchanged for the archive disc, i.e. for short periods the system is also functional with only one disc.

Documentation

One of the essentials of successful process programming is to compile comprehensive, easily managed documentation, and keep it up to date. This is particularly important with the project discussed here because the system is subject to periodic extension and modifications resulting from improvements in system management, the introduction of new control strategies for the pumping stations, etc. An ever recurrent problem is the large volume of data which must be stored and updated without forsaking clarity. As with the process software itself, close and intensive collaboration between customer and supplier is an essential prerequisite to good documentation.

Practical Experience

The control and monitoring system has been in service since early 1972. To date it has fully come up to expectations and has demonstrated that the installation can help greatly in improving and simplifying management of gas and water supplies. The opportunity to follow and study the behaviour of the system from a central point has provided a deeper understanding of the, at times complicated, hydraulic conditions. Plotter graphs show clearly the effect of variations in the pumping-station control parameters so that they can be examined easily. In this manner improvements have been made to the way the plant is used and loaded. The control room layout, with its passive mimic display giving an easily understood picture of the state of the system, has proved its value in the practical work of the operating personnel, as has the possibility of dialogue with the computer through the typewriter keyboard (see Fig. 3). Fully automatic control means also that under normal circumstances the control room can be unmanned. Urgent alarms are then passed to a picket by telephone via a remote alarm system.
The close cooperation with the St. Gallen gas and waterworks and with the consulting engineers, H. Grombach, in Zurich has also made it possible to achieve the set objectives regarding software development.

Bibliography

[1] *P. Grombach:* Planung von Wasserversorgungen. Gas, Wasser, Abwasser *50* 1970 (5) 123–135.

[2] *M. Schalekamp:* Die Wasserversorgung der Stadt St. Gallen gestern – heute – morgen. Gas, Wasser, Abwasser *49* 1969 (6) 191–198.

[3] *P. G. Harhammer:* Die Bedeutung von Betriebssystemen bei Prozessrechneranlagen. Elektrotech. u. Maschinenb. *88* 1971 (11) 467–471.

[4] *G. Gerner, F. Tisi:* Brown Boveri Indactic telecontrol equipment. Brown Boveri Rev. *59* 1972 (7) 318–323.

[5] *R. Hartwig:* Aufbau eines Prozessrechnersystems. IBM Nachrichten 1970 (19a) 68–73.

Generator Breakers for Large Power Stations

P. Burckhardt

Economic benefits and improved reliability are to be gained from using generator breakers in large power stations. The superiority of this concept becomes apparent at the planning stage for such switchgear configurations. The various application opportunities are reviewed and certain design features of the DR 36 range of breakers are described.

General

The auxiliary supply for large power generating units must be maintained and, for economic reasons, must involve as little expenditure as possible. The most reliable source of power for the generator auxiliaries is to tap-off at the l.v. connections of the generator transformer. Introducing a generator breaker in the heavy current connections between generator and main transformer has, amongst others, two important advantages; reliability is improved and costs lowered by dispensing with quite a number of components.

Power Station Configurations with Generator Breakers

A unit-connected power station with generator breaker is shown in Fig. 1 for comparison with the arrangement which has been most common until now (Fig. 2). Using the generator breaker does away with the separate infeed for starting up the plant. Even with the generator shut down, the station service supply is taken from the h.v. system through the generator unit transformers. As a general rule power stations with outputs of 600 MW and more supply direct into an interconnected system with a voltage level of 400 kV and upwards. The station service requirement of a thermal power station is 5 to 8% of the generator output, e.g. 60 to 100 MVA for a 1000 MW machine. A starting transformer for this rating is expensive, the more so the higher the voltage of the interconnected system.

In certain cases the existing h.v. system has an intermediate voltage level which, as such, would appear suitable for supplying the auxiliary load but often does not have the necessary stability for coping with the rapid load transfers which occur. It would be an expensive business to build up such a network accordingly and it would also be contradictory to the fundamental requirement for an independent auxiliary system. Also, availability is less than that of the interconnected system into which the generator is feeding.

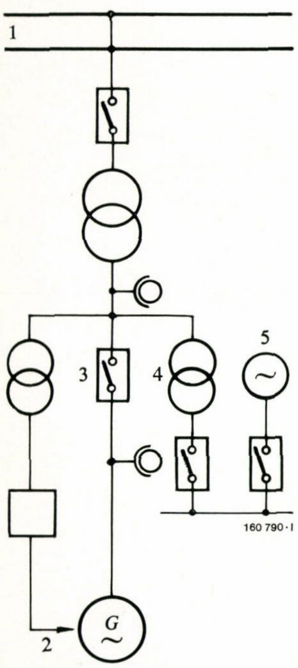


Fig. 1 – Plant with generator breaker

1 = E.H.V. network
2 = Rectifier excitation
3 = Generator breaker
4 = Auxiliary transformer
5 = Standby diesel generator set

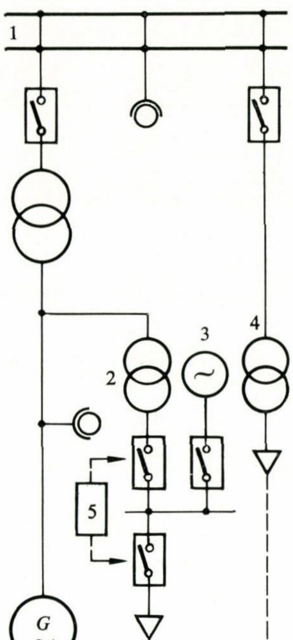


Fig. 2 – Unit connection with starting supply from e.h.v. network

1 = E.H.V. network
2 = Generator breaker
3 = Standby diesel generator set
4 = Starting transformer
5 = Quick-acting automatic changeover unit

Consequently there is a growing need to use generator breakers as unit outputs continue to rise.

Reliability of Auxiliary Supply

If the auxiliary supply for a power station is provided by direct connection to the generator and to the grid, its reliability is increased to a level where it is no longer necessary to provide separate infeed for starting [1, 2]. All switching operations can be carried out without changeover of the auxiliary supply. The uninterrupted supply from the same secure source reduces the risk of a fault to the minimum. All those problems associated with the transient phenomena occurring during motor change-over and which, in most cases, cannot be carried out at below rated frequency without causing surges, are also disposed of. Should the very rare case of simultaneous breakdown of both network and generator arise, the essential station service supplies are provided by a standby diesel generator set. The probability of the diesel plant being required to operate is the same for all power station configurations.

In some cases very large generators require two main transformers. This permits the generator output to be transmitted at two different voltage levels provided that the power flow can be controlled within acceptable limits during system faults. A generator breaker at the low-voltage side of each main transformer (Fig. 3) provides a high degree of protection for the auxiliary supply, in that two auxiliary supply transformers are connected to the busbars between the generator breakers and the main transformers. Two independent sources provide secure auxiliary supply should part of the system, one of the transformers or the generator develop a fault. Adding a further generator breaker, as shown in Fig. 4, provides optimum security for both auxiliary transformers [3]. Even if one of the main transformers is disconnected, full output is available from both auxiliary transformers. This is, of course, on condition that the busbar connections between the three breakers and the station service transformers are also adequately rated and reliable.

The Economics

Comparing the two basic circuits shown in Fig. 1 and 2 leads to a comparison of the economic aspects concerning the main components (see Table I).

At the same time it should be noted that the cost of a starting transformer and its switchgear increases more than proportionally as the voltage rating of the supply network while the outlay for a generator breaker is determined merely by the generator output and the required breaking capacity.

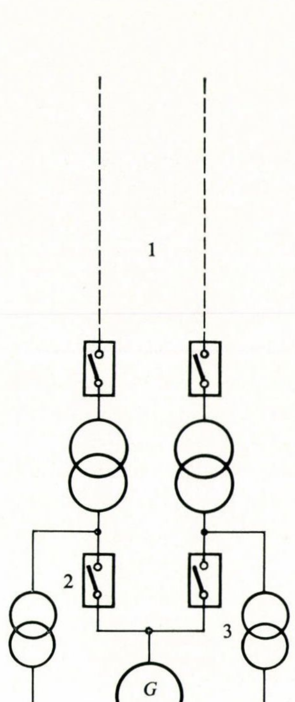


Fig. 3 – Feeding two parallel h.v. lines

1 = Overhead lines
2 = Generator breaker
3 = Auxiliary transformer

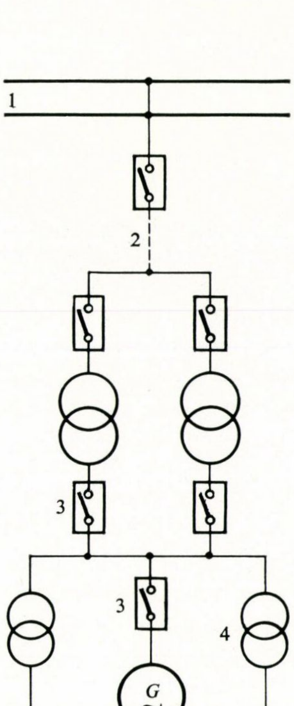


Fig. 4 – Connection with two secure station service feeders between two generator breakers

1 = E.H.V. network
2 = Overhead line
3 = Generator breaker
4 = Auxiliary transformer

Table I: Comparing the economics of two plant arrangements

Plant with generator breakers	Plant with separate starting transformer
Electrical equipment	
Generator breakers	Connection to starting network
Earthing system	High-voltage circuit-breakers, isolators, instrument transformers
Control and protection equipment	Starting transformer
Air compressors, cooling water plant	Cable connections
Low-voltage synchronizing voltage transformer	Feeder breaker for station service plant Control, protection and interlock equipment Quick-acting automatic changeover system High-voltage synchronizing voltage transformer
Building costs	
Installation and assembly costs	Space required for starting equipment Foundations for starting transformer Structural steelwork Switchgear cabinets Access ducts Installation and assembly costs
Other expenses	
Periodic inspection	Service and maintenance for many components
Low planning costs	Isolator in generator feeder High planning costs

Consequently, generator breakers become more economical with rising system voltage. Eliminating the starting equipment is very welcome where space is restricted. It is even possible to dispense with the h.v. switchyard at the power station if the output is fed over a line to a switching station nearby. This short spur line can be fully loaded and included in the main transformer protection zone.

Another consideration is that the generator breaker forms part of the generator busbars, which are essential in any case, and therefore does not occupy any additional space. The considerable savings in maintenance and overhaul costs must also be taken into account as the generator breaker is very modest in its service requirements. Introducing the generator breaker initially involves somewhat higher planning costs in designing the power station but these are more than offset by the savings in starting equipment and the considerable simplification of the control and protection systems of the plant due to decentralization of various functions.

The question of whether a generator breaker can bring economic benefits for a given plant must be decided on the basis of careful calculation [4, 5]. In any case it is a simple matter to demonstrate that the savings in eliminating the starting equipment are considerably more than the cost of a generator breaker, not to mention the higher plant security provided by a generator breaker and its associated increase in availability.

Type of Generator Switchgear

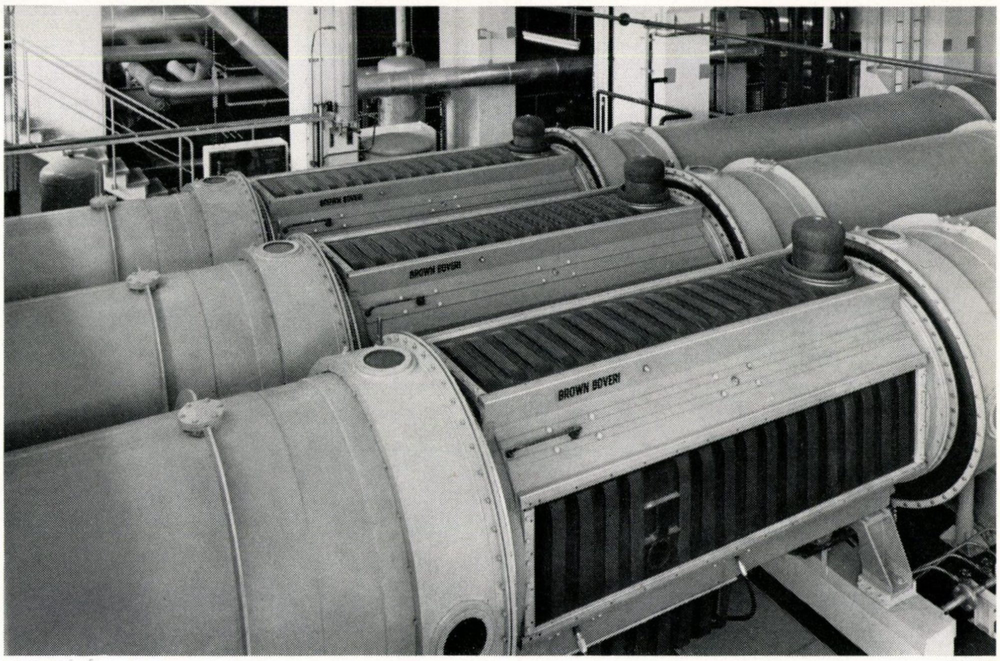
Primarily, the generator switch must be capable of coping with all switching operations, such as connecting to and disconnecting from the system under normal operating conditions. Consequently, the generator is under virtually no load and therefore only a small current has to be switched. If the switch is not required to perform any further tasks it will suffice to use a load switch designed to withstand the short-circuit stresses which could possibly occur.

In most cases, however, the switch will be required to perform further tasks: under normal circumstances it should be possible to break at rated generator current and also under overload conditions, particularly if immediate load shedding is required in the event of a fault in the plant. The switch must also be able to close on short-circuit currents resulting from non-synchronism.

If the generator switch is in the form of a circuit-breaker it can also perform the task of interrupting faults in the region of the main or auxiliary transformers, or in the

Fig. 5 – Power station with built-in generator breakers

The circuit-breakers are rated 28 kA and form an integral part of the isolated phase busbars.



generator. Difficult interruptions under phase opposition can also be carried out with suitably designed circuit-breakers.

Plant Security

Using a circuit-breaker presents the interesting proposition of bypassing the de-excitation system of the generator. All the de-excitation equipment of the generator operates slowly in comparison to the very short tripping time of the breaker.

Brushless generators have particularly long field discharge time constants. In addition to this a rapid field discharge system merely discharges the longitudinal field while the quadrature field remains unaffected [6]. Rapid interruption of a short circuit by means of a generator breaker reduces the effects in the vicinity of the fault.

In the case of large generators a short circuit results in a large d.c. component in the fault current which decays only slowly and consequently there can be no zero transient for some cycles. The generator breaker must be capable of interrupting such short-circuit currents with very large d.c. components. However, in the case of a three-phase short circuit, maximum asymmetry can occur in only one phase and no zero transients will appear in this phase or possibly in one of the other phases. That phase which still has zero transition is interrupted first by the breaker opening. The result is a considerable drop in the d.c. components in the other phases. In conjunction with the high arcing resistance of the airblast breaker poles the currents are forced to pass through zero and the short circuit is interrupted [7, 8]. Type DR generator circuit-breakers competently master these phenomena.

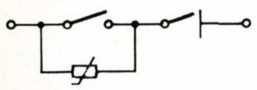
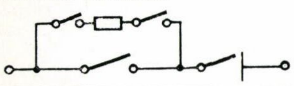
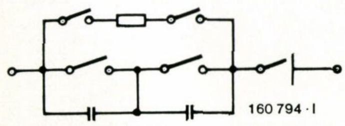
Before synchronizing the generator with the system there is intermittent phase opposition in the voltage across the breaker. This phenomena can exist for some considerable time and places a particular stress on the insulation across the open breaker. Type DR generator breakers have the decided advantage over outdoor high-voltage circuit-breakers that their isolating gaps are formed in atmospheric air and no parallel insulating path exists whose dielectric strength can be jeopardized by polluted air. Under phase opposition conditions its insulation is stressed only to earth and only to the same degree as with normal service voltage. In addition the isolator is an integral part of the DR breaker and provides the insulation between the two network components until the breaker closes. If a generator load switch is used, it has little effect on the arrangement of protection equipment for the plant [9]. The load switch can perform no fault switching duties apart from load shedding as a result of a mechanical fault in the plant. An overcurrent relay must be provided to ensure that under no circumstances is the breaking capacity exceeded.

In contrast to this the generator circuit-breaker can perform virtually all protective switching functions. As security has absolute priority over all other considerations, the level of security attainable justifies the use of this equipment in every case.

Design of Generator Breaker

Type DR36 generator breakers [9] were developed for incorporation in isolated phase busbars (i.p.b.'s) and include their main features. Reliable transmission of the high currents between the generator and unit-connected transformer is possible only with busbars whose phases are completely isolated. Three single-phase metal-enclosed busbars are virtually immune to short circuits and faults due to external influences. The magnetic screen eliminates forces between the conductors and also prevents tempera-

Table II: Range of DR 36 generator breakers

Equipment and diagram	Rated voltage kV	Rated current 50/60 Hz A	Breaking current r. m. s. (sym) at 25 kV kA	Breaking capacity (three-phase) at 25 kV MVA	Rated surge current (peak) kA
Isolator 	36	10 000 28 000 36 000	–	–	600
Load switch 	36	10 000 28 000 36 000	Load current	–	600
Circuit-breaker 	36	10 000 28 000 36 000	100–150	4300–6500	600
Circuit-breaker  160 794 · I	36	10 000 28 000 36 000	150–200	6500–8700	600

ture rise in nearby steelwork and reinforced concrete structures due to eddy currents. As far as the staff is concerned the earthed enclosure provides almost total protection against accidental contact with live parts. As shown in Fig. 5 the DR36 generator breaker blends smoothly into the system. Three parallel single-pole breakers, comprising series isolators and breaker chambers, from the active parts; each having its own cylindrical housing with removable panels. The housings are designed to carry the sheath current of the isolated phase system. Diameters and distances between poles coincide with those of the i. p. b.'s and therefore no extra space is occupied. The main data of this range of breakers are given in Table II.

Under normal operating conditions the breaker behaves exactly as part of the busbar. Even if the air pressure is lost, neither the dielectric strength nor the conducting capacity for continuous and short-circuit currents are affected. Switching is instigated by positive control commands only. Mechanical interlock holds the breaker in either the open or the closed position.

The open breaker has the same significance as an open isolating link. The series isolator is visible and can be quickly and effectively locked; an important factor for the safety of the personnel.

As is the case with the large generators, the generator breakers are water-cooled. This arrangement considerably improves the reliability of the breaker as the cooling water provides the information to permit continuous monitoring of the operating condition. This method of cooling permits heat dissipation direct from the source of heat without involving large temperature differences. In contrast to forced air cooling the noise level can be kept low and there can be no pollution of active parts through the cooling medium. If the breaker cooling loop is not connected to the generator cooling system, auxiliary cooling equipment can be supplied. This contains duplicated circulating pumps and metering and monitoring equipment. Continuous measurement of coolant temperature permits automatic monitoring of the breaker condition. The breaker is fully serviceable with cooling water of a relatively high conductivity. Its range of application is determined by the thermal loading.

The dielectric strength corresponding to a rated voltage of 36 kV according to IEC provides a large safety margin for all generator voltages in common use today.

All electrical and pneumatic control equipment for the individual breaker poles is easily accessible, clearly laid out and can be checked at any time, even with the breaker live.

Hints for Plant Lay-Out

Type DR36 generator breakers, with their main and resistor interruption chambers, interrupt the current in three stages and can cope with high short-circuit currents having the highest rates of rise of transient recovery voltage. On breaking, a single or dual frequency voltage can occur across the breaker and, because of the very high natural frequency of the main transformer of up to 80 kHz at amplitude factors of 1.6, can result in extremely high rates of rise. The transient phenomena are damped aperiodically by the resistor stages parallel to the break and the break itself is subjected to only slight voltage stresses.

The generator breaker is also capable of interrupting the magnetization current of an unloaded transformer without creating excessive overvoltages. Comprehensive tests have shown that the built-in non-linear resistors confine the voltage peaks to low values. With regard to the breaker it is therefore not necessary to provide any extra equipment for reducing transient overvoltages in the generator connections. If, for any other reason, capacitors or surge diverters are installed, they in no way affect the operation of the breaker.

Bibliography

[1] *G. Ofner, H. Poesposoetjipto:* Electrical auxiliaries for large power stations. Brown Boveri Rev. *60* 1973 (6) 287–297.

[2] *A. Borst:* Eigenbedarfsversorgung in Kernkraftwerken. Atomwirtschaft 1972 (5) 274–280.

[3] *A. Borst:* Electrical equipment associated with the 1200 MW Biblis 1 nuclear power plant. IEEE conference paper No. C 72 243-9, 1972.

[4] *R. Butterworth:* The case for generator circuit-breakers. Electrical Times *157* 1970 (15) 39–44.

[5] *G. Schmitz:* Auslegung und Bemessung von Eigenbedarfseinrichtungen im Kraftwerk. Elektrizitätswirtschaft *64* 1965 (23) 651–661.

[6] *I. M. Canay:* Beitrag zur Schnellentregung von grossen Turbogeneratoren. Elektrotech. u. Maschinenb. *86* 1969 (1) 4–9.

[7] *I. M. Canay, L. Werren:* Interrupting sudden asymmetric short-circuit currents without zero transition. Brown Boveri Rev. *56* 1969 (10) 484–493.

[8] *A. Eidinger:* Interruption of high asymmetric short-circuit currents having long delayed zeros – an acute problem for generator breakers. IEEE conference paper No. 72 114-2, 1972.

[9] *R. Wanner:* Protection of large generators. Brown Boveri Rev. *58* 1971 (7) 257–264.

[10] *P. Burckhardt, H. Knecht:* Type DR36 generator breakers are rated 12 to 36 kA. Brown Boveri Rev. *57* 1970 (12) 585–594.

Transformers for Arc Furnaces

P. Bonis and F. Coppadoro

The essential parameters for sizing furnace transformers are discussed. These are: the transformer rating and possible overload, the leakage reactance, the variation of leakage reactance in relation to the different tappings and the resulting influence on furnace operation, and also the possibility of balancing the asymmetry of the phase voltage at the furnace. Ways of connecting arc furnace installations to high-voltage networks are examined.

Transformer Requirements in Melting Operation

Arc furnaces are generally employed in the production of tonnage steels and low-carbon alloyed or special steels from scrap of ordinary quality. The liquid steel is either cast into ingots in moulds or emerges from a continuous casting machine.
The furnace process comprises the following basic operations:

– *Melting* the scrap at maximum current and voltage interrupted from time to time to add to the charge. The number of stoppages depends on the quality of the scrap.
– *Refining* during which the various metallurgical operations are carried out to achieve the required quality of the steel. The time needed for this depends on the quality of the scrap and of the steel to be produced. It is very short for tonnage steels and long for special steels.

The power and current diagrams in Fig. 1 relate to melting and refining in furnaces of conventional and large capacity for making tonnage and high-grade steels, with account taken of the UHP (ultra high power) method using very high melting power (from 400 to 600 kW/t).

From the power diagrams we can determine the equivalent secondary current with the aid of the approximation formula (1):

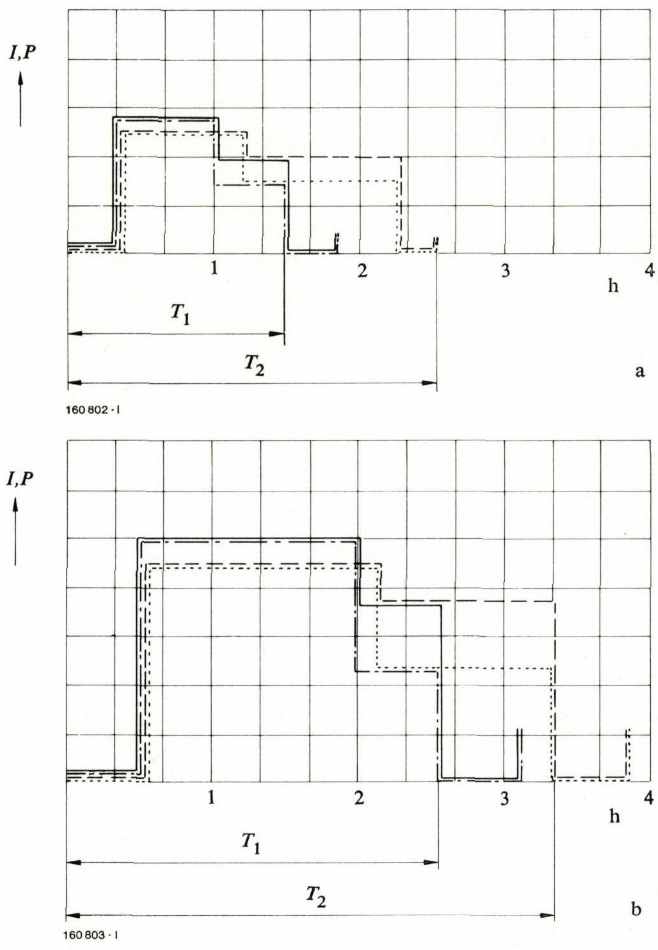
$$I_2 = \sqrt{\frac{I_{2E}^2 \cdot t_E + I_{2F}^2 \cdot t_F}{t_E + t_F + t_B}} \qquad (1)$$

in which

I_{2E} = Secondary current during melting
I_{2F} = Secondary current during refining
t_E, t_F, t_B Respective times for melting, refining and charging, including pouring and routine fettling

Fig. 1 – Operating diagrams for arc furnaces

a: Low-capacity furnace
b: High-capacity furnace
——— = Current I = f (t) } for tonnage steel
–·–·– = Power P = f (t) } for tonnage steel
– – – – = Current I = f (t) } for alloy steels
...... = Power P = f (t) } for alloy steels
T_1 = Tap-to-tap time for tonnage steel
T_2 = Tap-to-tap time for alloy steels



Owing to the asymmetry of the arc currents which occurs during melting, only approximate mean values can be inserted. When calculating the transformer, however, the duration of the maximum load must be taken into account to make allowance for the fact that the current determined with Eq. (1) is thermally equivalent only to the mean temperature, while the temperature of the copper in the secondary winding, which has a shorter time constant, can rise to dangerous levels.
The power determining the size of the transformer can be found from the maximum values of current and voltage in the primary and secondary windings.
The rated power, on the other hand, is taken as the product of the maximum secondary voltage and the thermal equivalent secondary current. In the case of three-phase transformers the factor $\sqrt{3}$ must be included as well.
The diagram in Fig. 2 shows the transformer ratings necessary for UHP operation as a function of furnace capacity for the two cases mentioned above.

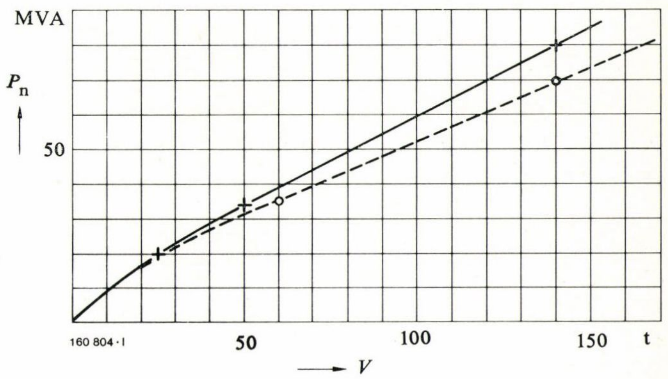


Fig. 2 – Nominal rating P_n of furnace transformers as a function of furnace capacity V (tonnes)

——— = Furnaces producing tonnage steel
– – – – = Furnaces producing alloy steels

Variation of Leakage Reactance

The leakage reactance of a furnace transformer affects operation of the furnace because it is added to the reactance of the heavy-current connections between the transformer secondary terminals and the tips of the electrodes.
From the circle diagram of an arc furnace (Fig. 3) it can be seen that the greater the reactance, the smaller the circle diameter, and hence the service and short-circuit currents decrease.
Inductance, and for the same frequency the reactance, is a function of the plant geometry. With small furnace installations the inductance is relatively low, and in some cases insufficient, so that reactors are required. In the case of large-capacity melting furnaces, on the other hand, all possible steps must be taken to reduce the inductance in order to achieve small voltage drops.
The leakage reactance of a furnace transformer should therefore be as small as possible, and this is practicable within certain limits.
In this context there arises the important problem of variations in the leakage reactance in relation to the setting of the tap changer, i. e. in relation to the secondary voltages. To illustrate this, the basic circuits and diagrams in Fig. 4 show curves of percentage impedance voltages U_K at constant secondary current I_2, and of leakage reactances X_2 referred to the secondary side, as a function of the relative secondary voltage $y = \frac{U_2}{U_{2\,max}}$.

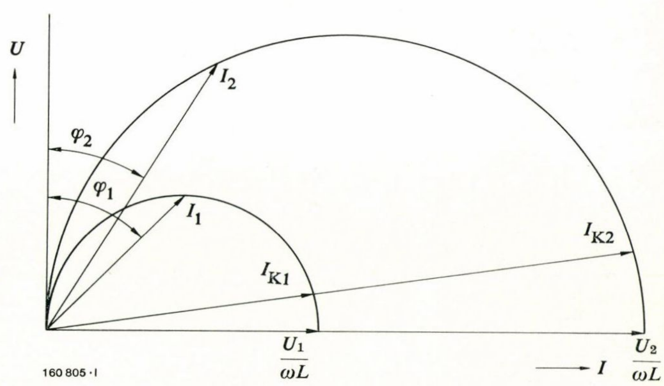


Fig. 3 – Circle diagram of an arc furnace (for symbols see text)

The types of furnace transformer considered are (Fig. 4):

1. An autotransformer with tappings and a fixed-ratio furnace transformer (Fig. 4a).
2. A main transformer with a tertiary regulating winding and a series transformer (Fig. 4b and c).
3. The transformer with direct regulation, in three different arrangements:

3.1 Secondary winding located between main primary winding and regulating winding (Fig. 4d, e and f).
3.2 Various arrangements of main, primary and regulating windings with the secondary winding as an outer coil (Fig. 4g, h, i and j).

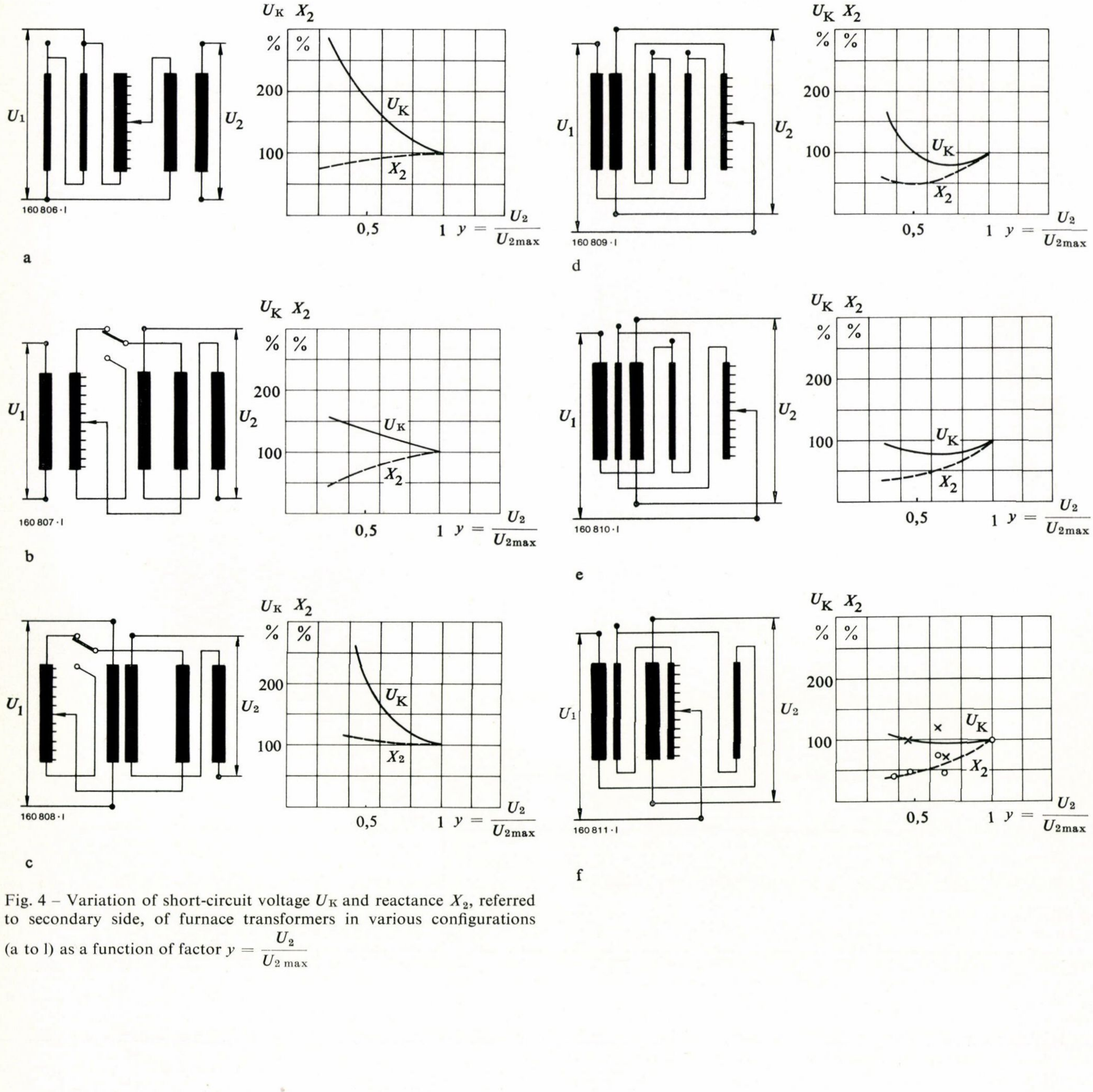


Fig. 4 – Variation of short-circuit voltage U_K and reactance X_2, referred to secondary side, of furnace transformers in various configurations (a to l) as a function of factor $y = \frac{U_2}{U_{2\,max}}$

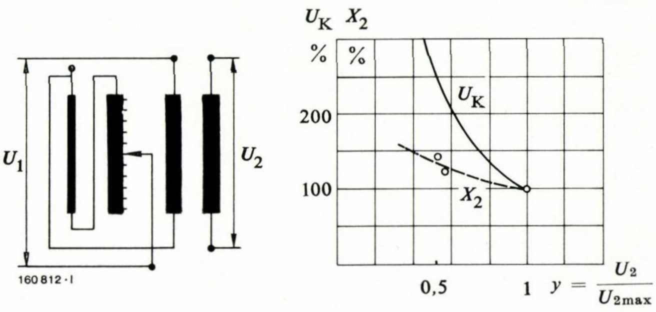
3.3 An arrangement as in 3.1 or 3.2, but with star/delta changeover for the primary winding. This will reduce the range of regulation by a factor of $\sqrt{3}$, but the changeover must take place at no-load (Fig. 4k and l).

Checking these configurations and diagrams leads to the following conclusions:

1. The combination of autotransformer and fixed-ratio furnace transformer as in Fig. 4a has been, and is still being used for high ratings, and has the following advantages:

- Regulation in voltage steps of equal size.
- An auxiliary winding for connection to a capacitor bank can be fitted to improve the power factor (cos φ).

At the same time, the following points need to be considered:



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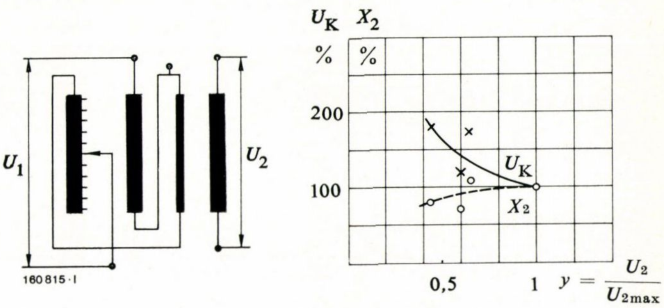

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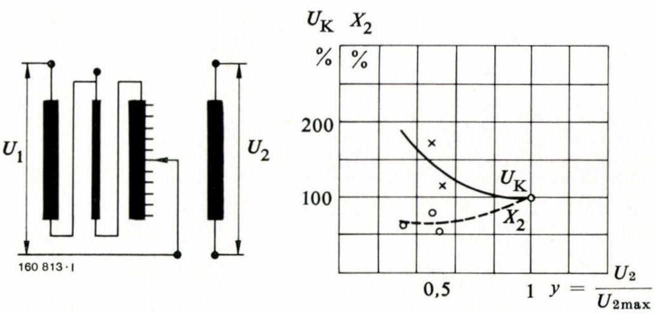

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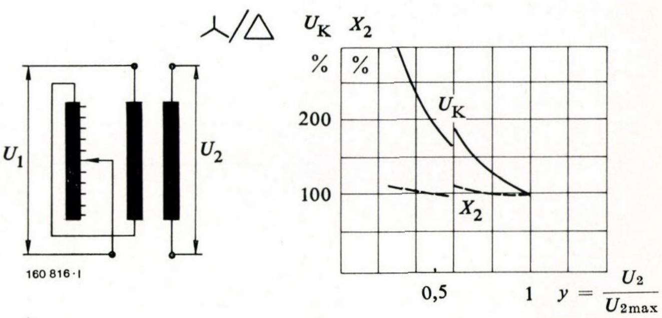

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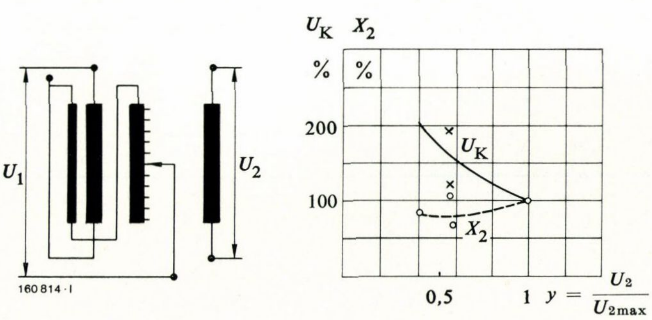

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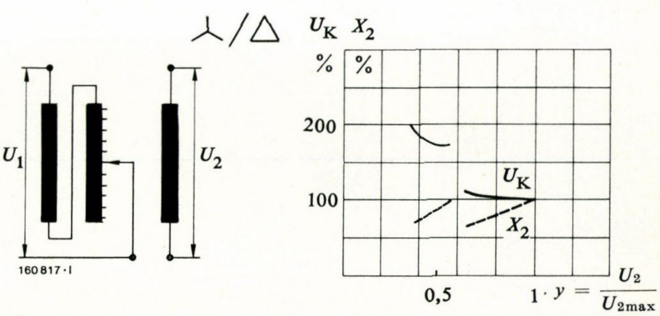


l

– The tap changer must consist of three single-phase switches, the price of which is higher than for a neutral-point tap changer.

– Impedance voltage increases sharply with decreasing secondary voltage $\left(U_K \approx \frac{I}{y} \text{ when } y = \frac{U_2}{U_{2\,max}}\right)$. On the other hand, reactance X_s remains practically constant.

– Two magnetic cores and their windings are contained in the same tank. However, if each unit has its own tank, at a slightly higher manufacturing cost, this offers the great advantage of simple secondary bushings, which in turn allow simple and symmetrically arranged heavy-current connections to the furnace.

2. In the solution with a main and a series transformer (Fig. 4b), one must take values of $U_k \approx$ constant and $X_2 \approx y$. Both arrangements allow direct connection to high-voltage networks (from 150 to 220 kV) and also provide equally sized voltage steps.

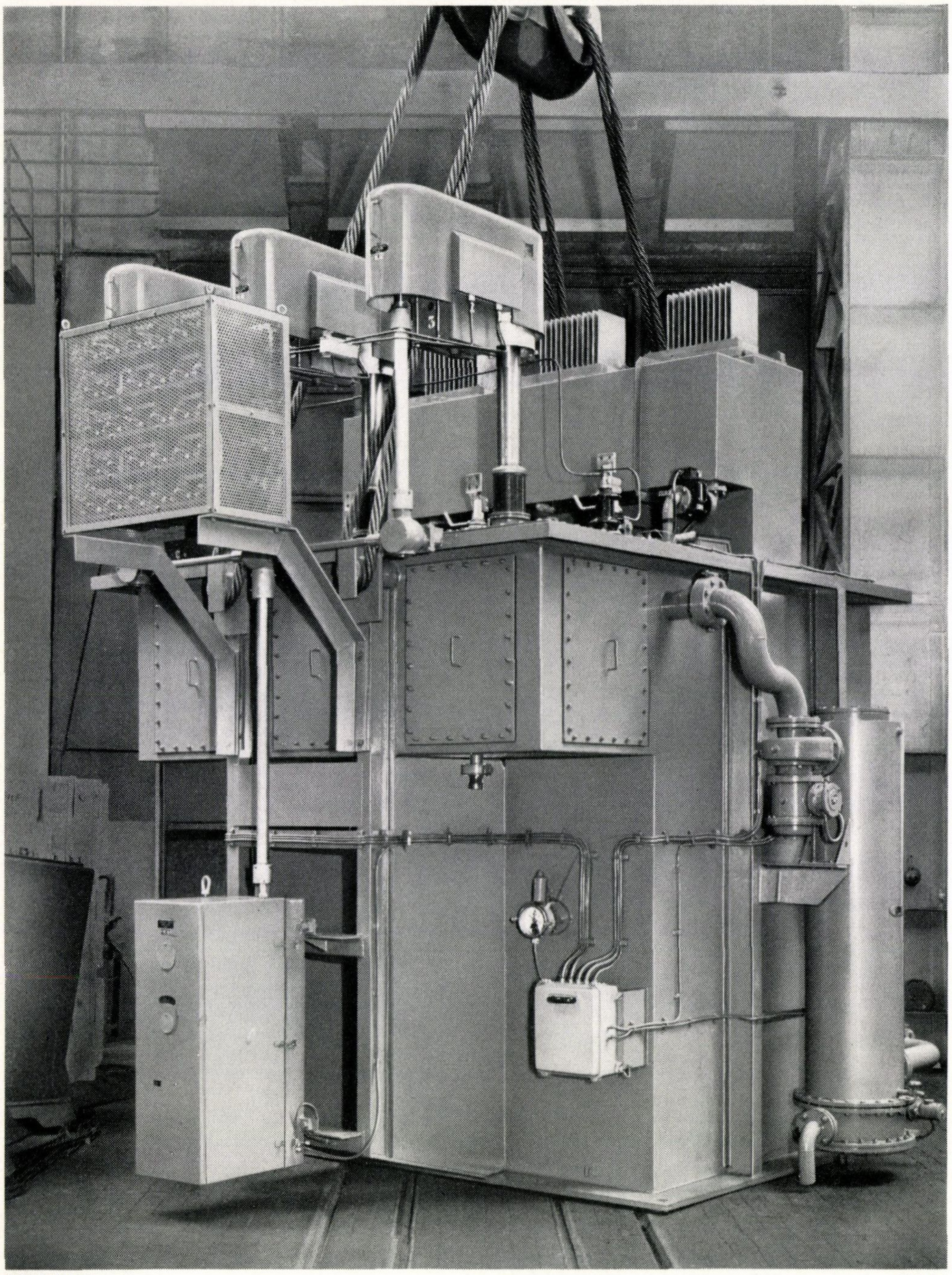


Fig. 5 – Three-phase furnace transformer for indoor installation, with circulating oil and water cooling

Nominal rating 25 MVA
Voltage 10 500/440–160 V
Arrangement as Fig. 4b

The connections between the main and series transformers, however, give rise to higher losses and costs than other solutions, particularly if the secondary current reaches high values. In certain cases, special measures can be taken to eliminate these intermediate connections.

3. The transformers in the diagrams of Fig. 4d to k are all intended for direct regulation.

3.1 Of these, in arrangements d to f, the low-voltage winding is located between high-voltage and regulating windings. With this configuration the reactance X_2 varies roughly in direct proportion to factor y. At the same time, the impedance voltage U_K stays practically constant over the entire control range.

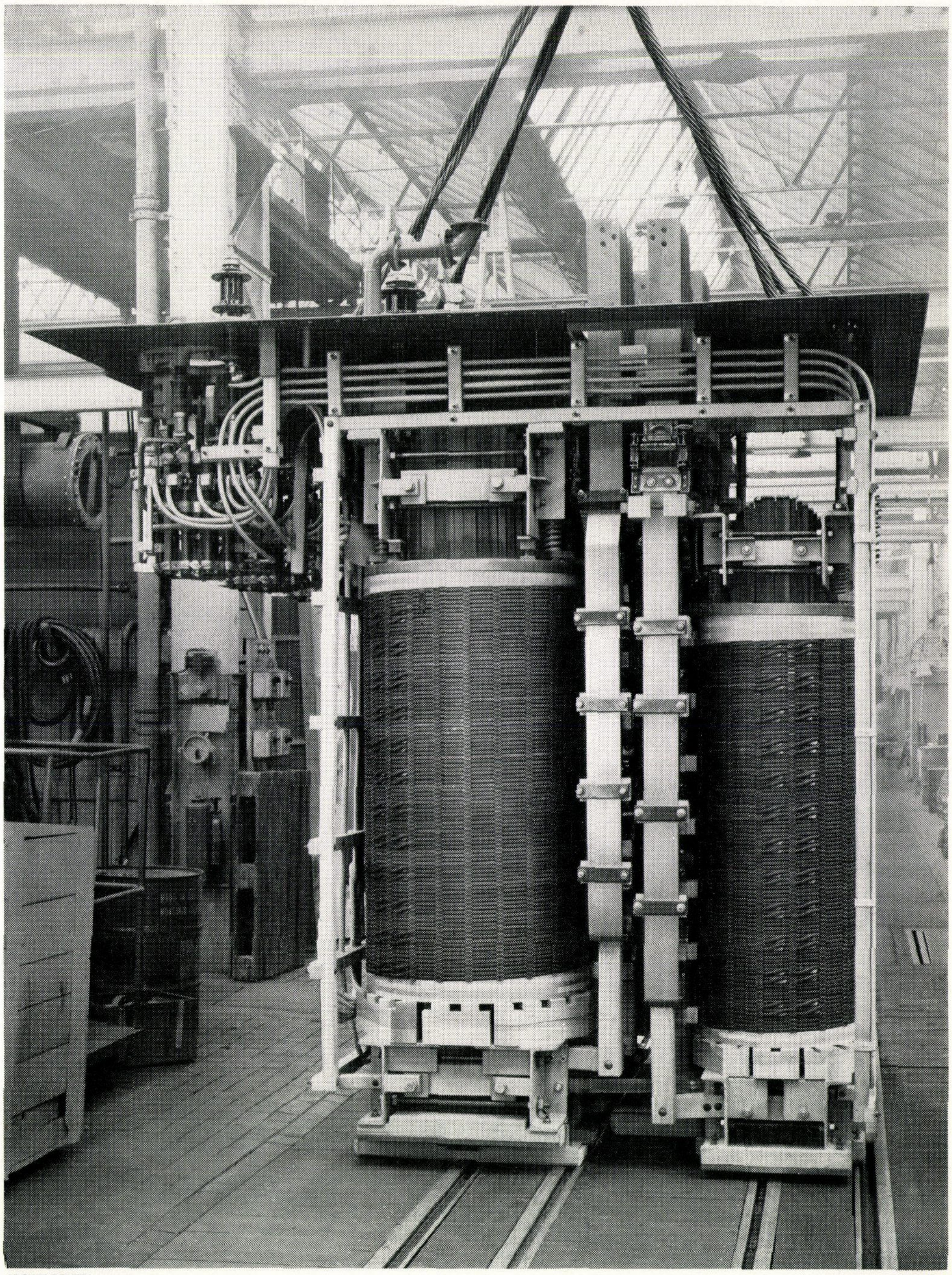
The only difference between the three arrangements d to f is the layout of the various parts of the regulating winding. The use of configurations d to f is limited by the maximum secondary current. Owing to the position of the secondary winding the current in the outgoing lines must not exceed 20 kA.

3.2 The transformers of diagrams g to j are also intended for direct regulation. Their application is not restricted by the secondary current because the secondary winding is located outside.

Arrangement g is not used owing to the wide variation of impedance voltage and reactance over the control range. The other three layouts, h to j, can be used, however, preference being given to h because at all tappings the reactance X_2 is lower than at $U_{2\,max}$.

3.3 Transformers with facilities for switching the primary winding between star and delta, diagrams k and l, require a fine selector for the tappings and a coarse selector for no-load switching from star to delta, and back again. However, this yields savings in the number of turns, and

Fig. 6 – Internals of the transformer shown in Fig. 5



hence copper, while the control range is unaffected. As already mentioned, the main circuit-breaker must be open during changeover.

For this reason layouts k and l are chiefly used for plant of low medium rating, where switching between tappings is usually not carried out under load. Arrangement l is to be preferred because reactance X_2 decreases with low secondary voltages, whereas in the case of arrangement k it remains almost constant.

Asymmetrical Voltage Distribution

The arc furnace, with its heavy-current connections between the transformer secondary bushings and the electrode clamps consisting of copper bars, flexible cables and copper tubes, is slightly asymmetrical as regards loading of the phases, even though the connections are located as much as possible at the angles of an equilateral triangle.

The different inductive voltage drops in the phases give rise to asymmetrical distribution of the arc voltages, and hence to unequal wear on the refractory lining of the furnace.

Depending on the degree of asymmetry, a uniform distribution between the three arcs can be obtained first by adjusting the currents to dissimilar values, and then in the least favourable case by employing different phase voltages.

Influencing the phase voltages requires:

1. Three single-phase tap changers, even if the chosen circuit layout would permit the use of a star-point unit. The tap changers do not usually have to be operated with three independent remote drives because the asymmetry is

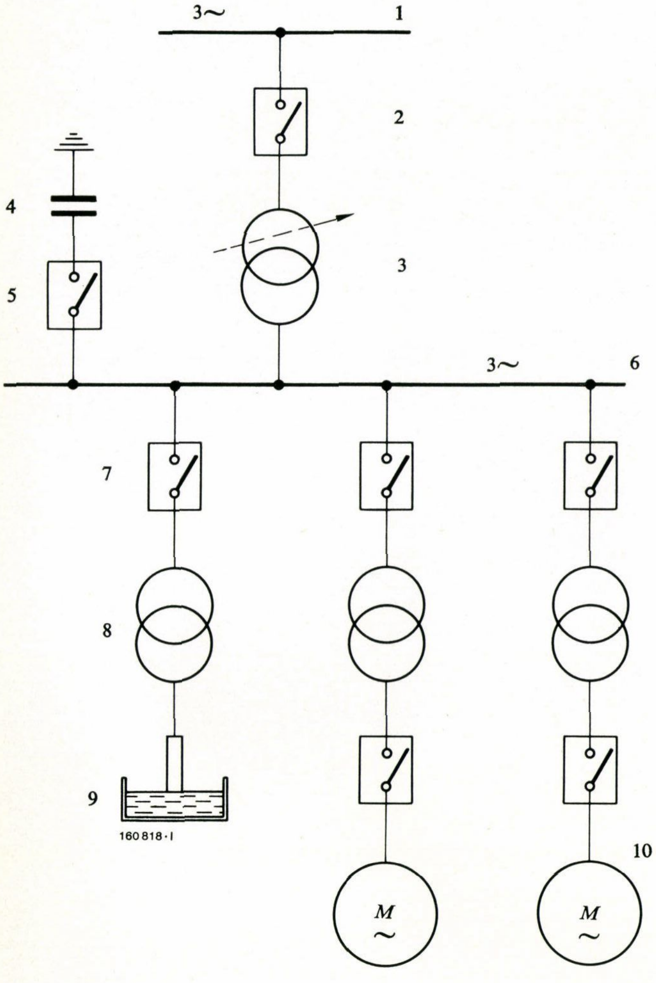


Fig. 7 – Diagram of power supply to a steelworks with an arc furnace installation, the power of which is negligible compared with the total installed power

1 = High-voltage supply network
2 = High-voltage circuit-breaker
3 = Power transformer
4 = Capacitor bank
5 = Capacitor circuit-breaker
6 = Busbar
7 = Furnace control breaker
8 = Furnace transformer
9 = Arc furnace
10 = Other loads

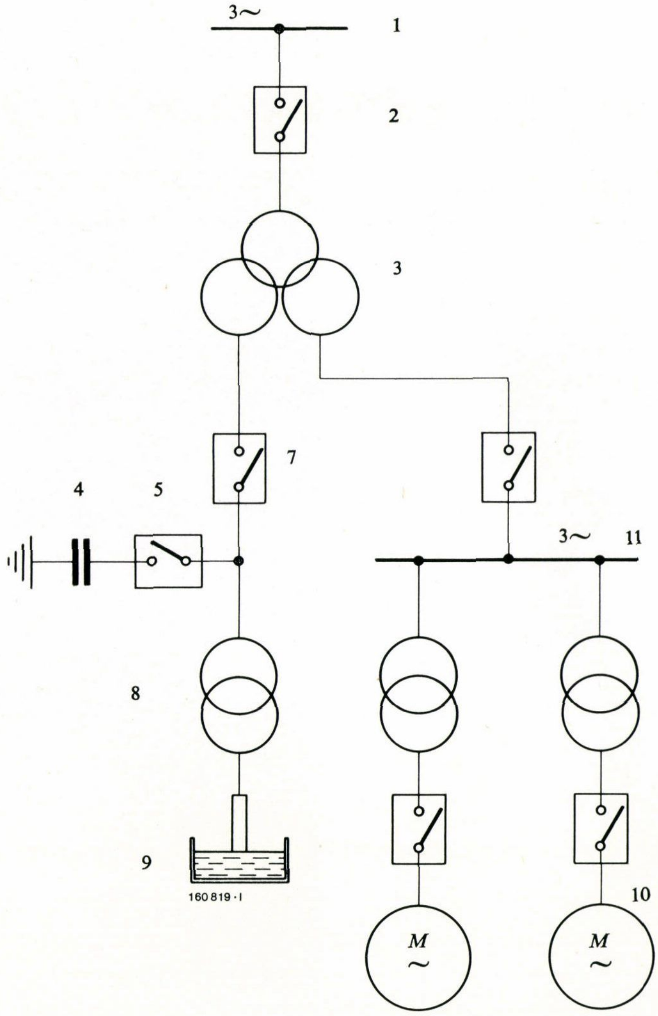


Fig. 8 – Power supply to a high-capacity arc furnace through a furnace transformer with three windings so as not to influence other loads

3 = Power transformer with three windings
11 = Busbar to other loads
Other symbols as Fig. 7.

of a geometrical nature, and in most instances has to be corrected only once.
2. The secondary voltages are made asymmetrical by selecting different tap positions in the three phases of the transformer.

The unequal furnace voltages cause the magnetic field in the limbs to become asymmetrical. Suitable compensating fields are acceptable only up to a certain strength. When this value is exceeded, additional limbs (4 or 5, instead of 3) have to be provided to accommodate these fields. Core-type transformers (Fig. 5 and 6) with an intermediate compensating circuit as in Fig. 4b, are particularly well suited to such conditions.

Direct Connection of Arc Furnaces to High-Voltage Networks

Until a few years ago transformers for arc furnaces were designed for connection to a maximum of 30 kV. With the rise in melting capacities and the associated problems of flicker, arc furnace melting plants are being connected to more powerful networks with ever higher voltages. Numerous furnace installations are now in operation, connected direct to 50, 63 and 150 kV. Recently, in fact, a plant has been built which has a furnace transformer designed for a primary voltage of 220 kV.
The advances achieved in manufacture over the last few years have been such that installations of this kind operate just as reliably as those which earlier were connected to a maximum 30 kV.
The possible ways of connecting arc furnace melting plant to high-voltage networks are described in the following.

Supply through a Fixed-Ratio Power Transformer

This transformer feeds the medium-voltage busbars to which the furnace transformer and possibly other loads are connected (Fig. 7). If these latter loads must not be affected by flicker, which is dependent on the short-circuit power at the point of connection, a three-winding power transformer (Fig. 8) can be used. In this version the primary winding is located between two secondary windings so that the voltage drops caused by the arc furnaces cannot seriously affect the supply voltage to other loads.
If the high power outputs are needed both for the furnaces and for the other loads it may be of advantage to install two power transformers.
To smooth out voltage fluctuations in the h.v. network the power transformers can be equipped on the primary side with an on-load or off-load tap changer.
The furnace transformers can have one of the circuit arrangements illustrated in Fig. 4.

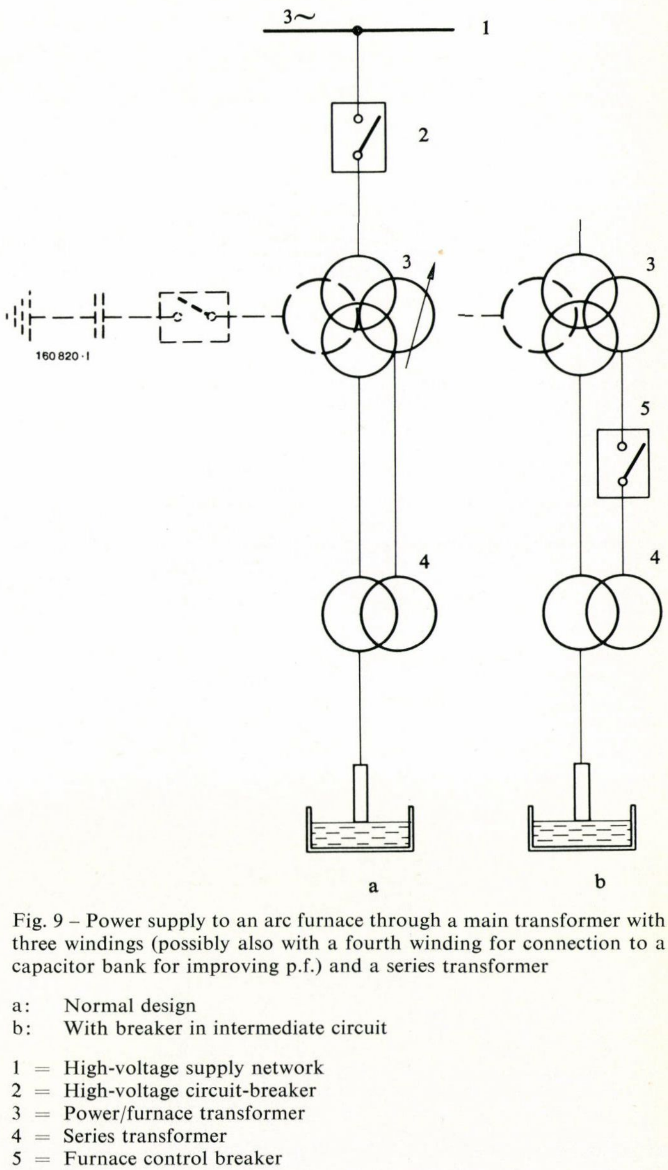


Fig. 9 – Power supply to an arc furnace through a main transformer with three windings (possibly also with a fourth winding for connection to a capacitor bank for improving p.f.) and a series transformer

a: Normal design
b: With breaker in intermediate circuit

1 = High-voltage supply network
2 = High-voltage circuit-breaker
3 = Power/furnace transformer
4 = Series transformer
5 = Furnace control breaker

Supply through a Single Furnace Transformer

In many cases the use of a furnace transformer connected direct to the high-voltage network offers major advantages, particularly with respect to a generally desired low reactance (Fig. 9).
A number of installations connected to 50, 63 and 150 kV networks have been in service for several years (Fig. 10), and one for a direct supply of 220 kV began operation a short while ago.
Circuit arrangements as shown in Fig. 4b or 4 are used for these transformers, i.e. a main transformer coupled in series with an auxiliary transformer supply uniformly distributed secondary voltages.
These furnace transformers provide a very attractive solution. Unfortunately, they are limited from the rating standpoint, not for any reasons of design but in view of the drying ovens and transport facilities required.

Supply through Two Unit-Connected Transformers

In this instance a field-ratio furnace transformer, fed through a voltage regulating transformer with a tap

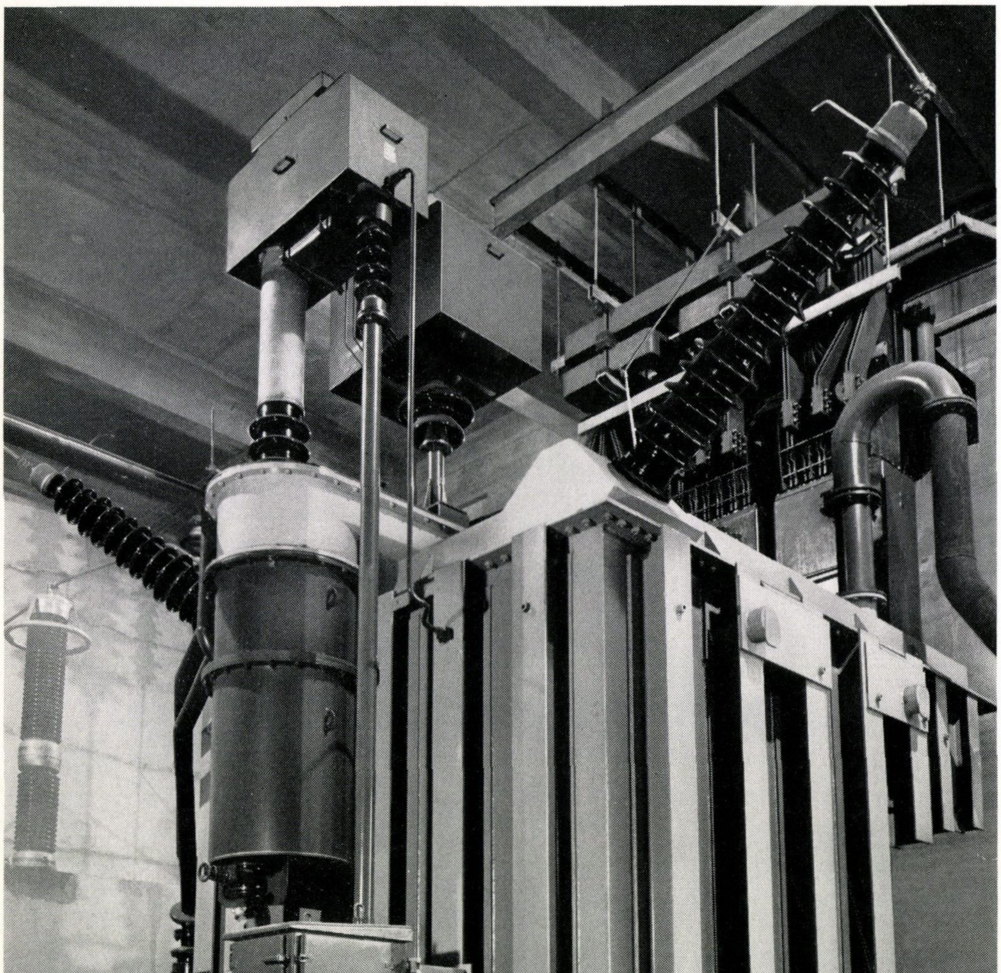


Fig. 10 – Transformer for a 60 t arc furnace

Melting power	22 MVA
Primary voltage	150 kV
Control range of secondary voltage (on-load)	140 to 420 V
Furnace current	32 kA

changer on the secondary side is used (Fig. 11). In this way the primary voltage can simply be selected up to 220 kV because the primary winding needs no tappings, as in the case described previously. On the other hand, the secondary winding consists of a base winding and a regulating winding connected to an on-load tap changer with coarse and fine selection.

Numerous configurations are possible with the four windings:

- high-voltage primary winding
- secondary winding
- windings for coarse regulation
- winding for fine regulation.

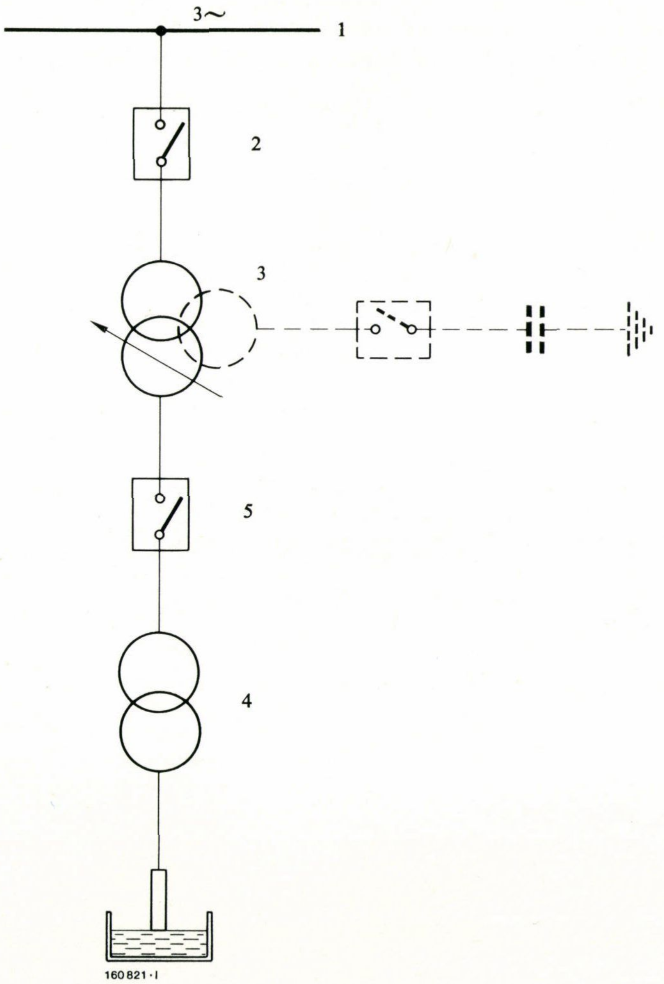


Fig. 11 – Power supply for a high-capacity arc furnace through a regulating transformer and a unit-connected, fixed-ratio furnace transformer

1 = High-voltage supply network
2 = High-voltage circuit-breaker
3 = Power/regulating transformer
4 = Furnace transformer
5 = Furnace control breaker

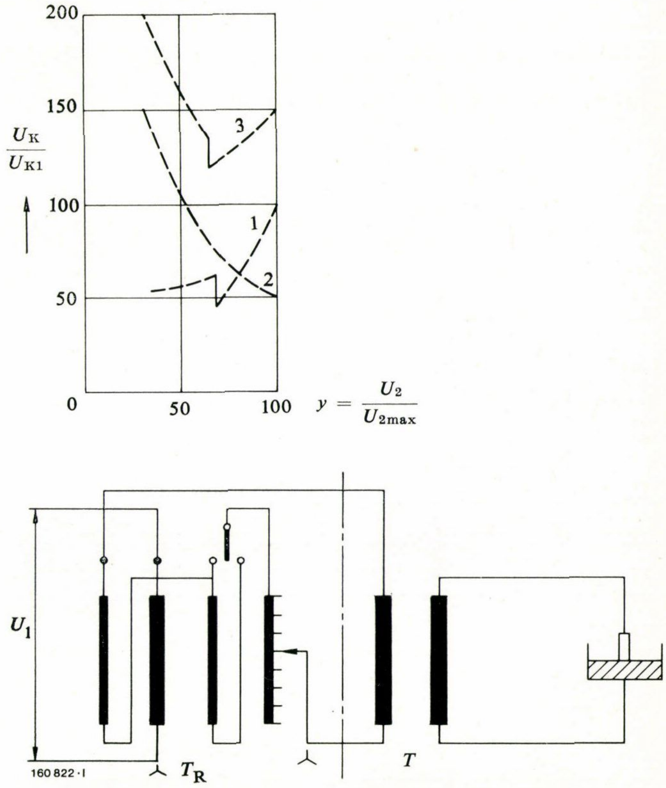


Fig. 12 – Variation of impedance voltage U_K of transformer group as in Fig. 11 and for winding configuration as shown, as a function of factor $y = \frac{U_2}{U_{2\,max}}$

Curve 1:
U_K of regulating transformer = 100% for $U_2 = U_{2\,max}$

Curve 2:
U_K of furnace transformer = 50% for $U_2 = U_{2\,max}$

Curve 3:
U_K total

T = Furnace transformer
T_R = Regulating transformer

In practical terms it is sufficient to examine three basic combinations, because arrangements where the primary winding is located close to the column are out of the question for constructional reasons.
The three layouts, together with curves of impedance voltage as a function of the adjustable secondary voltages, are shown in Fig. 12, 13 and 14.
It is very important to consider the short-circuit strength of the regulating transformer because in most instances this is connected to a very powerful network. In this respect the arrangement shown in Fig. 13 provides the best assurance against mechanical stressing, since it yields the smallest fluctuations in the impedance voltage.

There is no restriction on the rating of the group (regulating transformer and furnace transformer), but the sum of the two reactances is higher than that of a single transformer with a tertiary winding.
The total reactance of the group must be unequally distributed between the two transformers. The reactance of the fixed-ratio furnace transformer should be as small as possible so that the regulating transformer is mechanically well able to withstand the consequences of short circuits at the connections or on the secondary side.
With this version, too, the secondary voltages are evenly distributed.

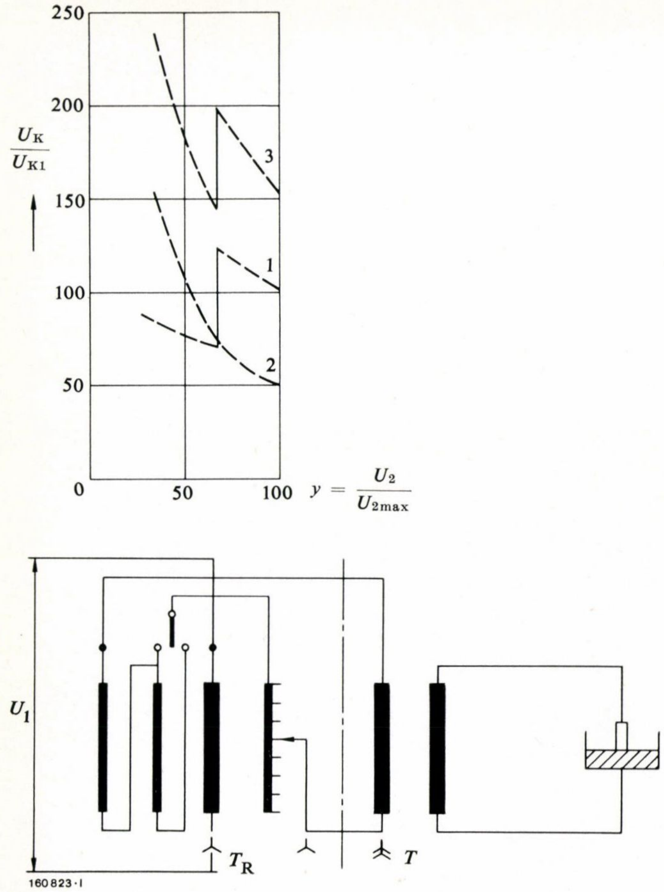
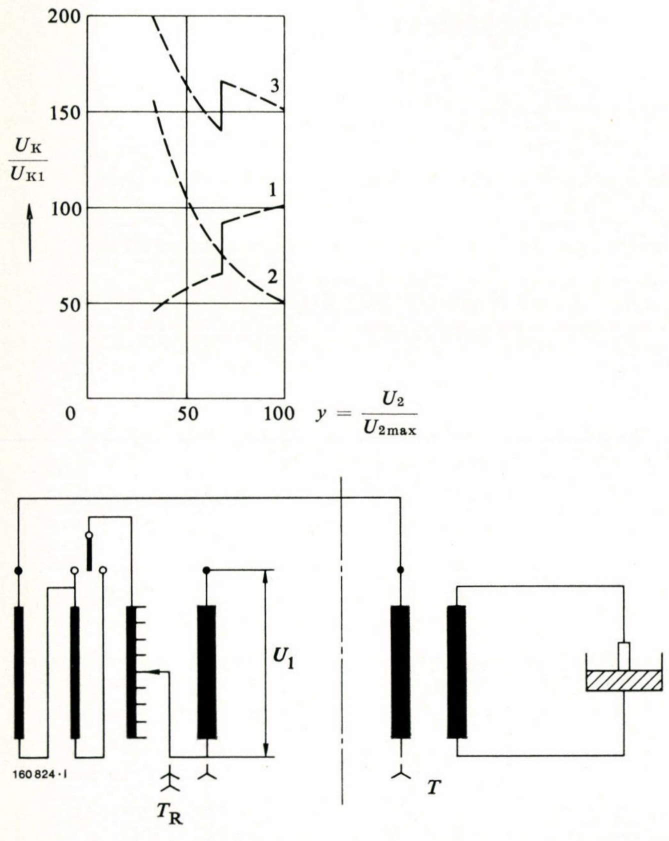


Fig. 13 – Variation of impedance voltage U_K of transformer group in Fig. 11 with winding configuration different from that in Fig. 12

Symbols as Fig. 12.

Fig. 14 – Variation of impedance voltage U_K of transformer group in Fig. 11 with winding configuration different from those in Fig. 12 and 13

Symbols as Fig. 12.



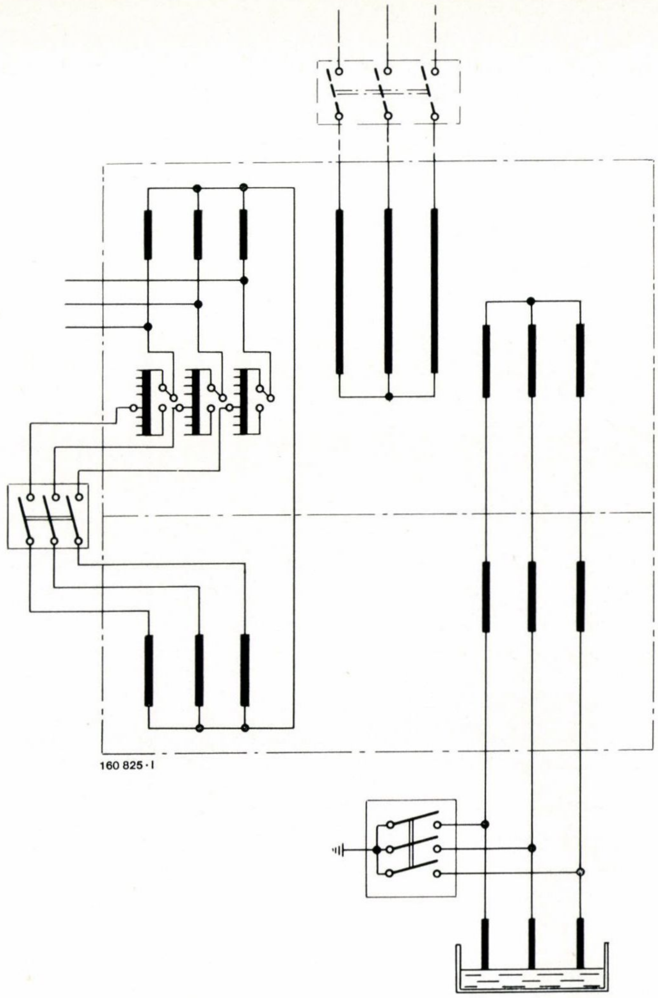
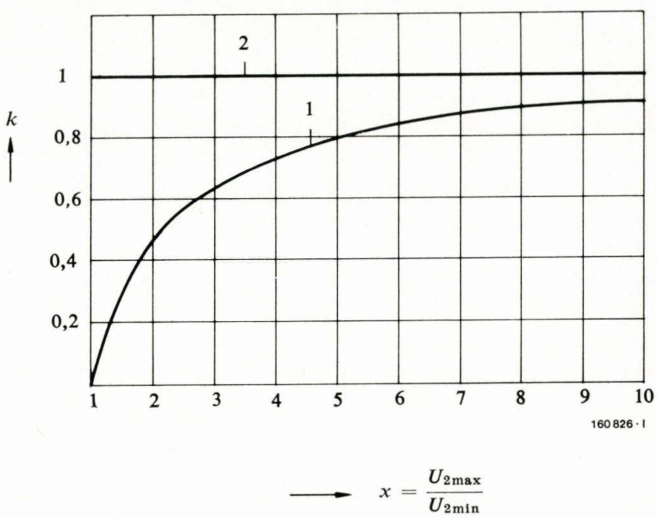


Fig. 15 – Winding arrangement of transformer group with breaker in intermediate circuit as in Fig. 9 b

Fig. 16 – Diagram showing the variation of factor k as the ratio between rating of series transformer and type rating $\frac{P_2}{P}$, where

$P_2 = U_{2\,max} \times I_{2\,max}$

1 = Series transformer, conventional
2 = Series transformer with breaker in intermediate circuit



Transformers with Three Windings and a Series Transformer

For furnace transformers supplied with very high voltage (more than 60 kV) a proposal was made a short time ago, and put into effect, whereby the connections between the regulating and primary windings of the series transformer are brought out through the top of the tank to enable a circuit-breaker of lower voltage rating to be used for controlling the furnace plant (Fig. 15).

In fact, the problem of the large number of switching operations when a high-capacity furnace installation is connected to a h.v. network of high fault level can be solved only with high-voltage airblast circuit-breakers, which for environmental reasons must, however, be installed in a noise-attenuating building.

In the case of the arrangement mentioned above, with a circuit-breaker in the intermediate circuit, the high-voltage circuit-breaker has only the function of protecting the furnace plant.

The other breaker interrupts the primary current of the series transformer, and hence the furnace current. The series transformer than acts as a choke so that only a magnetizing current flows.

This imposes the following condition on the design of the series transformer:

On interruption of the primary current, in other words when the secondary voltage is still present at the connections of the furnace transformer (the furnace electrodes are still carrying current), the flux density in the iron core must not be higher than the normal density, so as to avoid saturation of the magnetic circuit. To achieve this the furnace voltage must be equally divided between the secondary windings of the furnace transformer and the series transformer.

The required range of furnace-voltage control from $U_{2\,\min}$ to $U_{2\,\max}$ cannot be obtained with a normal circuit configuration; the regulating winding can, however, be connected either in phase or in opposition with the tertiary base winding. The latter can also serve to feed capacitors for improving the power factor.

Under certain circumstances the need to bring out the connections of the intermediate transformer may incur the risk of a short circuit between the regulating transformer and the series transformer, with consequent severe dynamic stressing of the regulating and base windings. These must therefore be specially strengthened, and the greatest care must be taken in building the equipment.

It should also be mentioned that, compared with a series transformer having no controlling breaker in the intermediate circuit, this version requires a higher type rating for the series transformer, amounting to $\frac{P_2}{2}$ instead of $\frac{P_2}{2}\left(1-\frac{1}{x}\right)$, where x is the control range factor $\frac{U_{2\,\max}}{U_{2\,\min}}$ (Fig. 16).

In addition, manufacturing costs are higher because three single-phase tap changers are needed, instead of one star-point tap changer.

For a control range factor of $x = \frac{U_{2\,\max}}{U_{2\,\min}} = 3$, the price of a furnace transformer with three windings and a series transformer with a breaker in the intermediate circuit is increased by 4 to 5%, while total losses are 10 to 15% higher. However, certain savings are achieved regarding the high-voltage breaker.

If a high-voltage breaker cannot be used for furnace control, the price comparison must be made with the unit-connected arrangement which has a regulating autotransformer and a fixed-ratio furnace transformer.

The Electrical Equipment for Steel Strip Process Lines in Finland

D. F. Higgins

This contribution deals mainly with the electrical equipment for the process lines and particular attention is paid to the pickling, galvanizing and shearing lines.

Early in 1972 the metal strip processing lines for which Brown Boveri supplied the electrical equipment were commissioned at the new works of Rautaruukki Oy in Hämeenlinna, Finland. The plant will cover a large portion of the national demand for galvanized and corrugated steel sheet. Raw material is supplied in the form of hot rolled coils from the main works in Raahe.

Material Flow

The process begins at the pickling line. The coiled, pickled strip is further processed either in the works or at the other production facilities. The main gauge reduction in the material takes place at the tandem mill. Technological reasons stipulate that the strip is annealed after cold rolling. The strip is then either slit or cut to length and sorted or surface treated in the galvanizing line and finally cut or formed into corrugated sheet.

Electrical Equipment

The electrical equipment is so designed that the requirements, namely

- strip speed
- strip tension
- acceleration and braking
- strip guidance
- quality supervision, marking, registering and special equipment of the installation, are fully met.

The four installed process lines include:

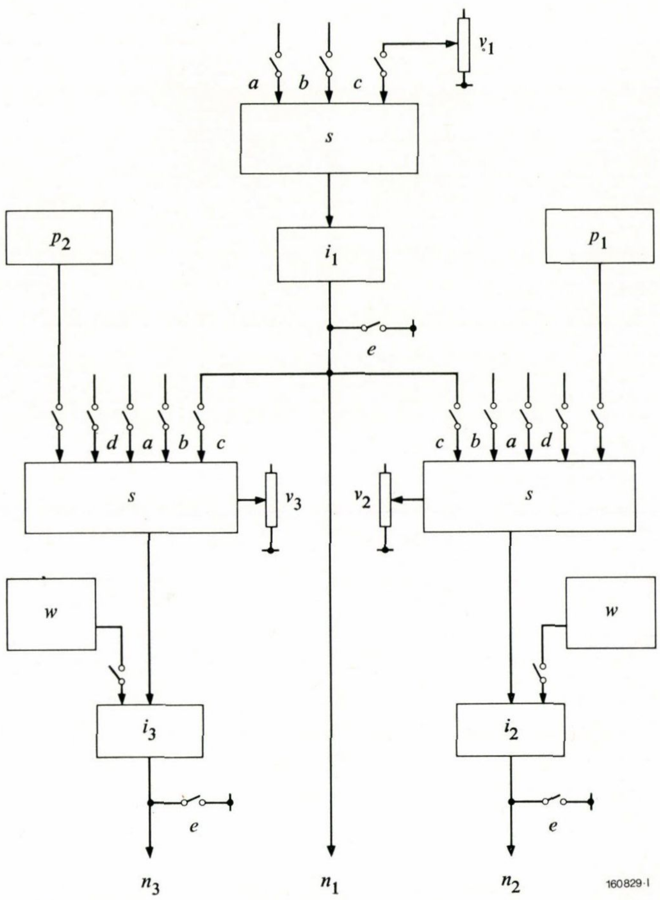
68 d.c. motors with a total rating of 3000 kW
270 a.c. motors with a total rating of 1800 kW
39 rectifier units
39 electronic regulation hinged frames for the drives
4 electronic regulation hinged frames for the line master speed control

Special equipment includes:

- loop and catenary control
- strip edge and strip centre control
- gauge and length measurement

Fig. 1 – Master reference unit for a process line

a = Threading
b = Minimum
c = Run
d = Automatic operation
e = Emergency stop
i = Integrator
n_1 = Speed reference value for process
n_2 = Speed reference value for entry
n_3 = Speed reference value for exit
p = Position regulation
s = Summation amplifier
v_1 = Strip speed reference for process
v_2 = Strip speed reference for entry
v_3 = Strip speed reference for exit
w = Wobble arrangement



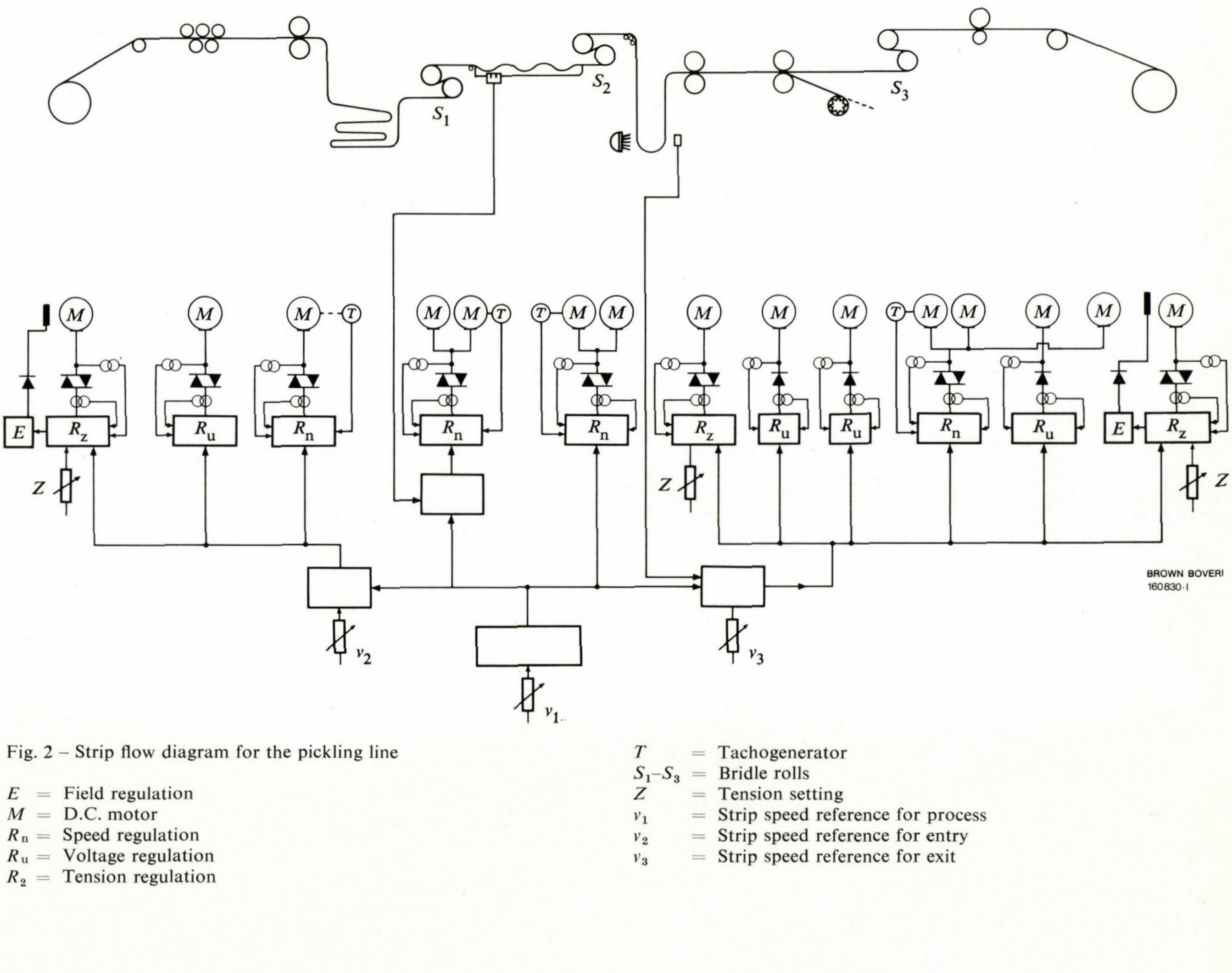


Fig. 2 – Strip flow diagram for the pickling line

E = Field regulation
M = D.C. motor
R_n = Speed regulation
R_u = Voltage regulation
R_z = Tension regulation
T = Tachogenerator
S_1–S_3 = Bridle rolls
Z = Tension setting
v_1 = Strip speed reference for process
v_2 = Strip speed reference for entry
v_3 = Strip speed reference for exit

- stretch measurement
- temperature control
- coating thickness measurement and control
- sorting

The main drives are d.c. motors mostly of standard industrial design, mill motors being used where the requirements are more exacting [1].
The rectifiers are plug-in modules of the Brown Boveri "Thysert" range [2]. The control electronics comprise standard printed circuit modules and sub-assemblies of the Brown Boveri electronic system arranged in hinged frames and co-ordinated with the individual drives. The large quantity of equipment supplied necessitated standardization to keep the stock of spare parts to a minimum.

Master Reference Unit

The master reference unit is decisive for coordinated operation of all sections of a process line. It issues the speed reference value to the drives of the installation and thus determines the strip speed. Also, if the strip speed is changed it gives the tension controlled drives and the coiler drives the respective acceleration command so that the energy to accelerate the inertia can be compensated.
The master reference unit consists essentially of integrators which provide a defined acceleration rate. It also includes monitoring units and a logic detecting certain operating conditions. This principle is basic for all process line installations. The master reference unit for the galvanizing line is described as an example.

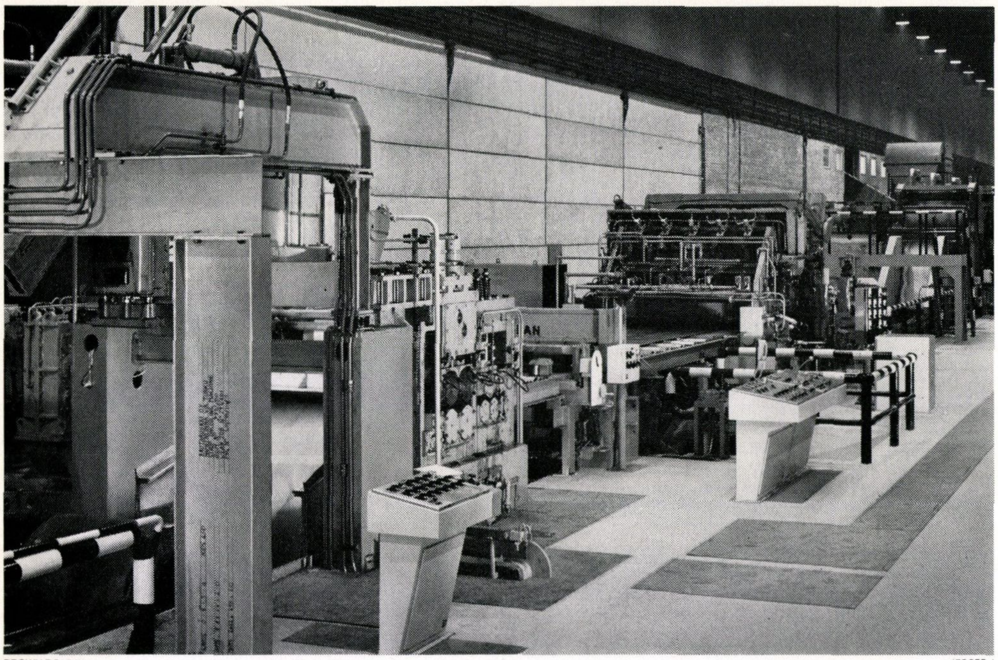


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Fig. 3 – Pickling line entry section

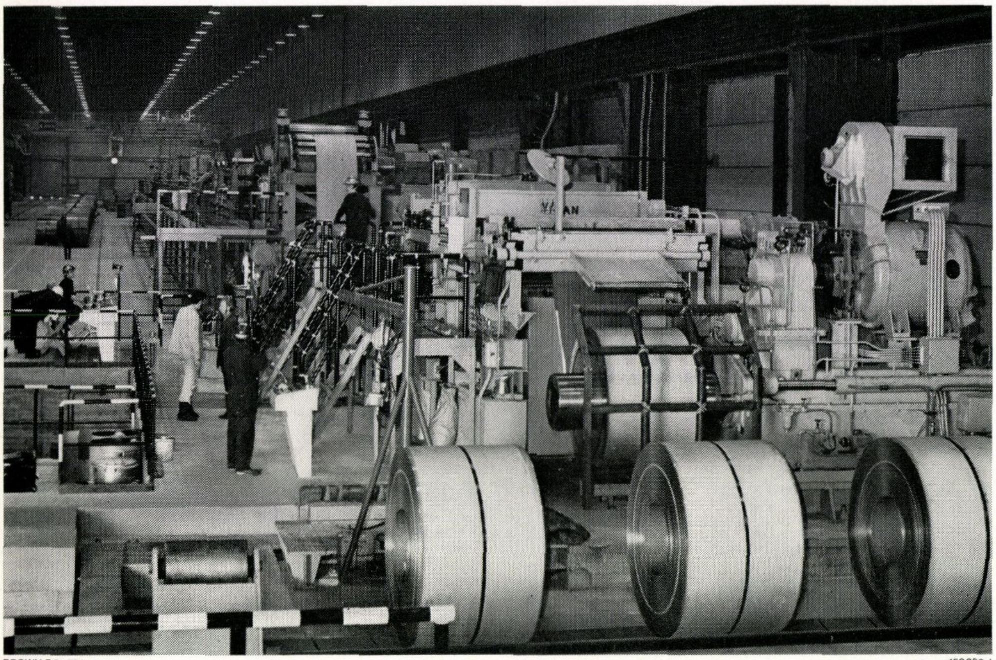

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Fig. 4 – Coil changing (exit section) at the pickling line

Figure 1 illustrates in block form the design principle of the master reference unit for the galvanizing line. The installation comprises three main sections: entry, process and exit, between each of which is a strip accumulator (loop car). Each section is equipped with its own reference value unit consisting of summation amplifier and integrator.

The reference value for the process is therefore the pilot value for the complete line. The three reference value units are interlinked such that a speed change in the process section automatically causes the entry and exit sections to follow, without involving separate intervention, this being on the assumption that the loop car is within the controlled range. Threading and minimum speeds can be set separately for each section, thus permitting optimum adjustment of the strip speed to the given operating conditions.

The entry and exit sections also have a position control for the loop cars in order to influence the strip speed in accordance with the strip stock. In addition there is a wobble arrangement for each of the two sections which prevents the loop car motor standing still under current and hence avoids excessive heating of the commutator. This is achieved by the wobble arrangement slightly changing the speed of the entry or exit sections at low frequency so that the position of the loop car is always slightly changing.

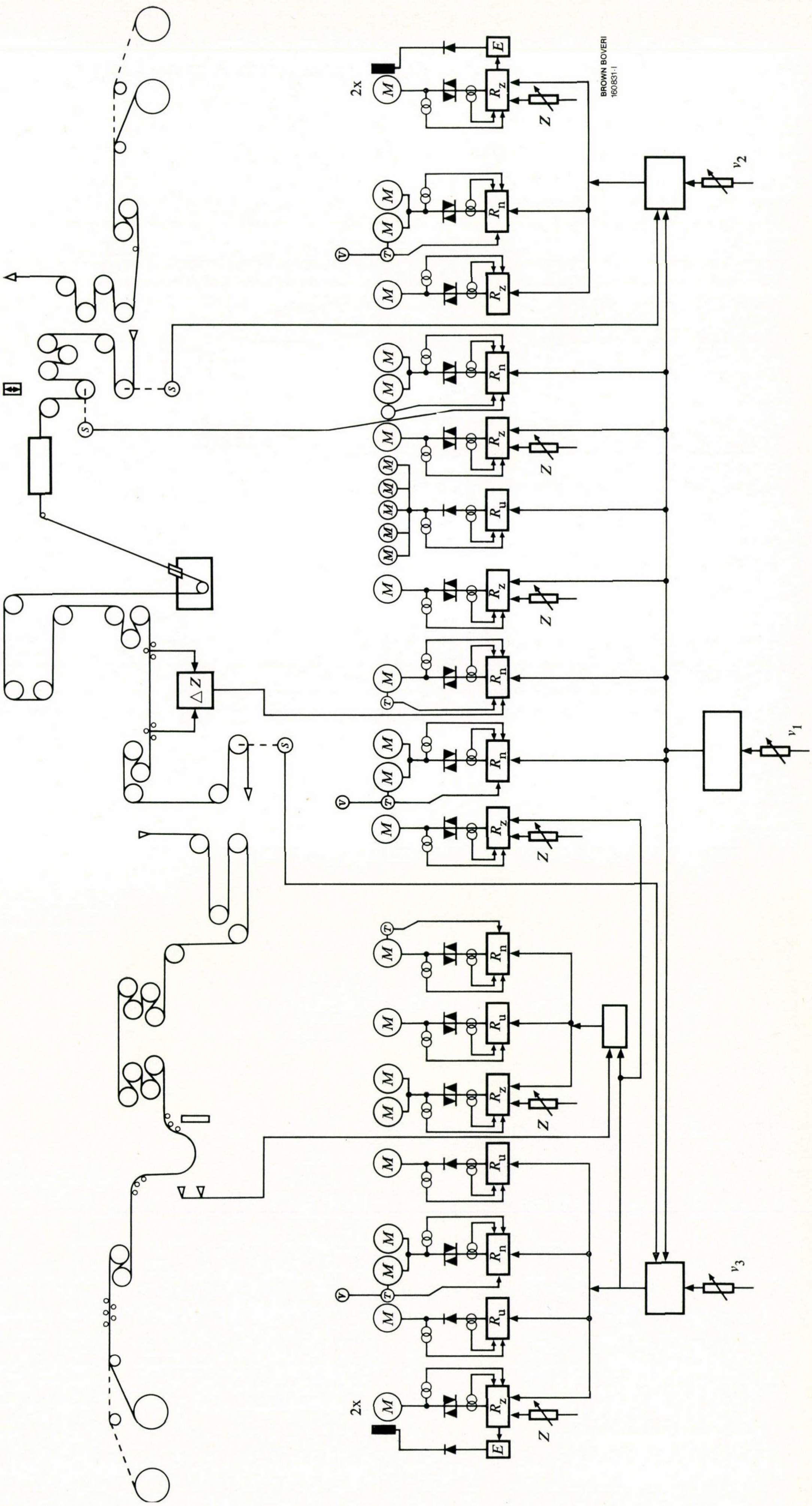
The block diagram also shows in principle the distribution of the corresponding reference values to the individual drives of the installation. These reference values are processed by the control system for each drive. Distinctions are made between the following control systems [3]:

- speed and/or voltage control
- tension control
- coiler control

Fig. 5 – Strip flow diagram for the galvanizing line

S = Selsyn

Other symbols, see Fig. 2.



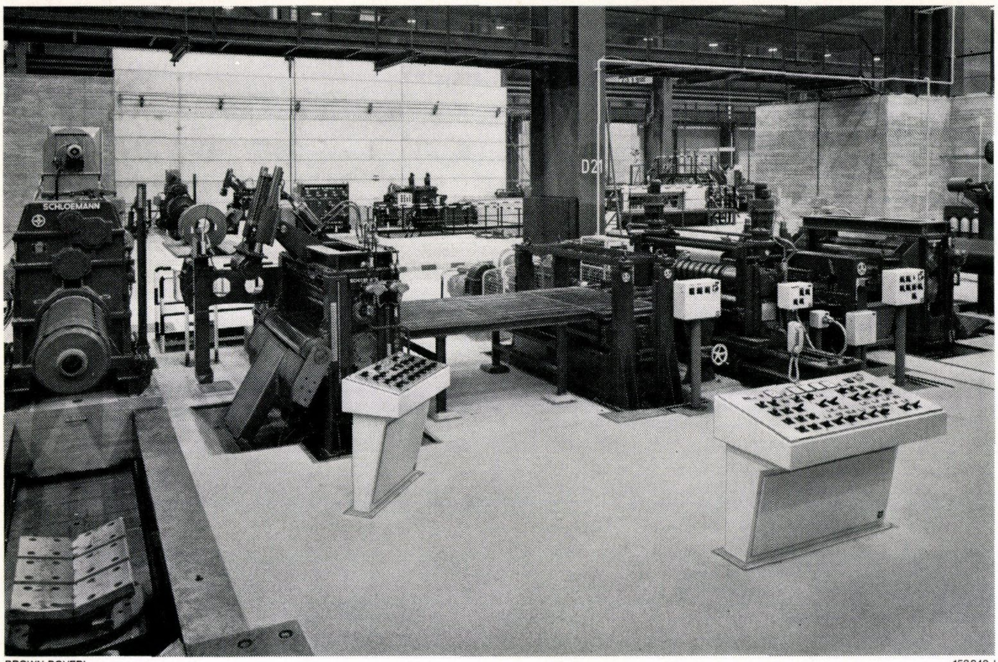


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Fig. 6 – General view of the slitting line

Pickling Line

The strip flow and d.c. drives of the line are shown in Fig. 2. The installation is so designed that entry and exit can run faster than the process section by a defined amount. In order to ensure continuous material flow in the process section it is necessary to have a strip store (loop pit) at either end to permit feed-in and take-up of strip during coil changing. Group and individual jogging of each machine is possible for all three sections. The entry section of the line is shown in Fig. 3.

The line speed can be infinitely varied by potentiometer and there are also fixed speed settings for "minimum" and "threading".

After coil changing at the uncoiler and successful jointing with the previous coil, the entry section runs at maximum speed until the loop pit is filled. The speeds of the entry and process sections are then synchronized.

Constant strip speed and constant strip catenary are important factors for the quality of processing in the pickle tank.

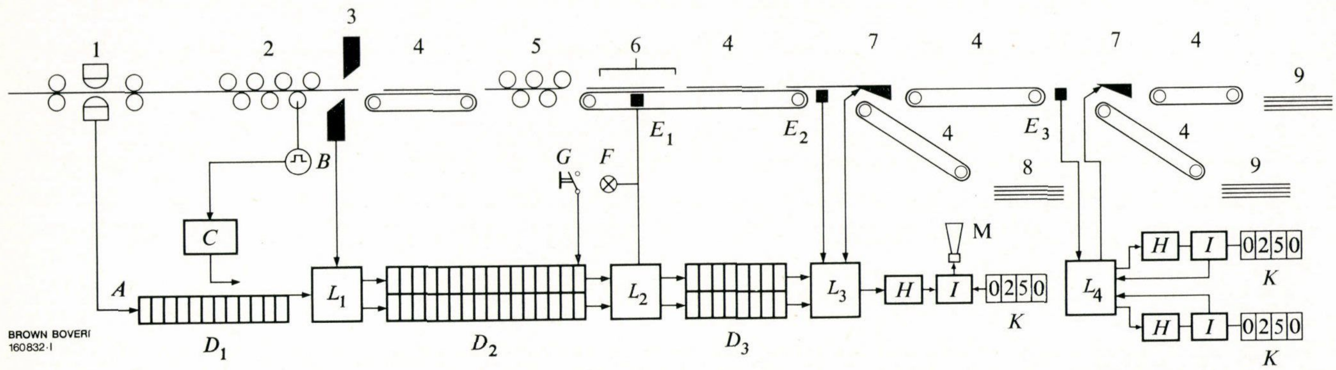
The process speed is determined by the bridle rolls following the tanks. The strip catenary is measured by a sensor in the first tank. Variations in the reference value influence the speed of bridle S_1 and consequently the catenary.

The strip store before the exit section is in the form of a loop pit in which the strip forms a free hanging loop. The reference position of the loop is high up towards the top of the pit. During coil changing at the tension reel the loop becomes continuously larger. Should the coil changing time be excessive, the speed of the process section is reduced to a minimum at a defined loop size. If the loop

Fig. 7 – Automation of the cut-to-length line

1 = Gauge measurement unit
2 = Synchronizing roll for shear
3 = Shear
4 = Transport conveyor
5 = Leveller
6 = Visual inspection
7 = Deflector
8 = Scrap piler
9 = Prime piler

A = Gauge measurement signal
B = Pulse generator
C = Unit counter
D = Shift register
E = Proximity switch
F = Synchronizing lamp for attention
G = Push button for visual inspection
H = Counter with illuminated indicator
I = Comparator
K = Decade switch
L = Logic
M = Acoustic signal



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increases to a second limiting value, the process section is stopped (Fig. 4).
The tension reel drive is equipped with automatic mandrel positioning which guarantees that the mandrel slot is in the correction position for each new strip to be fed in.

Galvanizing Line

This is a continuously operating line which receives individual coils, joins them to form an "endless" strip (as in the case of the pickling line), galvanizes it and rewinds it into individual coils. A single-line diagram of the electrical system is shown in Fig. 5. Entry and exit sections can be stopped independently of one another while the process section continues to operate. This is made possible by loop cars located between the entry and process sections at one end and the process and exit sections at the other. These double-loop cars each have a strip storage capacity of 184 m. The amount of strip stored at any time is indicated at the control desk. Limit switches monitor strip entry and stop the appropriate line section as soon as a maximum value is reached. Prior to this there is a signal which indicates that complete emptying or filling of the pit is anticipated.
The process section is physically the largest section of the line and comprises basically the furnace, the zinc coating unit and the cooling section.
The furnace roller drives are provided with changeover to emergency power supply to avoid roll deformation due to the heat of the furnace, should they come to rest due to power failure. They can be rotated at low speed independently of the remaining line sections.
The entry and exit sections each have two completely independent coiler arrangements to keep the coil changing time as short as possible. The coiler drive has an automatic strip length measurement system with digital display and based on digital distance measurement.
After galvanizing, the strip is flattened in a continuous stretch leveller. The resultant increase in length is measured digitally and displayed at the control desk.

Slitting Line

A general view of the installation is shown in Fig. 6. Steel strip up to 1575 mm wide is slit and re-coiled. The installation comprises uncoiler and coiler, pinch roll, shear, oiling machine and scrap bundler. All drives are electronically controlled. Because the shear is not power coupled to the material the strip speed is determined from the coiler. The coiler reel diameter is compensated by a calculator. Since the line can operate at two speeds the uncoiler and coiler are fitted with a.c. drives. The reference values are switched over for the remaining drives. The uncoiler is fitted with strip edge control for straight edge running of the strip.

Cut-to-length Line

In this line the steel strip is cut into sheets. It comprises pay-off reel, side trimmer, divide shear, two levellers, oiling machines and various transport conveyors. These drives are also electronically controlled. The strip speed is determined by the divide shear drive and the transporter conveyors have a certain lead speed compared with the shear. The result is a gap between each sheet which is necessary for deflector changeover. Reel, side trimmer and divide shear are separated from one another by loop pits. The loop height is measured by photoelectric cells and regulated. The cut sheets are measured electronically and, depending on their quality, are diverted to the relevant piler.
At maximum strip speed and shortest sheet length approx. 140 sheets per minute can be cut and sorted. The side trimmings are collected in a storage room in the basement and bundled as and when necessary.

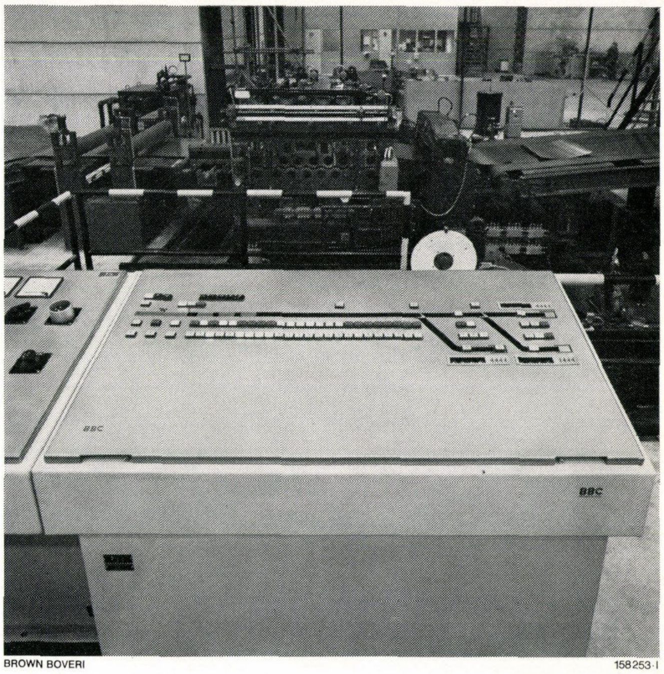


Fig. 8 – Main control desk for cut-to-length line

Automatic of Cut-to-length Line

The automatic control system ensures correct distribution of the cut sheets to the three pilers. For this reason, both deflectors in front of the first two pilers are operated by an electronic control system.
The first piler collects sheets of poor quality and the other two collect the high quality sheets.
The two main quality criteria are:

– Before the cutting, the strip gauge is measured continuously. The automatic measuring devices give the information "within limits" or "not within limits".
– When the sheet has been cut and levelled it undergoes visual inspection. The operator decides the surface quality and can issue the quality information "surface poor" independently of the gauge measurement.

The principle of the automatic control system is shown in Fig. 7. The control system receives the information *A* from the gauge measuring unit for a certain sheet section. This information is passed on to the shift register D_1 together with the strip speed. The information shift in the register is controlled by the unit counter *C*. The unit counter receives pulses from the mechanically coupled pulse generator *B*, and the frequency is proportional to the strip speed. When the measured strip section reaches the shear, the information arrives at the logic L_1 which decides whether a cut sheet is of high or poor quality. The quality information "gauge" of each cut sheet is transferred to the first free bit of the accumulator register D_2. This is a double register and stores the sheet number and quality. When the sheet is over the proximity switch E_1, the lamp *F* lights up. During this time it is possible to carry out the visual inspection and give the quality signal "poor" by means of push button *G*. When the sheet end passes over E_1, the logic L_2 accepts the information and passes it to register D_3 which is of the same design as D_2. When the sheet passes over the proximity switch E_2 the information must be passed on to logic L_3. This controls the first deflector 7 in accordance with the quality signal. E_2 is mounted ahead of the deflector.

If the sheet is of poor quality it goes into the scrap piler and is recorded by counter *H*. The comparator *I* compares the count in *H* with the preset number of sheets set at decade switch *K*. When the two values coincide, an acoustic signal is given by siren *M*.

If the sheet is of high quality it is transported further. When the sheet passes over the proximity switch E_3 a signal is given into the logic L_4 which controls the second deflector in accordance with the selected piler. If this piler has received the desired number of sheets the deflector is automatically switched over. The two high quality sheet pilers have the same sheet counter system as the scrap piler.

A mimic diagram with two rows of lamps is located on the control desk (Fig. 9). Each row corresponds to a quality information (top lamp illuminated = high quality, bottom lamp illuminated = poor quality). Each lamp represents a cut sheet. The input and output of the first shift register can be seen on the left. Also indicated are the conditions of the magnetic proximity switches ($E_1 - E_3$). The manual controls for the deflectors are on the far right. The decade switches and indicators for the three pilers can be seen to the right. In addition to this the desk is equipped for simulation of the complete sorting procedure.

Bibliography

[1] *W. Berger:* Brown Boveri d.c. mill motors. Brown Boveri Rev. *56* 1969 (1) 36–42.

[2] *H. Pisecker, X. Vogel:* "Thysert" – a new element of the Brown Boveri electronics system. Brown Boveri Rev. *54* 1967 (5/6) 241–249.

[3] *J.-P. Tack, E. Strebel:* Electrical equipment for cold rolling mills. Brown Boveri Rev. *58* 1971 (2/3) 65–77.

New Control and Monitoring System for Shuttle-Service Aerial Cableways

W. Ott and H. Hasler

With the object of catering for present-day tourist traffic and also complying with the demands for increased haulage capacity in transport systems, Brown Boveri have developed a new generation of drive controls for shuttle-service aerial cableways. Passenger comfort is improved although the time taken to accelerate from rest on leaving the station is reduced by up to 20% and the time taken to decelerate on approaching the opposite station is reduced by up to 40%. Safety is also increased by the additional monitoring equipment which is in excess of the requirements stipulated by the supervisory authorities.

Introduction

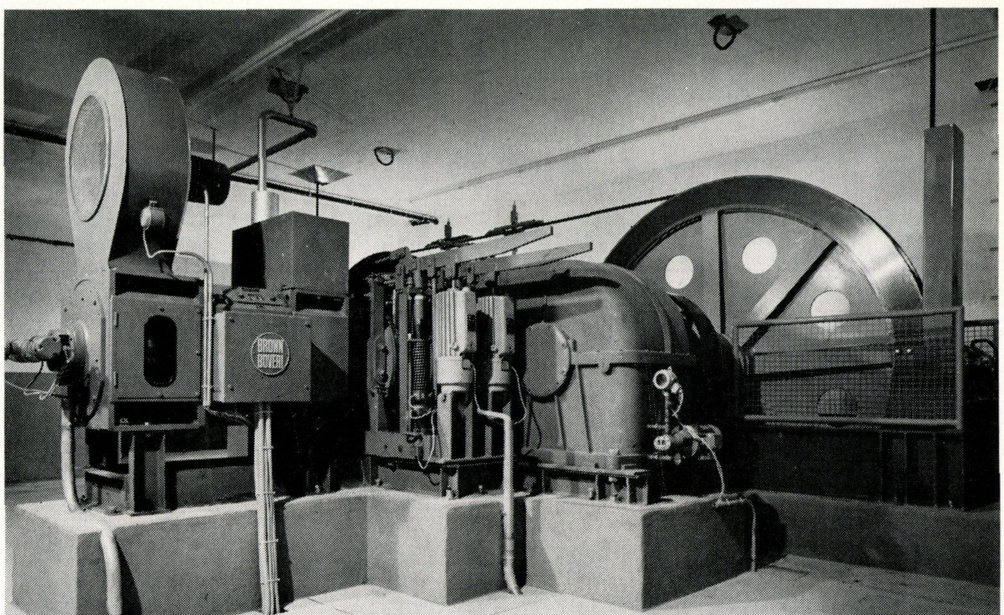
The new range of electronic control equipment for shuttle-service aerial cableways was developed with the object of providing an up-to-date, clearly arranged and easy-to-service control system, which increases both safety and carrying capacity of the transport system and conforms to the latest engineering principles. To this end, operating experience over many years was taken into account and every attempt was made to conform with practical operating requirements [1, 2].

Previously it was common practice to reduce speed in the approach zone in several steps but this did not result in optimum conditions during station approach. However, the new equipment permits station approach at the maximum permissible deceleration without affecting safety.
In the case of previous control systems the nature of the fault which had caused the safety circuit to trip was not immediately apparent. The reason for this lies in the fact that the safety requirements demand series connection of all tripping criteria but this makes it considerably more difficult to display each individual fault. The new monitoring equipment permits individual display of up to 64 tripping criteria.
It should also be noted that the new concept does not affect the power equipment; either a Ward-Leonard set or static convertor can be used [3, 4].

Speed Set Point

As is common practice in modern drive control systems, servo amplifiers based on integrated circuits are now used exclusively for aerial cableways. The control principles have not changed relative to the earlier arrangement [3]. The only significant change is the method of forming the speed set point in automatic operation.
Automatic operation means completing a journey once the start command has been given either through the remote control system in the car or from the control room. It is required of the speed set point that the car leaves the

Fig. 1 – Machine room of Signalbahn, St. Moritz



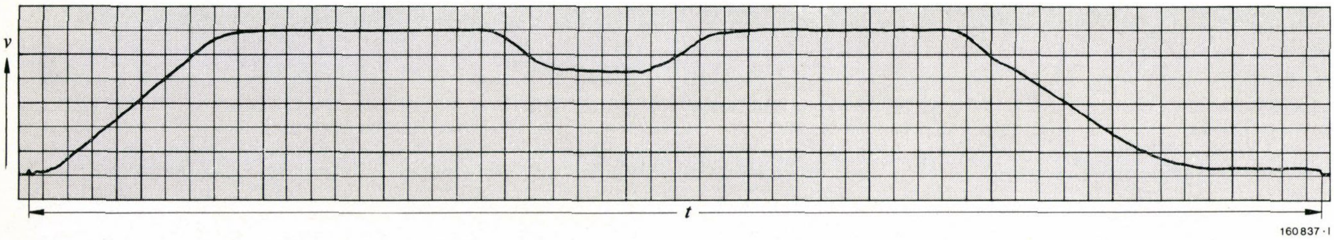


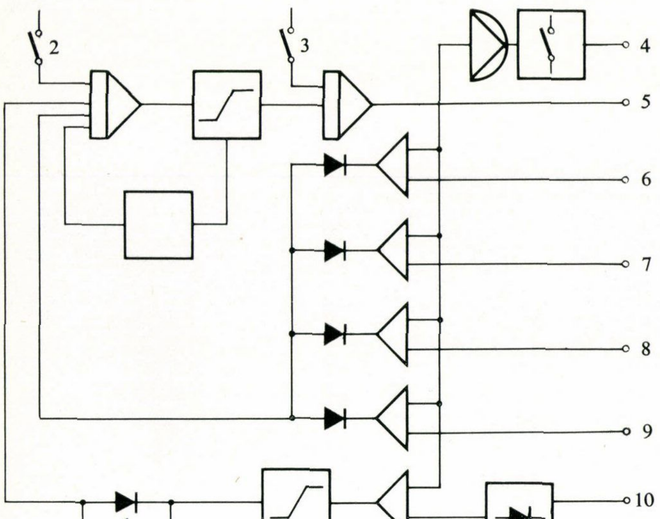
Fig. 2 – Speed/time diagram of Signalbahn, St. Moritz

Length of travel	1450 m
Journey time	3·5 min
Max. speed	10 m/s
Speed over tower	7·5 m/s

station smoothly, that the speed is reduced when passing over a support tower and, that the car approaches the opposite station at optimum deceleration.
This is achieved with the new set point unit which guarantees smooth departure from the station and accelerates the car at a maximum acceleration of 0·3 m/s² to the preselected speed. In the case of a cableway with a maximum operating speed of 10 m/s (e.g. the Signalbahn at St. Moritz) the acceleration time can be reduced by about 20% to around 40 s.

Fig. 3 – Block circuit diagram of set point generator

1	=	'Faster' command
2	=	'Slower' command
3	=	'Electric stop' command
4	=	Set point 'zero'
5	=	Output
6–9	=	Inputs from cam controllers
10	=	Speed over tower
11	=	Max. speed



The same unit takes care of speed reduction when the car passes over a support tower.
In order to keep the station approach time, i.e. the time from deceleration commences until the car comes to rest at the buffers, as short as possible the new equipment decelerates the car at the maximum permissible rate (usually 0·3 m/s²). This is referred to as *constant deceleration approach*. It is brought about by an improved cam controller which varies the potentiometer position in the approach zone from maximum (at start of deceleration) to zero (a few metres from the station). A correction of the travel-dependent voltage curve at the potentiometer and a further correction by means of the new control unit results in an almost ideal voltage curve. In the case of a cableway with a maximum operating speed of 10 m/s the approach time can be reduced by 40% compared to a conventional control system, with the result that it takes only about 60 s from maximum speed to rest. The speed/time curve of the Signalbahn in St. Moritz, the first cableway to be equipped with the new Brown Boveri electronic control system, is shown in Fig. 2. It is particularly with short cableways that the time saved increases the carrying capacity.
The unit also provides the set point for the so-called electric stop. The braking system takes only half the time of normal stopping with a 'slower' command.
The block circuit diagram of the set point unit is shown in Fig. 3. The three inputs 'faster', 'slower' and 'electric stop' determine the momentary operating mode of the unit. The set point signals from the cam controller potentiometers are given through four analogue inputs during the approach zone.
Two further inputs are provided for the signals for maximum speed and for the speed over the tower. The minimum signal always dominates. The two integrators ensure that for any change in speed set point the speed/time diagram (Fig. 2) is initially parabolic and then linear, and finally follows an exponential function. This characteristic not

only ensures a comfortable ride for the passenger but also prevents oscillations in the complex sprung-mass system formed by the cars and the cable sag.

Monitoring Functions

As already mentioned, the conventional safety system for a cableway makes it difficult to locate the cause of an emergency stop because the first trip starts a chain of others, and this can lead to misinterpretation. The new equipment enables all emergency stop criteria to be monitored at a control centre and also indicates *that* fault which caused the first trip. This fault is indicated digitally at the control console (Fig. 4) and remains illuminated until the fault is cleared and a new start command given.

The monitoring system, based on up-to-date integrated circuit engineering, enables 16 trip criteria, either analogue or digital, to be processed by each unit. This new concept of cableway control uses *one* unit for manual control and an additional one for automatic operation.

In spite of their different tasks all units are identical and can be exchanged without further tuning.

The trip criteria for the Signalbahn at St. Moritz are shown in the Table together with the corresponding illuminated digits which appear at the control console.

Display	*Emergency stop initiated by*
00	Buffers
01	8% excess speed
02	Gearbox oil pressure
03	Safety brake
04	Earth fault or overcurrent at Ward Leonard set
05	M.c.b.'s
06	Remote control, control console or check switch
07	Motor or generator field
10	Service brake, main contactor
11	Fixed point check
12	2 m/s check
13	Electric stop
14	Motor or generator fan
15	Actual value too low
16	Actual value too high
17	Zero speed switch, starting monitor, starting bypass
21 or 22	Synchronous operation, car 1 down
23 or 24	Approach speed monitor, car 1 down
25 or 26	Synchronous operation, car 2 down
27 or 30	Approach speed monitor, car 2 down
31 or 32	Speed indicator monitor

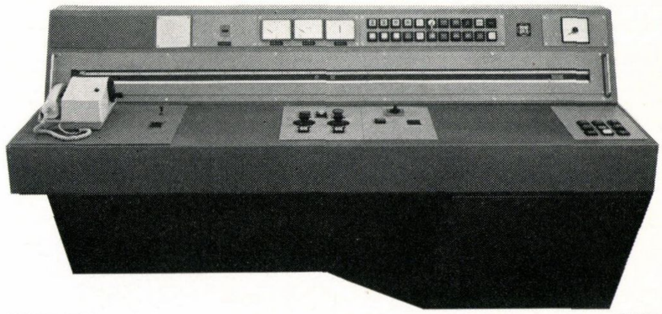


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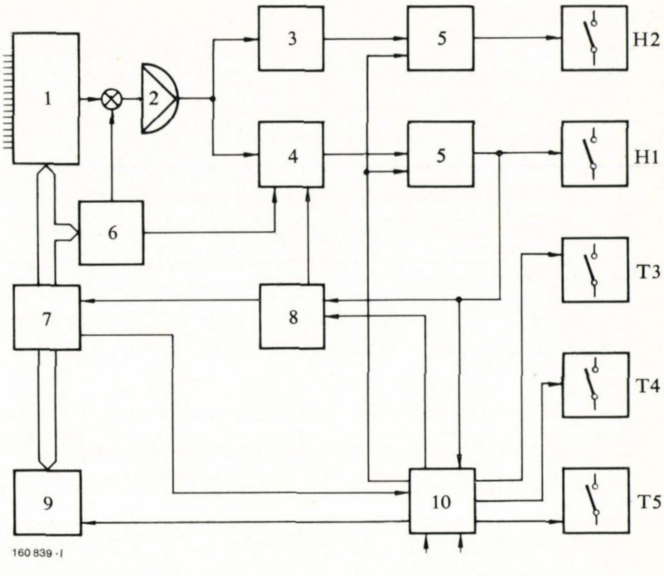
Fig. 4 – Control console

Right: Control and display for auxiliary drive
Centre: Control and display for main drive. The remote display for emergency stop is to the left of the instruments.
Left: Space provided for remote control

Fig. 5 – Block circuit diagram of monitoring unit

1 = Selector for 16 inputs
2 = Comparator
3 = Signal change monitor
4 = +/— Selector
5 = Memory
6 = Self-check
7 = Counter
8 = Clock generator
9 = Display selector
10 = Test circuit
H1 = Emergency stop 1
H2 = Emergency stop 2
T3, T4, T5 = Tests



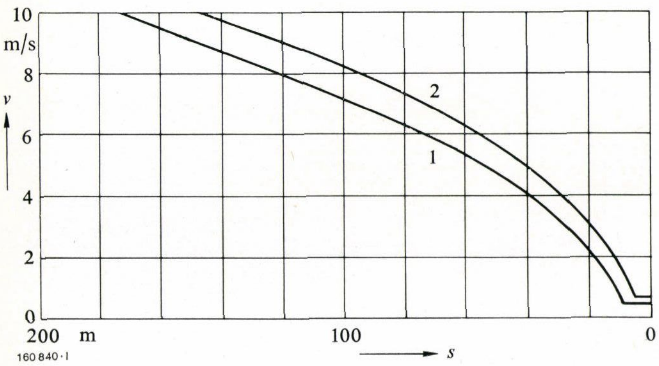


Fig. 6 – Approach curves

v = Car speed (m/s)
s = Distance from station (m)
1 = Approach speed
2 = Envelope for approach check

The components of the monitoring unit are shown in the block circuit diagram (Fig. 5). The voltages of the criteria being monitored are standardized by passive components (comparison resistors) and fed to the input selector. This is switched sequentially by the counter and clock generator. The input signals are thus available at the selector output. They are fed to the polarity comparator whose output signal is checked according to a programme which is controlled by the counter. If an input signal does not have the correct polarity a fault is recognized and an emergency stop command is given through output channel H1. At the same time the counter is stopped and the registered value and the fault input is displayed through the display circuit and the remote display.

Safety was the prime consideration in designing the control system. All central components, such as input selector, comparator, polarity check module, self-check module and counter are functionally associated, and the signals must change their condition according to a given frequency. If one component develops a fault the corresponding output signal remains stationary and this causes output circuit H2 to trip. Trip circuits H1 and H2 operate according to entirely different principles, providing an exceptionally high level of security within the monitoring unit.

It is a feature of the monitoring system that it not only checks itself continuously but also checks all trip criteria before each journey commences. Consequently, a start command instigates a check sequence which, when completed (approx. 100 ms) releases the travel command. This check is carried out with modified analogue signals which ensures that the monitoring system responds to that value which deviates slightly from the permissible value. In the case of digital signals the check phase is restricted to checking the wiring, switches and relay contacts.

A new feature of *constant deceleration approach* deserves special mention. An envelope curve given by the cam controller potentiometers determines the maximum permissible speed in the approach zone. If at any point the actual speed exceeds this envelope the monitoring system instigates an emergency stop (Fig. 6).

Conclusion

Various other modules from the new range of Brown Boveri electronics equipment based on integrated circuits are used in addition to the units described here, which are specially developed for cableway control. All modules plug in to a hinged frame and have a wide range of check facilities.

It can safely be said of the new concept described here that it complies with many requirements of cableway manufacturers and operators and that it definitely contributes towards further increasing safety in cableway operation.

Bibliography

[1] *O. Manz:* Automatic control of aerial ropeways and funiculars. Brown Boveri Rev. *47* 1960 (9) 647–653.

[2] *G. Glauser:* Automatically controlled aerial ropeways. Bull. Oerlikon. 1960 (341) 82–88.

[3] *W. Ott:* A Ward-Leonard drive and its electronic apparatus for an aerial cableway. Bull. Oerlikon. 1969 (387/388) 45–46.

[4] *W. Ott:* Die elektrische Ausrüstung der Luftseilbahn Saas-Fee–Felskinn. VTP Mitt. 1970 (5) 19–21.

Electrical Equipment for a Cold Rolling Mill in Norway

H. Dallermassl

The electrical equipment supplied for a four-high cold mill which went into service in Norway during the spring of 1973 is discussed.

As part of the expansion scheme for their Holmestrand plant, A/S Nordisk Aluminiumindustri awarded the contract for the electrical equipment for the cold rolling mill jointly to Norsk Elektrisk and Brown Boveri in Oslo and Brown, Boveri & Co., Ltd., Baden. Holmestrand is roughly 70 km south of Oslo and the plant is built on reclaimed land in Oslo fjord. The cold rolling mill is a four-high non-reversing stand for aluminium and aluminium alloys and was supplied by Loewy Robertson Engineering Co., England.
Hot-rolled coils up to 1650 mm wide and weighing up to 10 t are stored at the entry side and transported to the pay-off reel by a coil car equipped with an automatic drum locating device. A certain number of coils are rolled with the same roll settings, then they are annealed and returned to the entry side. The strip thickness is regulated by electronically controlled hydraulics. Maximum operating speed is 1060 m/min. The wind-up reel has a belt wrapper for overhung reeling. As the coils can also be wound on spools, spool changers are provided at both pay-off and wind-up reels. The general layout of the plant is shown in Fig. 1.

Technical Data of Main Drives

Stand drive:	rating	3600 kW
	voltage	770 V/machine
	speed	200/740 rev/min
Wind-up reeler:	rating	1000 kW
	voltage	720 V/machine
	speed	450/1350 rev/min
Pay-off reeler:	rating	500 kW
	voltage	720 V/machine
	speed	450/1350 rev/min

Motors

By suitably arranging the supply it was possible to restrict the main drives to only two types of d.c. machine of the Brown Boveri 'G' range [1]. The stand drive (pinion gear with two inputs) comprises 2×2 motors using three journal bearings and mounted on two bed-plates. This arrangement permits operation with two motors while servicing is being carried out. The wind-up reeler has two motors; the pay-off reeler one. These machines have end-shield roller bearings and are fully interchangeable. All main drive machines are to protection type P33r, have separate ventilation through the foundations and have shutdown heating.

Static Convertors and Rectifier Transformers

Thyserts [2] are used for supplying the main drives. In addition to the semiconductor elements these plug-in modules also contain the protection and control equipment, heat sink, pulse transmitter, fuses and so on. These modules can be replaced while the mill is in operation. Identical semiconductor components are used throughout to simplify spares storage.
The circuit arrangement was designed for utmost component uniformity and to avoid excessive demands on the supply system. Electrical equipment of this size always places a burden on the supply system in respect of reactive power and harmonic content. The sequential control of the two stand supplies and of the wind-up reeler supply, together with the different primary connections (star, delta) of the rectifier transformers for the stand considerably improve the network conditions [3]. The four rectifier transformers satisfy the requirements in respect of short circuits and decoupling the secondary windings. This decoupling is necessary to permit the second static con-

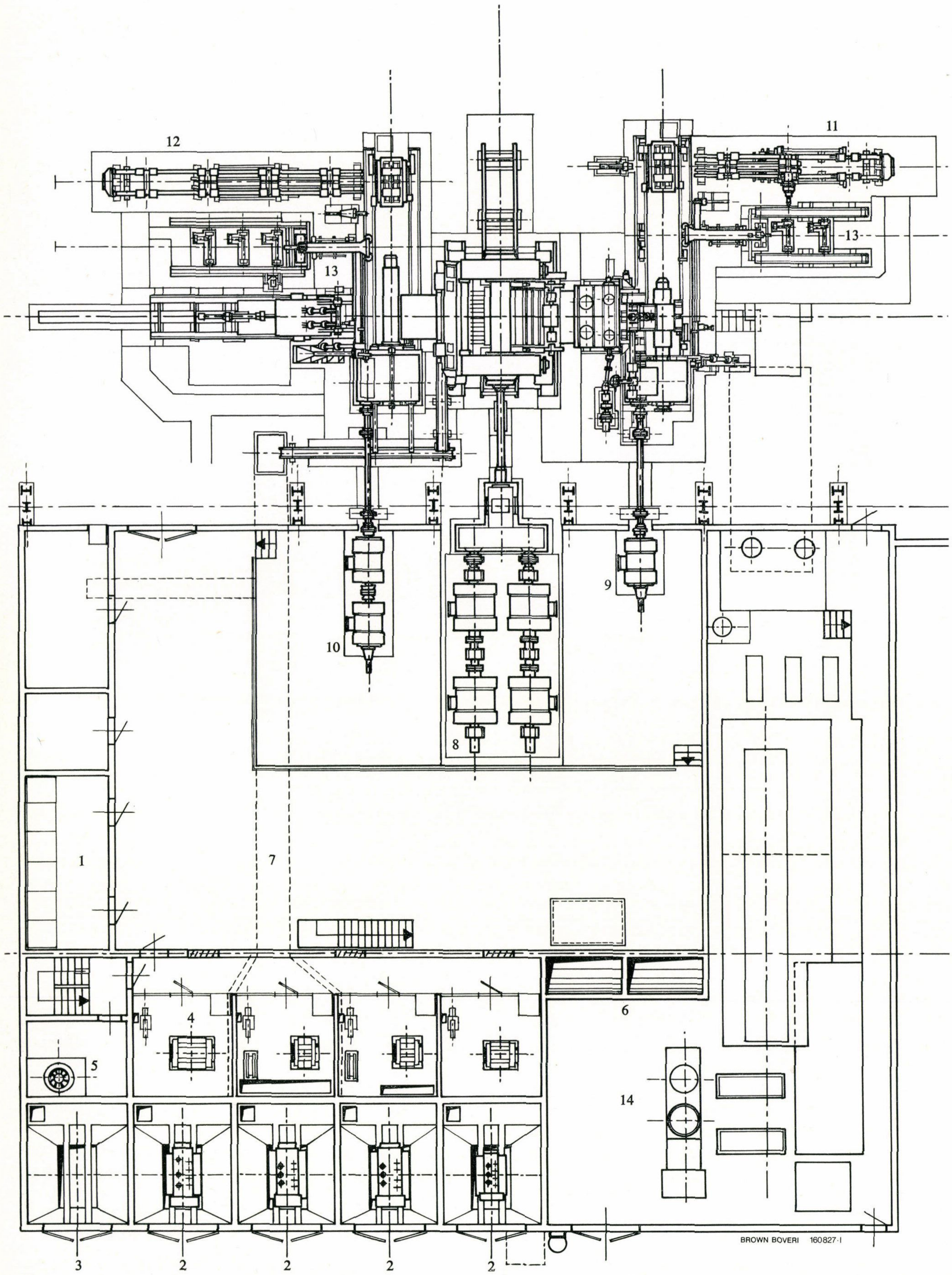


Fig. 1 – Layout of plant

1 = Power supply (h.v. and l.v.)
2 = Rectifier transformers
3 = Auxiliary transformer
4 = D.C. cells
5 = Ventilation for electrical equipment rooms
6 = Air inlet and outlet ducts for motors
7 = Main cable duct
8 = Stand drive
9 = Pay-off coiler drive
10 = Wind-up coiler drive
11 = Entry
12 = Exit
13 = Spool remover
14 = Basement oil tanks

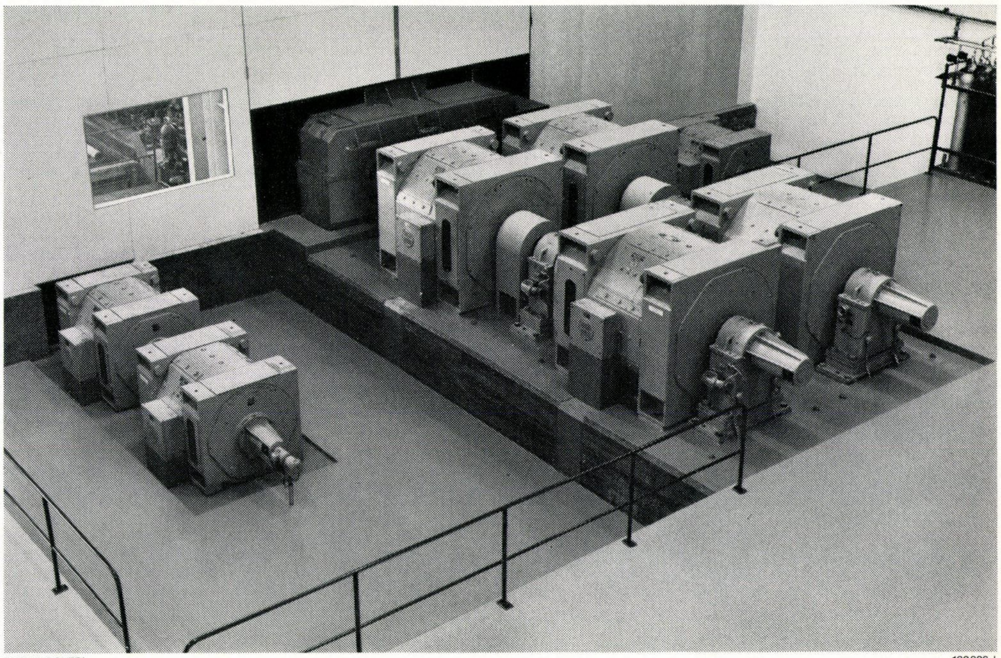


Fig. 2 – Main drive motors

vertor unit in series to be fired during sequential control operation while firing the first unit, in spite of voltage drop (commutation).

Control

Constant reeler tension and constant strip speed during operation, as well as controlled acceleration and braking, are supervised by an electronic control system. A diagram of the equipment is shown in Fig. 3 and the relationship between the overriding system for start-up and the actual drive controls is clearly shown. The components are arranged in three hinged frames according to their corresponding drives.

All drive controls are arranged in cascade with the speed control overriding the current control. In the case of the stand drive, comprising two machine sets, the speed control overrides two current regulators. The drive is controlled on the principle that torque reversal is carried out by field reversal [3]. A special coiler control system [4] for high-performance cold rolling mills is incorporated where the motor field is kept constant up to base speed and for higher speeds it is weakened such that the motor voltage remains constant. This results in improved motor efficiency and also the static convertor operation is more favourable in respect of reactive power consumption and creating harmonics. The machine control electronics are analogue; the coil diameter calculator and pass reduction calculator digital. To this end impulse generators are fitted to all main drives and also to a deviating roller at the mill input for measuring the exact strip speed.

Auxiliaries

The supply, control and monitoring equipment for all auxiliaries (7 d.c. machines, 20 three-phase motors and around 70 solenoid valves) are contained in 25 individual cabinets with aluminium frames and sheet steel panels.

In selecting the three-phase motors, limit switches, etc., special attention had to be paid to the risk of fire near the mill stand due to the roll coolant.

In the case of a power failure the pay-off coiler is brought to rest by resistance braking. Consequently a minimum of aluminium strip is paid-off into the mill, thus preventing any damage to the mechanical equipment due to the strip coming freely to rest.

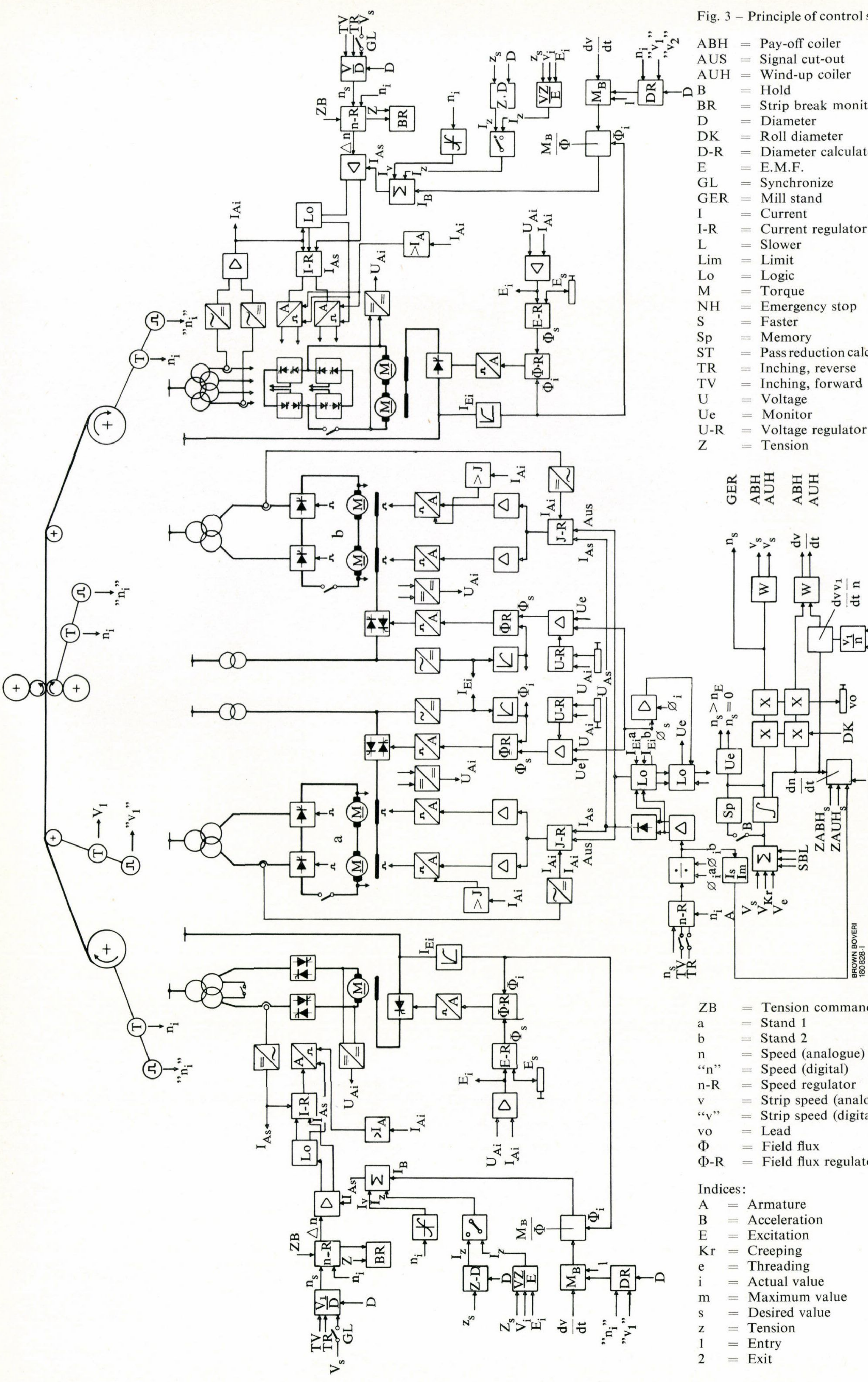


Fig. 3 – Principle of control system

ABH	=	Pay-off coiler
AUS	=	Signal cut-out
AUH	=	Wind-up coiler
B	=	Hold
BR	=	Strip break monitor
D	=	Diameter
DK	=	Roll diameter
D-R	=	Diameter calculator
E	=	E.M.F.
GL	=	Synchronize
GER	=	Mill stand
I	=	Current
I-R	=	Current regulator
L	=	Slower
Lim	=	Limit
Lo	=	Logic
M	=	Torque
NH	=	Emergency stop
S	=	Faster
Sp	=	Memory
ST	=	Pass reduction calculator
TR	=	Inching, reverse
TV	=	Inching, forward
U	=	Voltage
Ue	=	Monitor
U-R	=	Voltage regulator
Z	=	Tension

ZB	=	Tension command
a	=	Stand 1
b	=	Stand 2
n	=	Speed (analogue)
"n"	=	Speed (digital)
n-R	=	Speed regulator
v	=	Strip speed (analogue)
"v"	=	Strip speed (digital)
vo	=	Lead
Φ	=	Field flux
Φ-R	=	Field flux regulator

Indices:

A	=	Armature
B	=	Acceleration
E	=	Excitation
Kr	=	Creeping
e	=	Threading
i	=	Actual value
m	=	Maximum value
s	=	Desired value
z	=	Tension
1	=	Entry
2	=	Exit

Fig. 4 – Electrical equipment

Ventilation

The d.c. machines have a ventilation system for year-round operation where a thermostat controls the amount of fresh air intake according to outside temperature. This is then mixed with circulating air and fed to the motors. At extremely low outdoor temperatures the ventilation is a closed-loop system. Each motor has its own fan providing the correct amount of air. The mixture of fresh and circulating air is filtered and contact manometers behind the fans in the air inlet ducts monitor the air pressure. Standstill heating is provided in the air intake ducts to eliminate excessive temperature differences with their associated condensation.
The ventilation system for the electrical equipment room is similar to that for the motors where a mixture of fresh and circulating air is supplied to both storeys. The air processing plant is common and the fans circulate 60000 m³ of air per hour. The exhaust air contributes towards-heating the shop.

Bibliography

[1] *J. Meister, R. Renold:* Electrical design of the new series of d.c. machines. Brown Boveri Rev. *55* 1968 (10/11) 611–617.

[2] *H. Pisecker, X. Vogel:* 'Thysert', a new element of the Brown Boveri electronic system. Brown Boveri Rev. *54* 1967 (5/6) 241–249.

[3] *J. Tack, E. Strebel:* Electrical equipment for cold rolling mills. Brown Boveri Rev. *58* 1971 (2/3) 65–77.

[4] *J. Tack, K. Schmuck:* Reaction effects on the supply system caused by static converters in large cold rolling mills. Brown Boveri Rev. *58* 1971 (2/3) 83–86.

Electrical Equipment for a Kraft and Coated Paper Plant in France

M. Adam

A new paper production line comprising paper machine and coater (Fig. 1) supercalender and slitter-rewinder commenced operation at Papeteries René Sibille at Pont-l'Evêque in France during the autumn of 1972.

Data of Machines in Production Line

Machine Suppliers:	
Paper machine	Allimand, Rives, France
Coater	Joseph Eck & Söhne, Düsseldorf, Germany
Supercalender	Bruderhaus GmbH, Reutlingen, Germany
Slitter-rewinder	Jagenberg, Düsseldorf, Germany

Paper machine:	
Wire width	5400 mm
Working speed	75–500 m/min
Product	Kraft papers, coated on one side, 36 to 100 g/m^2
No. of drives	29
No. of controlled groups	15 including slitter-rewinder with thyristor supply in unit connection
Installed power	2800 kW
Supercalender:	
Trimmed width	4600 mm
Maximum speed	400 m/min with constant torque 600 m/min with constant power
Main drives	820 kW, 745 rev/min, thyristor supply
Pope reeler	56 kW, 1660 rev/min
Cooling roll	16 kW, 1660 rev/min
Slitter rewinder:	
Trimmed width	4600 mm
Maximum speed	1500 rev/min
Main drive	160 kW, 1875 rev/min, thyristor supply

Supply to the fifteen controlled groups of the paper machine is through thyristor convertors in fully-controlled

Fig. 1 – Paper machine and controls

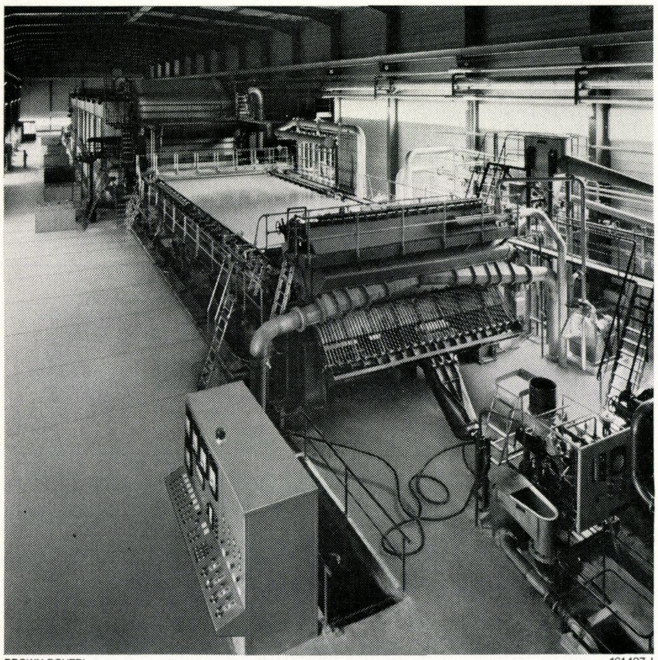


Fig. 2 – Some of the paper machine drives

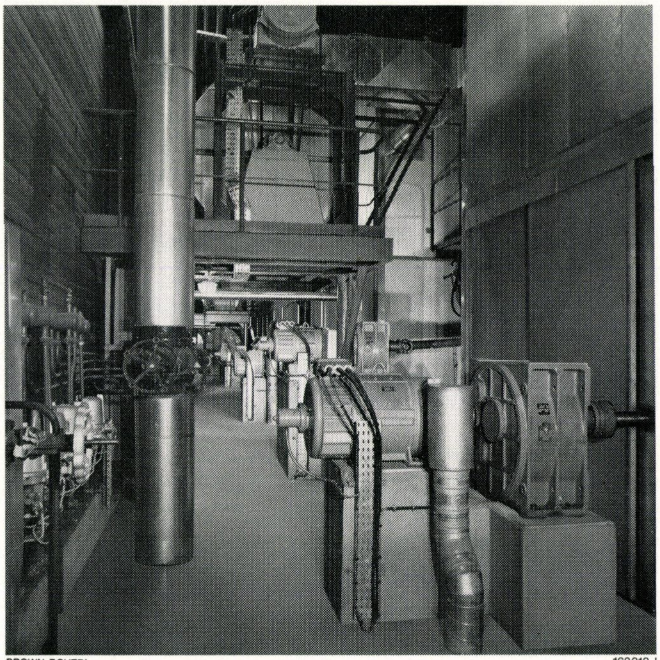


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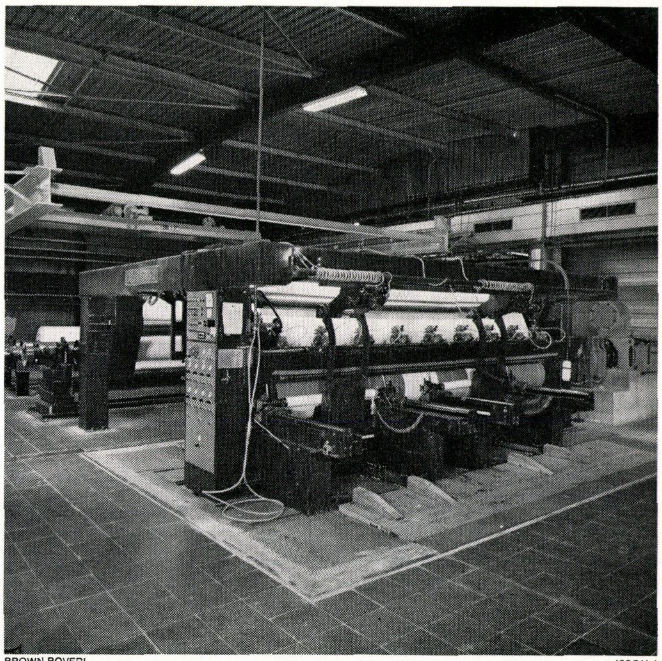
Fig. 3 – Supercalender with reelers, main drive and controls



BROWN BOVERI 162311-I

Fig. 4 – Slitter-rewinder with controls built into machine frame

three-phase bridge connection (Fig. 2). This arrangement enables the machine operator to control each group independently. Because of the wide operating range of 75 to 500 m/min the transformer for the paper machine has tappings for improving the power factor.

The wire drive comprises two controlled d.c. machines with load distribution between suction couch roll drive and wire roll drive.

The drives for the dry end are braked electrically to bring them to rest as quickly as possible.

The blade coater with high-performance drying hood is driven by a total of 13 motors divided into 2 controlled groups. Originally it was intended to fit measuring cells before and after the coating head for direct control of web tension but this was found to be superfluous because the fluctuations in tension due to raising and lowering the blade are adequately compensated by the normal speed control of the drive motors.

After drying the paper is again moistened and reeled at a combination pope reeler/core winder with automatic spindle change.

The main drive for the 16 cylinder supercalender has an output of 820 kW at a maximum working speed of 600 m/min. The unwinder has a mechanical brake. Individual drives are provided for the cooling cylinder and pope reeler at the reel-up end. The clearly laid-out controls make life easier for the operating staff (Fig. 3).

The Jagenberg Vari-Roll slitter-rewinder with a maximum operating speed of 1500 m/min completes the plant. The reel-up motor has an output of 161 kW at 1875 rev/min and the unwind roll is braked mechanically. The controls are clearly arranged and built into the machine frames for convenience and to save space (Fig. 4).

Maximum operational flexibility in varying the product and optimum reliability were stipulated by the paper manufacturer. The drive and control system developed by Brown Boveri in close cooperation with the machine suppliers is flexible enough to permit all demands to be complied with in every respect.

Electrical Equipment for a New Wire Rod Mill in England

M. Aeschbach

In the face of fierce competition Brown Boveri won the contract in 1970 for supplying the complete electrical equipment for a continuous wire rod mill of Johnson and Nephew (Steel) Ltd., in Manchester, England. The mill has been in three-shift operation since the end of May 1972, to the entire satisfaction of the client (Fig. 1).

Material Flow

The plant comprises a two-strand wire rod mill which simultaneously rolls two billets of 100×100 to 150×150 mm cross section and 4 to 12 m long to produce wire.
The mechanical part of the plant (Fig. 2) was supplied by Davy United of Sheffield and Schloemann of Düsseldorf. The billets are heated to about 1100 °C in a furnace and an ejector brings them onto a roller table which transports them through a deviator to the continuous mill. The final component which is involved in forming the material is a

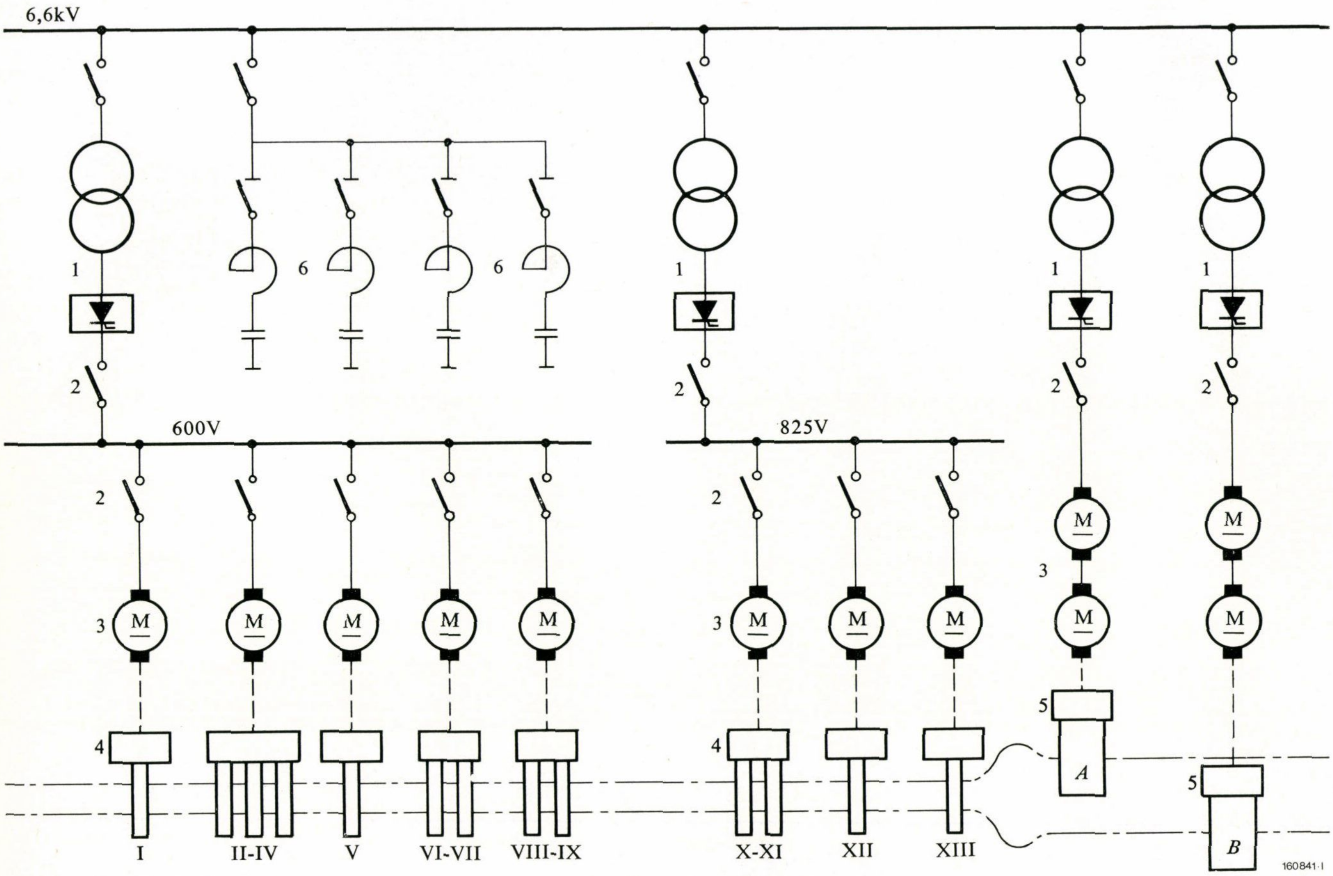


Fig. 1 – Combined electrical and mechanical arrangement of main drives and their supply

1 = D.C. supplies
2 = D.C. breaker
3 = Drive motors
4 = Mill stands I to XIII
5 = Wire stands *A* and *B*
6 = Harmonics filters

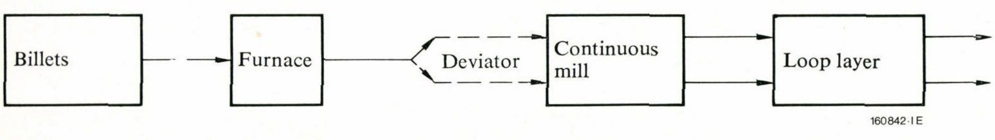


Fig. 2 – Simplified diagram of continuous hot rolling mill

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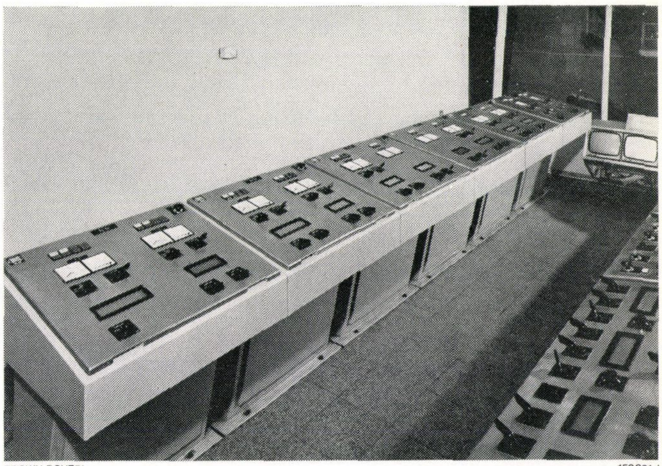
Fig. 3 – Loop layer



BROWN BOVERI 159361-I

Fig. 5 – Part of the control panel

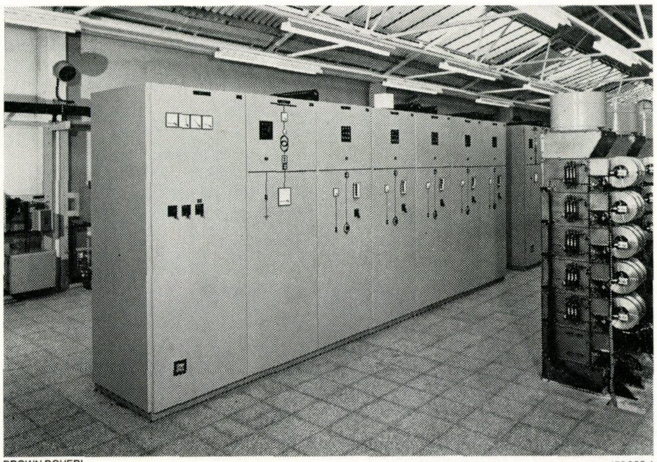


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Fig. 4 – Electrical equipment room

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Fig. 6 – Thyristors for supplying main d.c. drives

Morgan wire stand. The end product is wire of 5 to 11 mm diameter produced at a rate of 50 m/s and fed to the loop layer (Fig. 3). The wire loops cool on the conveyor which carries them to the coiler where they are formed into coils and bound, ready for transporting away for further processing.

Electrical Equipment

The total installed power, including main and auxiliary drives, is 7360 kW.

The thyristor rectifiers for supplying the d.c. drives and also the control panels and equipment are contained in a

separate room (Fig. 4). All preliminary switching operations preparatory to rolling are carried out from here. A special display array indicates any faults.
The mill is started up and operated from a control station situated centrally above the line of stands. The speeds of the mill motors are set from here and all important functions of the continuous mill are monitored through cctv. The required speeds for the main drives are set at digital units developed by Brown Boveri. These ensure very accurate speed control which is of prime importance for trouble-free rolling. The speed of each individual drive is displayed digitally at the control panel (Fig. 5).
Only three types of the Brown Boveri G series d.c. motors were used for the main drives to rationalize the stock of spares. The machines are of the end shield bearing type and the customer specified plain journal bearings. All motors are fitted with built-on heat exchangers which saved the customer considerable building costs.
All d.c. supplies for the main drives are of traditional Brown Boveri thysert arrangement and only one type of thyristor is used for both field and armature supply, again to keep spares to a minimum (Fig. 6).
To improve the power factor and suppress the harmonics the plant is fitted with filters for the 5th, 7th, 11th and 13th harmonics.

A New Rod and Merchant Mill in Brazil

G. Bauer

In 1971 Brown Boveri won the contract for supplying the electrical equipment for a rod and merchant mill for Companhia Siderúrgica da Guanabara S.A. The equipment was delivered to Brazil in 1972 and installed under the supervision of Brown Boveri engineers.

Plant Layout

As shown by the illustration the plant comprises a three-high roughing mill and an intermediate and finishing train arranged for continuous operation and rolling is carried out either on a two-strand, two-high twisting stand followed by wire production lines or on a cooling bed.
The three-high stand is driven by a slipring motor and the stands in the continuous mill by d.c. machines supplied by thyristors in direct connection. Their speed set-point is given by a digital impulse generator.
The control equipment comprises IC components. In addition to the control engineering, Brown Boveri also provided the layout for the substation.

Special Features

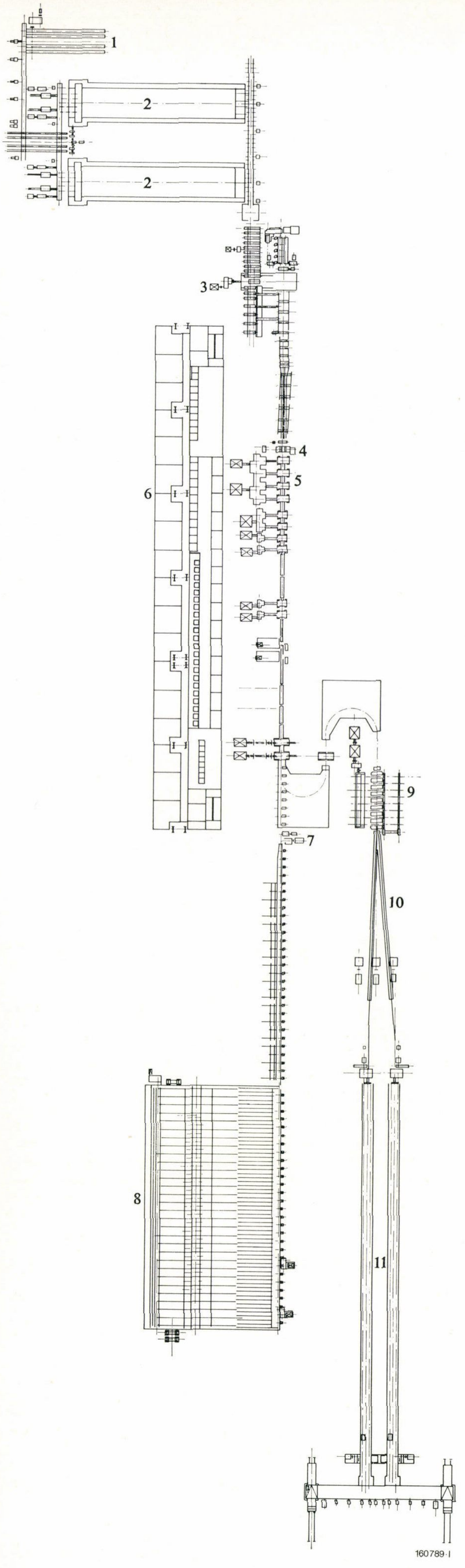
Features of the mill include the cooling bed for finished lengths with its peripherals such as cooling bed shear and scrap disposal unit.
In many cases the rolled product is deposited on cooling beds in many different commercial lengths, usually with some excess. When the material is cold it is divided up by cold shears and the excess is lost in trimming the ends. These jobs, which cost time and material, are eliminated by the finished length cooling bed where the finished product arrives already cut to commercial lengths.
Obviously the accuracy requirements are much more stringent for all equipment involved in cutting and depositing the material in finished lengths. As the commercial lengths have to be of a transportable size the cooling bed is considerably shorter than in conventional plant but at the same time the number of cuts by the shears and the number of working cycles of the cooling bed equipment are raised considerably.
In this particular case the cooling bed is 36 m long and the maximum rolling speed is 10 m/s. As the minimum cut length is 10 m the cooling bed shears perform 3600 cycles per hour.
In order to fulfil these requirements the operating commands for the cooling bed, scrap disposal unit and braking slides are given by digital equipment. The advantage of this arrangement lies in the fact that this cooling bed control system is much more precise and operates independently of the roll diameters, thus reducing the number of potential sources of error.
In order to guarantee the required cutting accuracy of $\pm 0{\cdot}5\,\%$ a calibration section was provided and this serves as a fixed reference length. The required length set at the thumbwheel switches is a multiple of this fixed length, i.e. the number of pulses corresponding to this length is a multiple of the number of pulses of the reference length. The shear is run-up and braked to rest for each cut, and brought to the rest position and held there by a position control unit.
Similar equipment is provided for the two braking slides.

Main Data

Ratings

Slip-ring motor for three-high stand	2000 kW	720 rev/min
Main drives for continuous stands	5 × 670 kW	0–480/1200 rev/min
	1 × 935 kW	0–520/1250 rev/min
	1 × 1070 kW	0–500/1070 rev/min
	2 × 500 kW	0–390/1070 rev/min
	1 × 2 × 1400 kW	0–700/1265 rev/min

Power supply 23 kV, 60 Hz



Rod and merchant mill

1 = Billet input
2 = Pusher-type furnace
3 = Three-high stand
4 = Pendulum shear
5 = Continuous mill stands
6 = Substation
7 = Cooling bed shear
8 = Finished length cooling bed
9 = Two-high twisting stand
10 = Cooling sections
11 = Wire dressing machines

Electrical Equipment for a Plant Producing and Printing Non-Woven Materials

M. Premužić

In March 1972 the Société Française des Non-Tissés of Brignoud, France, awarded Brown Boveri the contract for supplying the drive equipment for expanding an existing production machine (Fig. 1) and for a new printing machine for non-wovens.
In spite of the very tight schedule the equipment was supplied and in service on time in August 1972.

Data of Production Machine after Extension

Type of machine	wet layer
Wire width	2630 mm
Trimmed width	2580 mm
Design speed	250 m/min
Working range	20 to 200 m/min
Leaf weight	15 to 150 g/m^2
Product	non-wovens based on synthetic and natural fibres
Installed power	125 kW

Data of Printing Machine

This machine was developed on the basis of research carried out by the La Rochette-Cenpa group at their applied research centre.

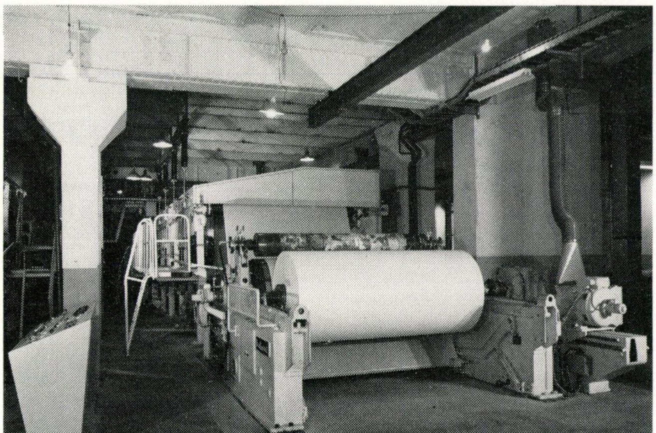
Leaf width	2580 mm
Design speed	250 m/min
Working range	20 to 200 m/min
Leaf weight	15 to 150 g/m^2
Installed power	50 kW

The application spectrum given below demonstrates the flexibility of these multi-purpose machines and also of their electrical equipment. Products include

– decorative materials in 30 shades and with 30 patterns for shop windows, exhibition stands, etc.
– industrial materials such as bases for pvc sheets, impregnating media and abrasives, filters for cooking oils and milk, flocks, interlining for clothing, bookbinding material, cleaning materials for industry and household,
– household goods such as table cloths, serviettes, bed sheets and nappies, linen for hotels and restaurants, publicity items,
– medical articles for hospitals and clinics, such as bed linen, pillow cases, waterproof undersheets as well as clothing for surgeons and operating theatre staff.

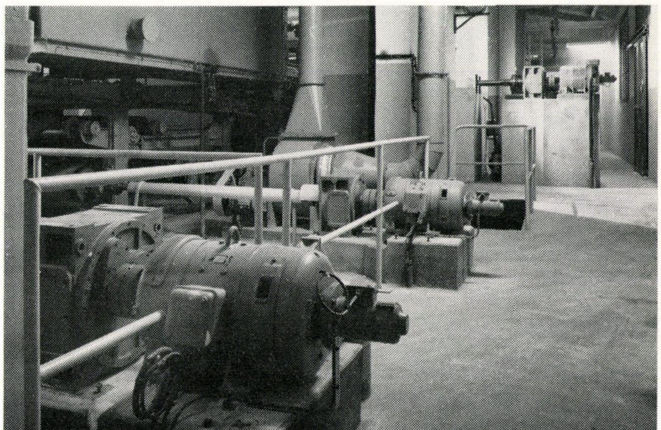
Fig. 1 – Production machine

The strip is reeled on leaving the hot-air dryer. An empty spindle can be seen. The winder motor with bevel gearing can be seen at right and the reeler control panel at left.



BROWN BOVERI 161626-I

Fig. 2 – Through-draught ventilated d.c. motors, with built-on tachogenerators, for driving the printing machine



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The d.c. motors for driving the individual groups of the production and printing machines have through-draught ventilation (Fig. 2). This ensures protection for the active motor components against any possible chemical attack through the surrounding atmosphere even in the event of future programme changes or experiments. An eight-section cabinet in a separate room contains all the supply, switching and control equipment for both production and printing machines.

Unit-connected sectional drives were used in extending the production machine, i.e. each controlled group (hot-air drying section, surface reeler and core winder) has a static convertor in fully controlled three-phase bridge connection. The armatures of the group motors are controlled through a speed/current cascade. The set point is supplied by a tachogenerator driven by the existing line shaft. Two load cells at a guide roll ahead of the pope roll accurately measure the actual sheet tension and feed this signal as a correcting value to the winder control circuit.

The demands made of the drive system for the printing machine are characterized by the fact that it must be possible to inch, feed-in and run-up from rest to maximum operating speed and brake to rest without tearing the web. Here again a multi-motor drive in unit connection was chosen and the set point is supplied by an electronic set-point integrator. The electronic control system ensures controlled run-up and run-down of all drive groups (pressure roll, printing section, hot-air dryer and winder) in common operation. Experience gained with paper and coating machines enabled optimum arrangements to be derived for these machines.

Extending a Rod and Merchant Mill in Denmark

M. Aeschbach

Subsequent to the order for the complete electrical equipment for a continuous rod and merchant mill in 1961, Det Danske Staalvalseværk A/S in Frederiksværk, Denmark, ordered the electrical equipment for a three-high train from Brown Boveri. The extended plant went into service in July 1972.

Three-High Train

The following advantages were achieved by placing the new No. 2 three-high train in front of the existing No. 1 three-high train in the continuous rod and merchant mill:

– the cross section of the billets was raised from 105 to 150 mm², increasing the efficiency of the cogging mill by reducing the rolling time,
– the number of passes in the rod and merchant mill is reduced by 50%,
– the amount of scrap at the cold shears is also reduced by 50% because only half as many billets are required for the same output.

Power Supply for Drive

Both field and armature supply for the motor are through thyristors. Sequential control is provided for the armature supply to reduce the reactive power at the static convertor. The static convertors (thyserts) comprise the tried and tested Brown Boveri plug-in modules. The field supply is in anti-parallel connection (Fig. 1), as requested by the customer, to permit rapid reversal of the drive motor.

Motor data

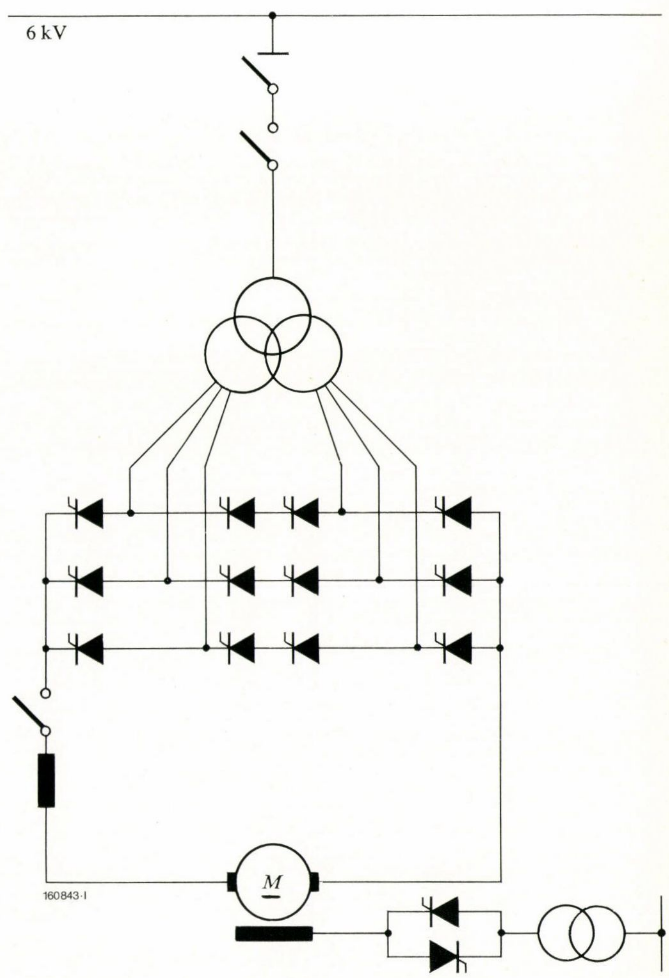
Rating	1725 kW
Rated voltage	900 V
Rated current	2020 A
Speed	0–280/400 rev/min
Overload capacity	2·5 × rated current

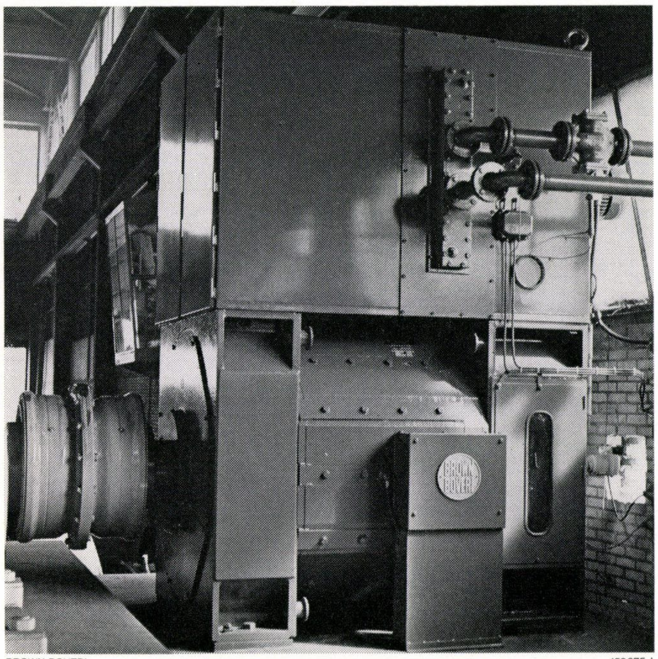
To avoid constructional problems when the plant was extended, the motor was fitted with a compact, built-on heat exchanger, for which the new range of Brown Boveri d.c. machines is particularly suited (Fig. 2).

Control

The speed and field control equipment is based on integrated circuits in line with the latest in electrical engineering. Notable features include the very small space requirement and high degree of reliability attained with integrated circuits. The IC-A range of equipment complies with the requirements of VDE 0160 and its design and technical specifications make it eminently suitable for solving control problems in the automation of industrial processes (Fig. 3).

Fig. 1 – Circuit of thyristor supply equipment





BROWN BOVERI 159375-I

Fig. 2 – 1725 kW d.c. drive motor with built-on heat exchanger

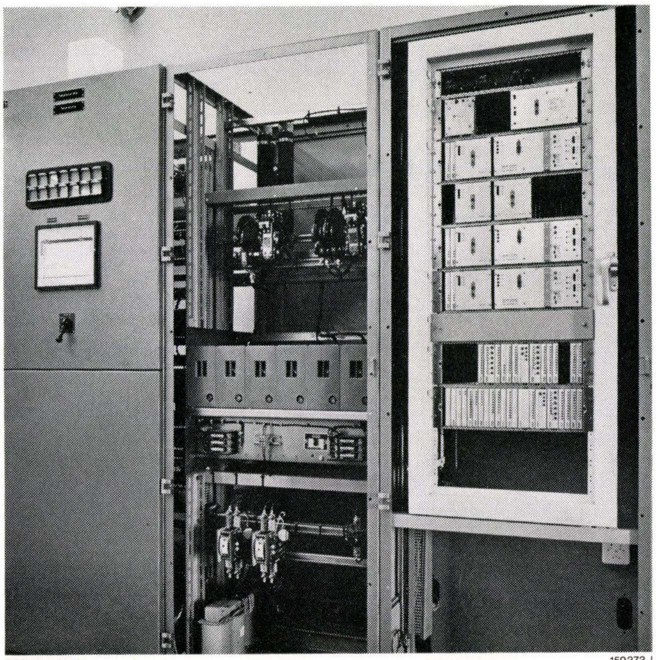


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Fig. 3 – Switchgear cabinets with front panels removed

Left: Static convertor for field supply and control equipment
Right: Hinged frame with control electronics

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