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The IFS-1 PCM Integrated Telecommunication System

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1 Introduction

PCM integrated communication systems have attractive characteristics. They can handle signals from a variety of sources; their transmission characteristics are practically independent of distance and the number of switching points in a link; they allow flexible and economical network planning and open up new possibilities for solving the communications problems of the next decades [1], [2]. Although this has been known for some time, the technology enabling such systems to be built has become available only in recent years. In the early sixties, general interest was concentrated on digital transmission on a PCM basis. However, it was soon found that, because of their binary nature, PCM signals are ideally suited for switching over electronic crosspoints. Digital microelectronics, which at that time began to dominate the market, provided the basis for quick development in this field.

In Switzerland, for example, the telecommunications industry designed PCM transmission systems and switching matrixes based on the results of studies by the PTT Research and Development Division. At the same time, the problems of system control and network configuration were being examined [3, 4, 5]. This initial work led to the completion of an operational laboratory model of a PCM switching system in 1970 [7]. The model confirmed some of the important fundamental principles. It proved that the method of switching by storing an entire frame is feasible [6, 8]. The model also showed that the principle of modular construction – system blocks with uniform interfaces are combined to form complete networks – is both practicable and flexible. The interface of a PCM multiplex enables the system units to be remote-controlled. Adaptation to the various types of operation can be achieved by means of a real-time processor for system control. On the other hand, experience with the lab model has shown that much further effort will be needed to attain the ambitious aim of a digital integrated telecommunications network.

In the meantime, the suppliers have developed their PCM transmission plant to the latest technical standards, so that the systems can now be used in the public network [9, 10].

In 1970, a PCM joint development group was founded for the purpose of closer cooperation and concentration on the project in hand. It is directed by the PTT Research and Development Division and includes the three telecommunications firms of *Hasler AG, Berne, Siemens-Albis AG, Zurich*, and *Standard Telephone & Radio AG, Zurich* [11, 12].

The following article outlines the system principles and technical solutions worked out so far. It is based on two papers read at international conferences in 1972 [13, 14].

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2 The IFS-1 Telecommunication Network

The IFS-1 network comprises all the equipment needed to set up, transmit and supervise a call. It is designed to handle normal telephone or similar analog calls, telex or teleprinter connections, medium and high-speed data and many other types of digital information. IFS-1 therefore extends from the subscriber's station via the switching stages with their control mechanisms to the long-distance lines. Four-wire digital transmission and switching on a PCM basis enables a uniform network of high quality to be provided. Analog services are digitalized as near to the subscriber as possible. In a later phase, telephone stations with built-in coders/decoders and data terminals will permit the use of digital subscriber lines, together with long-distance PCM transmission circuits, so that a homogeneous digital network is obtained. IFS-1 may therefore be considered integrated in two respects: first, time division multiplex and pulse code modulation are used for switching and transmission; secondly, several services are combined into one uniform switched network [15].

The need for flexible network layout, simple installation of new equipment, easy replacement of life-expired material, reduced maintenance time and cost as well as increased standardization in development and construction calls for a limited number of functional units or system blocks that are interconnected by means of a few standardized interfaces. Processor control and time division multiplex techniques permit and necessitate both large-scale concentration of the switching and control functions. Spatial concentration of the control and supervisory functions requires an effective and reliable system of control information transmission. This is available throughout the network in the form of the universal PCM channel.

The IFS-1 network is therefore built up modularly, using remote-controlled, freely locatable system blocks or units that are interconnected by means of CEPT-compatible PCM multiplexes carrying 32 time slots each of 8 bits and with 8 kHz sampling frequency [16]. Each unit in the network is controlled over at least one normal PCM channel individually allocated to the unit and switched through the network semi-permanently.

21 *Configuration of the IFS-1 Network*

Functionally, the network is divided into four sections: the peripheral field, the concentration field, the switching network, and the processor field (*fig. 1*).

211 *The Peripheral Field*

This field comprises both the analog and digital subscriber equipment and the exchange lines (subscriber lines). The inter-exchange voice-frequency and FDM carrier

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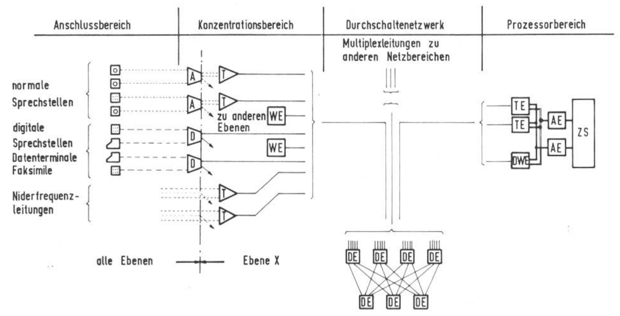

Fig. 1
General network layout in the IFS-1 system

Anschlussbereich – Peripheral field
Konzentrationsbereich – Concentration field
Durchschaltenetzwerk – Switching network
Prozessorbereich – Processor field
Multiplexleitungen zu anderen Netzbereichen – Multiplexes to other network areas
Alle Ebenen – All planes
Ebene X – Plane X

A	Analog-Konzentrator – Analog concentrator
D	Digital-Konzentrator – Digital concentrator
WE	Wahleinheit – Register unit
DE	Durchschalteeinheit – Switching unit
TE	Telegrammeinheit – Telegram unit
DWE	Digitale Wahleinheit – Digital register unit
AE	Anpassungseinheit – Interface unit
ZS	Zentrale Steuerung – Central control
———	PCM-Multiplexleitung – PCM multiplex
·-·-··	Niederfrequenzleitung – Voice-frequency line
– – – –	Digitale Teilnehmerleitung – Digital subscriber line

circuits linking IFS-1 to the existing networks also form part of this field, since both the speech channels and the signalling systems must be adapted to the uniform PCM channel.

The analog subscriber network corresponds to the present exchange-line system for telephones. Therefore, all current types of subscriber station can be connected, and existing local cables used.

The digital subscriber network comprises the digital subscriber lines and apparatus, including voice terminals with local coders/decoders and data stations for various applications. The digital subscriber line uses a 10-bit code and has the following functions and characteristics [17]:

- Fully transparent transmission of 8-bit words;
- Additional code combinations for signalling;
- A simple method of synchronization;
- Good line transmission characteristics (low dc component, etc.).

212 The Concentration Field

The second stage in the functional hierarchy of the system performs both switching and transmission-type functions:

- Concentration of the subscriber-line traffic so as to permit economical medium-distance transmission and directional switching;
- Supervision and control of the subscriber and inter-exchange lines;
- Conversion of the various signalling codes into a standardized form;
- Physical concentration of up to 30 lines into a PCM multiplex;
- Two-wire to four-wire conversion, where necessary;
- Analog to digital conversion, where necessary.

The concentration field consists of analog and digital concentrators, terminals and register units.

213 The Switching Network

The time division multiplex switching network interconnects all the multiplexes from the concentration field, serves as a register coupler by giving access to the register units, and acts as a switching matrix for the control channels. It therefore performs all the directional switching functions. It is built up modularly and consists of a number of standard switching units. The control system allows the formation of dispersed networks by remote location of switching units in satellite exchanges [18].

The switches are arranged in non-directional three or five-stage folded networks affording high availability and low blocking between the multiplexes. The three-stage symmetrical network employing A and B stages provides for a maximum switching capacity of approximately 4000 erlangs, corresponding to 400 multiplexes connected to the A stage *(fig. 2)*.

Small networks may be built by using fewer switches in the A and B stages, and by interconnecting the A stage switches direct, if necessary. Networks with only 6 to 8 A switches are still capable of processing about 1000 erlangs. Those parts of the switch that occur on a per-multiplex basis are modular and pluggable, thus permitting economical under-equipment.

The concentration field cannot directly interconnect two subscriber lines or a subscriber line and an inter-exchange circuit; it merely concentrates calls. In order to keep transmission costs in the district network as low as possible, it is necessary to switch the traffic at points mutually close to the calling and called subscribers. The use of satellite A-stage switches helps to achieve a good economical balance in practical applications. These switches are connected direct to the central B stages, whereby a loss of symmetry occurs in the network. A-B-stage interconnections are arranged in such a way that low-numbered B switches have access to all A switches, whereas higher numbered B switches have access to progressively fewer A switches *(fig. 3)*. Path-search methods matched to this organization of the inter-switch links provide for low blocking in the network, in spite of the asymmetry.

All the multiplexes to concentration field units (analog and digital concentrators, terminals, register units) as well as the multiplexes to processor-field units having direct access to the PCM network (telegram units, digital register units) and the PCM multiplexes to other network areas are invariably connected to the A-stage switches. Since the links between the switches are also PCM multiplexes, only one type of interface is used throughout the IFS-1 network.

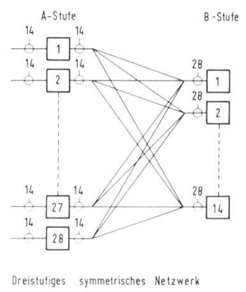

Fig. 2
Three-stage symmetrical switching network

A-Stufe – A stage
B-Stufe – B stage

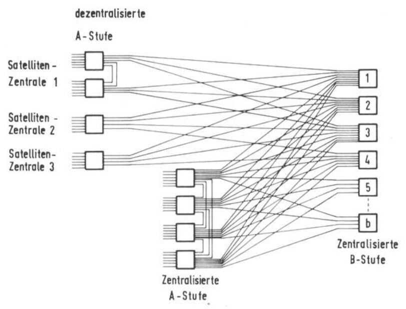

Fig. 3
Switching network with satellite exchanges

Satellitenzentrale 1, 2, 3 – Satellite exchange 1, 2, 3
Zentralisierte A-Stufe – Centralized A stage
Zentralisierte B-Stufe – Centralized B stage
Dezentralisierte A-Stufe – Distant A stage

214 The Processor Field

With the aid of a programmable computer, the processor field (fig. 1) performs all the control and supervisory functions necessary for the operation of the network. It consists of a central control unit holding all switching and supervisory programmes, and of the peripheral input/output equipment. Separate IFS-1-related system blocks (interface unit, digital register unit, telegram unit) constitute auxiliary processors relieving central control of routine functions.

22 The IFS-1 System Blocks

Besides the central control unit, 8 standardized hardware system blocks are used:

a) The *Switching Unit* (DE) consisting of a combined space-time switch is the actual PCM switching apparatus. It interconnects the multiplex time slots on a one-word-at-a-time basis, dealing separately with the two directions of transmission [6, 8]. This involves the three basic operations of synchronization, space and time switching. The full-availability switch is non-blocking and interconnects up to 28 multiplexes. Where desirable, each multiplex may be phase and frequency-independent with regard to the internal clock. On the other hand, frequency-synchronous operation is also possible, being used in particular for data transmission at low error rates.

b) The *Analog Concentrator* (AKT) is the connecting unit between the subscriber lines and the PCM network. It gives each subscriber access to the channels of different multiplexes, and vice versa, thus acting as a plane switching point (see chapter 3). The analog concentrator concentrates the calls from analog subscriber lines. In order to avoid extensive information exchange and interference between the sub-planes, it performs certain operations autonomously, such as line seizure detection, path search in its own switching matrix, and discrimination of plane access. The analog concentrator is built modularly and consists of a number of standardized electromechanical switching matrixes (TKN) and a control unit. Certain control functions are individually allocated to each plane. Connection to the PCM network is always by means of terminals. It is possible to accommodate the standardized switching matrixes in distant locations and to operate them by remote control. This allows outlying concentrators to be built.

c) The *Digital Concentrator* (DKT) uses an electronic matrix and performs similar functions for digital subscriber lines. The digital subscriber-line circuits and junctors interface the 10-bit and 8-bit transmission systems and supervise the various call conditions.

d) The *Terminal* (T) multiplexes 30 speech channels into the PCM line format and performs the analog/digital conversion. A junctor is allocated to each of the 30 channels of a PCM multiplex. According to the type of connection, the junctor functions like a cord circuit (subscriber line) or like an incoming or outgoing junctor (inter-exchange lines). Separate junctors are planned for each signalling system, so that they constitute the actual interface to the peripheral field. As they are connected to the terminals with standardized plugs, any desired combination of junctors is possible. Special junctors by-passing the coders are provided for digital signals, and enable digital concentrators to be connected *(fig. 4)*.

e) The *Register Unit* (WE) consists of 30 registers forming a time division multiplex unit. Each register is capable of receiving register pulses from the peripheral field and converting them to a standardized format, or of sending out register pulses upon instruction from central control. The registers are designed to handle pulses from all types of signalling system, including two-tone pulses from keyphones and multi-frequency code signalling used for long-distance lines.

f) The *Digital Register Unit* (DWE) also consists of 30 registers. It processes the signalling pulses from digital subscriber stations and signalling systems with a common data channel (eg CCITT No 6). Because of the expected high information flow (up to several hundred characters per second) it has direct access to central control over an interface unit.

g) The *Telegram Unit* (TE) operates 31 control channel registers by means of time division multiplex. These registers handle the exchange of control information for units outside the processor field, and in this way also monitor the data flow. In addition, they relieve the processor of routine functions, such as scanning of monitor points, detection of line-state changes, and routine

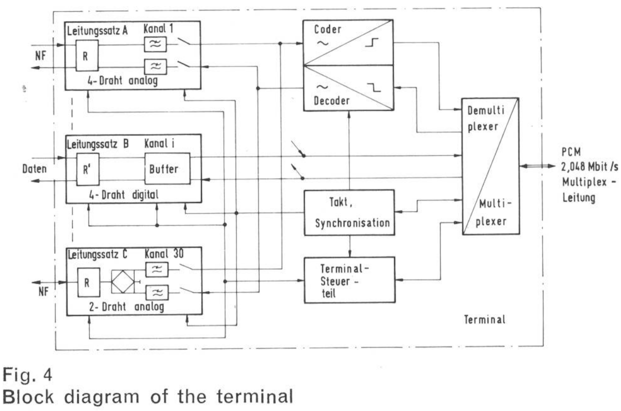

Fig. 4
Block diagram of the terminal

R Relaissatz – R Relay set
R' Elektronischer «Relais»-Satz – R' Electronic «relay» set
Leitungssatz A, B, C – Junctor A, B, C
Kanal 1, i, 30 – Channel 1, i, 30
4-Draht analog – 4-wire analog
4-Draht digital – 4-wire digital
2-Draht analog – 2-wire analog
Takt, Synchronisation – Clock, synchronization
Terminal-Steuerteil – Terminal control section
NF Niederfrequente Leitung – Voice-frequency line
Daten – Data line
PCM 2,048 Mbit/s Multiplexleitung – PCM 2.048 Mbit/s multiplex

checks of control messages exchanged within the PCM system.

h) The *Interface Unit* (AE) connects up to 16 digital register units and telegram units to the central control system and controls the information transfer between the processor and the above units. In addition, it meters the calls and generates the pulses for call-charge indicators on the subscriber's premises. The interface unit is part of the central control system and functions as an auxiliary processor.

i) The *Hasler Dataflex*® T-202 computer is being used as control processor in the development phase. This efficient real-time machine for telecommunications applications accommodates 32-bit words and has an expandable storage capacity up to 512 k lines [19].

The telegram units, digital register units and the switching network are interconnected by means of the uniform PCM multiplex interface. The interface between the control processor and the interface units is determined by the computer system used. The interface units, telegram and digital register units are interconnected over a standardized fast parallel data channel.

3 The Multi-Plane System

The network described in chapter 2 could handle the entire traffic of up to 60,000 subscribers. In view of the highly centralized switching and control functions, however, a basic safety concept has had to be worked out, meeting the stringent requirements regarding service quality and protection against total system failure [20]. These requirements are, in brief:

- To protect both the system and its users against all kinds of simple hardware and software failure. The operation of the network must not be severely impaired by transmission failures, unavoidable subscriber mistakes or logic faults originating in the system.
- Failures of entire system units must be tolerated, but a reasonable standard of service maintained at the same time. The safety requirements for system blocks must not exceed appropriately fixed, economically feasible limits.
- In case of total failure of one or several vital system blocks, it must be possible to maintain a minimum of service.

This operational safety is achieved, and total system failures avoided, by dividing a PCM network area into two or four basically independent planes. In normal operation, traffic is distributed evenly to these planes. In case of fault, it is thought preferable to have, for a short time, a limited reduction in the standard of service to many subscribers, instead of depriving few customers (eg those of a local exchange) of all communication over the same length of time.

31 The Division of the Network into Planes and Sub-Planes

Each network area is divided into one or two pairs of planes (pair 1 and 2) *(fig. 5)*. These pairs are independent from one another and can set up, supervise, meter and clear all types of call from any of the area's subscribers. Each pair of planes is again divided into two sub-planes (n/1 and n/2). The sub-plane has its own switching network, terminals, switching units, telegram units, digital register units and interface units. It is autonomous with regard to supervision, fault detection, reconfiguration, initiation and maintenance functions for all units and equipment permanently allocated to it.

By means of concentrators, each subscriber of a network area can be connected to each sub-plane. The information relating to the subscriber (call number, position number, connection class, handling characteristics, etc.) and data regarding the concentrator are contained in a store SN, which is common to both sub-planes of a pair.

The outward appearance of a pair of planes composed of four sub-planes is that of a four-level system. Normally, it must be possible to reach any destination (eg a subscriber) over each sub-plane, so that most incoming calls can be dealt with in one and the same sub-plane. Therefore, connections to concentrators and lines to conventional exchanges or large PBXs are distributed evenly over all four sub-planes.

Path search provides for a call to be set up entirely within one and the same sub-plane, unless there is no free outlet to the called group of lines in one of the multiplexes allocated to the sub-plane. In that case, overflow connections between the two sub-planes of a pair are used. In this way, a division into only two sub-groups is achieved, reducing the blocking loss for traffic from a pair of planes to the terminating groups.

Overflow connections between two sub-planes of different pairs in the same network area are admitted only as an exception, or in case of faults.

Cross connections between pairs of planes of different areas are always possible, being necessary for all trunk calls.

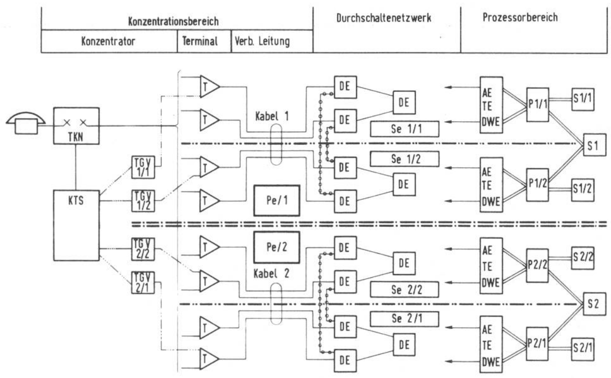

Fig. 5
Plane system concept

Konzentrationsbereich – Concentration field
Konzentrator – Concentrator
Verb(indungs)leitung – Connecting line
Durchschaltenetzwerk – Switching network
Prozessorbereich – Processor field
Pe/1, Pe/2 Paarebene 1, 2 – Pe/1, Pe/2 pair of planes 1, 2
Kabel 1, 2 – Cable 1, 2

TKN	Teilkoppelnetz – Satellite coupling network
KTS	Konzentratorsteuerung – Concentrator control
TGV	Telegrammverarbeitung – Telegram processing
T	Terminal
DE	Durchschalteeinheit – Switching unit
Se	Subebene – Sub-plane
AE	Anpassungseinheit – Interface unit
TE	Telegrammeinheit – Telegram unit
DWE	Digitale Wahleinheit – Digital register unit
P	Prozessorsystem – Processor system
Sn	Paarebenen-Datenbasis – Data base of a pair of planes
Sn/k	Individuelle Subebenen-Datenbasis – Individual sub-plane data base
—...—	Verbindungen zu Konzentrator – Connections to concentrator
—.—.—	Überlaufverbindungen (Beispiel) – Overflow connections (example)

32 *IFS-1 as Compared with the Existing Network*

Considering the structure of the present telephone system as well as operational and administrative aspects, one finds that an existing network group is comparable to an IFS-1 multilevel network area. As a rule, existing groups can be replaced by IFS-1 network areas with two or four sub-planes. Very small network groups may be combined with neighbouring groups of the same district into one network area. On the other hand, it is also possible to divide very large groups (eg Zurich) into two network areas, if necessary.

Within an IFS-1 network area, three types of exchange will be used: PCM local, PCM minor and PCM main exchange.

The *PCM local exchange* consists of concentration field units, i.e. analog and digital concentrators as well as terminals. The greater part of the existing terminal and local exchanges will be PCM local exchanges. It is also possible to replace present small terminal exchanges by satellite concentrators.

A *PCM minor exchange* is made up by adding to the PCM local exchange at least one detached switching unit per sub-plane as a satellite exchange. It will not only replace many of the existing large minor exchanges, but may also be added to the network as required for optimum handling of calls.

The *PCM main exchange* is the centre of a pair of planes. It comprises the principal parts of the switching network for both sub-planes, the processor field and supplementary equipment consisting of register units and terminals. The PCM main exchange replaces the existing main exchange of a network group. It is always permanently allocated to one pair of planes. If a network group has two pairs of planes, the two main exchanges are accommodated in separate buildings for safety reasons.

4 Organization and Functions of the Remote-Control System

Whereas the intelligence of IFS-1 is highly centralized, the various system blocks must be placed in accordance with the geographical distribution of the various functions to be performed. This requires a remote-control system that has the following features:

1) Rapid and reliable data transfer between central and peripheral units.
2) Supervision of the peripheral units and all control paths.
3) Information exchange based on a highly standardized but flexible system that is largely independent of the functions performed by the peripheral units.

41 *The Control Channel*

The 64-kbit/s data channels available throughout the PCM network are an ideal means of remote-control for all system blocks. As use is made of the possibility of integrating the control and communication networks, no additional transmission interfaces need be defined; the high data rate permits a rapid information exchange, and switchable control channels can be adopted.

Each peripheral unit has at least one control channel for each direction of transmission. Units operating to several multiplexes (concentrators, switching units) have two or more control channels. Each channel passes through at least one switching stage, where it can be switched to any channel of another multiplex (*fig. 6*). This enables the switching network to concentrate up to 31 control channels on to the multiplexes connected to the telegram units.

In addition, the following principles are employed:

1) Each telegram unit has two completely independent ways of communicating with the central processor over two different interface units.
2) If a unit has two control channels, they are linked to different multiplexes, which are themselves connected to different switches.
3) Such units continuously supervise the incoming data on both control channels, and decide themselves which one is active.
4) Adequate reserves of telegram units are provided, so that control can be maintained if a telegram unit breaks down.

These principles enable each unit having two control channels to always be reached over a new path if any single failure occurs in the network. New paths can also be found in many cases of double failure. Each unit having only one control channel may be reached over at least one new path up to the A-stage switch to which it is connected (fig. 6).

When the system is switched on, central control establishes a connection through the switching network to each peripheral unit. These paths remain semi-permanently switched, until, as a result of a fault, replacement paths must be set up.

42 *Data Transmission over the Control Channels*

The data exchanged between central control and the system blocks may be roughly divided into four categories:
- *Orders* from central control to any system unit;
- *Acknowledgement* by the controlled unit of an order received;

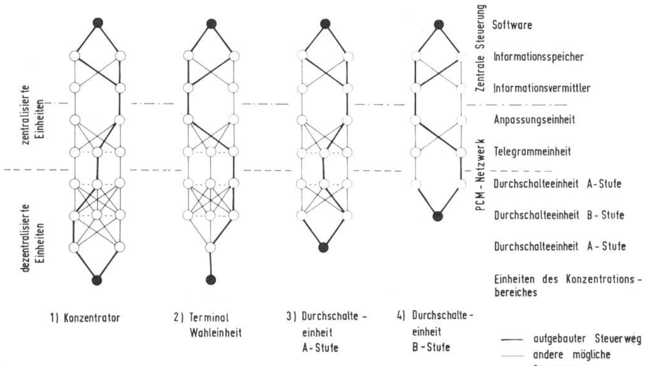

Fig. 6
Control path routing

1 Konzentrator – Concentrator
2 Terminal, Wahleinheit – Terminal, Register unit
3 Durchschalteeinheit A-Stufe – Switching unit A stage
4 Durchschalteeinheit B-Stufe – Switching unit B stage
Zentralisierte Einheiten – Centralized units
Dezentralisierte Einheiten – Distant units
Zentrale Steuerung – Central control
PCM-Netzwerk – PCM network
Informationsspeicher – Data store
Informationsvermittler – Data exchange unit
Anpassungseinheit – Interface unit
Telegrammeinheit – Telegram unit
Durchschalteeinheit A-Stufe – Switching unit A stage
Durchschalteeinheit B-Stufe – Switching unit B stage
Einheiten des Konzentrationsbereiches – Concentration field units
Aufgebauter Steuerweg – Established control path
Andere mögliche Steuerwege – Alternative control paths

- *Reports* generated as a result of external events or faults;
- *Messages* exchanged between two central control units.

This data is exchanged by means of an addressed-message or telegram system [21] divided into two levels: the central telegram system between processor and telegram unit, and the peripheral telegram system between telegram unit and remote-controlled system blocks.

The peripheral telegram system uses the following basic principles:

- *Acknowledgement principle:* the telegram unit expects a reply to every message it has transmitted.
- *Collecting principle:* a remote-controlled unit may send telegrams only in reply to an enquiry or order.
- *One-at-a-time principle:* the telegram unit does not transmit a message until the one last sent has been acknowledged. If, due to a fault, the acknowledgement is not received within a given period, the telegram unit repeats the message last sent.
- *Error checking principle:* each unit checks the correctness of telegrams received in so far as it is directly interested and capable of doing so.

By means of these basic principles a compelled message flow is achieved, with telegrams being alternately exchanged in both directions of transmission *(fig. 7)*.

A telegram consists of a heading and a data field *(fig. 8)* and is transmitted in the two-pulse mode. The heading contains a 12-bit address (label L) indicating the destination of an order or the origin of an acknowledgement or report. The serial number K distinguishes new and repeated telegrams. The modus M shows the nature of the telegram and the length of the data field. The data field carries the actual control or signalling information, its length and composition depending on the controlled unit. The data field of an order addressed to a switching unit, for example, consists of 32 bits, 20 marking the cross points to be switched (10 bits a coordinate) and 12 bits specifying the nature of the order. Such a telegram has the modus 4.

Certain telegrams, such as "collective enquiry", "no report" and "wait", carry no data field, being identified by their modus.

In the peripheral telegram system the continuous compelled message flow is achieved by each system block having to acknowledge a telegram received from the telegram unit. If the telegram unit has no order to pass on from central control to a particular controlled unit, it generates a collective enquiry to that unit, which then has to reply with a report or a no-report telegram.

In this way, the connection between the control-channel register of the telegram unit and the remote-controlled unit is continually checked, even if no significant information has to be transmitted.

43 The Supervisory Functions of the Remote-Control System

In the case of multiplexes carrying control channels, all faults not occurring on a per channel basis (eg repeater faults) will be automatically detected as a result of the compelled telegram exchange being interrupted. This enables every multiplex in the system to be supervised by allocating to it at least one control channel. In this way, a separate multiplex supervisory system can be avoided.

Each of the time-multiplexed units in the system is provided with a store for each channel of each multiplex connected to it. The contents of this store define the function to be performed; the address corresponds to the channel number.

With such stores, the network contains a complete record of its own state. This immediately raises the question of how to ensure that the store contents in the central control unit correspond to the actual state of the network. IFS-1 achieves this in the following way:

1) Central control alone is allowed to change the contents of peripheral channel stores.
2) Central control may transmit to the channel store only one order at a time, and until this is acknowledged no further order may be sent to the peripheral unit concerned.
3) The acknowledgement telegram reports the latest state of the channel store, thereby not only confirming receipt of the order, but also indicating whether it has been carried out correctly.

In this way, the computer system can check any alteration to the channel store and immediately react to a discrepancy. This simple method of compelled supervision is sufficient for terminals and register units.

If, however, the contents of a channel store change because of a fault occurring in the period between two orders, this is not revealed by the above procedure and may provoke interruptions or false connections in the switching unit. Additional protection must therefore be provided.

The three switching operations of setting up, clearing and transferring a call are involved in establishing a connection. As the third operation has been excluded from the instruction system, a call is always transferred by means of clearing and resetting. The switching unit will carry out a setting-up order only if the addressed channel store has the contents "free"; otherwise it responds by merely reporting back the contents of the store. Similarly, a clearing order will be executed only if the information added by central control corresponds with the contents of the channel store addressed. In case of a discrepancy, the switching unit again responds by merely reporting back the stored information. In this way, central control can check whether the state of the network corresponds with its own

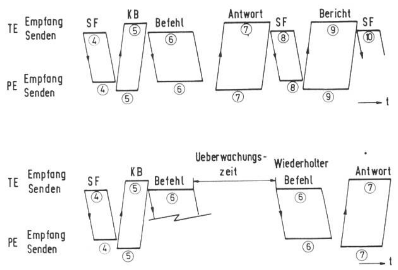

Fig. 7
Compelled telegram exchange, normal and interrupted

TE Telegrammeinheit – Telegram unit
PE Ferngesteuerte Einheit – Remote-controlled unit
SF Sammelfragetelegramm – Collective enquiry telegram
KB «Kein Bericht»-Telegramm – «No report» telegram
Befehl – Instruction
Antwort – Acknowledgement
Bericht – Report
Empfang – Reception
Senden – Transmission
Überwachungszeit – Supervision period
Wiederholter Befehl – Repeated instruction
⊗ Laufnummer der Telegramme – Serial number of telegram

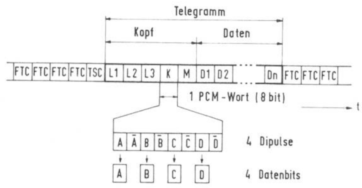

Fig. 8
Telegram format in the peripheral telegram system

Telegramm – Telegram
Kopf – Heading
Daten – Data
1 PCM-Wort (8 bit) – 1 PCM word (8 bits)
4 Dipulse – 4 double pulses
4 Datenbits – 4 data bits
L Label
K Telegrammnummer – Serial number
M Modus
D Daten – Data
FTC Frei Telegramm Code 11110000 – Free telegram code 11110000
TSC Telegramm Start Code 11001100 – Telegram start code 11001100

store contents, and detect faults in the channel stores when giving the next setting-up or clearing order.

44 Call Rejection

When faults occur anywhere in the network, it is desirable to isolate the affected units or transmission paths, i.e. to prevent them from being engaged, and to clear parts of the network of all traffic. For all units, with the exception of terminals and concentrators, this is achieved by software procedures in central control. Concentrators and terminals are only partly controlled by the central processor, so that, for instance, subscribers are not prevented from making new calls.

It is also advisable to reject calls entering the system, since several ways of access, distributed over all sub-planes, are open to each subscriber via concentrators, and to each incoming group of lines over cross-connections. In such a case, the concentrator or the outgoing exchange will divert the rejected calls to other sub-planes of the network, with each plane accepting as many calls as it can process.

The control system has been designed in such a way that calls can be rejected in all cases of operational failure *(fig. 9)*.

a) Time lag circuits T 1 and T 2 continuously monitor the telegram flow between terminal and telegram unit. Short interruptions in the flow cause all incoming lines to be

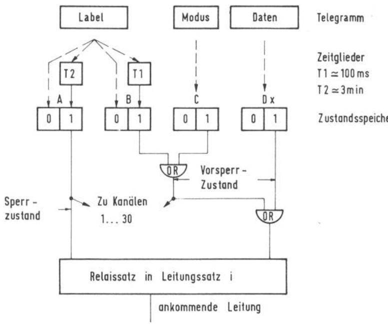

Fig. 9
System of call rejection in the terminal

Telegramm – Telegram
Daten – Data
Zeitglieder – Time-lag circuits
Zustandsspeicher – State store
Vorsperrzustand – Pre-blocking state
Sperrzustand – Blocking state
Zu Kanälen 1...30 – To channels 1...30
Relaissatz in Leitungssatz i – Relay set in junctor i
Ankommende Leitung – Incoming line

pre-blocked, and continued interruptions lead to forced releasing or blocking of all junctors. Such interruptions may occur due to faults on the transmission path between terminal and switching network, or on the control channel passing through the switching network to the telegram unit. However, the telegram unit also blocks all traffic when a supervisory circuit in central control detects total failure of that unit.

b) Each peripheral telegram carries a pre-blocking signal that forms part of the modus. This signal, too, pre-blocks all free incoming lines, unless it is suppressed by special order from central control to the telegram unit. However, suppression is only possible with the transmission path between central control and telegram unit functioning normally. By software means, pre-blocking can be individually applied to each control channel, that is each terminal, or to the telegram unit as a whole.

c) In addition, the software can pre-block or block each individual junctor by means of an appropriate order, thereby enabling faulty units to be bypassed.

When central control can no longer process traffic (system out of operation for extension or conversion purposes, or because of overload or total failure) the calls are automatically offered to sub-planes functioning normally.

5 Signalling

Three different types of information are exchanged between the units of the concentration field and the processor field:

a) Control information for remote-control of the terminals, register units and concentrators;
b) Line signals indicating the state of a call;
c) Register signals (eg dialling information).

All control information is handled by the telegram system and transmitted as orders and acknowledgements over channel 16 of the multiplex between terminal and first switching stage (see chapter 4). The junctors allocated to each channel of the terminal both control and supervise the line signals. For the information exchange between junctors and central control the same path over the telegram system is used as for the control signals. The register signal transmitters and receivers are concentrated in the register units. Between the junctors and registers the signals are exchanged over the speech channel. Between the register unit and central control the telegram system is used. All types of signal are processed by central control. *Figure 10* illustrates the various transmission paths.

The IFS-1 system must be able to work with a variety of apparatus and conventional exchanges with a wide range of different types of signalling. Planning provides for hardware standardization on a common basis of all line-associated signalling systems, so as to relieve the software of real-time consuming functions. Depending on the type of signal and call condition concerned, standardization is performed either by the junctor, together with the telegram unit, or by the register unit.

51 Line Signals

For each type of peripheral line a separate junctor is provided, whose state central control can monitor at any time by means of read-only orders. A specific line state is established by order telegram to the junctor concerned. The telegram unit recognizes changes in the state of in-

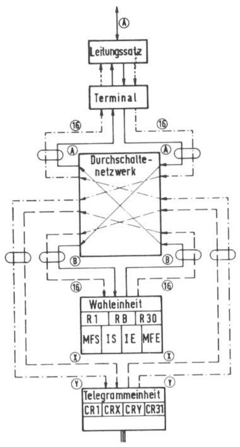

Fig. 10

Signalling paths in the IFS-1 system
Leitungssatz – Junctor
Durchschaltenetzwerk – Switching network
Wahleinheit – Register unit
R 1...R 30 Kanalassoziierte Register in der Wahleinheit – Channel-associated registers in the register unit
MFS Mehrfrequenzsignal-Sender – Multi-frequency code signalling transmitter
MFE Mehrfrequenzsignal-Empfänger – Multi-frequency code signalling receiver
IS Impulssignal-Sender – Pulse transmitter
IE Impulssignal-Empfänger – Pulse receiver
Telegrammeinheit – Telegram unit
CR 1...CR 31 Kanalassoziierte Register in der Telegrammeinheit – Channel associated registers in the telegram unit
PCM-Multiplexleitung (für jede Übertragungsrichtung gezeichnet) – PCM multiplex (shown for each direction of transmission)
Ⓧ Belegter Kanal auf der Multiplexleitung – Multiplex channel engaged
— — — Semi-permanent geschalteter Steuerweg für die Telegrammübertragung von und zur Wahleinheit – Semi-permanently switched control path for telegram transmission from and to register unit
—·— Semi-permanent geschalteter Steuerweg für die Telegrammübertragung vom und zum Terminal – Semi-permanently switched control path for telegram transmission from and to terminal
——— Sprechpfad während der Registerphase – Speech path during dialling phase
═══ Sammelschienensystem für die Ein/Ausgabe zur Anpassungseinheit – Input/output collecting bus to interface unit

coming lines by scanning all junctors periodically with a collective enquiry telegram, and by each junctor reporting back the momentary state of two scanning points. This state is compared with the one last stored in the telegram unit and passed on to central control if a change has taken place.

52 Register Signals

Register signals are always transmitted over the respective speech channels to one of the registers of a register unit. For this purpose, central control establishes a path between the junctor and a free register through the switching network during the corresponding phase of a call. The signalling traffic is thus concentrated by the switching network.

Depending on the type of signalling to be processed, central control selects one of two transmission modes. For dialling information from conventional subscriber stations, the terminal can be ordered to operate in a 7+1-bit mode to the junctor concerned. The speech path is then switched through with 7-bit coding, the 8th bit signalling the line condition. Accordingly, loop-disconnect pulses are transmitted by the 8th bit, whereas two-tone signals from push-button stations use bits 1–7. The dialling completed, the terminal is switched to normal 8-bit transmission. The 8-bit mode is also used for inter-exchange multifrequency code signalling such as MFC, R2 and CCITT No. 5.

The register analyses the dialling information and transfers it, digit by digit, to central control by means of report telegrams.

6 Establishing Connections

To illustrate the way in which IFS-1 operates in practice, the different phases in establishing a connection will now be shown in an example. It is assumed that the calling and called subscribers are connected to the same network area, and that they both have normal categories and conventional apparatus. The connection can then be established within one plane, and the stations reached over analog concentrators.

61 Call Recognition and Connection to the Register

Calling condition from subscriber TN-A is detected by periodic scanning of his line circuit, controlled by the analog concentrator. The concentrator selects a plane to which the call will be offered, by checking which planes are sending enquiry telegrams and whether these are accompanied by a pre-blocking signal. A path search within the concentrator leads to the setting-up of a path through the switching matrix to a free outlet connected to a junctor. The concentrator performs these functions without the intervention of central control, and then reports to the latter the equipment number of the subscriber line and the number of the seized junctor. In this way, one plane is ordered to handle the call, and subsequent operations involve that plane only.

The connection being switched through the concentrator, the junctor LS-A detects loop condition on the subscriber line. Since the state of each junctor is periodically scanned and reported back by means of telegrams, the telegram unit recognizes the junctor seized and informs central control. In this way, central control checks the correct switching by the analog concentrator.

Register connection involves the search for a free register R-C in a register unit, a path search, and the establishment of a link between terminal T-A and register R-C. Before dial tone is sent out by the register, the switched path is tested by means of a continuity check *(fig. 11)*. This check is a useful means of supervising the switching operations involved in establishing a connection. It is made by looping the 4-wire path at a reflection point and comparing the received code sequence with that transmitted. Checking is performed by either the register unit or the digital register unit. The reflection point may be in the switching unit (a channel is switched to its own address by setting a half-connection), in the terminal (when a channel is in the "free" state, the digital side is automatically looped) or in the digital concentrator.

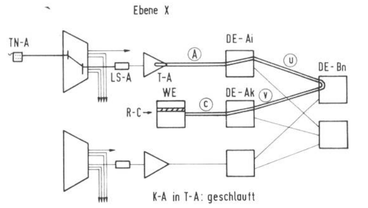

Fig. 11
Paths switched for 1st continuity check

Ebene X – Plane X
TN-A Teilnehmer A – Subscriber A
LS-A Leitungssatz A – Junctor A
T-A Terminal A
DE-Ai Durchschalteeinheit Ai – Switching unit Ai
DE-Bn Durchschalteeinheit Bn – Switching unit Bn
DE-Ak Durchschalteeinheit Ak – Switching unit Ak
R-C Register C
⊗ Nummer des belegten Zeitschlitzes – Number of time slot engaged
K(anal) A in T(erminal) A geschlauft – Channel A looped in terminal A

The check consists of a short-duration loop test over the entire connection, and shows whether:

- The transmission paths employed are operating correctly;
- The system units engaged have responded correctly to the instructions received;
- All the speech stores of the switching units through which the connection passes are operating normally.

The register performs the continuity check in response to an order from central control and reports back the result after a short time (eg 10 ms). If it is negative, all units involved in the connection are released, the fault localization programme is updated with the corresponding information, and a new path search to a different register unit is initiated. If the check is positive, central control disconnects the loop by switching the channel through T-A, thereby changing the state of junctor LS-A from "free" to "in-band". The speech path is now switched through with 7-bit coding, the 8th bit carrying the condition of the subscriber loop. Register R-C reports a discontinuity and sends out dial tone *(fig. 12)*.

62 Dial Phase

As soon as the register is connected, it supervises the subscriber line by checking the 8th bit, and in this way detects any premature release. If the subscriber uses a conventional dial, the loop-disconnect pulses are signalled by the 8th bit, whereas with push-button dialling, the multi-frequency signals are transmitted by bits 1–7. As the register discriminates between these two types of signalling, dial and push-button instruments may be connected to the same line.

The register analyses the dialled information and transfers it, digit by digit to central control by means of reports.

63 Continuity Check After Identification of the Call Destination

When central control has received a number of digits, it is able to identify the call destination within its network. This destination consists of a channel (K–B) of a multiplex connected to a specific switching unit. Before the connection is switched through, the remaining section must be checked. Since the path from the calling side has already been tested up to the switching unit DE-Ai, the second check is restricted to the path between this switch and a second loop point. It involves the following operations:

- When the destination channel K-B has been identified, a path between it and DE-Ai is searched for and switched through. This constitutes a section of the speech path to be set up.
- Another free register (R-D) is selected and connected to DE-Ai over a second path.
- The test loop is then established by means of instructions to DE-Ai, which connects the register path to the second half of the speech path.
- The continuity check is made *(fig. 13)*.

In general, this connection passes over five switches and six multiplexes when a three-stage switching network is involved. However, in some cases it may pass over fewer switches.

64 Through-Connection and Ringing

Having received the complete dialling information, central control identifies the called subscriber, his equipment number and the number of the concentrator to which he is connected. It instructs the concentrator to establish a connection from the called subscriber to a free junctor attached to the plane processing the call. If the subscriber is engaged, the concentrator notifies central control, which orders LS-A to send out busy tone. If the called subscriber is not engaged, the concentrator looks for a free junctor, performs the switching in its matrix and reports the number of the engaged junctor LS-B to central control. LS-B, too, having reported its seizure, central control is satisfied that the operation has been carried out correctly.

The continuity check, as described in section 6.3, is now made of the second half of the connection.

The continuity check completed, central control instructs LS-B to switch on ringing and ringing tone. The subscriber channels in T-A and T-B having changed to "busy" state, i.e. 8-bit coding, a transparent link is established to the switching network. Finally, the calling and called subscribers are interconnected in DE-Ai.

Registers R-C and R-D, as well as their connections to DE-Ai, can now be released.

From this moment, both subscribers are monitored by junctors LS-A and LS-B. If the calling station rings off, the entire connection is released; if the called party answers, LS-B disconnects ringing and sends back a report. The subscribers may now speak *(fig. 14)*.

7 Final Remarks

Fully integrated PCM networks enable all current types of switched information, such as speech, data, facsimile, telex, etc., to be handled by a uniform communication system.

As the basic concept of IFS-1 differs substantially from present switching plant in this country, the main question

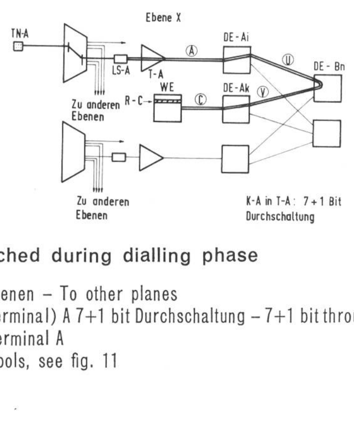

Fig. 12
Paths switched during dialling phase

Zu anderen Ebenen – To other planes
K(anal) A in T(erminal) A 7+1 bit Durchschaltung – 7+1 bit through-connection of channel A in terminal A
For other symbols, see fig. 11

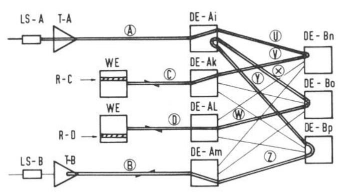

Fig. 13
Paths switched for 2nd continuity check during dialling phase

LS-A	Leitungssatz A – Junctor A
T-A	Terminal A
DE-Ai...Am	Durchschalteeinheiten Ai...Am – Switching units Ai...Am
DE-Bn...Bp	Durchschalteeinheiten Bn...Bp – Switching units Bn...Bp
WE	Wahleinheit – Register unit
R-C	Register C
R-D	Register D
LS-B	Leitungssatz B – Junctor B
T-B	Terminal B
Ⓐ	Nummer des belegten Zeitschlitzes – Number of time slot engaged

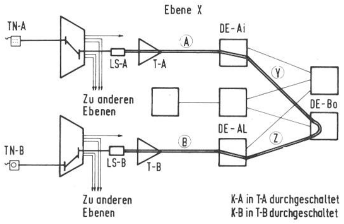

Fig. 14
Paths switched during conversation phase

Ebene X – Plane X
Zu anderen Ebenen – To other planes
O Nummer des belegten Kanals – Number of channel engaged
K(anal) A in T(erminal) A durchgeschaltet – Channel A connected in terminal A
K(anal) B in T(erminal) B durchgeschaltet – Channel B connected in terminal B
For other symbols, see fig. 11

was whether the new system could be integrated at all into the existing network. The studies conducted so far have shown that this is technically feasible [22]. It neither involves alterations to conventional exchanges, nor is it necessary to first introduce the new system in the group main exchanges, although this may offer some advantages.

Special consideration has been given to the following aspects of the system design:

- Compatibility with existing types of exchange, i.e. interconnection without alterations to conventional plant.
- Definition of functions and interfaces in such a way that they are not directly dependent on technology. This means, for example, that system blocks can be exchanged for units built to a new technique, or that the network can be expanded in stages of different technological generations, without any change to existing plant.
- Simplified maintenance by extensive standardization of units.

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