

Control and Supervision System for Railway Traffic

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Ericsson has developed and marketed centralized control and supervision systems for railways since the middle of the 1930s. The latest system, JZA 715, is a standardized system intended for Railway Administrations with varying requirements and rules. A modular program structure enables the system to be adapted for networks with different ambition levels and different geographical conditions.

The author gives a brief history of the need for and development of control and supervision systems, and describes the function and structure of the new system.

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The advantages of controlling wide-spread railway networks from one and the same place were realized quite early on. Such centralized control meant better utilization of resources, not only personnel and rolling stock but above all the capital-demanding ground structure, track network and other fixed installations. History shows several early examples of how one or two tracks in four-track railway lines could be closed down when centralized control of the railway traffic was introduced. The traffic capacity was maintained or even increased, and at the same time the cost of track maintenance was reduced considerably. It has also been possible, more recently, to avoid expensive building out of single-track lines to double track lines because of the increased capacity provided by centralized control. On lines with increasingly intensive



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traffic it has often been possible to manage the greater load without having to engage more staff.

At first the centralization consisted of control of switches and signals over individual lines. The foundation had thereby been laid for CTC (Centralized Traffic Control), which is a form of operation with its special rules and regulations, and not synonymous with remote control. A big step forward was taken when the first real remote control and supervision system was installed on New York Central Railroad in 1927. The route Stanley–Berwick in the state of Ohio, with 32 switches and 102 signals, was controlled via one single pair of wires.

Development by Ericsson

Ericsson developed its first control and supervision system in the 1930s. The system, which operated at a transmission speed of 10 bauds, used step-by-step selectors. It was put into operation in 1938 on the Stockholm-Saltsjön Railway, a route of 16 km, and comprised seven substation equipments.

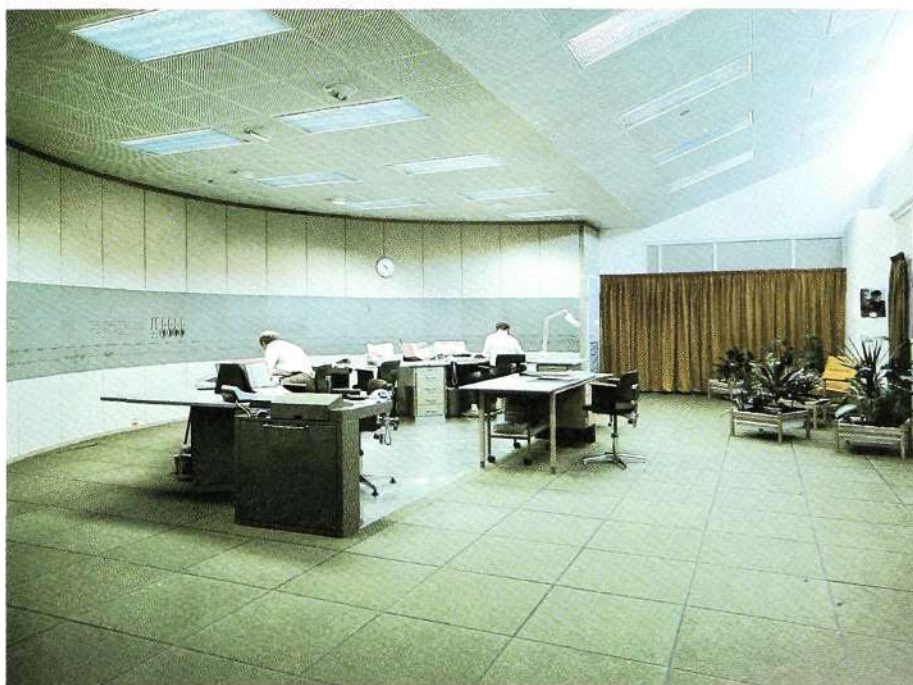


Fig. 1
Right from the start the Swedish State Railways planned centres for large geographical areas. The picture shows the CTC centre in Gothenburg



Fig. 2
To the right a key-set for controlling train traffic and to the left sets for different telephone systems

At the beginning of the 1950s the CTC systems with relays were developed which were to dominate the Ericsson production for two decades. These relay systems were the fastest in the market, since they operated at 25 bauds, and only the changes in the sensed states were transmitted.

Ericsson introduced key-set control already at this early stage. At all CTC centres control had previously been given by means of individual function buttons or switches mounted on an indication panel, which restricted the size of the controlled area. With the new system the operator could control the traffic while sitting back from the panel, thus getting a good view of a much larger area. The Swedish State Railways accepted key-set control at an early stage, and could therefore right from the start plan centres which covered large geographical areas, figs. 1 and 2.

Several electronic systems were designed during the 1960s. The first were experimental systems using germanium technology. These were followed by various systems containing discrete components in silicon technology, with an information transmission speed of 1000 bauds.

Modern systems

The now well-established system family JZA 700 was developed in 1970, when integrated circuit technology had been stabilized. The JZA 700 family consists of a number of printed board assemblies, each of which has a standardized interface towards the JZA 700 bus. These assemblies can be combined in different ways to give several system variants for different capacities and sizes, without any new design work being required. This means, for example, that there is no need to install unused physical capacity. The system contains many interesting technical designs, for example the JZA 700 bus, which without

strapping or other programming determines the number of transmitted or received words merely through the number of assemblies inserted in the shelf.

The railway application, unlike normal data transmission with star-shaped networks, means that

- many terminals are placed in series along the railway lines
- there is often a shortage of wires in the cables
- the cables are often of poor quality and heavily loaded, which gives a low upper frequency limit (<2.7 kHz)
- the cable routes often suffer interference caused by longitudinal voltages induced as a result of the traction current.

An optimum design requires that the same number of wire pairs is used along the whole length of the route, and that the number is as low as possible. JZA 700 is designed for half duplex operation, with regeneration of the transmitted signal in each terminal, fig. 3. In addition the two line sides are galvanically separated and floating relative earth, which automatically gives great immunity against induced voltages.

Right from the start JZA 700 was designed with the control and transmission system integrated to form a common control and supervision system, which made the system very economical. It has been sold to many countries and is also manufactured by Ericsson subsidiaries in Australia and Italy.

Introduction of computers

During the late 1950s and early 1960s Ericsson worked on ways of simplifying the work of the operators and thus making even more efficient use of the control centres, i.e. heavier traffic, control of larger areas etc. Auxiliary systems based on relays were developed, such as train identification, train describer and destination tagging systems. The

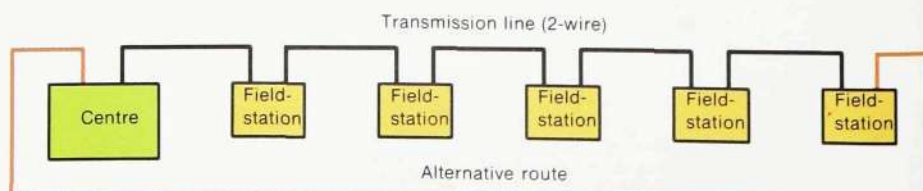


Fig. 3
Alternative circuits between a CTC centre and substations

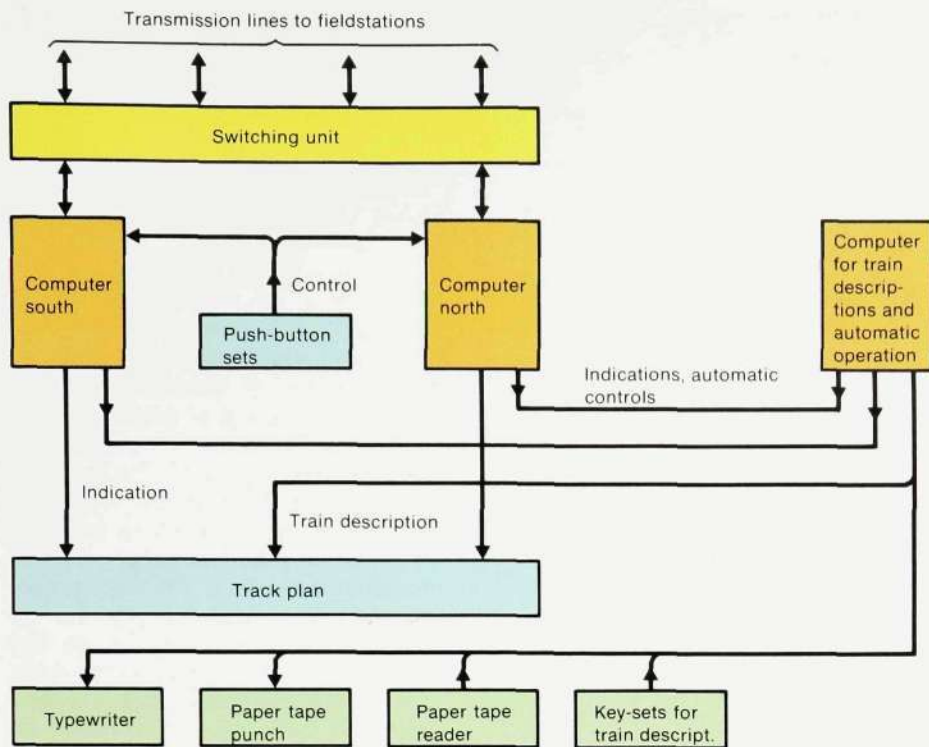
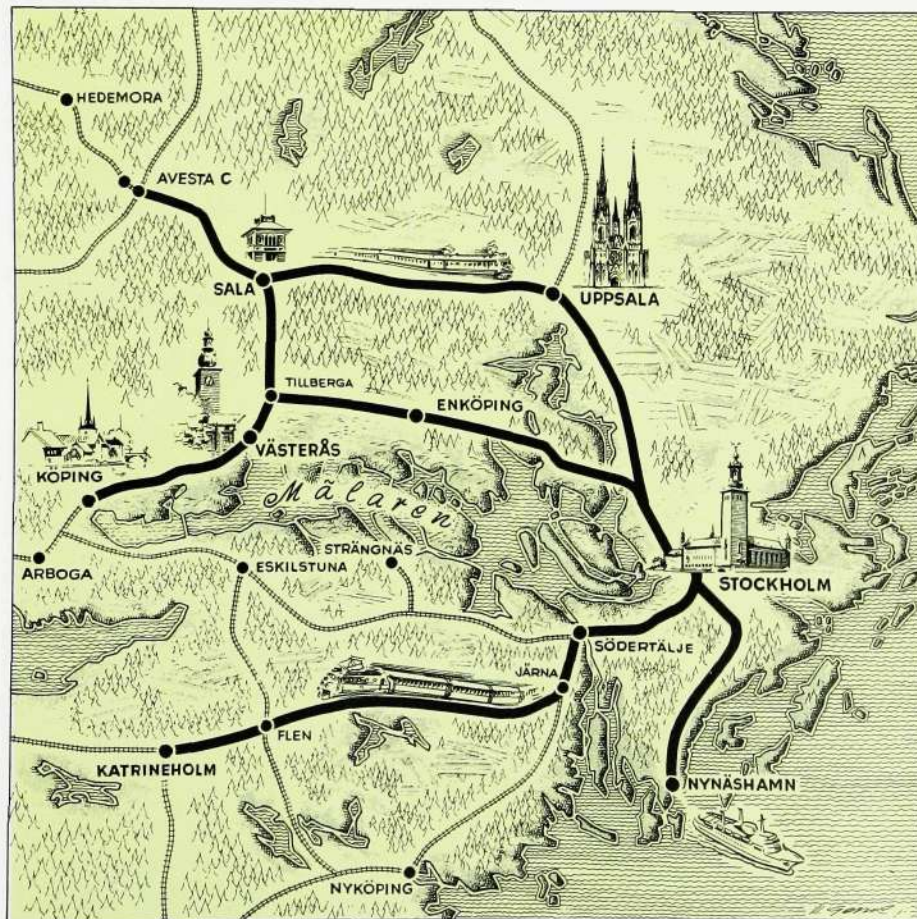


Fig. 4
Hardware configuration for the UAC 1605 systems

last system, for example, gave the different trains a destination tag, after which the control system guided the trains to the correct destinations by setting up appropriate routes at the correct moments. This system was developed in close collaboration with the Danish State Railways.

Fig. 5
The remotely controlled interlocking system in Stockholm was one of the first computer-controlled systems in the world

These types of systems tended to become increasingly voluminous. At the same time computer technology was



becoming more practically applicable with the development of silicon components. There were as yet no usable mini-computers on the market, and Ericsson therefore developed its computer UAC 1605. It was intended particularly for traffic control and used parts from the Ericsson AKE systems.

During the latter part of the 1960s and the beginning of the 1970s a program system was developed for UAC 1605 having the following functions:

- transmission to approximately 100 terminals (substations) over four transmission lines, control and indication function with a key-set and panel (JZA 410/411)
- transfer, manual input, automatic input, remote input, search, display and remote display of train descriptions (JZF 20/21)
- automatic setting up of train routes, timetable comparison and platform sign control based on a timetable, using a traffic plan, time schedule and sign plan, which can be entered up to a year in advance (JZK 20/21).

Two computers are used for the first group of functions above, and a third computer is used for the other groups, fig. 4. The first two computers each serve one half of the geographical area. In case of a fault in one computer the other will automatically take over the whole area. The third computer contains only auxiliary functions and there is no standby. If a fault occurs the operation is taken over by the operators, who control the traffic manually and without train descriptions. Such computer systems were installed in two centres, one for controlling all train traffic in the Stockholm area, fig. 5, and one for controlling the local traffic on the S-railway in Copenhagen, Denmark. The Stockholm centre was one of the first computer-controlled systems in the world. The Copenhagen centre is one of the most advanced, with fully automatic operation. The traffic statistics from that centre are very good, with less than 3% of the trains delayed by more than two minutes.

In addition to the actual control systems Ericsson has also developed application aids in the form of systems for generating installation data and traffic plans.

Present-day systems

Prerequisites

A railway system has to meet certain traffic requirements, fig. 6.

The purpose of the control and supervision system is to help regulate the railway traffic so that the traffic requirements are met.

The railway traffic process includes the interlocking process. For safety and technical reasons the interlocking limits the traffic flow over and above the limitations set by the track network, rolling stock and regulations. For optimum traffic control it must be possible to predict the restrictive effect of the interlocking process. Access to information regarding the conditions for the interlocking process is therefore a prerequisite for such prediction, fig. 7.

As regards the function of JZA 715, the system can be considered as consisting of two main parts:

- the basic function, which controls the subordinate interlockings
- superior functions, which supervise and control the traffic process, and which therefore reduce the operators' work load considerably.

The earlier computer systems were controlled by means of tables in order to adapt them towards the actual track layouts of different railways, but extensive individual programming was still required for each Administration. Dif-

ferences in traffic rules and other requirements meant considerable work, even if certain parts of previously prepared programs could be used. Hence, when the systems were to be modified for use with more modern computers it was decided to design a new program system which would be suitable for any Administration. Thus the new system also had to be table-controlled for adjustment to different traffic rules and other individual requirements. Additional programming should only be necessary for very special individual requirements.

The system should also have a modular structure, so that demands for different ambition levels could be met by building up a system using only the required standard function units, plus any specially developed units. Moreover, the interfacing towards different types of safety equipment by means of individually constructed relay sets in the substation equipments was to be replaced by table-controlled software in the central unit.

Discussions held with different Administrations and comparative field tests have shown that conventional panels can with advantage be replaced by colour visual display units, CVDUs, as long as these are used in an appropriate way.

JZA 715 includes two types of CVDUs for:

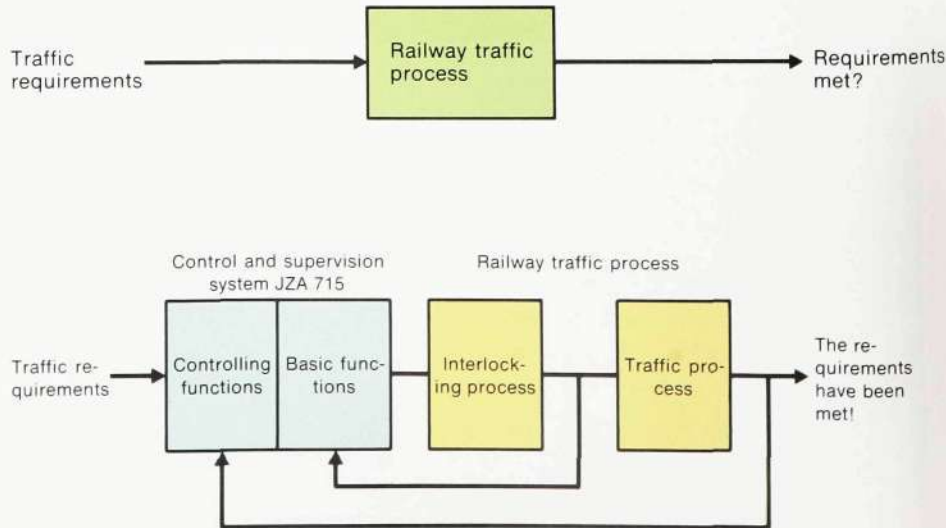
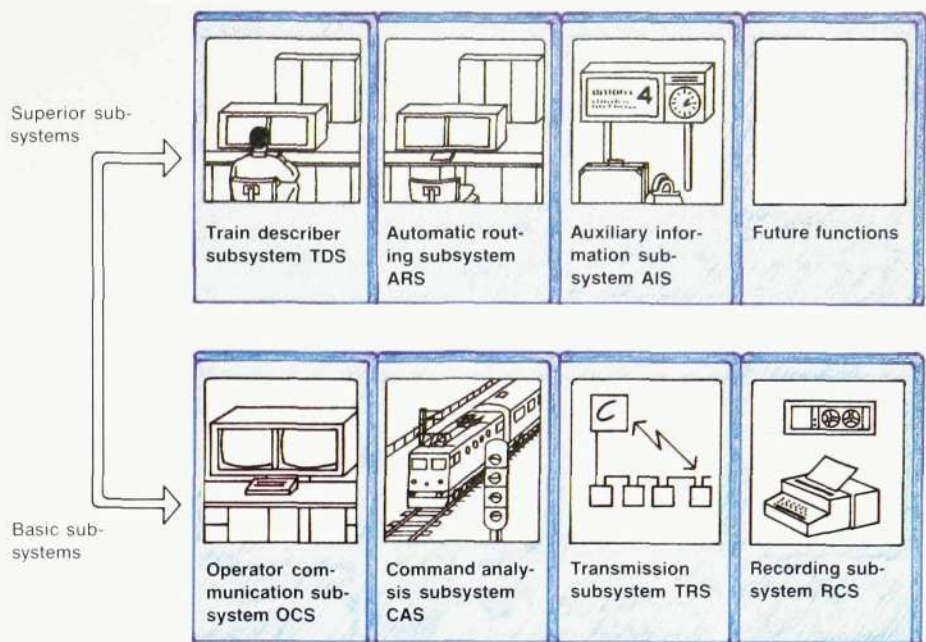


Fig. 6
A Railway system has to meet the traffic requirements

Fig. 7
JZA 715 consists of two main functional parts, which together regulate the traffic so that the requirements are met

Fig. 10
Subsystems in JZA 715



- Overview display, which gives an overall picture of the traffic situation, with little signalling information. It shows mainly the track layout and train positions, fig. 8.
- Detail or area display, which gives a more detailed information, showing signalling as well as traffic information, fig. 9.

The CVDUs can also give other types of information, such as alarm lists and route plans. When necessary the operator can be provided with a larger number of displays, fig. 15.

The controls are usually given from a keyboard similar to that of a typewriter. From this, each command is fed in in the form of a three-digit mnemonic code, followed by the number of the object. By means of an auxiliary function the most common commands can also be issued from a panel containing individual key-sets for the objects and for certain commands.

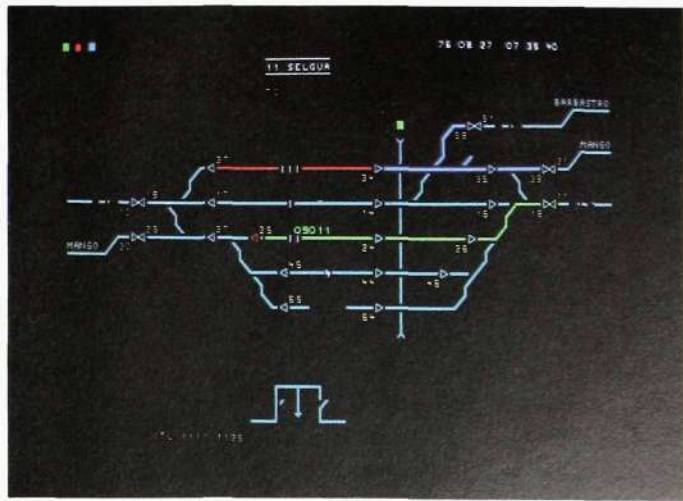
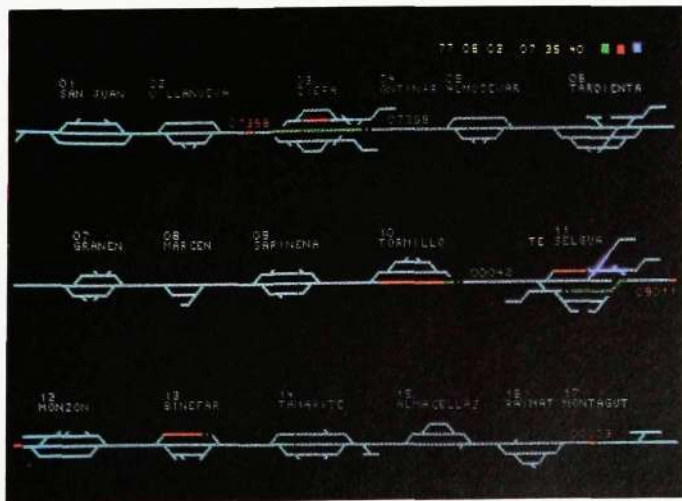
Basic functions

The basic functions are provided by

- four subsystems which together form the actual control system, fig. 10:
- Operator communication subsystem (OCS), which handles the man-machine communication, i.e. all manual input of commands and all display of information to the operators.
- Control and indication analysis subsystem (CAS), which analyses outgoing commands and incoming indications. It includes static and dynamic checking of the feasibility of the commands, a breakdown of the commands and logic conversion of the incoming "raw" indications into such a form that it can be displayed.
- Transmission subsystem (TRS), which handles the transmission of messages to and from the interlockings and provides the interface towards them. This subsystem, together with CAS, provides the necessary logic matching towards the different types of interlocking systems that are encountered.
- Recording subsystem (RCS), which records occurrences in the controlled process that concern the traffic and also the maintenance. The sub-

Fig. 8
Key display—the railway traffic in general (left)

Fig. 9
Sub-area display—detailed information for the operator



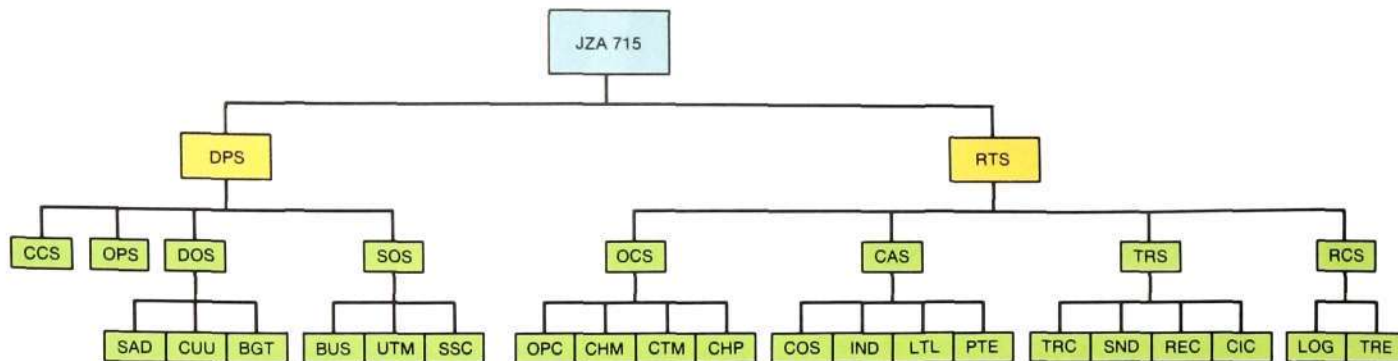


Fig. 11
The structure of JZA 715, the basic version

system also prints reports of pre-selected types of occurrences during a specified period of time.

In addition to the operational functions (RTS) there are a number of functions that are necessary for operating the system itself. These are provided by subsystems in the data processing system (DPS), fig. 11:

- Computer subsystem (CCS), which consists of the necessary hardware.
- Operating subsystem (OPS), which consists of the standardized software associated with CCS.
- Dual operation subsystem (DOS), which consists of a specially developed standby system with a continuously updated standby computer.
- System operation subsystem (SOS), which consists of a specially developed communication system, for communication between programs within a system as well as between systems that control different geographical areas.

All the basic functions described above are included in the basic version of JZA 715, which can handle all ordinary control and supervisory functions for the controlled interlockings, regardless of type. This applies both when JZA 715 is used as the control system for a large, local computer-controlled or conventional interlocking, and when it works as the centre in a remotely controlled area with many subordinate interlockings, or both, fig. 12.

JZA 715 can also be used as a modern centre in an older, remote control system. The new centre need not necessarily be situated in the same place as the old one.

Controlling functions

The basic functions can be supplemented by several functions provided by superior subsystems, namely:

- Train describer subsystem (TDS), which provides central input, transfer and display of the descriptions of the supervised trains, and the possibility of remote input and remote indication of train descriptions, fig. 13. The last two facilities, which are usually used for communication to and from manually controlled border station fringe boxes, present the train descriptions to the operators just as if they were coming from a local system. TDS also includes facilities for tracing a certain train, listing all trains and automatic input of train descriptions.
- Automatic train routing subsystem (ARS), which makes possible automatic setting of train routes on the basis of train descriptions and the time table, and with the possibility of taking into consideration different conditions such as the location of other train movements. The system also includes a simpler, programmable automatic function intended primarily for installations that lack train descriptions.
- Auxiliary information subsystem (AIS),

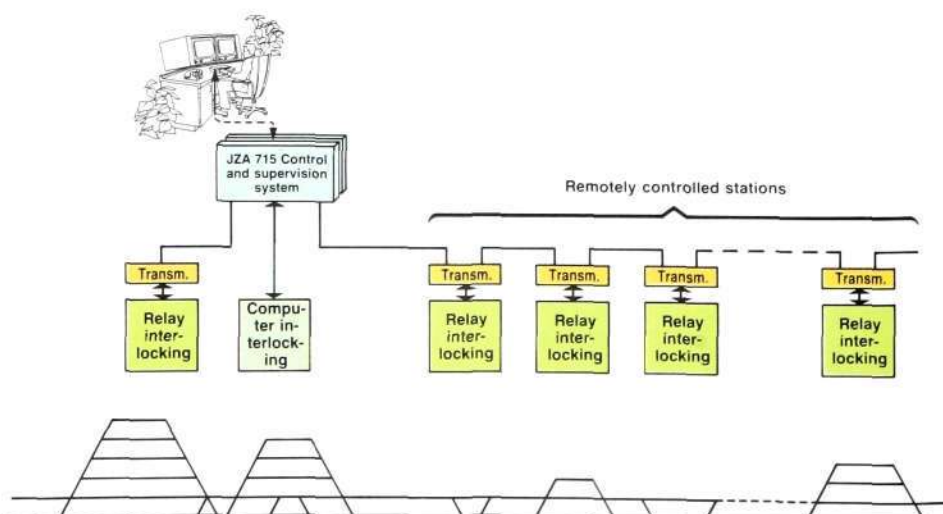
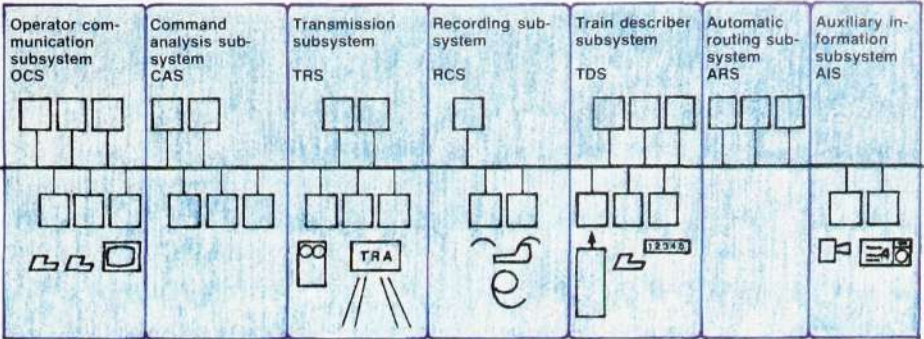


Fig. 14
Bus-oriented program system



which provides automatic control of platform signs on the basis of train descriptions, automatic timetable checks when trains pass by, with reporting of any deviations, and display of selected timetable information. The control of platform signs, for example, means that the system automatically provides correct information to connected local systems for platform displays, regardless of any delays or changes in the order of trains. Simple sign systems can be controlled directly. AIS also gives an automatic blanking signal when the train in question has left the platform.

Most of the controlling functions are based on the train running plan (timetable). Temporary alterations may have to be made in the case of severe traffic disturbances. Such alterations are made with the aid of an editing function (DTG). The alterations are automatically erased when they have been used.

Realization

All functions are realized in subsystems which consist of a number of function blocks. These in their turn consist of a number of programs. (Of course, an installation need not be equipped with

blocks that are not used.) The blocks in the system communicate with each other via the program data bus (BUS), a function in SOS, fig. 14. This communication system means that new blocks can easily get access to the process information that passes through the system.

The geographical aspects and interlocking characteristics of the controlled area, as well as the current states and characteristics of the objects in the area, have been compiled to form a common data base, "the geographical field", which is used for several functions. Yard objects and interlocking characteristics are represented in this field by different modules, which are geographically connected to each other on the basis of the track configuration. The system contains some twenty different types of modules, fig. 16. Areas with interlocking systems which are not in accordance with the geographical interlocking method are also represented in this way in JZA 715. Inconsistencies in existing interlockings have sometimes been discovered during the site adaptation of JZA 715, thanks to this stringent representation method!



Fig. 15
A control position with four colour video displays and one black and white display for information in the form of text

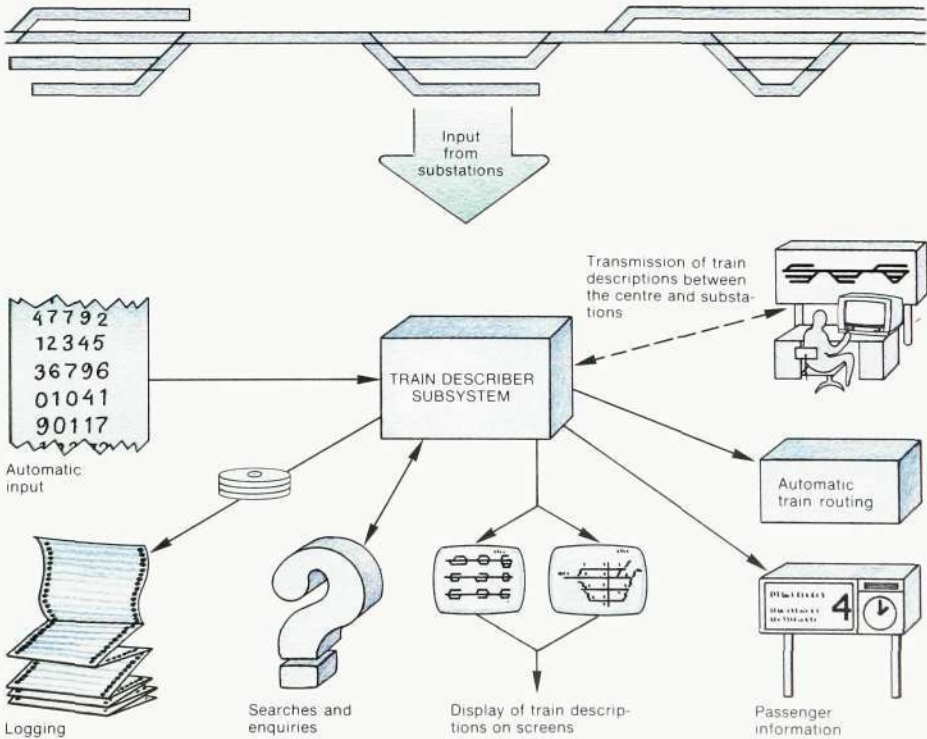
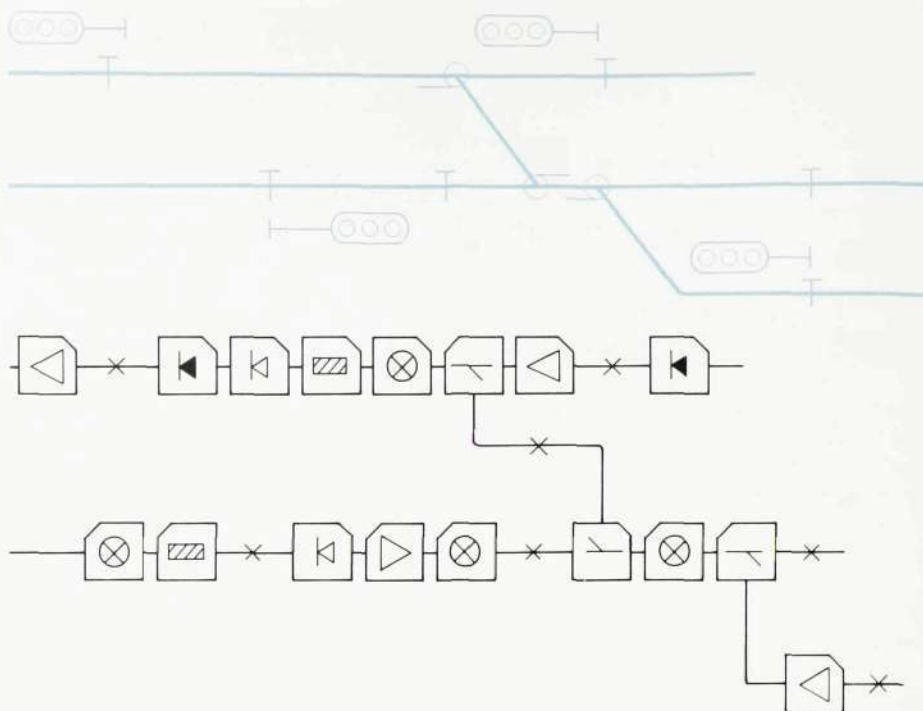


Fig. 13
Train describer subsystem, TDS

Fig. 16
The geographical features and interlocking characteristics of the controlled area are represented within JZA 715 by the geographical field



Project planning

A special data generating system has been developed which simplifies considerably the project planning of systems, fig. 17. The generating system produces the majority of the necessary individual system data, which includes the display pictures and geographical field. The installation testing is also simplified, since many errors in the input data are detected during the automatic checks carried out during the project planning stage.

A special train plan generating system has also been developed for generating train plans (route plans, time plans, sign plans) for the superior subsystems. It is intended both for new installations and for modifications. The Administrations themselves will also be able to use it, for example in connection with a change of timetable. The basic information used for new installations consists of the Administration's normal basic data for the preparation of timetables. It is fed in, either manually or automatically from the Administration's ADP system, and is then supplemented by additional information, which is entered interactively.

which have not yet reached the system's own area

- transmission of temporary timetables for special trains.

The systems may also need to act as a digital information collector and provide other controlling systems, such as a locomotive dispatching system, goods waggon administration system, timetable system and statistics system, with the real-time information concerning the traffic process that the control and supervision system already contains.

The control and supervision centres are usually placed at large railway junctions. Each JZA 715 system contains a geographical representation of the track network, with the correct distances and all other information concerning the traffic in the area supervised from the junction. It seems natural that in future the centres will be connected together and form a decentralized system. This would avoid the vulnerability of central controlling supersystems. In the case of a fault at a junction, whether it is in the equipment or in the track, the railway traffic itself could find alternative routes.

Development tendencies for the control and supervision systems

Present-day JZA 715 systems are already equipped with functions that enable adjacent installations to exchange certain information about train descriptions, delays etc. concerning the trains that pass the boundary. It is expected that in future this information will need to be extended, for example by

- enquiries regarding delayed trains

The linkage envisaged above could in the future depending on the amount of information and processing required, be arranged either directly between different JZA 715 systems or indirectly, by means of a decentralized superior system, such as an information system. Whichever the alternative it is likely to need a data network for communication. Such data networks could either be public or exclusive to the Railway

Fig. 17
Project planning aid, GEN 715

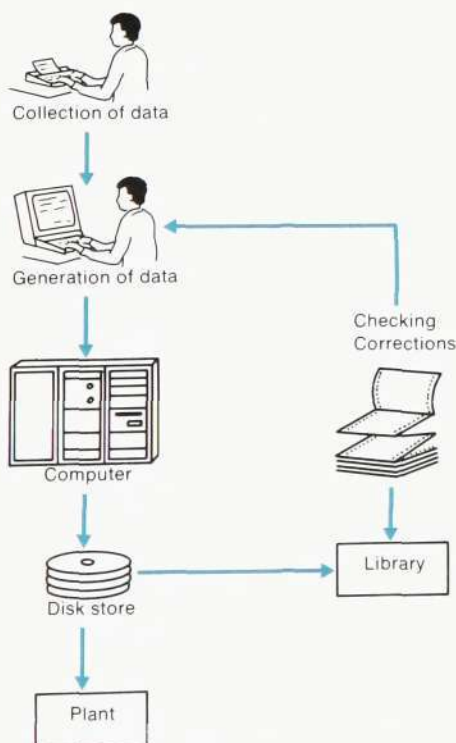


Table 1
Computer-controlled CTC centres, in operation or on order

Place	Put in operation	Number of objects	Computers, number, type	System type
Stockholm, Sweden	1971	2350	3×UAC 1605	JZA 410
Copenhagen, Denmark	1972	1450	3×UAC 1605	JZA 411
Gothenburg, Sweden	1978	560	2×PDP 11/05	JZM 750
Oslo S, Norway	1979	1200	2×PDP 11/34	JZA 715
Arlöv, (Malmö), Sweden	1981	397	2×PDP 11/34	JZM 750
Melbourne, Australia	1982	2950	4×PDP 11/70	JZA 715
Doboj, Yugoslavia		1000	2×PDP 11/44	JZA 715
Olskroken, (Göteborg), Sweden		1200	2×PDP 11/44	JZA 715
Broadmedows, Australia		1250	2×PDP 11/70	JZA 715
Barcelona, Spain		400	2×PDP 11/34	JZA 715
Oslo F, Norway		1000	2×PDP 11/44	JZA 715

The junctions may then be equipped with different algorithms for optimizing the resources, such as:

- optimizing and allocating the transport route
- reorganizing the traffic during work on the track, derailments and other disturbances.

The energy crisis is likely to lead to more intensive railway traffic, which will mean greater demands on the operators to make correct decisions very quickly. In order to prevent the work load from becoming impossible to master, the control centres must in future be provided with auxiliary functions, for example:

- passing and by-passing optimization algorithms, which gives the operator the necessary data to show the consequences of shifting the passing of trains to alternative stations. The operator then chooses one of the alternatives by making temporary changes in the train running plan.
- optimization of the choice of track, which provides the operator with an alternative track arrangement in the case of disturbances. The operator can then carry out the alternative plan by changing the destination labelling of the train plans concerned.

Functions can also be added which enable these traffic changes to be carried out automatically as soon as the operator has chosen an alternative.

Summary

Centralized control gives better utilization of resources, as regards personnel as well as other resources. It is therefore possible to increase the capacity considerably, with only the limited investment for a control and supervisory system. Large centres with heavy traffic can be regulated with the aid of controlling functions to ensure a reasonably uniform traffic intensity. System JZA 715 contains a whole range of functions for controlling railway traffic. Such functions have previously only been available in separate systems, which have often been manufactured by different manufacturers and realized in older technology.

Up to now Ericsson has delivered equipment for 64 control and supervision centres for 1459 substations along 10 419 track kilometres. Fig. 18 shows the parts of the railway network in Scandinavia that are equipped with centralized train control. Table 1 shows the computer-controlled centres which have been supplied by or ordered from Ericsson.

Fig. 18
The extent of centralized train control in Scandinavia



References

1. Westcott, L. H.: *Begin CTC*. TRAINS, September 1947.
2. Boberg, I.: *Ericsson's CTC Successful*. Ericsson Rev. 37 (1960):3, pp. 84–91.
3. Berg von Linde, O.: *Computers can now perform vital safety functions safely*. Railway Gazette International, November 1979.
4. Andersson, H. S.: *Railway Signalling Systems*. Ericsson Rev. 57 (1980):4, pp. 118–123.
5. Sjöberg, A.: *Automatic Train Control*. Ericsson Rev. 58 (1981):1, pp. 22–29.
6. Andersson, H. S. and Hagelin, G.: *Computer Controlled Interlocking System*. Ericsson Rev. 58 (1981):2, pp. 74–80.