Microcomputer Controlled Interlocking System

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The Danish company, Dansk Signal Industri A/S, a member of the Ericsson Group, has developed a microcomputer controlled interlocking system. The system was developed in collaboration with the Danish State Railways (DSB), and the first system is now in operation on the Vejle–Holstebro line in Jutland. The authors outline the circumstances that have made it possible to use microcomputers in interlocking systems and describe the structure and functions of the system. They also describe briefly how it is possible to plan and test the system using a general purpose computer.

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Interlocking systems are used on railways to ensure the safety of train movements. The primary aim is to prevent collisions and derailments. Another purpose of the signalling systems, of which the interlocking system forms part, is to ensure the traffic flow in accordance with the timetable and to permit easy operation at the lowest overall cost.

For more than 40 years safety relays have been the predominant component in railway fail-safe systems. Many attempts have been made to replace the clumsy and expensive safety relay with electronic components, but the cost has previously been too high. The increasing use of microcomputers has led to a drastic price reduction as a result of mass production. This has made the introduction of solid state technology into railway signalling attractive.

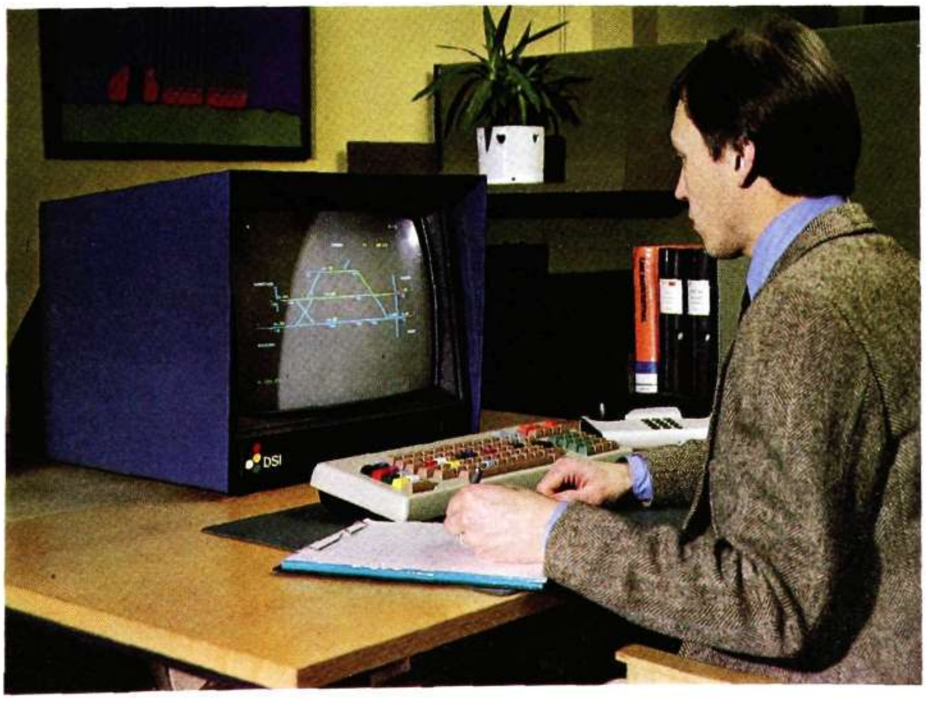

Fig. 1
Local control of a station with the aid of a colour VDU and an alphanumeric keyboard

Dansk Signal Industri A/S has developed a microcomputer controlled interlocking system, which was first commissioned in December 1980. Today the system is in operation at 14 stations in Denmark ranging from 20 devices (signals, point machines etc.) to more than 170 per station.

Development of the new interlocking system began in 1976, initiated by the need to modernize signalling on the line between Vejle and Holstebro in Jutland, so as to obtain reliable track circuit detection from a new generation of lightweight trains introduced by the Danish State Railways.

The interlocking function is computer controlled and relays are only used to interface the track devices. The computer processes the interlocking functions by means of two program systems which are independent of each other. The devices communicate continuously with the interlocking computer via concentrator computers common to several devices.

With the microcomputer interlocking, most of the wired logic specific to one installation is replaced by stored data. As manual preparation of these data would be as cumbersome as the planning and implementation of traditional installations, an off-line support program has been developed. It is run on a general purpose computer to produce the engineering and interlocking data needed. The resulting outputs is data ready for direct loading into the computers of the interlocking installations, with printouts to be read as signal and route control tables.

The dispatcher's control of the interlocking system at each station is carried out either locally or remotely (CTC) through microcomputerized interfaces. The equipment for local control consists of a colour video display unit (VDU) showing the track diagram with an indication of the actual status of all track devices, including track circuit occupancy and route setting. Provision has been made, especially at small stations, for the alternative use of a local control panel with keys and lamps.

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System JZSD 770

Interlocking system JZSD 770 consists of a number of subsystems, fig. 3:

- A subsystem for local control consisting of the VDU with keyboard and a computer CAPP
- A subsystem for remote control consisting of a computer FU
- An interlocking computer SID
- A number of concentrators each consisting of a concentrator computer KC with associated relay equipment RS.

The track devices (signals, points, track circuits etc.) are connected to the concentrators. Transmission of data between the different subsystems takes place via transmission links. The data messages are transmitted in serial form, and each message is supplemented with redundant information in order to ensure faile-safe function.

Subsystem for local control

The subsystem for local control consists of a VDU with a standard keyboard and a microcomputer, CAPP, which handles the exchange of commands between the the dispatcher's equipment and the interlocking computer. CAPP processes and stores commands from the keyboard and transmits them to the interlocking computer, SID.

Status information from the devices is transmitted continuously in the opposite direction, from SID to CAPP. This information is processed in CAPP and then used for updating the information displayed on the screen.

Alarms received from the interlocking computer, for example burn-out of a filament in a signal lamp, and internal alarms from CAPP are recorded and stored for display on the screen and for later printout. All control commands and changes in the status of devices are also logged continuously, and the overall state of the system is logged at specific time intervals. Printout of logged information is used in connection with investigation of accidents and for system fault finding.

The local control computer contains facilities for adjusting and testing the VDU. The presentation on the display is refreshed alternately from the two data systems A and B. The computer continuously monitors receipt of status information from all track devices.

Subsystem for remote control

A microcomputer, FU, is used as interface to a remote control system. This computer handles the exchange of information between the interlocking computer and the remote control system. Commands are received, processed and transmitted to the interlocking computer. In the opposite direction there is a continuous flow of indications, which are processed and stored before being transmitted via the remote control system.

Interlocking subsystem

All information about the geographical layout of the station is stored in the interlocking computer, together with all possible train routes and the corresponding positions of all track devices. The computer processes commands from the control computer such as:

Establish train route from signal no. 01 to signal no. 02.

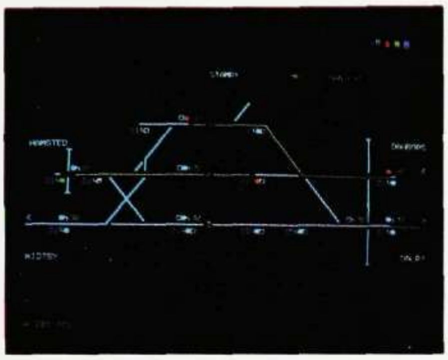


Fig. 2
Track-diagram, train routes, train movements etc. are presented on the VDU

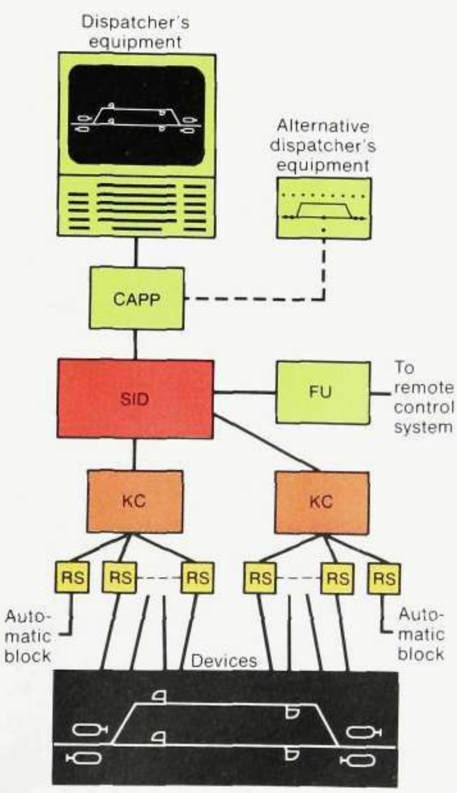


Fig. 3
Block diagram of interlocking system JZSD 770

Dispatcher's equipment
Keyboard and semigraphic colour video display unit with 80 characters per line in a 48-line format. Eight different colours are used and each character is displayed by means of an 8x6 matrix

Alternative train dispatcher's equipment for small stations
Panel with lamps for indications and keys for setting of train routes

Computer CAPP for local control
Microcomputer Intel 8085 with 56 kbit memory is used for local control. The computer controls the exchange of information between the dispatcher's equipment and the interlocking computer. It records alarms and is also used for functional testing of the VDU

Computer FU for remote control
Microcomputer Intel 8085 is also used for remote control. This computer controls the exchange of information between the interlocking computer and the remote control system

Computer SID for interlocking
The Ericsson computer APN 163 with microprocessor circuits AMD 2901, 64 k word memory and 16-bit word length is used for the interlocking

Computer KC for concentrator function
Microcomputer Intel 8085 with 2.25 kbit memory is used for the concentrators. KC controls the exchange of information between the relay equipment and the interlocking computer. A maximum of 31 controlled devices and 28 track circuits can be connected to each concentrator

Relay sets RS
The circuits with safety relays are mounted in standard relay sets. The track circuits have free-wired relays connected directly to KC

Track devices
The track devices comprise different types of signals, points, track circuits, automatic blocks, level crossing plants etc.

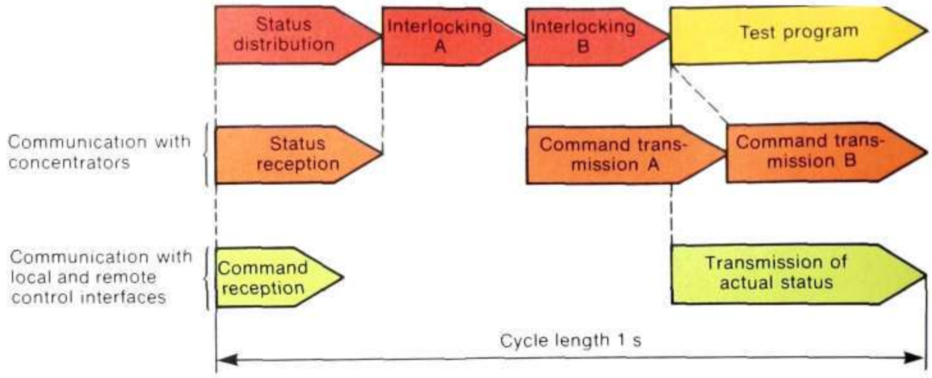


Fig. 5
Program execution in an interlocking computer

Information received from the devices via the concentrators is simultaneously processed – status information such as:
Signal no. 01 shows stop.

The interlocking computer performs a number of tasks such as verification of commands, prevention of set-up of conflicting routes, setting train routes with the associated operation of points, signals etc.

Concentrator subsystem
Each concentrator consists of a computer with associated relay equipment controlling the function of the devices. Commands from the interlocking computer are stored in the concentrator computer. The commands are checked with respect to correct concentrator address (for example) and then fed to the relay equipment.

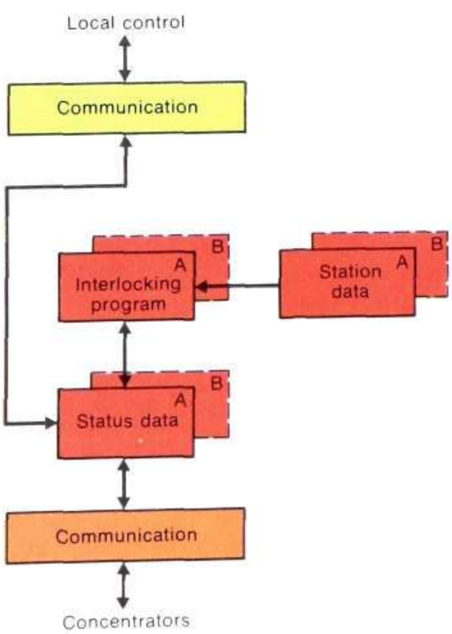
The concentrator computer continuously records the status of all connected devices during each operating cycle and transmits the corresponding data to the interlocking computer. Changes of the status of the track circuits are recorded more often, and any occupancy longer than 30 ms is detected.

The relay equipment consists of relay sets for signals, points and other devices, and track relays for the track circuits. The relays used are safety relays. Each device normally has a relay set of its own.

Fail-safe interlocking

Fail-safe interlocking is obtained by means of an interlocking process (A118) proposed by ORE (Office de Recherches et d'Essais) of UICF (Union International des Chemins de Fer). The interlocking process is carried out by a single computer with two completely independent programs, A and B, fig. 4.

Fig. 4
Software structure in the interlocking computer



The system concept adopted is that the whole interlocking process be divided into two separate channels, A and B. The diversity is in space and in time as well as in coding. Track devices cannot be activated unless the output from the two channels agree, which is determined by fail-safe comparison in the relay sets.

A common functional specification forms the basis of the programs, and the coding as well as the testing of these programs uses separate data sets (also designated A and B) in which corresponding data bits are mutually inverted and the address bits mutually reversed.

The programs contain the general interlocking rules applicable for any installation, whereas the data define characteristics specific to each station.

Interlocking programs A and B are executed sequentially once every operating cycle of 1 s. Based on updated information on the actual status of track devices, and depending on the dispatcher's commands, and routes already established, programs A and B process the respective A and B commands which are then transmitted to the relay sets controlling the points and signals in question. If commands for a device processed during a cycle are in disagreement, transmission is blocked by the computer. The program execution of the interlocking computer is shown in fig. 5.

The relay set for a particular device performs a fail-safe comparison between the A and B commands transmitted to it at any time. If the commands are in agreement and legal, the relay set activates the device. If the commands are either illegal or in disagreement, the relay set shifts to a locked state keeping the device in a restrictive position.

For a signal to maintain a "proceed" aspect, this activation must take place every second cycle. Lack of command information for more than 2.5 s will automatically switch the signal to "stop".

In a similar way every relay set generates A and B indications representing the actual status of the device to which they correspond. All devices, including the track circuits, are scanned cyclically by the computer. The A and B indications must agree if they are to be accepted by the computer.

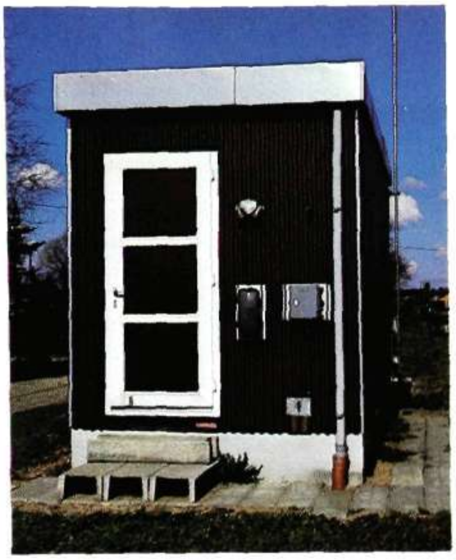


Fig. 7
Cabin in the station area containing the equipment for one track sector

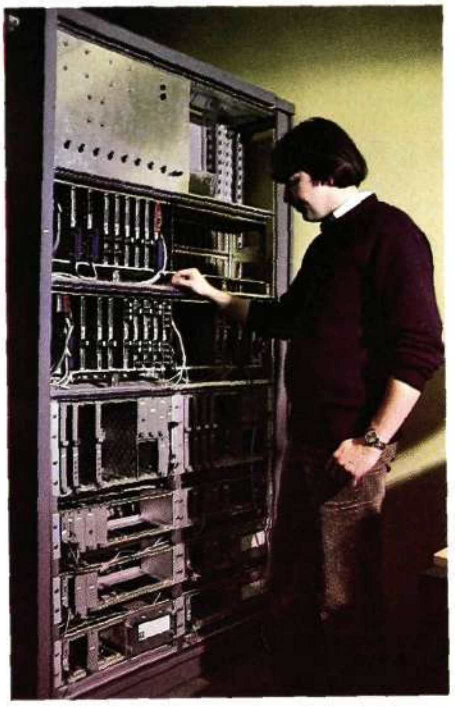


Fig. 8
Interior from a cabin showing SID, CAPP, FU, and a number of KCs

Project planning

When planning a system for a station it is usually best to divide the station area into sectors in order to keep the cables between the devices and their relay sets short, fig. 6. Cable costs as well as the risk of malfunction due to induced electrical interference are thereby reduced.

A concentrator, controlled by a microcomputer, is installed together with the relay sets for each sector. It handles the exchange of commands and status information with the interlocking computer.

The equipment for each sector is placed in a cabin of the type shown in figs. 7 and 8. One of these cabins also contains a separate room for the dispatcher's control equipment.

Control facilities

The devices at a station can be controlled either locally or remotely from a remote control centre.

For local control a colour VDU is used, showing the track diagram with an indication of the actual status of all track devices, including track circuit occupancy and route settings. The VDU echoes commands fed from an alphanumeric keyboard. Stored commands and error messages can be displayed on the VDU by means of special commands.

Research studies as well as experience gained in the field have proven that colour displays convey the information more efficiently than any other visual method. Furthermore, colour dispalys lead to easier information recognition, thus permitting faster dispatcher response.

The dispatcher uses a standard type keyboard. Commands are given in the form of abbreviations, consisting of letters and figures, and built up in a standard pattern that is easy to learn. The symbol for the selected device flashes when the command is entered, so that the dispatcher can immediately check that the correct track device is addressed.

The system automatically checks that a command does not contain any syntax errors. The number of characters must be correct, the command must be correct, the addressed device must exist etc. Each command is also checked in the interlocking computer before it is accepted. A red star is displayed on the screen and an acoustic alarm is given if a faulty command is entered.

It is possible to edit a command during entering by erasing either the last character or the whole line. When a

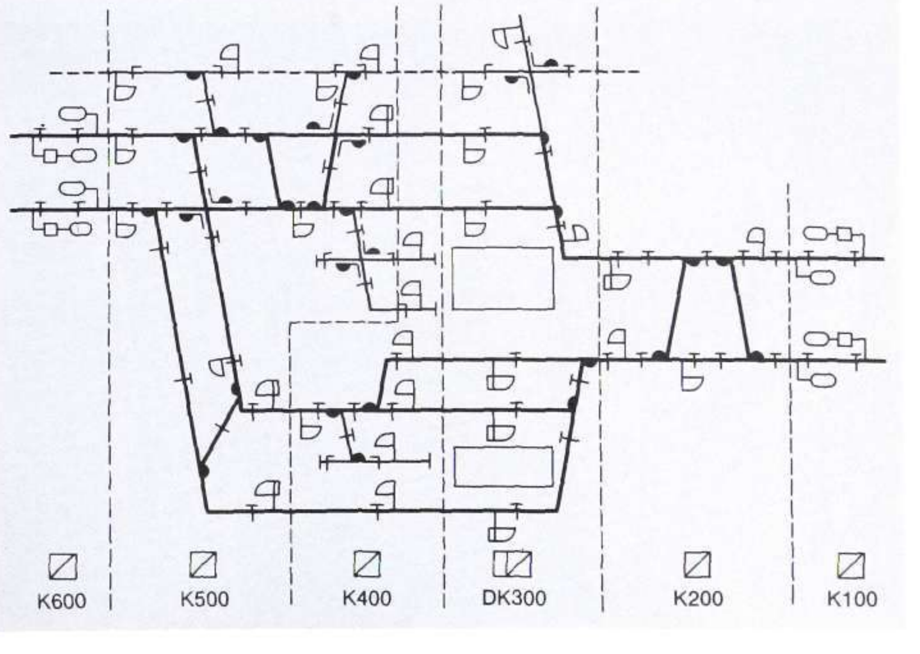


Fig. 6
The track network at Herning station has been divided into six sectors, each with a cabin for the concentrator, relay sets, track relays, power supply etc.

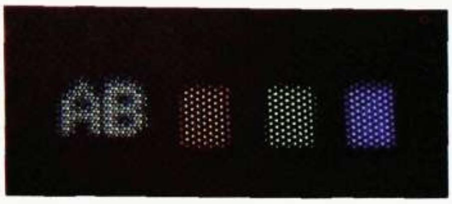


Fig. 9
Shifting between the letters A and B on the VDU indicates that the presentation is refreshed from both data systems. The red, green and blue colour symbols are used to check correct colour information

correct command has been entered it will be executed when the key "Carriage return" is depressed. If a route cannot be established immediately, the command is stored until all conditions are met.

The system also allows the dispatcher to enter commands in advance. Priority rules and input order determine the order in which the commands are executed. It is also possible to store previously prepared command sequences, which can be released for execution by means of a single command.

In order to ensure high reliability the indications on the display screen are updated alternately from the two independent computer programs. In addition there is continuous monitoring to ensure that indications are obtained from all devices. Symbols for devices of great importance to safety, such as signals and points, are always indicated by at least two characters.

A number of check indications are continuously displayd on the screen. In the top right-hand corner three symbols, one red, one green and one blue, show whether the colours are properly adjusted. Next to them another indication shows alternately A and B, proving that the display is being updated from both computer programs, fig. 9. In the top left-hand corner a flashing yellow star is shown as an indication that the transmission between the interlocking computer and the control computer functions properly.

Different types of train routes and train movements are indicated by different colours. For example, shunting operations have a special colour indication. As regards the signals, the display indicates which signal aspect they show, and for the points it indicates both their positon and whether they are controlled locally or centrally. The significance of the various colours is:

Turquoise	Neutral devices (not part of any train route)
Blue, flashing	Faulty device
Green	Established main route
Green, broken line	Overlap route
Yellow	Established shunting route
Red	Occupied track circuit
White	Signal aspects for shunting
Lilac	Point released for local control
Black	Key-locked point and line block.

System planning

In a microcomputer controlled interlocking system all information that is individual to a specific system (station) is stored in the computer memory.

A project planning system has been developed which, on the basis of certain fundamental conditions, generates all information that is required for a station. The program is run on a general purpose computer.

The project planning system is of the interactive type and based on the geographical concept. An operator feeds the computer with information regarding the track network, the type and position of signals and points, signalling conditions, release conditions for train routes, overlaps and suitable positions for the concentrators and relay sets in a system.

On the basis of this information the project planning system provides a plan of the individual system data, i.e. the data that determine the safety logic in

Fig. 10
Control of 66 level crossing plants on the line is integrated in the interlocking functions

the interlocking subsystem and the command and indication data for the local control equipment.

These individual system data are fed into test equipment having the same computer configuration as is to be used in the final interlocking system. The traffic and control functions of the whole system can then be tested by simulating the functions of devices, device relay sets and track circuits. All this can be done long before the real planning of the installation work starts.

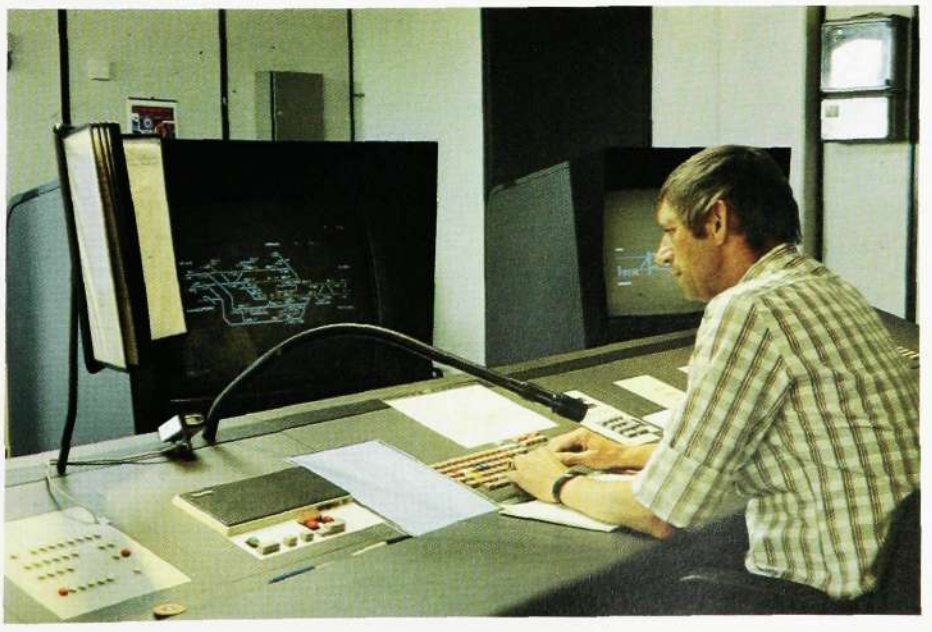
When the characteristics of the system have thus been tested and accepted, the individual system data are fed into the computer memories.

All equipment for a station can be supplied mounted and installed in prefabricated cabins. Before the equipment is delivered it undergoes a computer-controlled test procedure with artificial devices. The function of the concentrators and devices, and the rack installation are then tested before the interlocking computer is connected.

The only testing required when the system is installed consists of checking that the devices are connected correctly, adjusting the signal lamp currents and possibly also carrying out a functional test with the devices connected up, after which the system can be put into operation.

If an interlocking installation has to be modified at a later date, the operation of the modified system can be tested in advance in the test equipment. In this way the time required for the modification of the equipment in the field can be considerably reduced.

Fig. 11
Herning is equipped for two control positions. One is used for local control of Herning station. The other position is used for remote control of Holstebro station



Summary

The use of microcomputers in interlocking systems has opened up new possiblities. The new technology has many advantages over the old:

- greater immunity against electrical interference
- improved dispatcher control facilities
- automatic event logging
- project planning time greatly reduced
- simple and efficient testing of installations
- functional test off-site in advance of delivery
- modifications easy to carry out
- investment costs reduced.

The microcomputer controlled interlocking systems that are now in operation in 14 Danish stations have fulfilled all expectations. The experience gained hitherto proves that this new generation of interlocking systems is reliable and will be very attractive also to Railway Administrations outside Denmark.

The success of the system has further been confirmed by the fact that the Danish State Railways have placed another order for delivery of similar equipment to be installed at seven stations on the line Roskilde–Køge–Naestved in Zealand.

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