Computer Controlled Interlocking System

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LM Ericsson, in collaboration with the Swedish State Railways, have developed a computer controlled interlocking system for railway yards. The computer control means a considerable modernization of equipment compared with electromechanical technology. This modern interlocking system is already in operation in Sweden in the Gothenburg and Malmö areas.
The authors describe the system and how its fail-safe function has been achieved. This is followed by a description of a planning system for installations, and the article concludes with a brief account of the installations already in operation.

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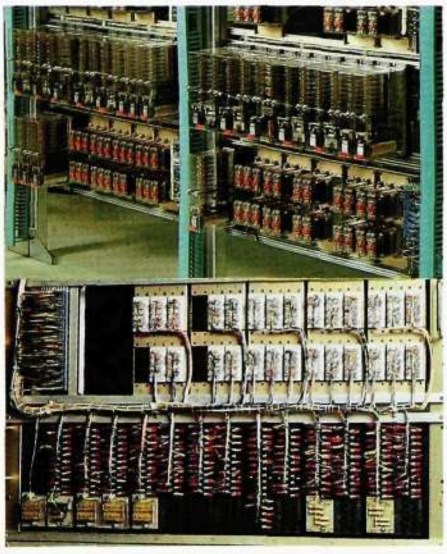

Fig. 1
The degree of safety obtained with robust relays, large insulation distances between the circuit elements, guided contacts and simple circuit structure corresponds to what is obtained with large information and system redundancy in a computer controlled system

Interlocking systems are used in railway signalling systems in order to ensure the safety of train movements. Before any train is moved a train route is prepared, which is then protected by the interlocking system against

- other trains in the train route, by checking that the track is clear
- other frontal train movements, by checking that there is an overlap area also beyond the end of the train route and that signals in the opposite direction show stop
- other flanking train movements, by checking that conflicting train movements are prevented by trap points and signals at stop
- changes in the point positions, by checking that all points in the actual train route, the overlap area and the flank protection area are locked in the correct position.

The protection is supplemented by a regulation that instructs the driver to keep within the applicable speed limit and to stop the train at the end of the train route. Equipment is also available which supervises the speed of the train and brakes it automatically if the driver does not comply with the regulations, as has been described in previous articles in Ericsson Review[1,2].

The checking that all conditions for authorizing a train movement have been met is carried out wholly automatically in modern signal safety systems. Conventional systems use safety relays, the contacts of which are connected together to form current paths that correspond to the different conditions. In LM Ericsson's new system, the interlocking conditions are checked by a computer, figs. 1 and 2.

System principle

Stored program control has been chosen for the interlocking function because the increasing demands for more complex interlocking conditions have made it very difficult to design systems using relay technology that can easily be modified and extended. The use of

Fig. 2
The LM Ericsson computer UAC 1610 P for stored program control of the signal box for the Malmö railway yard area, in south Sweden


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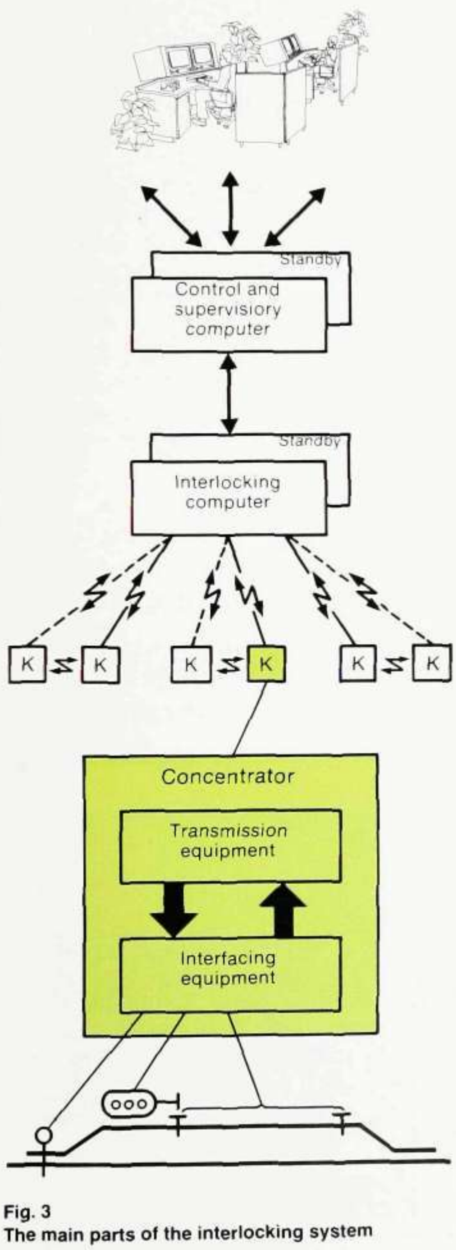

Fig. 3
The main parts of the interlocking system

computer control for the interlocking function makes the matching to the remainder of the signalling equipment easier. The overall cost is lower, not only for the equipment itself but also for the planning and installation.

The trackside devices, such as track circuits, points, signals etc., are connected in groups to concentrators, which are then connected, via transmission links, to the interlocking computers. Messages are transmitted in both directions in serial form, and each message is supplemented with redundant information in order to ensure fail-safe function.

The system comprises (see fig. 3):
- control and supervisory subsystem
- interlocking subsystem
- transmission network between the interlocking subsystem and the trackside concentrators
- subsystem for interfacing between the concentrators transmission terminals and the trackside devices.

The first two subsystems are computer controlled and the computers are duplicated to ensure availability. The transmission network is supplemented with alternative routes.

A documentation system, which uses a separate computer has also been developed for the planning of installations.

Control and supervision subsystem

In the new interlocking system colour displays replace the old type of indication panels, where lamps were used to indicate train positions, signal conditions, point positions etc. Each operator now has a work position with two display units and a keyboard which is used to give all commands, figs. 4 and 5. One display gives an overall picture of the supervised track area, and the other gives detailed information for a selected part of the track.

Different types of alarms are also shown on the display units, and the operator can enter commands via the keyboard to display alphanumerical information concerning a particular alarm.

The system also permits automatic commands. Such commands are programmed in advance and are released when certain conditions are met. The operator can also compile automatic functions himself, for example for frequently recurring shunting movements.

Commands to the interlocking system, for example the setting up of a train route, are always reviewed before the interlocking system starts to arrange safeguards, block devices, change points etc. This is done to prevent the system

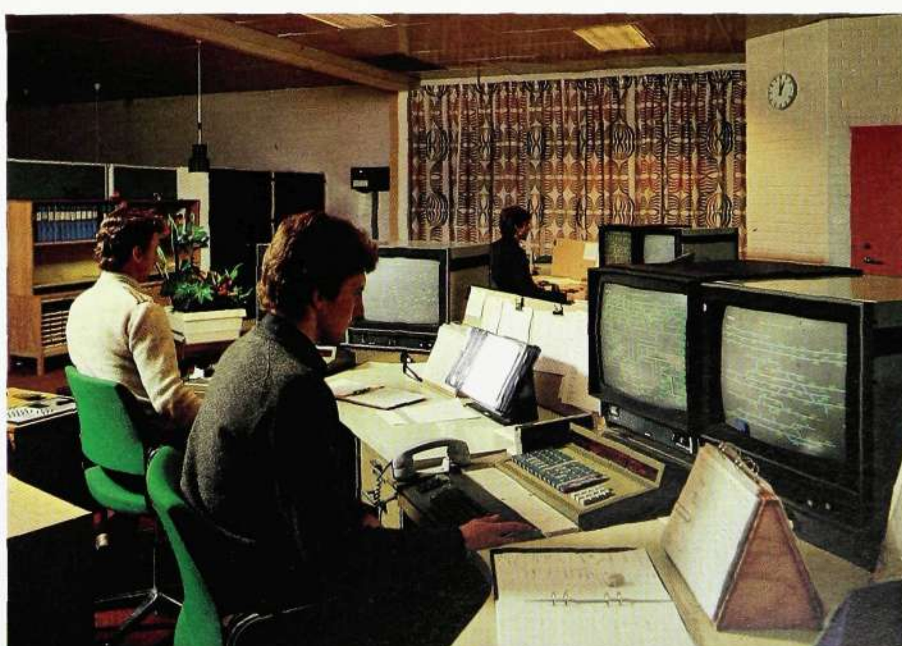

Fig. 4
The control office for the Gothenburg railway yard area, western Sweden

Fig. 6
The processing stages during an operating cycle

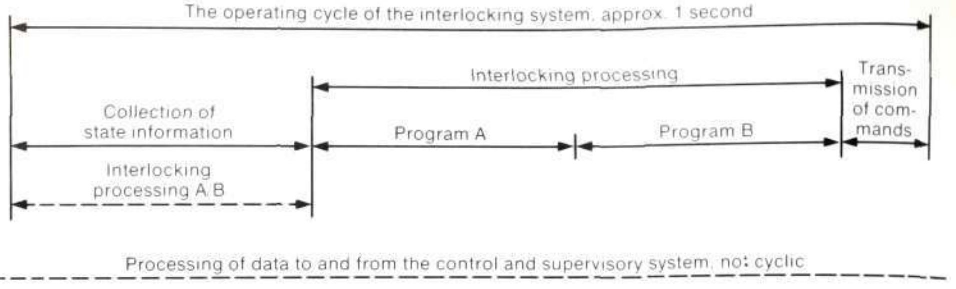

Fig. 5
Keyboard for the input of commands

from being loaded with unnecessary blockings. A command that is not accepted in the review is put in a command queue, and is then reviewed repeatedly until the conditions are met or the command is cancelled manually.

Interlocking subsystem

The interlocking subsystem acts as a safety filter and prevents dangerous commands from the control system from being executed. The stored program control in the interlocking system uses an algorithm for this filter function, so that

- correct commands from the control system are safely transmitted to points, signals and level crossing equipment
- devices that are to be included in a train route are blocked against use in other routes
- blocked devices are relased when the train is clear of the route.

The processing in the interlocking computer is cyclic. The cycle time is approximately one second. During each cycle, fig. 6,

- all information concerning the state of the various devices is collected
- any commands from the control and supervision system are processed
- the interlocking data are processed in two separate program sequences
- commands to the devices are compiled and transmitted
- information concerning the yard status is transmitted to the control and supervision system.

Commands from the control and supervision system are transmitted in a background program and not as a part of the fixed cycle.

The data processing is duplicated for safety reasons. Two different program sequences each process the yard device data in accordance with the algorithm. The processing results in two commands per device, and check bits are added to both in order to ensure safe transmission. Finally the command message from one program sequence and the check part from the other are combined and sent via the concentrator to the interfacing equipment for the trackside device.

Interlocking conditions according to the geographical method

The interlocking conditions have been given a stringent mathematical descrip-

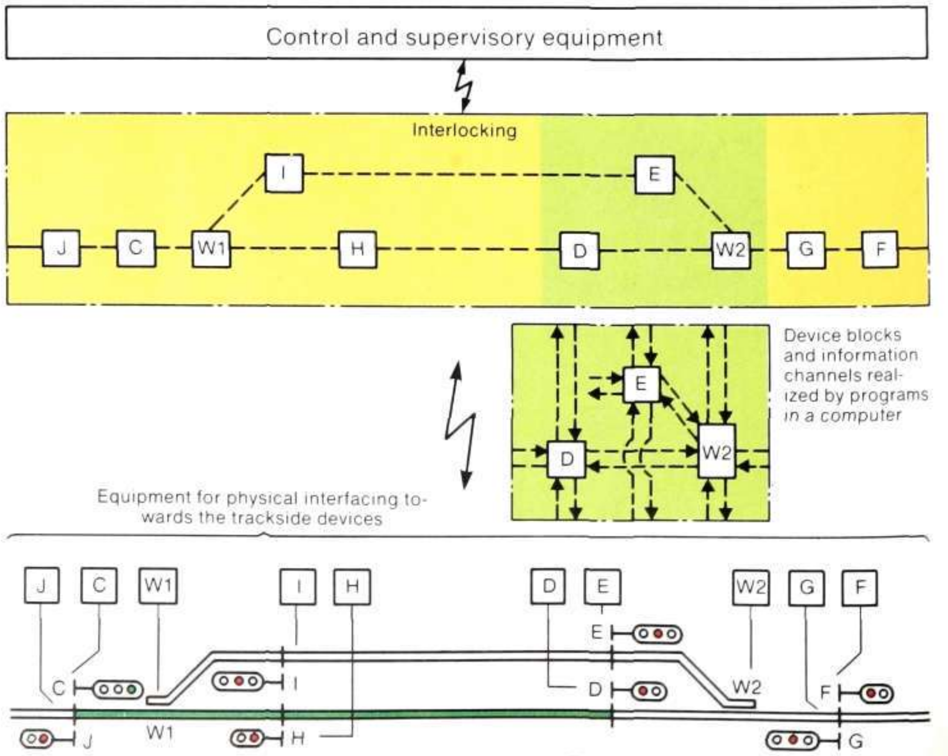

Fig. 7
The basic principle of the geographical method

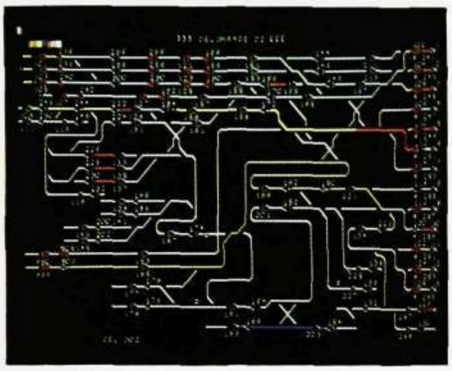

Fig. 8
A set train route is marked with a green line on the display screen and a shunting route is marked with yellow or blue alternatively

tion. The conditions are described in accordance with the geographical method, which means that they are related to the various trackside devices: points, signals, derailers etc.[1] For each device the conditions for every possible state and every possible change of state are set. Fig. 7 shows the geographical method in principle. Each device has an associated block with interfaces towards
- the control system
- the trackside device
- the blocks for the "geographical neighbours".

The interfaces towards the neighbours are the same for all devices, whereas the interfaces towards the control system and towards the trackside device are the same for each type of device.

When a train route is set up, figs. 7 and 8, the block for signal C receives an order from the control system to seek the necessary protection for the train route, so that command to show green light can be sent to the signal. At the same time the other blocks in the train route are ordered to assume states that form the conditions for establishing the route. For example, signal D is ordered to form the end point of the train route, which in its turn means that signal D must seek the necessary protection for the overlap area beyond the signal. Messages are then exchanged between the blocks in accordance with the program, and the blocks successively change state until the states of the whole chain of blocks in the train route agree with the interlocking conditions. The changes of state of the blocks also mean that the points in the train route and the flank protection are set and locked in the correct position etc. When all this has been completed, all conditions for the train route have been fulfilled and the block for signal C can send a command to set the signal to "clear".

The messages that are exchanged between blocks which are geographical neighbours can be divided into the following categories, namely messages that
- state the type of train route that is to be established, and which command the locking of the route
- indicate the type of flank protection and the length of the overlap area required for the train route
- inform that flank protection and overlap protection are achieved
- indicate clear track along the train route, in the overlap area and in the flank protection areas
- state the maximum speed for the train route
- control the level crossing devices
- release the devices in the train route when the train has passed.

Types of blocks

For each block there is a description of how the block must react to an incoming message, and which messages the block is to send to its neighbours, its own device and the control system.

The system contains the following eight types of blocks:
- signal blocks for signals
- advance signal blocks for independent advance signals
- point blocks for points and stop blocks
- crosssing blocks for track crossings
- road blocks for level crossing devices
- boundary blocks for the boundary towards areas without interlocking
- line blocks forming boundaries against lines between stations and against other signal box areas
- obstacle blocks, which add dependence on extra track circuits.

Processing of blocks

The conditions for each type of block are described by a number of equations in algebra that is similar to Boolean algebra, fig. 9. However, each variable can normally take up more than two values.

When processing a block, for example signal block D, the computer program uses the equations that apply for signalling blocks on the data of signal D, fig.

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IF (K.EQ.4.AND.(P1.EQ.2.OR.P1.EQ.3).AND.RØ.EQ.1.AND.
*(PK.NE.Ø.OR.R6.EQ.1.AND.(U2.NE.8.OR.
*I2Ø5.EQ.Ø.AND.T2.EQ.Ø)))R6=1.
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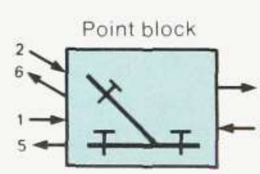
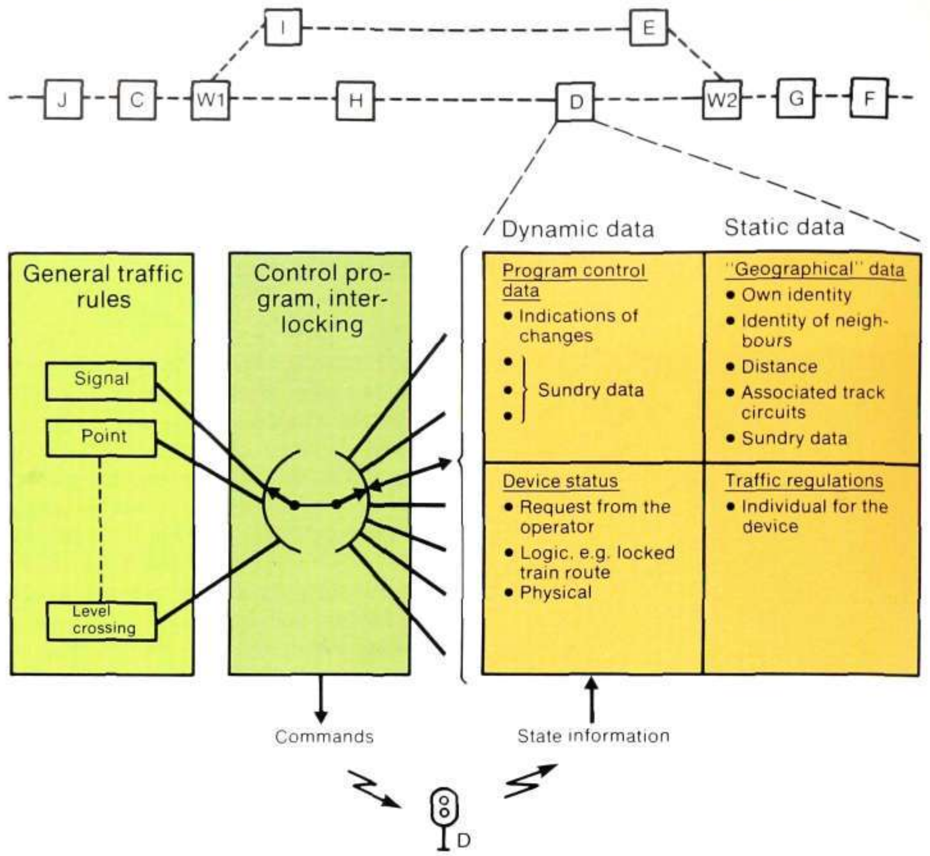


Fig. 9
An equation that describes a sub-condition for a device

Fig. 10
The basic principle of the processing of the data concerning an object block



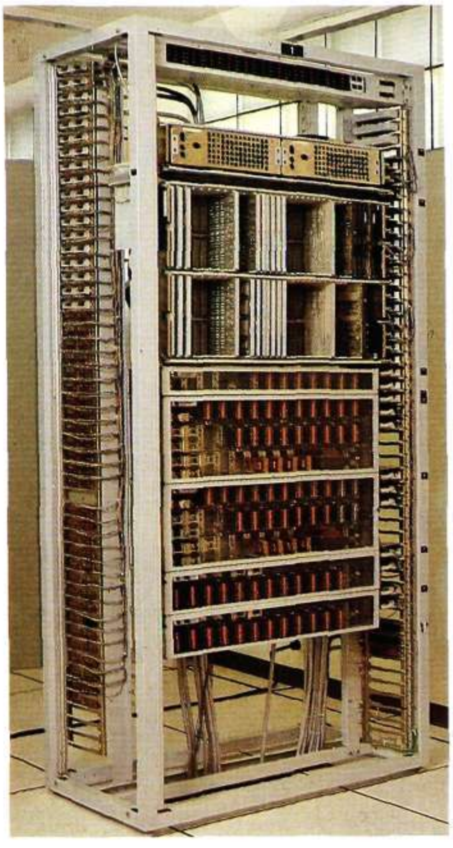


Fig. 11
Transmission terminal and interfacing relay units in a concentrator

10. The processing, including the exchange of messages with neighbouring blocks, continues until the equations have been satisfied and have resulted in
- a change of state for the block in question
- a change of state for the geographical neighbours
- the necessary commands to the device associated with the block
- information to the control system.

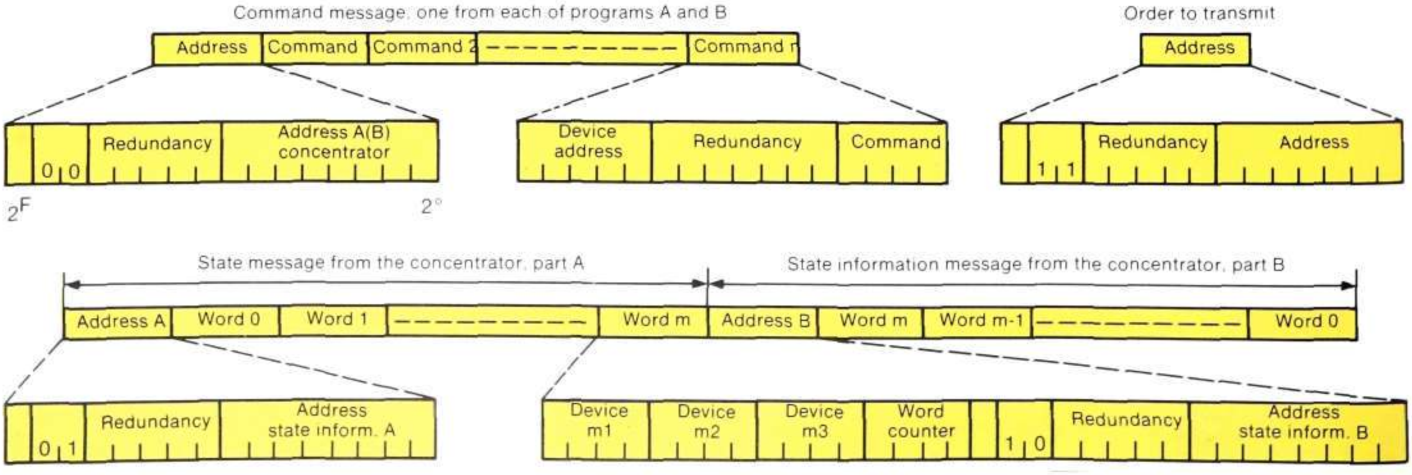
Transmission network

Concentrators are placed in the track area near groups of devices. Each concentrator contains interfacing equipment for the various devices and a transmission terminal, fig. 11. The system is dimensioned so that each terminal can serve 24 track circuits and 31 other devices. The system can address 64 terminals. However, the cycle time, one second, limits the number of devices that can be served to less than the total addressing capacity. Two important parameters in this connection are the interdependence of the devices and the number of simultaneous train movements in the track area served.

The exchange of messages between the interlocking computer and the concentrators is serial in half duplex form over two-wire circuits. The transmission rate is 4,800 bit/s. Two concentrators can be connected to each two-wire circuit. The transmission terminals can be reached from the computer via two alternative routes.

The exchange of messages must meet the fail-safe requirement. Each message therefore contains a number of check bits in addition to the actual information, which ensure that distorted messages cannot be misinterpreted and cause danger. Fig. 12 shows the struc-

Fig. 12
The format of telegrams between the interlocking computer and the concentrators



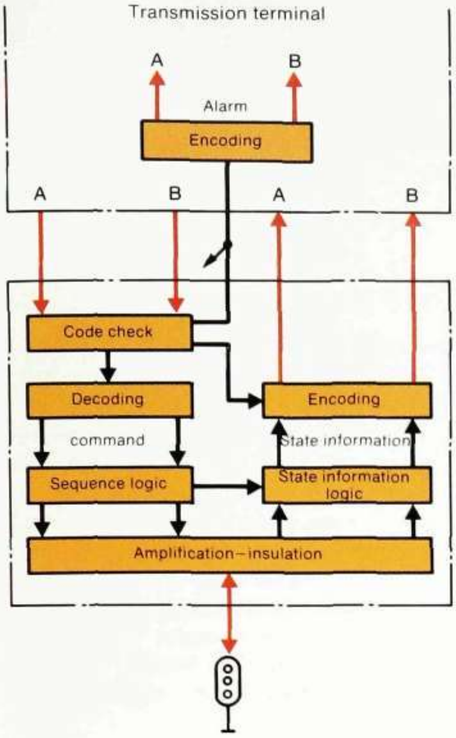


Fig. 13
Block diagram of the interfacing circuits for a trackside device

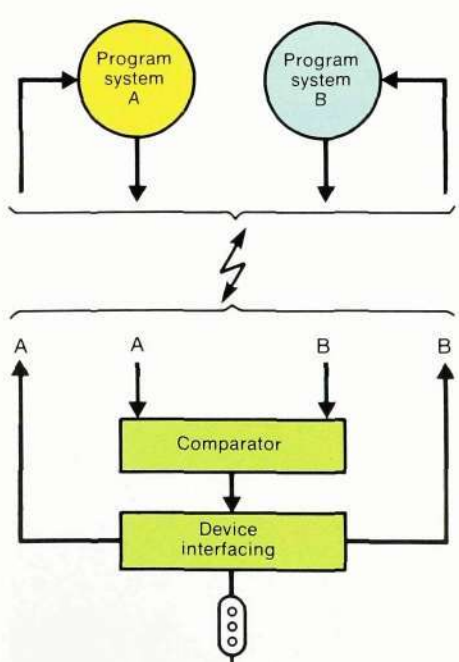


Fig. 14
Duplicated processing of commands to ensure fail-safe function

ture of the messages to and from the interlocking computer.

Trackside interfacing equipment

The equipment for interfacing towards the trackside devices is realized in conventional relay technology. It also includes relays for the decoding and checking of orders from the interlocking system. In addition it contains equipment for encoding the information about device states that has to be sent back to the interlocking system, fig. 13.

For example, for a point the following information is exchanged between the interlocking system and the interfacing equipment:

Commands
- release the locking of the point
- lock the point
- set the point to the reverse position
- set the point to the normal position
- release the point for local operation
- resume control of the point.

State information
- switching is taking place, or the position is not under control for some other reason
- the point is locked in the reverse position
- the point is locked in the normal position
- the point is released for local operation.

Fail-safe function

The use of computers in equipment with fail-safe function requires a system design that can never set the controlled devices in dangerous positions, even if faults occur in the hardware or the software. Thus the data processing that leads to such commands as "clear" for signals is always carried out in two separate program sequences, and the results must be compared outside the computer before the command can be executed, fig. 14.

The two program sequences have been designed by two separate programming teams and have both undergone careful examination and testing. The program sequences with the assocciated data are stored in different places in the computer memory, so that any hardware faults will also be discovered.

One prerequisite for the system is that the data to be processed are not too old. The stored information in the computer concerning the state of the different devices etc. is therefore updated every program cycle. Furthermore the data are labelled with the time, so that their age can be checked.

The mathematical description of the safety conditions, which forms the basis for the whole system, has been examined in detail by signal and traffic experts and has also been tested in a simulator. There is only one version of the description, but it is stored in the memory area of each of the two progam sequences, and will therefore be used in two different ways.

Individual data, which describe the various devices and their neighbours in each installation, also occur in only one version, but are also stored in both program areas.

The system contains further functions to ensure fail-safe operation. This problem has been discussed fairly comprehensively in a previous article[2].

Fig. 15
The control office for Malmö railway yard area

Project planning system

A project planning system is used to prepare installation documents and the individual data for the control computers. An off line computer is used for the project planning system. The input data for this system are specified on standardized forms by the customer's project planners. The input data consist mainly of information concerning the structure of the track network and the individual characteristics of the yard devices.

The system provides
- data files for the control computers
- information for the installation of concentrators, cabinets, cables etc.
- materiel lists.

The project planning system is also used to plan extensions, handle version numbering etc. The data concerning each installation are stored in a data base.

Installations

Interlocking systems of the type described above are in operation in Gothenburg and Malmö yard areas.

Trial operation started in a small part of the Gothenburg yard area in May 1978. The results were satisfactory, and after minor modifications to the program system the installation was extended in November 1979 to include the central parts of the yard area.

The Gothenburg yard area is extensive and includes a large number of passenger stations as well as goods, harbour and industrial yards. Before the installtion of the new system the five passenger stations had individual signal boxes. These were worn and the operation was very personnel-demanding. The goods yards, and the tracks between them, lacked adequate safety arrangements, which meant that a large staff was required for the traffic handling and that the traffic capacity was low.

With the new system the traffic control and the safety interlocking have been centralized to one place, fig. 4. The trackside devices are successively being connected into the system. At present over 600 devices are under control, including 115 points, 216 signals and 203 track circuits. The central equipment communicates with the devices via 15 concentrators. When fully extended the installation will comprise about 1,200 devices.

The Malmö installation will comprise three passenger stations, two of which were completed in February 1981 and which contain about 330 trackside devices, including 40 points, 145 signals and 110 track circuits. The devices are connected to the central equipment via nine concentrators.

References

1. Andersson, H.S.: *Railway Signalling Systems*. Ericsson Rev. *57* (1980):4, pp. 118–123.
2. Sjöberg, A.: *Automatic Train Control*. Ericsson Rev. *58*(1981): 1, pp. 22–29.