Interlocking system technology.
We set the course.


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1 Operating technology background

1.1 Origins of depot and yard control systems
Depot and yard control systems as a special discipline within control and signalling systems have their origins in high-performance hump-yard control applications. In both operational requirements and technical approach these systems diverge completely from typical control and signalling systems. Computer systems were thus in use here at a time when their use in conventional interlocking systems was still unthinkable. The use of computers was made possible here by the fact that the extremely high safety requirements of main line signalling systems were not necessary in these systems.

1.2 The principle of gradated safety
As the concept of investing only in such signalling technology as is really necessary in each case had been proven workable with hump-yard control systems, the principle of gradated safety was developed for the field of depot and yard systems. The simple operating conditions during shunting and train formation (such as low speeds, no passenger involvement, driving on line of sight) mean that this form of train operation involves fewer dangers, and that a simplified and hence more cost-effective form of safety technology is therefore sufficient.

Pintsch has developed a variety of technologies to adapt to the various operating procedures of train formation, stabling and maintenance, and these are available for safety and rationalisation purposes:
- In high-performance marshalling yards, this means the hump-yard control computer with complex technology (e.g. the MC-ZBA system from Pintsch)
- At facilities with special operating requirements, local-electrically operated point-switch (LOPS) systems are widely used (e.g. the MC-LOPS system from Pintsch) as an "aid for driving on line of sight".
- In terms of both cost and performance, the depot signalling & control system of type MC-RaStw can be classified between the LOPS and marshalling yard systems.
- MC-RaStw system was also upgraded to support interlocked routes with speeds of up to 60 km/h being controlled by main line signals, which ensures accelerated clearing of access routes to the depot and thus optimally supplements the above technologies.

These technologies are all based on the principle of investing only in such safety technology as is actually necessary in each case. There are defined boundary conditions and prescribed safety requirements for the use of each of these technologies, which have been proved in consultation with the German Federal Railway Authority (EBA) and documented in appropriate approvals.

1.3 Depot signalling and control systems of type MC-RaStw
The MC-RaStw depot signalling and control system is a computer-based interlocking system that differs only marginally in operation and effect from conventional SSI systems. The field of application is defined here as follows:
- Train movements with interlocked routes signalled by shunting signals ("stop"/"proceed with caution")
- Driving speed up to $v_{max} = 25$ km/h or up to $v_{max} = 40$ km/h (Movement with route reported as clear)

Due to the clearly defined field of application (for example no danger to passengers), depot signalling and control systems can be given a much simpler technical design than conventional main-line signalling systems.
1.4 Signalling and control systems for freight tracks $v_{\text{max}} = 60 \text{ km/h}$

A variety of functional extensions are provided for the use of the depot signalling and control system with gradated safety precautions, some of which have already been approved by the Federal Railway Authority (EBA).

Of particular importance here is the introduction of (partial) routes for freight trains and empty passenger trains with driving speed up to 60 km/h, without departing from the basic design structure.

The comparatively high speed relative to shunting speed has the advantage of enabling the transition points to the main line to be cleared faster. Control systems using this technology have already been set up in Germany and other countries, and have been approved by the responsible supervisory authorities.

The following table compares the conventional SSI with the MC-RaStw.

<table>
<thead>
<tr>
<th></th>
<th>SSI</th>
<th>MC-RaStw</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operator (typically)</strong></td>
<td>Signal man, points man</td>
<td>Signal man, points man, dispatcher (PICOM)</td>
</tr>
<tr>
<td>Indication</td>
<td>Secure panel or screen e.g.</td>
<td>Non secure screen, procedurally secured for</td>
</tr>
<tr>
<td></td>
<td>by reading back</td>
<td>auxiliary operations</td>
</tr>
<tr>
<td>Individual point operation</td>
<td><strong>yes</strong></td>
<td>yes</td>
</tr>
<tr>
<td>Shunt signals</td>
<td><strong>yes</strong></td>
<td>yes</td>
</tr>
<tr>
<td>Main line signals</td>
<td><strong>yes</strong></td>
<td>yes, up to 60 km/h</td>
</tr>
<tr>
<td>Computer configuration</td>
<td>2 of 2, 2x2 of 2 or 2 of 3</td>
<td>Single computer with various safety procedures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>at processing level</td>
</tr>
<tr>
<td>Requirement class</td>
<td>AK 7 (corresp. SIL 4)</td>
<td>AK 5 (corresp. SIL 3)</td>
</tr>
</tbody>
</table>

As far as the operating task description of a Signalling & Control project can be fulfilled under these conditions, and provided certain rules are adhered to at the transition points to the conventional signalling technology, the MC-RaStw system represents a cost-effective alternative solution. The requirement class (under DIN V19251) specifies what precautions must be taken in a technical system in order to achieve the safety goal, and is thus an indicator of the technical expense. It is not possible to achieve a higher requirement class than AK7 through control technology precautions.
2 Technical structure

2.1 System structure

The depot signalling & control system MC-RaStw is of modular structure and has the following function levels and function groups (Figure 1):

- Operation level (non-vital)
  - Operator’s screen work station, optional extra (separate) operator stations, train number display etc.,
- Interlocking/Control level
  - Interlocking/Control computer with site-specific software,
  - Interfaces with other control substations,
- Field level (point controller modules with MC interface, Position Light Signal (PLS) module,
  - Train detection system with axle counter evaluation units).

The function groups at the field level are connected to the elements of the outdoor system such as point machines (PM), light signals (PLS) and axle counter sensors (double wheel sensors – "DSS").

Typically, the elements of the indoor system (interlocking/control and field levels) are housed centrally in a modular building (standardised concrete shell building). As the distances between points or point areas are of several hundred metres in typical shunting yards, this structure makes sense. Furthermore, it facilitates servicing.

Figure 1: Block diagram of MC-RaStw
It is however also fundamentally possible to structure the function groups in a decentralised manner. To do this, points modules, signals modules and axle counter devices can be housed in decentralised cabins or trackside cabinets, and connected via a serial data bus to the control computer. The decentralised arrangements of the control computers are called substations. Such a structure is always sensible when large distances occur between individual point areas, and it is thus possible to save costs on the cabling.

2.2 Hardware structure

The hardware for the entire system is structured in service-friendly Euro-style plug-in board technology, in 19" racks. In order to reduce the cabling costs for the internal system, the following techniques were used:

- Use of a field bus system RS485 interface for interconnecting the function groups (for example points modules, substations of the control computer).
- Backplanes as a parallel bus in the function groups at the control computer.

All modules have LEDs on their front masks that display the important system statuses and thus increase their service-friendliness.

The system hardware racks are typically housed in indoor equipment cabinets that for reasons of optimal space management are fitted with swivelling frames. System components or even the entire control system can optionally also be housed in external (outdoor) equipment cabinets. Neither variant requires air conditioning.

2.2.1 Points controller with MC interface

The points controller of the MC-RaStw depot interlocking & control system supports the classic four-wire control and detection interface, and is thus compatible with all of the 400V AC point machines approved by Deutsche Bahn AG (German Rail). Alongside modules with printed circuit board signal relays, a newly developed microcontroller module (MC) is used, which in addition to offering a field bus interface also takes over some of the failure detection checks that are necessary for the AKS / SIL 3 level.

2.2.2 Interlocking and control computer with COMPEX microprocessor system

For the construction of the signal box computer control system, the modular microprocessor system COMPEX is used. The COMPEX system (COMP - computer system and EX - for explosion hazard areas) was originally developed and successfully used by Pintsch for intrinsically safe, explosion-protected, high-availability control systems in subterranean coal mines and in the metal and chemical industries.
The intrinsically safe structure of the control system module with extended temperature range, correspondingly dimensioned air and creeping distances and high insensitivity to influences of any kind ensures exceptionally high availability. Alongside the CPU module, there are various input, output and interface modules available to facilitate flexible adaptation of the points control system computer to the local requirements. The modular structure of the COMPEX points control system computer is shown in Figure 3.

Figure 3: Modular structure of the control computer

### 2.2.3 Signals module

A signals module was developed for controlling and monitoring the light signals, which itself is controlled and monitored via decoupled input and output from the control computer.
The module has corresponding relays for switching on the current and monitoring the power, although the lamp filaments are also monitored when not switched on (cold filament monitoring). In this way, lamp filament failures due to service life limitations can also be detected early, even in an inactive state. This process supports the operating condition-related maintenance required by the operators of such signalling installations, as not every lamp failure will automatically lead to an operational effect.

2.3 Track locking and train detection with the TAZ axle counter system

The Pintsch Axle Counter System (TAZ) is based on the proven double wheel sensor (DSS) that since 1979 has been approved for depot and yard applications by Deutsche Bahn AG (amongst others) and is used at such facilities in its thousands.

The functional principle of the DSS may be compared to the inductive proximity switch that picks up the metal mass of the wheel flanges of rail wheels. The impulses of the two sensor systems of a DSS are each carried by a pair of wires to the evaluation facility, which also supplies the individual sensor heads with power (approx. 8 VDC). A DSS thus requires the 4 cable cores of a quad-star formation signal cable. The maximum distance from counter to the internal system is dependent upon the DC loop resistance of the signal cable and with a cable core diameter of 1.4 mm, for example, this maximum distance may be around 8.5 km.

The electronic evaluation unit of the axle counter system is located in the indoor system of the interlocking and control system. Apart from the double wheel sensors, no further electronic devices are required near the tracks. Given that there are already numerous devices at the track, this was a requirement for shunting yard technology from the outset, and it facilitates servicing significantly.

The DSS and the associated interface module in the evaluation unit can be used for both of two neighbouring axle counter sections. The output signals of the interface modules are distributed across two axle counter modules here.

The exchange of information between axle counter systems and interlocking & control systems takes place over the voltage-free contacts of signal relays (free and occupied information and axle count basic setting) and in the computers via optical coupler input and output and the I/O modules provided for this purpose.
2.4 Operator's screen workstation

A customary PC with a Windows® operating system is used as the central operator work station in the MC-RaStw depot interlocking & control system (Figure 6).

The PC can optionally be connected to the central computer via a serial data bus connection or via a LAN connection. The operator's work station of the RaStw can thus be set up anywhere, and corresponds to the concept of centralised operation management.

Customary TFT flat screens are used as Visual Display Units (VDU). The actual screen size can be selected according to the project design for the specific location. It is equally possible to operate large areas with a single input device as it is to distribute the areas over different operator stations. The latter can also be done for limited periods, or interchangeably, as required.

If necessary, functions for diagnosis and maintenance (service PC) and other services (for example train number table, points heating system, track area lighting, washing facilities etc.) can be integrated within a single screen system or be projected as separate operator stations.

The simple operation of the system using a mouse and a pop-up window and dialog based guidance through the graphical interface ensures a high degree of acceptance by the users.

2.5 System software

The COMPEX computer control system uses the OS 9 operating system. All the elementary functions and routines for safe operation of the control computer are implemented in the mother software, in compliance with the requirements of AK5 / SIL 3.

In the application software, the location-specific data (control tables of the interlocking) are stored in tabular form.

The interlocking & control computer is a single-channel device. The safety required for the specified area of application is achieved, amongst other factors, through the following methods:

- **Avoidance of hazardous statuses by e.g.**
  - Self-testing of the individual computers,
  - Antivalent computer inputs with time slots,
  - Antivalent computer outputs with read-back output data,
  - Upstream relay level,
  - 2-cycle or 3-cycle switch commands with time slots for regular or auxiliary operation and additional protection measures;

- **Precautions for faults detection, such as**
  - Plausibility checks,
  - Read-back output with time slot monitoring,
  - Monitoring of the process reaction times and
  - Test cycles.
The operator's PC runs the Microsoft Windows 2000® operating system. Industry standard programming tools are used for the visualisation software. The Visual Display Unit is designed according to the Deutsche Bahn AG standard for electronic interlocking systems.

Special safety procedures with fault tolerance are used for the exchange of data between the operator’s PC and the interlocking & control computer. The safety required for the application is achieved in the operator and visualisation systems mainly by means of fundamental process safety measures. For example, the input of track routes is secured by the start and finish information to be entered within a specific time slot. The entries are graphically marked on the screen and additional text outputs require the operator to confirm his entries. This confirmation must again take place within a specific time slot, otherwise the entry is rejected.

An integral component of the MC-RaStw systems is a real-time event memory for logging all operator actions, system status and fault messages of the RaStw. These event data are collected and saved in the control computer, and frequently archived in a database by the operator PC.

### 2.6 Power supply

The power supply connection of the MC-RaStw equipment is structured with an insulating transformer and a continuous residual current (RC) monitoring - as is also standard for conventional interlocking equipment. The insulation monitoring is implemented on the operator's PC, where it is displayed visually and acoustically with a two-level alarm and logging.

For reasons of cost, the RaStw dispenses with a complete uninterruptible power supply system. In order to maintain availability and reduce restart times in the event of power failures, all parts of the system which have a memory element as e.g. points detection, train detection (axle counters), interlocking & control computers and operator’s PCs are equipped with a battery-buffered power supply. Other parts of the system as e.g. light signals can be integrated as an option.

### 2.7 Interfaces

When the MC-RaStw depot interlocking & control system was introduced, the development of software or data interfaces was dispensed with, as the associated expense of testing in combination with the interface software of conventional SSI would partially negate the cost advantages of the RaStw.

Instead, interfaces to neighbouring signalling and control systems are set up via voltage-free relay contacts, which amongst other things ensure absence of feedback in a simple fashion. The method of antivalent output with read-back is used for the driven signal relays of both neighbouring signalling systems.

The following interfaces are already available as standard for the MC-RaStw:
- Acceptance switching for shunting movements to and from main line SSI "Alcatel L90",
- Exchange of information on "back-to-back locking" of position light signals between RaStw and main line SSI "Alcatel L90"
- Interface for Alcatel train number reporting systems with train numbers table.
3 Prospects

The existing depot depot signalling and control systems have proven themselves to be practical and cost-effective alternatives to conventional signalling systems.

In the foreseeable future, however, further developments will take place in two very different directions. On the one hand, there will be technical organisational developments, while on the other hand, long-overdue extensions of the operating possibilities for the user will become available.

3.1 Technical organisational development

One important task will be to make the depot points control system software available "off the shelf", like that of the conventional signalling systems. In the design and execution here, experience from completed and current projects can be applied. These projects show that it is precisely the interfaces to the conventional systems within the stations that demand particular attention.

3.2 New operating functions

3.2.1 Integration of Local-electrically Operated Point-Switches (LOPS) into the RaStw

For the operators, a maximum of operating flexibility is provided by the combination of Local-Electrically Operated Points with the MC depot control system.

The temporary switch-over of selected points of the depot interlocking & control system into a LOPS allows e.g. a train operator to operate reception and departure movements in a depot with a signalled movement (e.g. during peak hours) and then let shunters carry out internal movements in the depot with local points operation (via trackside plungers and route setting panels).

The PC workstation is then not to be served all the time.

Such mix of signalled and local operating areas with LOPS have already been set up on some schemes with private rail infrastructure.

3.2.2 Decentralised operating facilities

For the rationalisation of operations in shunting yards and maintenance depots, the requirement arose for it to be possible to operate signalling installations in a decentralised manner as in LOPS systems, without losing the higher safety of signalled movements.

For this reason, proven route setting panels were involved for regular operations in RaStw systems. Auxiliary operation can be carried out as before on-screen, which requires a high degree of system reliability.

Such a solution was first implemented in 2006 at the SüdostBayernBahn (DB Regio) company, with the Mühldorf RaStw.

3.2.3 Radio-controlled operation

A further possibility for decentralised operation is requesting routes via radio systems. The aim here would be to make it possible to use the existing radio systems of the train operators (e.g. GSM-R) for this application. Concepts to this end are currently being developed at Pintsch.
3.2.4 Integration of Depot Protection Systems

In depots and maintenance facilities, technical installations for the protection of the workforce (e.g. wagon masters, cleaning staff) are required within the framework of health and safety regulations.

Completely separate facilities with industrial automation technology have until now been designed and implemented for this purpose, which in addition to protective function have simultaneously been used for the automation of work processes.

Example of this are:

- control of track and shed gates
- control of electric de-railers for the protection of personnel from train movements at the entrances to shed buildings
- control of warning systems (beacons, claxons etc.) for the entrances and exits of halls and sidings
- use of card-readers for logging in and out, to automate the protective functions, including event logging and visualisation

In addition to the advantages of integrative conception and design (see also chapter 3.2.5), the integration of such functions into a MC depot control system can offer cost-saving potential in the application of technology. Thus there is e.g. no need for de-railers if points can be locked in an exclusive position that prevents movements to protected sidings and if depot sidings are fitted with trafficability locks in the route control software.

3.2.5 Integration of other services in the RaStw control system

On a non-vital control level various technical interfaces can be integrated to reduce operating facilities in the operations control room. These can be for example:

- Point heating systems
- Yard lighting systems
- Special rolling stock test facilities (e.g. for ATP)

3.2.6 Integration of management tools into the on-screen workstation

The operation of the MC-RaStw via the screen work station offers various possibilities for entering, administrating and displaying additional operational information. There is thus the option, for example, of entering vehicle numbers in the sidings as an aid for the allocation controllers.

Axle counter technology makes it possible to automatically count the number of axles or vehicles and display the information on-screen.

In complex points control system applications, it is also possible to implement automatic sequential switching of train numbers, as implemented e.g. at the Pintsch depot signalling and control systems for construction logistics at the Gotthart Tunnel in Switzerland.

A vehicle number reporting system was integrated into the depot points control system for the S-Bahn maintenance depot in Frankfurt am Main in a similar manner (Figure 7).