The future challenges of wheel detection and axle counting – Part 2

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Long since, in many countries of the world modern axle counting systems have taken over from track vacancy detection based on the track-circuit principle and are increasingly understood as an integral component of higher-level technical interlocking and signalling equipment. Nowadays, they are able to provide a great deal of information to the complete system beyond track vacancy detection.
Here, the challenge is to meet the widest range of requirements of the track operators and system integrators with reference to environmental conditions, interfaces, reset procedures, direction information, diagnostic information, etc. at the lowest possible life-cycle costs.
As Part 2 of a comprehensive survey [1], this contribution gives an overview of the state of the art in axle counting, future requirements, technical opportunities and in particular the resultant benefit for rail operators and system suppliers (Figure 1).

1 Track vacancy detection – The basis of safe management

Track vacancy detection systems permanently monitor the clear or occupied status of sections, as well as points and block sections. Automatic track vacancy detection replaces visual checks by people and thus increases the safety of the respective signalling equipment.

Nowadays, track vacancy detection is the basis of automated and safe operational management.

The influential systems in automatic track vacancy detection are track-circuit and axle counting technologies. The first systems based on track circuits were developed and patented in around 1870. This technology found its way into many rail networks worldwide by the mid-to late-20th century and is still in use today in some areas.

Due to the weaknesses and limits of the principle of track circuits and the meteoric development of digital technology, track circuits are increasingly being replaced by axle counting systems [2,3]. Swiss rail operators were the first to introduce axle counting in around 1950. Today, the majority of rail operators rely on this safe and highly-available technology.

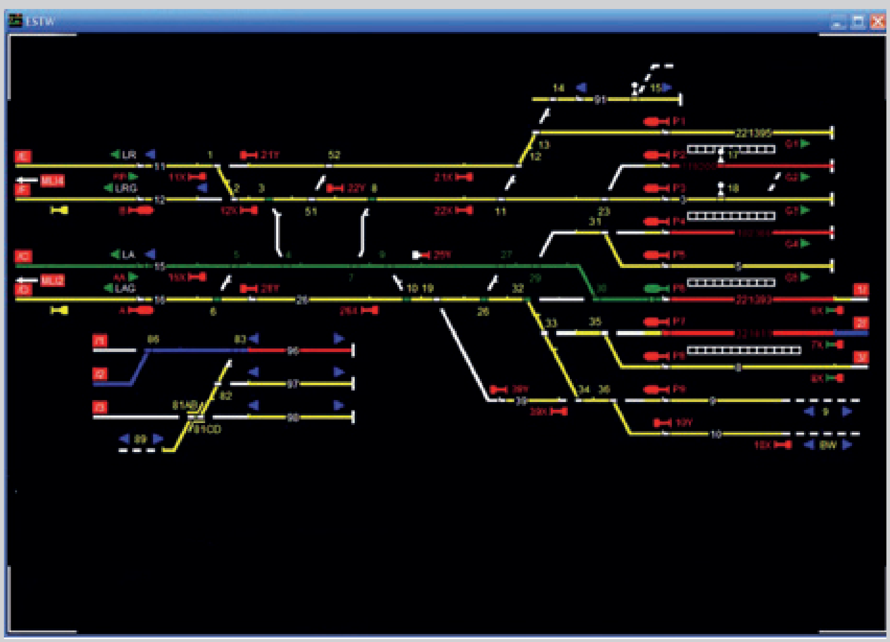

Figure 1: Track vacancy detection as a basis for safe rail operation

2 Track-circuit technology versus axle counting technology

The use of track circuits is still widespread today. This primarily relates to countries in which these systems are also used for transmitting signal information to the vehicle (e. g. Russia, France and China). But this technology is increasingly becoming less significant in modern railways due to its technical limitations with reference to the scope of information and the introduction of modern train-control systems such as ETCS, CTCS and CBTC.

One advantage of track-circuit technology is that the system requires no reset devices or procedures. An additional main argument for this principle is the ability to identify rail breaks under certain circumstances. There are numerous investigations and studies that conclude that track circuits in no way guarantee reliable identification of rail breaks. Figures of 20 % to a maximum of 60 % are cited [4].

In addition, practice shows that the majority of possible rail faults (see UIC Catalogue 712) have already been detected and investigated before a rail break occurs. Modern systems to monitor the state of the rail, regular rail work (grinding, milling) and also the rail-manufacturing procedures that have improved significantly in the last 25 years have allowed track circuits to be pushed to the background as rail-break recognition systems.

The disadvantages of track-circuit technology can be clearly seen when compared directly with axle counting systems. On the one hand, under specific environmental conditions, it is difficult to maintain rail insulation at the requisite quality level, due to inadequate ballast resistance (dirt, moisture, flooding). On the other hand, the unreliable electrical contact by light vehicles on rails with low train frequencies may lead to faults (availability, safety).

In the meantime, axle counting technology with its crucial benefits compared to the principle of track circuits has proved itself in practice to be a highly-available and safe system for track vacancy detection in the widest range of applications. Essentially, this technology is based on high-end wheel detection technologies. The quality of the wheel sensors used decisively determines the safety and reliability of each axle count.

Table 1 (compares the most important properties of modern axle counting technology with the principle of track circuits. See also [5, 6].

	Track circuit	**axle counting technology**
Track superstructure requirements	Electrically insulating	None
Measures with reference to track return current	Special measures required (meshing)	None
Sensitivity to external influences (e.g. overvoltages, track currents, etc.)	High	With high-quality wheel detection, can be compensated to the greatest possible extent
Sensitivity to climatic influences (e.g. heat, cold, dirt, etc.)	High, particularly with reference to ballast resistance (leaves, wetness, etc.)	With high-quality wheel detection, can be compensated to the greatest possible extent
Section length	Less than 2000 m	No restriction
Recognition of rail breaks	Possible under certain circumstances	Not possible
Reset	Not required	Required – various variants available
Functional scope	Track vacancy detection	Track vacancy detection, direction information Number of axles, number of wagons, speed, etc.
Monitoring of complex point structures, etc.	Can be carried out under certain circumstances	Can be carried out without restriction
Can be modified	Only with great outlay (superstructure adaptations; rail joints)	Simple (by mounting wheel sensor using rail claw)
Installation	Installation of rail joints Drilling of connection cable	Rapid assembly through the use of rail claws
Availability	TF – Gsk high NF – Gs average	Very high
Required travel cycles	24 hours	Up to 2 years
Maintenance outlay	High	Low
Installation costs	High	Low
Investment costs (components)	Comparable	Comparable

Table 1: Comparison of the most important characteristics of track-circuit and axle counting technology

3 Worldwide applications of axle counting systems

It is now impossible to imagine the main and regional railways in many countries of the world without axle counting systems. A significant increase has also been seen in metros, tramways and industrial railways. The benefits of the system and the additional functionalities of axle counting technology compared to the traditional principle of track circuits are increasingly winning out at an international level.

3.1 Sections and stations

The main application of axle counting is a consistent track vacancy detection in association with interlocking systems on open line and station sections. In addition to monitoring station sections that are short due to operational reasons (from a few metres up to several hundred metres), sections between two stations (up to several kilometres) are also monitored here. Fixed track vacancy detection is also a mandatory component of the complete system on the introduction or upgrading to ETCS Level 1 and 2 (Figure 2).

3.2 Back-up systems

Modern train control and train protection systems (e.g. CBTC, ATP, etc.) allow a high train density and an optimised running of trains. These highly-complex systems generally use proven fixed and automatic track vacancy detection as a back-up or fall-back plan.

Figure 2: Axle counting technology on modern main lines

Figure 3: Axle counting technology in the areas of shunting and industry

Figure 4: Tramway de Reims

3.3 Point changeover protection

Axle counting is often used as highly-reliable changeover protection for points. The clear or occupied notification is then evaluated as a release or locking of the point mechanism. A further application is the implementation of EOWs (locally operated electric points systems). Unlike track-circuit technology, axle counting technology can also be used unrestrictedly and easily for depicting multiple branching gridirons.

3.4 Level crossings

There are numerous opportunities for monitoring level crossings using signal technology – including with the use of axle counting. In this variant, a wheel detection component [1, 7] is used as activation and an axle counting section located in the centre of the level crossing (train has completely passed the level crossing) is used as a releasing element.

3.5 Shunting and industry

With its robust properties, its economy and, in particular, its higher range of functionalities (axle/wagon counting, wheel diameter, speed, etc.), axle count-

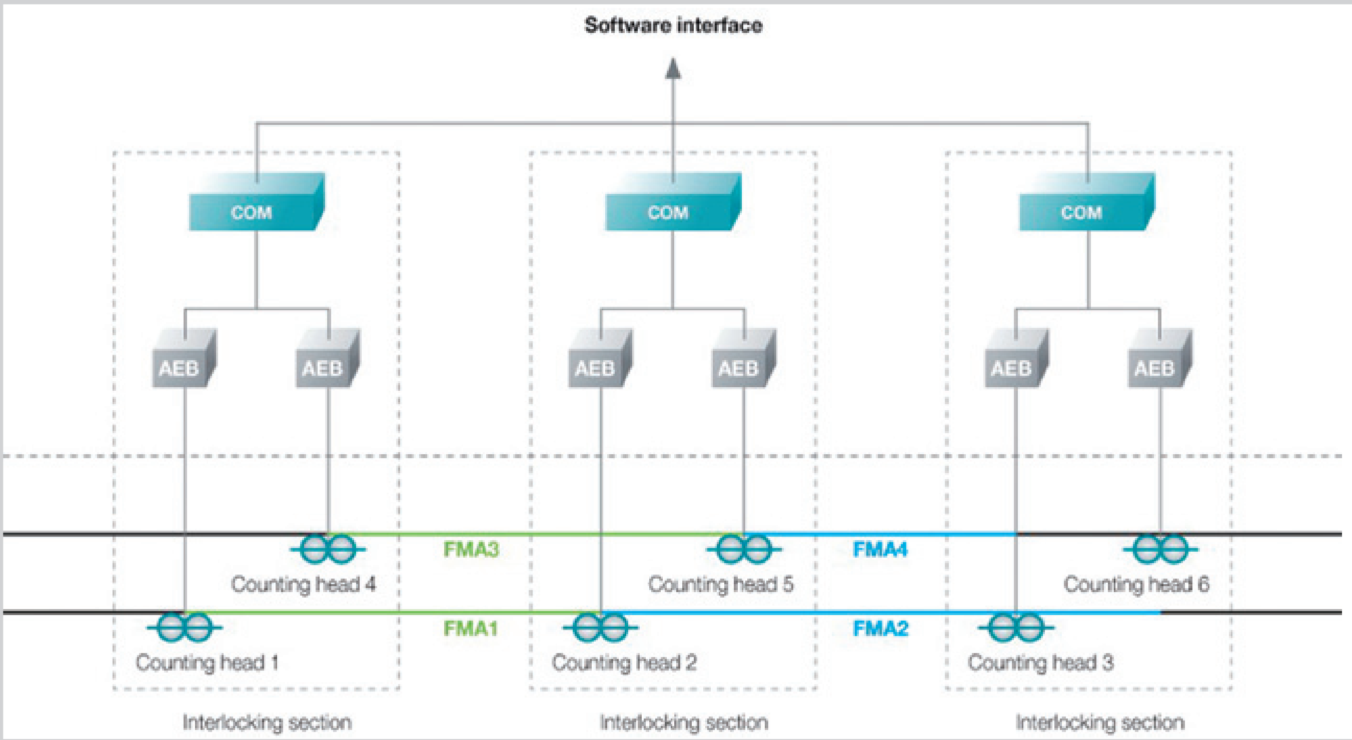

Figure 5: Centralised architecture as exemplified by the Frauscher ACS2000 axle counting system

ing technology has spread particularly quickly in the field of industrial plants, depots, and shunting and marshalling yards (Figure 3).

3.6. Metros and tramways

An area of application of axle counting that is not yet widespread but is growing rapidly is the field of metros and tramways. In addition to high levels of safety, aspects such as low repair and maintenance costs, as well as compatibility with all rail vehicles, are at the forefront. Here, particularly high requirements are set for wheel detection; see [1] (Figure 4).

Figure 6: ACS2000 – centralised architecture with fail-safe relay interface

4 Architecture

Track vacancy detection and axle counting are integrative components of technical signalling systems (e.g. interlocking, level crossings, EOWs, etc.). Also decisive for the future-proofing of axle counting systems will be their integration in modern signalling systems. Implementation in both centralised and decentralised architecture must be fully mastered.

4.1 Centralised architecture

A centralised architecture is understood as the entire arrangement of axle counting components at one site (e.g. interlocking area). The entire axle counting logic is bundled and positioned here. This design has so far been the rule, and is carried out using both a secure computer for several track sections (software configuration) and a secure computer per section (hardware configuration). Communication with the interlocking as well as the configuration, diagnostics, etc. takes place centrally. The depiction of section blocks can be implement-

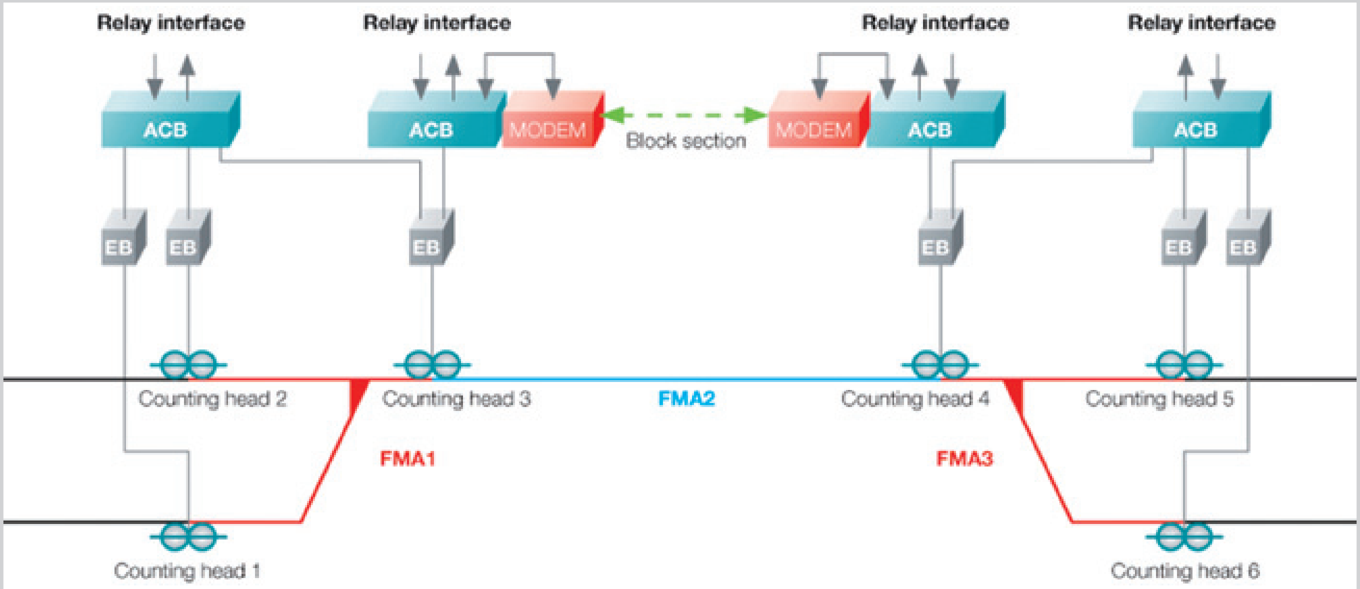

Figure 7: Decentralised architecture as exemplified by the Frauscher FAdC Advanced Counter)

ed using copper lines or optical-fibre lines (closed networks to EN 50159-1) (Figure 5, 6).

4.2. Decentralised architecture

Thanks to modern transmission technologies, decentralised arrangements are gaining in significance; they are becoming more economical in terms of the cable infrastructure, amongst other things. Unlike with a centralised architecture, the axle counting logic here is decentralised, distributed across several, freely-selectable locations. Here individual interlocking clusters along the section (field controller; area controller; object controller) are arranged, for example, in cabinets. These clusters communicate with each other through existing or new network infrastructures (open networks to EN 50159-2, Class 5). They are operated and maintained in decentralised mode from a higher-level location (Figure 7, 8).

5 Interfaces

Further significant features of integrability are the physical interface of axle counting technology to the higher-level system, as well as its information content.

5.1 Relay interface

The voltage-free, fail-safe relay interface has proven itself over the course of de-

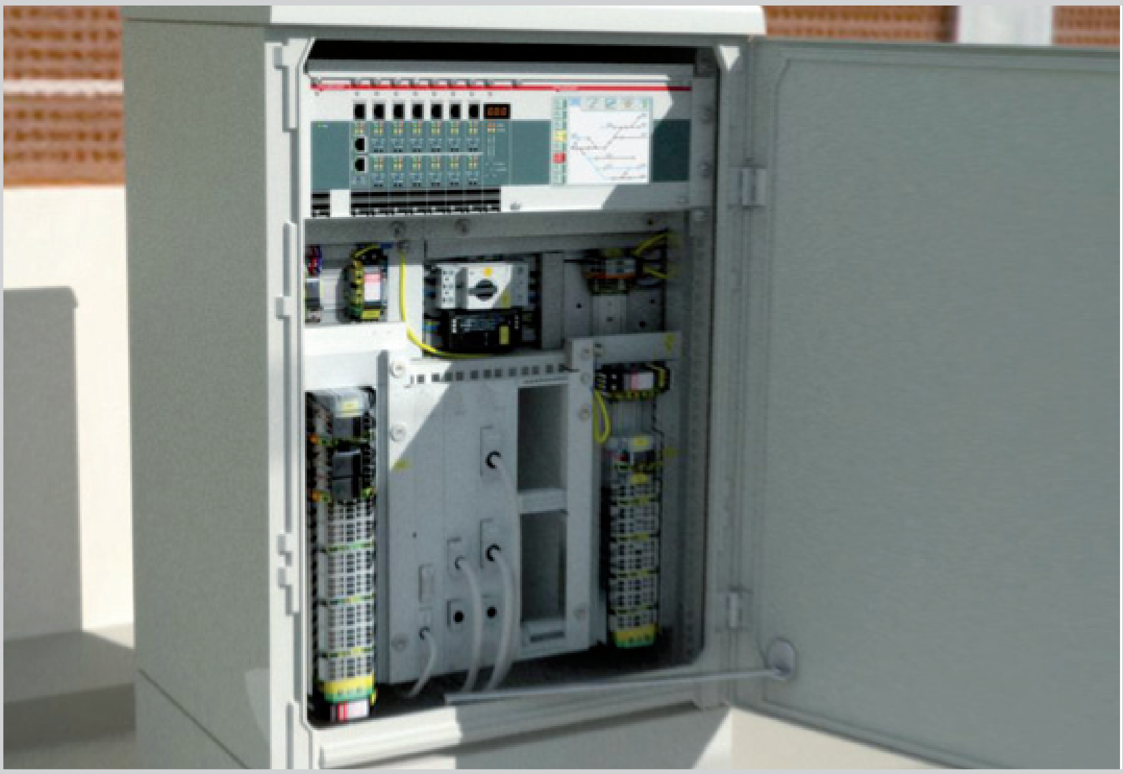

Figure 8: FAdC – decentralised architecture using a fail-safe software interface

velopment. At the forefront was the integration into electromechanical, relay and electronic interlocking. The information content generally includes “clear” / “occupied” as an output variable and “reset” as an input variable of the axle counting system.

5.2. Software interface

Decentralised architectures require modern serial and safe software interfaces. A link to existing, safe communications within an interlocking system must be possible. Compared to a relay interface, this technology allows the exchange of innumerable additional items of information. The serial connection and flexible configuration of the axle counting system open up almost endless opportunities.

The centralised and decentralised arrangement, as well as the interfaces, to some degree shape the optical appearance and the mechanical integration of the axle counting components. While standard modules have so far been used to a large extent in 19” board rack format, it is anticipated that the axle counting components will also be installed in modern plug-in housings or customer-specific container systems.

6 Functionalities of modern axle counting systems

At first glance, a current axle counting system provides information on whether a defined section is “clear” or “occupied”. Modern axle counting systems, however, are able to provide significantly more information than this. Significant functionalities and those that may be required in the future are described briefly here:

6.1 Reset variants

During the commissioning phase, and also for operational reasons (faults, maintenance, etc.), it is necessary to reset the axle counting system to a fault-free state.

Conditional (restricted) and unconditional (unrestricted) reset variants must be able to be achieved. The status of the track section, for example, is drawn on as a criterion for this (“last axle counted in”, “last axle counted out”, “partial traverse”, “negative axis”, etc.).

At times, the reset should be able to be carried out by the station master (CTC) alone or in collaboration with maintenance staff at the site of the equipment, dependent on the type of fault and the status of the system. Furthermore, reset variants with an urgent clearance drive (clearing of the section) may be requested – depending on the requirements of the operator. Figure 9 shows an overview of the various reset variants (Figure 9).

6.2 Partial traversing management

Fail-safe wheel sensors [1, 7] consist of two sensor systems, one for the clear detection of the direction of the vehicle and the other for reaching the safety level (CENELEC SIL 4). If the wheel sensor is not completely traversed for operational reasons (only one sensor system is traversed), the track section generally switches to the “occupied” status. In the case of a subsequent complete traverse, the partial traversing is then automatically reset. If no traverse is made, the section remains in the “occupied” state and must be returned to its original setting by the interlocking system.

From an operative point of view, including the safety of the complete system, the operator can request that the axle counting system has to suppress several partial traversing procedures (no “occupied” output). The number of per-

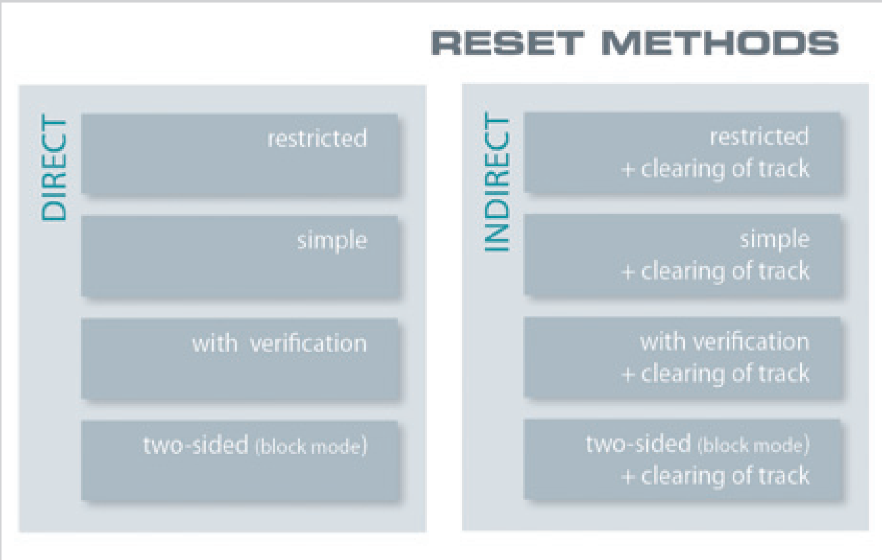

Figure 9: Reset methods of axle counting systems

mitted partial traversing procedures can also be configured.

6.3. Diagnostic information

Preventive maintenance, the optimisation of fault rectification, unrestricted online access to data from the axle counting system, the minimisation of maintenance work and the reduction of life-cycle costs are important aspects that are possible using modern diagnostic systems. With integration into a higher-level system, diagnostics play an increasingly important and system-critical role. A good overview of diagnostic tasks and requirements is given in detail in [8].

6.4. Direction output

The output of the traversing direction can be required in the case of safety systems on level crossings and in the shunting and industry areas. If this information is safely provided in accordance with CENELEC SIL 4, it can also be used for closing and opening level crossings and for the control and release of points in shunting areas. For reasons of integration, the direction output generally takes place using galvanically isolated optocouplers or voltage-free relays.

6.5. Speed, wheel diameter

The wheel detection [1,6] on which the axle counting is also based allows the complete system to output the traversing speed and wheel diameter if the wheel sensors are of a correspondingly high quality. A combination or integration of axle counting in SCFs (speed-check facilities), speed-dependent level crossings and in the case of humps (point position dependent on wheel diameter) is possible.

6.6 Counting head control

Naturally, the safe function of the axle counting system takes priority. At least as important is the maximum availability of the complete system. Availability can be further increased using the “counting head control” functionality, by which counting heads are moved to a type of stand-by mode under certain circumstances (e.g. if adjacent track sections are “clear”. In this idle state, a freely-configurable number of non-permitted dampings by tools, trolleys, pedestrians, vandals, etc. can be suppressed. With this procedure, no “occupied” status will be generated. This means that a reset is not required. Approaching vehicles switch off the stand-by mode and are therefore safely detected and output.

6.7. Configuration, control and operation

Railway operators and maintenance staff are being confronted with different and ever more complex equipment. In order to be able to handle these systems as optimally as possible, a simple and compact structure, as well as intuitive operation, is required. This starts back in the planning and design phase and continues through the configuration and commissioning phase to the operation and maintenance phase.

6.8. Parameterisable time response

The integration in various systems (ESTW, relay interlocking, SPS controls, etc.) and the use of radio in transfer sections require individual adaptation of the input and output variables of the axle counting system.

7 Development trends and challenges

Based on the functionalities shown and discussed above, there are several challenges in the development of axle counting systems.

Frauscher Sensortechnik GmbH has already brought out the main innovative features and is continuing to work on the implementation of these developmental trends, which are seen as follows:

7.1 Architecture and interfaces

The integration of axle counting systems will doubtless make advances in the existing architectures and interface plans of respective interlocking manufacturers. An expansion or push towards decentralised architecture and fail-safe software interfaces (Ethernet-based) is conceivable. A standardisation of these interfaces at European level would be desirable.

7.2. Compact and compressed construction

A prevalent trend is the often restricted space availability in interlocking environments and in enclosed cabinets arranged on each section. It is necessary to combine various functionalities (counting head evaluation, axle counting function, diagnostics, direction output, communication, etc.) and thus reduce them to a few components.

7.3. Remote maintenance

The increased centralisation of maintenance staff by its nature requires unrestricted remote access. Efficient diagnostic functionalities and mobile access (via web browsers, smartphones, etc.) will be the answer to this.

7.4. Simple configuration concepts

The merging of axle counting systems and interlocking will also need to be accompanied by an adaptation in terms of configuration and operation. Close collaboration and joint agreement by all parties involved in these areas is essential in order to be able to deliver a consistent and comprehensible concept to the rail operator.

7.5. Power consumption

As the decentralisation of components in the interlocking structure progresses, so does the requirement to minimise power input to the axle counting system (e.g. operation using solar cells, buffer batteries, etc.). Optimisation of these features will also shape further developments.

7.6. Trolleys, maintenance vehicles and special vehicles

The increasing spread of axle counting technology requires the reliable detection of various vehicle types. For example, in some countries the counting of trolleys must be suppressed, but maintenance vehicles and special vehicles must be accurately recorded. Depending on the rail operator, the requirements here may vary enormously. Special evaluation algorithms and functionalities of the axle counting system may be the solution.

7.7 Reset variants

In addition to the wide range of reset variants described above, there are increasing requirements for automated resets using "supervisory track sections". Here a higher-level track section (supervisory section) is defined for several freely-configurable track sections. As long as it is itself "clear", this higher-level section automatically resets lower-level faulty sections. Under certain conditions, this functionality may lead to a further increase in availability.

7.8 Additional information

"Clear" or "occupied" will no longer be sufficient as an input for the interlocking systems. Axle counting systems of the future must be able to deliver additional information such as wheel diameter, direction information, speed outputs, defined and freely-configurable output impulses or diagnostic information.

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8 Outlook

With the increasing, worldwide spread of axle counting technology as track vacancy detection, the demands on as well as the potential of such systems are also increasing. Modularity, flexible modern interfaces and comprehensive but optimal configurability of additional functionalities in axle counting systems provide the best conditions to meet the necessary requirements both as a stand-alone solution and as highly-integrated components in modern interlocking systems.

Modern communication interfaces between the interlocking and axle counting systems allow more economical, decentralised solutions with a maximum availability of information and data to be designed at any particular location.

The safety and availability of modern axle counting systems are crucially determined by extremely available wheel detection systems tolerant of interference. Further optimisation of the interface between the vehicle and the wheel sensor, as well as increasing standardisation in this area, will further accelerate the replacement of track-circuit technology by axle counting systems.

In addition to classic track vacancy detection, the potential for generating further additional information from wheel detection and passing this to higher-level systems will surely enable a whole series of new, integrated applications based on this.

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■ ZUSAMMENFASSUNG

Die Herausforderungen an Raddetektion und Achszählung in der Zukunft – Teil 2

Moderne Achszählsysteme sind heute in der Lage, viele über die Gleisfreimeldung hinausgehende Informationen an Gesamtsysteme zur Verfügung zu stellen. Funktionalitäten wie einfache Konfiguration unterschiedlichster Grundstellungsvarianten, kundenspezifisches Pendelmanagement, Diagnoseinformationen zur Minimierung der Life-Cycle-Costs, Ausgabe von Richtung, Geschwindigkeit oder Raddurchmesser sowie die innovative Zählpunktsteuerung sind nur einige Vorteile dieser Technologie.
Die Gleisfreimeldung bzw. die Achszählung sind mittlerweile integrativer Bestandteil einer Signaltechnikanlage (z. B. Stellwerk, Bahnübergang, EOW, etc.). Mitentscheidend für die Zukunftsfähigkeit von Achszählsystemen wird die Integration in moderne Signalsysteme sein. Dabei muss die Umsetzung sowohl in zentraler als auch dezentraler Architektur sowie die Datenübertragung mittels moderner und sicherer Softwareschnittstellen vollständig beherrscht werden.
Die Sicherheit und die Verfügbarkeit moderner Achszählanlagen werden maßgeblich von extrem verfügbaren und beeinflussungstoleranten Raddetektionssystemen bestimmt. Durch die weitere Optimierung der Schnittstelle zwischen Fahrzeug und Radsensor sowie die zunehmende Standardisierung in diesem Bereich werden Achszählsysteme weiter an Bedeutung gewinnen.
Längst haben moderne Achszählsysteme in vielen Ländern der Welt Gleisfreimeldeanlagen auf Basis des Gleisstromkreisprinzips abgelöst. Sie verstehen sich zunehmend als integraler Bestandteil von übergeordneten Stellwerks- und Signaltechnikanlagen.