Background information

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Holistic safety concepts for automating and operating AGV systems

Efficient and safe flow of goods

Ostfildern, February 2023 – **Mobile platforms such as automated guided vehicle (AGV) systems are making a considerable contribution to efficient processes in production and logistics. Both humans and AGV systems must be protected from collisions, and downtimes must be avoided. But what is needed to guarantee this? The right safety solution and an understanding of the specific application and the normative framework. A holistic approach is the best way to harmonise safety and productivity – from the individual vehicle to the complete system.**

Spatial, static separation between humans and machines is the traditional way to ensure safety in factory buildings. In modern industrial environments, however, rigid production lines are replaced by flexible production processes. Against this backdrop, it is becoming more and more necessary to use AGV systems – especially when, as autonomous mobile robots (AMRs), they are increasingly autonomous, flexible and less dependent on the fixed infrastructure they are operating in. This transition means that safety concepts must change too, so as to ensure that accidents do not happen in places where the workspaces of humans and machines overlap.

Part 4 of ISO 3691 is the normative framework

Part 4 of ISO 3691 (entitled “Driverless industrial trucks and their systems”) provides the normative framework for the safety of intralogistics applications. It elaborates on the requirements placed on AGV systems’ safety functions and the validation of vehicles’

automated functions, making it the most important international standard for AGV systems. In Europe, Part 4 of ISO 3691 is complemented by the standard EN 1175:2020 (“Safety of industrial trucks”), which relates to specific electrical aspects of driverless industrial trucks (including AGV systems).

Individual automated guided vehicles (AGVs) are defined as machines. Within Europe, this means that they must comply with the Machinery Directive and the associated standards, and the manufacturer must have them CE-marked. Part 4 of ISO 3691 adopts the methodology set out in Part 1 of EN ISO 13849 for determining the performance level (PL) required for using the various vehicle monitoring functions, operating modes and brake control.

Safe automation of individual AGVs

One risk that AGVs pose is the risk of impact with a moving vehicle. So, if a simple AGV follows a predefined track and may encounter obstacles along the way, Part 4 of ISO 3691 requires the AGV to comply with warning and safety zones based on speed, for example. If a person or an object enters the warning zone, then the AGV reduces its speed or emits a visual or acoustic signal to warn of an impending collision. If the safety zone is breached, the AGV is brought to a stop.

Safety sensors and safety controllers are used to technically implement the safety functions (such as zone monitoring) on the vehicles. Safety laser scanners take over such safeguarding and thus barrier-free and more productive area monitoring for collision

protection when compared to solutions with light curtains. In conjunction with a safety relay, the AGV is brought to a safe stop in case of danger. If additional safety functions (e.g. emergency stop) are to be covered too, a more flexible product solution is available, such as with myPNOZ – Pilz's modular safety relay. Users can put together a needs-based, individual safety solution from a wide range of possible variations. This can be supplemented at will, should the functions be expanded in the future, and thus offers a high degree of flexibility when designing mobile applications.

Safe automation of complex AMRs

Freely navigating mobile platforms (autonomous mobile robots, known as "AMRs" for short) can avoid obstacles or people without stopping – a feature that makes the required safety functions more complex. Especially for steering around bends, it must be possible to switch between several protection zones – the supreme challenge for safe automation in the mobile environment.

Safe sensor technology such as safety laser scanners continuously log the surroundings to ensure free navigation. For example, the navigation data can be read out directly over UDP interfaces to the robot operating system or software library (e.g. the C++ library or robot operating system (ROS)). Users can use this data for their own SLAM (simultaneous localisation and mapping) algorithm. Maps of the surroundings can thus be created for navigation purposes, enabling the mobile platform to avoid obstacles. The up to 70 protected fields of Pilz's safety laser scanner PSENscan allow such dynamic protected field adaptation. At high speed, these protection zones are larger to ensure that obstacles are detected at

an early stage. At slower speeds, they are correspondingly shorter to keep downtimes to a minimum. And that is how efficient AGV movement is guaranteed.

The safety laser scanner is also just one component of a safety solution when it comes to safe automation of AMRs. Because the protection zones are so complex, more parameterisation possibilities from the safety controller are also a must. The configurable and modular small controller PNOZmulti 2 from Pilz monitors one or two axes (per module) using motion monitoring modules. In the configuration tool PNOZmulti Configurator, an independent module program is parameterised by means of software blocks, allowing reliable selection of the corresponding zone of the PSENscan with just a few quick clicks.
With the E-STOP pushbuttons PITestop and the muting lamps PITsign, what users get is a complete package of solutions designed to efficiently and safely monitor mobile applications.

No safety without industrial security

Machinery safety isn't the only important aspect; industrial security plays an important role in intralogistics too. Increasing networking calls for additional protection. As freely navigating AGVs, AMRs communicate with their master controller by radio – making them vulnerable to external data access or tampering. Map data could be queried, and – in the worst-case scenario – AGVs and, therefore, ongoing production could even be shut down. An industrial firewall – such as the SecurityBridge from Pilz – protects the control network from tampering and ensures that no unauthorised

individuals can access the mobile platform’s internal IT network during operation.

Comprehensive identification and access management is a solution that extends beyond pure data and network security to protect AGVs from physical tampering or misuse. So, for example, mobile applications can be protected from unauthorised access using an access authorisation system such as the PITreader from Pilz.
To this end, depending on their qualifications the user receives their individual permissions on a compact RFID transponder, which they can use to authorise themselves directly within the process. The possibilities range from simple enabling as a replacement for a password and authentication for specific machine subfunctions, to company-specific coding for additional tamper protection.
Clear responsibilities, relevant permissions and logging of user actions all prevent mistakes and ensure optimum traceability.

Efficient solutions for robot and AGV transfer stations

Interfaces to and from AGVs must also be safeguarded accordingly. Two specific examples of this are as follows: In the tertiary or end-of-line packaging segment, products are grouped into larger containers. Robots then generally palletise them for shipping. Delivery of the “heavy” packaging materials to the plant and onward transport of the finished pallets are both often performed by AGVs or forklift trucks. To perform this task, they may enter the packaging plant’s danger zone, but people must be protected from the hazards they pose. In this situation, stationary safety laser scanners such as PSENscan from Pilz can be used for access or presence regulation purposes. Only if the laser scanner does not detect anybody in the

protection zone can the AGV enter the loading zone. If the AGV passes through the loading zone, individual switching through the AGV's protection zones takes place to dynamically "track" the position at all times. This prevents a machine stop, while the material flow remains undisturbed and productivity is ensured.

Maintaining a safe overview – even when palletising

In contrast, when loading and unloading pallets – as in the case with a sluice – an almost 3D protection zone monitoring system should be implemented with the help of a solution consisting of safe radar technology and safety light curtains. Safety light curtains such as PSENopt II from Pilz allow safe access to danger zones. Using an invisible infrared field, the light curtains protect against access to or entry into hazardous machine areas in accordance with Parts 1 and 2 of EN IEC 61496 ("Safety of machinery – Electrosensitive protective equipment") and detect either static or dynamic obstacles such as mobile robots. As safety devices running in the background, safe small controllers ensure that the area between the safety light curtains is monitored for human presence and that the packaging machine is brought to a safe standstill in case of danger. After loading, the safe radar system – e.g. PSENradar from Pilz – takes over enabling of the robot cell, including encroachment behind the protected area, so that everyone has vacated the danger zone when the robot starts back up again.

Safe operation of automated guided vehicle systems

Operators of single or even multiple AGVs or AMRs in the system face the task of complying with the requirements set out in Part 4 of

ISO 3691, all the while achieving the highest possible level of productivity. To achieve this, a variety of factors must be taken into account, even at the application planning and design stage. What are the structural conditions like? How can safety distances between tracks, objects and other vehicles as prescribed by occupational health and safety law be maintained? How can possible causes for collisions be minimised in advance? Where do additional protective devices and guards such as safety fences and doors or sensors (such as light curtains) need to be installed?

In any case, including safety as a topic in the initial planning process for an AGV system application is a sensible move. As soon as an initial idea for the application has been proposed, there is a basis for discussion and work can already start on a risk assessment. It is also important to bring all the faculties (particularly including electrics, mechanics and health and safety at work) to the table right from the start.

From the risk assessment to CE marking

A review of the AGV manufacturer’s risk assessment and a detailed analysis of the most important safety functions are also useful. Considering AGV system safety early on in the procurement process helps with avoiding unnecessary costs later on and minimises potential AGV system productivity constraints. On the user’s premises, this is followed by the final AGV system risk assessment, taking into account the entire environment of the on-site application. All the AGVs in use can be examined as part of this process.

The subsequent and required safety validation focuses on the installation and integration of AGV safety components such as scanners or encoders, the planning and switching of safety fields / zones, the safeguarding of the AGV's environment by means of further protective devices, as well as consulting services up to the declaration of conformity for the AGV system application as a whole. With its range of services for AGV system manufacturers and operators, the safety expert Pilz provides advice and support through to international conformity assessment (such as CE marking in Europe or OSHA conformity in the USA) and takes responsibility for the safety of entire AGV system applications.

After commissioning, it must be regularly checked that the AGV system is in a proper condition and working safely. Regular inspection of protective devices to ensure that they are up to date, installed properly and working safely ensures compliance with safety regulations and thus lays the foundation for improved staff protection or minimising risk and liability. As a result, a detailed inspection report is available for documentation. Independent inspection bodies accredited by DAkkS (the national accreditation body of the Federal Republic of Germany) in accordance with ISO IEC 17020 – including the likes of Pilz GmbH & Co. KG, Ostfildern – can carry out such an inspection in accordance with the strict specifications.

For sustainable knowledge building, users should also receive training on safely operating an AGV system application. In addition to the normative principles, the various safety devices or the technical functions of an AGV system also form part of the training content at Pilz.

Conclusion

Safety is the result of a bespoke AGV system solution for the application and an understanding of the specific application and the normative framework. Taking such a holistic approach with respect to the appropriate safety solution depending on the type of AGV – not to mention the AGV conformity to be achieved in the system – is the best way to harmonise safety and productivity. Both human and machine are protected, and goods flow.

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Illustrations

Fig. 1:
F_A_NAiSE_Traffic_Control_cold1_3c_1000x562 (© Pilz GmbH & Co. KG)

Caption: Everything flows. Taking a holistic approach to a bespoke AGV system that is specific to the application and having an understanding of the specific application and the normative framework is the best way to harmonise safety and productivity. Both human and machine are protected, and goods flow.

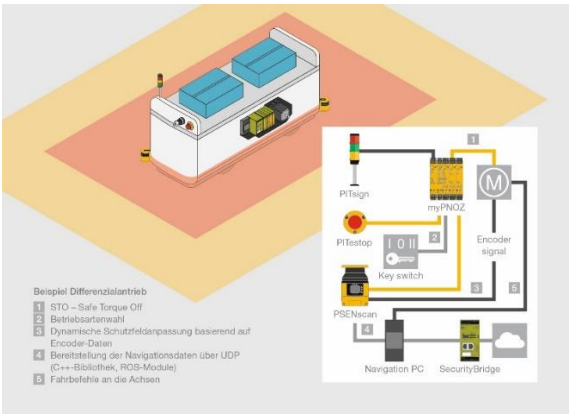
Fig. 2:
F_Group_3_PSENradar_SecurityBridge_myPNOZ_3c_1000x562 (© Pilz GmbH & Co. KG)

Caption: The Pilz complete solution includes the safety laser scanner PSENscan (collision protection for humans and AGV systems; see left), the modular safety relay myPNOZ (as one of two potential evaluation units; see right) and the industrial firewall SecurityBridge (tamper protection; see rear).

Fig. 3:
F_Press_Group_3_PSENopt_PSENscan_PSENradar_P1_B8_2_cold (© Pilz GmbH & Co. KG)

Caption: For safeguarding danger zones in end-of-line packaging: PSENradar, PSENscan and PSENopt II – safe radar systems and optoelectronic sensor technology for greater productivity.

Fig. 4:
F_Press_AGV_Example_of_a_differential_drive_de (© Pilz GmbH & Co. KG)



Caption: Pilz complete solution for safeguarding track-bound AGV systems consisting of the safety laser scanner PSENscan for productive area monitoring, the modular safety relay myPNOZ if additional safety functions such as emergency stop should be covered and the industrial firewall SecurityBridge for tamper protection.

Box

Five tips for safe operation of AGV systems

- Familiarise yourself with the details and limits of your AGV system technology. What safety functions are required for your AGV system solution, and where does the sensor technology reach its limits?
- Prepare the environment of your facility in good time. Perform a risk assessment in order to ensure that the environment is suitable for AGV systems and ascertain the extent to which safety requirements have an impact on productivity (e.g. due to speed restrictions in certain areas).
- “Less space”, “Higher speeds” or “Higher material throughputs” are counterproductive in terms of safety and require appropriate zone classifications and additional safety measures.

- Consider the risk not only for the AGV system, but also for the AGV system's entire intralogistics environment (e.g. during load transfers) within your existing infrastructure and potential requirements placed on additional participants in the flow of traffic.
- Carry out regular training, process audits, vehicle inspections and maintenance in order to guarantee the safety of your AGV system.

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ROS communication

The ROS framework is a popular, open-source robot operating system. The ROS packages of the Pilz safety laser scanner PSENscan can be used to write software for your very own robot deployments or entire robot applications. The packages contain specific functionalities and drivers. They are provided to users free of charge via a community. One advantage of the open source framework is the joint collaboration within the ROS community and the exchange with experts from various sectors – from research institutions to robot manufacturers. Together, users are able to implement even complex robotics applications successfully. Pilz develops and tests its ROS packages in accordance with the industrial quality criteria and requirements set out by the ROS Industrial Consortium, providing high-quality code for challenging industrial tasks.
ROS shows its particular advantages in dynamic environments, such as in the navigation of AGV systems and collision avoidance.

As the individual packages are modular they are versatile to use and are compatible with hardware from a variety of manufacturers. The use of programming languages such as Python or C++ is – alongside the open and free availability of the source code – another advantage of ROS. ROS can be used across a range of manufacturers, providing a networked, interoperable system completely in the spirit of Industrie 4.0.

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Fig. for ROS box: F_Press_PSENscan_6A00000_Q_B8_2_cold_2020_03 (© Pilz GmbH & Co. KG)

Pilz offers CE marking for AGV systems as a global service

If required, Pilz's automation experts around the world will perform the international AGV system conformity assessment right through to CE marking – even for the entire application. How is something like this implemented in practice? Pilz's Canadian subsidiary, for example, supported and carried out the CE conformity assessment for an AMR manufacturer based in Canada. The project involved CE marking three

types of AMR vehicles to be exported to Europe – including auditing and certification. The planned self-driving forklift truck series was to receive the CE mark too. All the vehicles needed to be compliant before being sold into Europe. The challenge: The vehicles were equipped with a non-certified, proprietary control system that naturally includes safety-related functions. No certification process was in place yet. Products carrying the CE mark are not subject to national regulations in the EU. After all, it is with good reason that the CE mark is also referred to as the “passport to Europe”.
Pilz used Part 4 of ISO 3691 as a working base, as it defines the safety-related requirements and verification with respect to industrial trucks. In close consultation with the client, the various aspects were worked out so a checklist could be created at the end to verify the EHSRs (essential health and safety requirements) in accordance with Annex E of Part 4 of ISO 3691.

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Fig. for CE marking box
F_material_handling_AGV_two_engineers_Tablet_iSt538053478_iSt1294795475_cold1 (© Pilz GmbH & Co. KG)

Manufacturer-independent fleet management

In addition to suitable safety solutions, software solutions for fleet management can also ensure that AGV systems get from A to B smoothly. In cooperation with NAiSE GmbH (the expert for material flow automation), the automation company Pilz offers the world's first traffic and order management software for all participants in intralogistics – for both humans and industrial trucks such as AGV systems or forklifts. Using sensor infrastructure and intelligent – as well as integrated and manufacturer-independent – communication, the traffic and order management software NAiSE Traffic safely and efficiently analyses the flow of traffic and goods in intralogistics applications in real time. As a result, operators have a complete, manufacturer-independent material flow automation solution. Congestion, bottlenecks or accidents are avoided. This increases safety and optimises traffic control – for greater transparency, efficiency and productivity.

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Pilz Group

The Pilz Group is a global supplier of products, systems and services for automation technology. The family business is based in Ostfildern and employs around 2,500 staff. With 42 subsidiaries and branches around the world, Pilz supplies safe solutions for human, machine and the environment. The technology leader offers complete automation solutions comprising sensor, control and drive technology – including systems for industrial communication, diagnostics and visualisation. An international range of services with consultancy, engineering and training completes the portfolio. Pilz solutions are used in many industries beyond mechanical engineering, such as intralogistics, railway technology or the robotics sector for example.

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