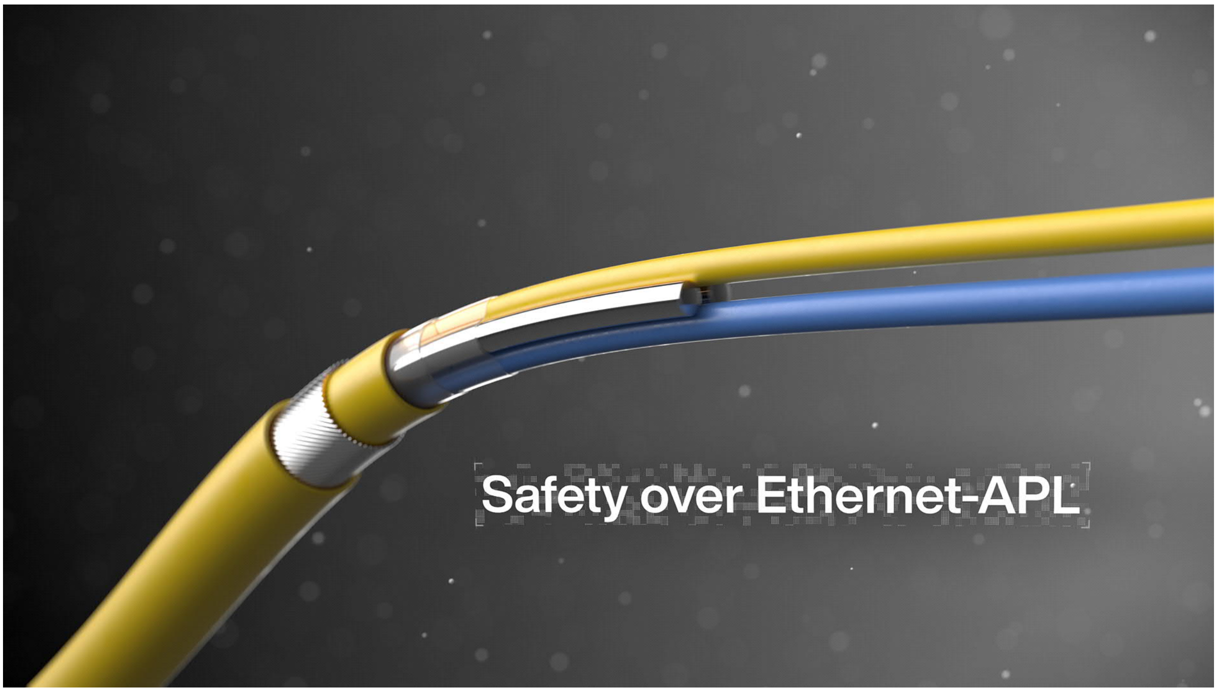
Ethernet-APL in the Field for high-availability Safety Applications

White Paper



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Executive Summary

Ethernet-APL [1] is a technology that enables powerful and consistent digital communication in process automation from the sensor to the control level. Ethernet-APL has all the features required by a modern, future-proof network in process automation. To fully exploit these advantages of digitalization, this white paper recommends taking the next logical step: Functionally safe (safety) automation should also be implemented utilizing the same network architecture.

Ethernet-APL's features and the advantage of its consistent use are presented and explained in this white paper. There is now a unique opportunity to consider the requirements for safety applications when investing in Ethernet-APL in process automation. In order to facilitate market entry and avoid additional subsequent investments.

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1. Status Quo

The dominant transmission technology worldwide today for process control and safety connection of field devices in the process industry is the analog 4-20 mA technology.

Around the turn of the millennium, process plants provided the platform for the first installations with the PROFIBUS PA and Foundation Fieldbus H1 (FF) fieldbuses developed for the process industry. Compared to 4-20 mA technology, the use of fieldbus technology offers cost and application advantages, including the reduction of cabling effort, higher signal quality through digitalization and faster commissioning. However, initial technical difficulties, caused by faulty device implementation and the lack of experience with the application on the operator side caused significant problems with adoption of this technology in the process industry.

Even today, fieldbus technology is often perceived as too complex. A closer look reveals two major problem areas: the mapping of fieldbus functionality to the control system, and the lack of possibilities and willingness to train and educate operating personnel. In the meantime, fieldbus technology has developed further, e.g. through the introduction of new device profiles, which have made it easier to use in the control systems. While the use of fieldbus solutions in other automation areas (e.g. factory automation, building automation) is state of the art, the fieldbus remains rare in process automation.

For new plants in which the fieldbus is used for process control, safety infrastructure continues to be implemented conventionally with 4-20 mA technology, even though NAMUR has been advocating the use of integrated digital communication for years. Over time, this has become an accepted practice by both operators and manufacturers. Due to the lack of acceptance of fieldbus technology, manufacturers have shied away from the very high investment costs for the development and market launch of safety field devices. For operators, the focus of safety applications is on proven operation.

Today, the safety infrastructure from the field device to the controller is built separately from the infrastructure required for process control. This is justified by the recommendations of the standards relevant to safety, such as IEC [2] and IEC 61511 [3], as well as the required reduction in complexity when planning and applying safety systems. A physical separation of both systems increases diversity and independence of hardware and software, which in turn increases availability. However, maintaining two independent technologies increases the overall effort, for example in warehousing and training.

2. The Enabler Technology: Ethernet-APL

With Ethernet-APL [1] new network concepts are available for process automation. The significantly increased bandwidth compared to previous fieldbus systems and the suitability for hazardous areas, zones 2/1/0 offer the possibility to establish uniform digital communication in the entire plant. This results in new types of use cases (e.g. NOA [4] 2nd channel) that are either currently not able to be implemented with fieldbus or can be solved only at great expense using conventional transmission technology. Figure 1 shows an exemplary Ethernet-APL architecture.

A power switch is the link between the control system network and an Ethernet-APL 2-wire, 10 MBits/s segment. It adapts the baud rate and the transmission physics and simultaneously provides the power for the Ethernet-APL segment. The field switches connected to the power switch are supplied by the segment and in turn supply the field devices connected to it. This trunk-and-spur topology is supplemented by the use of separately powered field switches, which are both the link between the control system and the Ethernet-APL and also enable the connection of field devices. (See topology picture, Figure 2 in chapter: “Benefits when Using Ethernet-APL“)

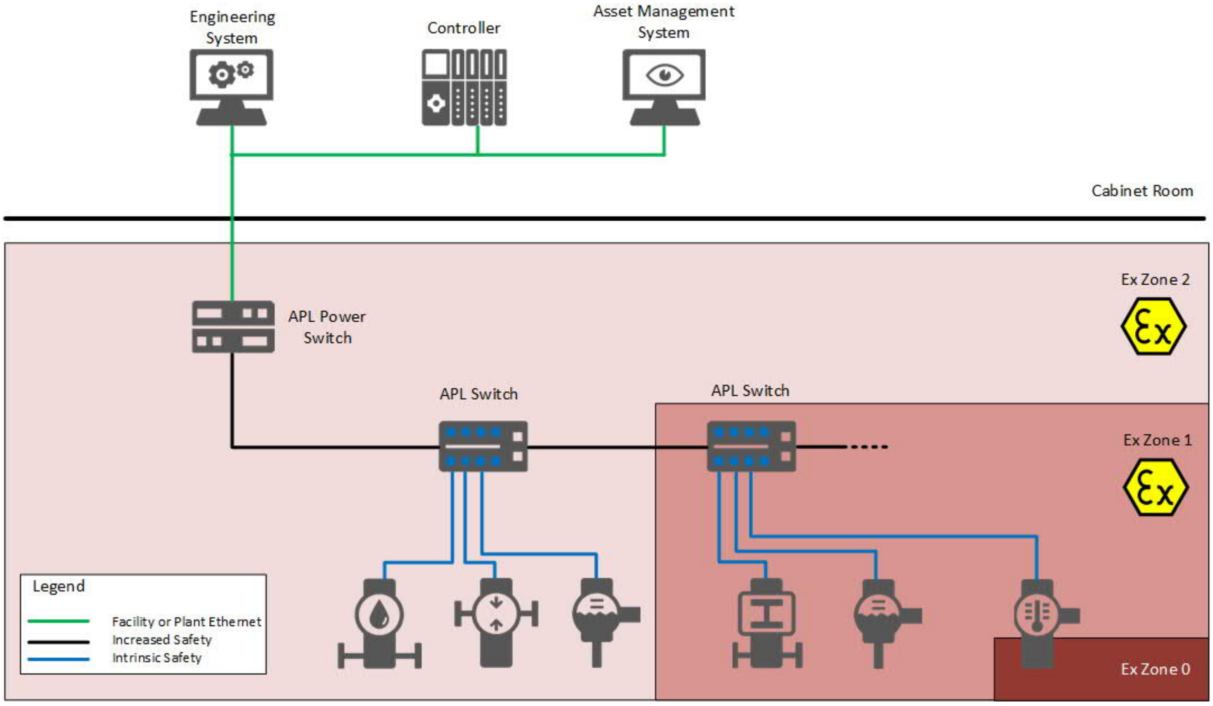

Figure 1: A possible Ethernet-APL architecture

As Ethernet-APL is an innovative concept, it might be applied primarily to new plants (greenfield). For existing plants, the solutions described in this white paper may be of limited use.

A Note on Security

This white paper considers only the safety-relevant aspects and does not cover topics beyond that, such as security. Security concepts are discussed in NAMUR working groups, fieldbus organizations and standardization committees. The solutions (see [12] and [13]) developed there must also be applicable to safety applications and are then integrated into this concept. Since safety depends on sufficient security, it is strongly recommended that the recommendations of the protocol providers and the relevant guidelines and standards are followed. In particular, these are IEC TR 63069 [5], the IEC 62443 [6] series and the ISO/IEC 27000 [7] series. The measures described there are also fully applicable to the solution shown here.

3. Benefits when Using Ethernet-APL

Ethernet-APL offers many advantages, the most important of which about safety applications are mentioned here.

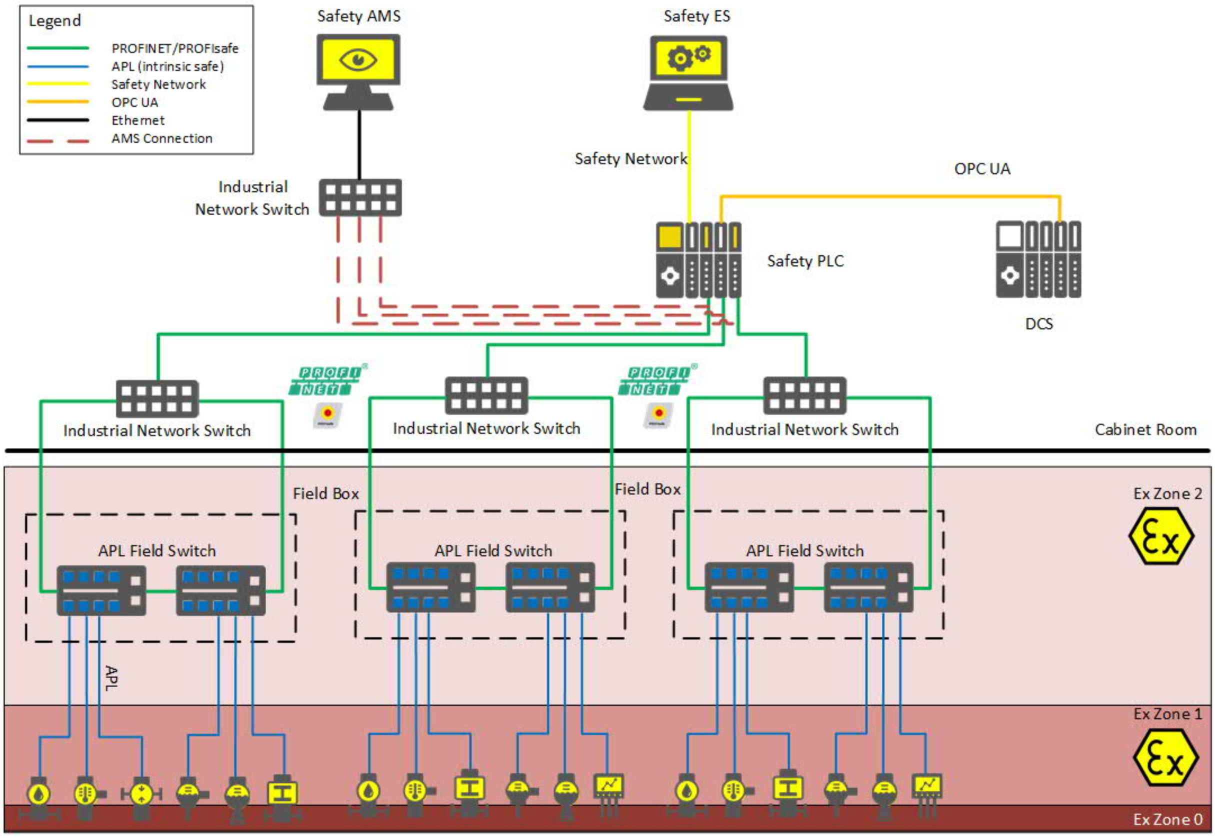

Figure 2: A possible safety-related architecture with Ethernet-APL and connection to a plant asset management system. The picture shows a high available architecture. Because Ethernet-APL is scalable, for example a single ring for SIL 3 applications is sufficient.

Applications up to SIL 3

With its increased performance, Ethernet-APL also enables safety data exchange. PROFIsafe is a solution that is widely used in factory automation with many years of experience on which process automation users and vendors can rely. The existing requirements for safety applications are handled by such a safety technology, such as:

- Compliance with current requirements according to IEC 61784-3 [8]. (Industrial communication networks)
- Reaction times sufficient for the process, even with additional acyclic data exchange
- Sufficient consistent data quantities for the control and interrogation of actuators and sensors

Although safety can be used in combination with non-safety protocols, it is strongly recommended that these be set up in physically separate networks for increased safety.

An agreement on uniform safety communication when using Ethernet-APL offers the most economical solution for all parties involved (component manufacturers and plant operators):

- Manufacturers of sensors, actuators and controllers only need to implement, certify and maintain one protocol.
- Operators and integrators only need to provide the commissioning and maintenance know-how for one infrastructure and one protocol family.

Increased Measurement Accuracy

The widespread application of modulating a HART signal to the 4-20 mA signal provides (non-safety) access to additional parameters and allows better maintenance concepts. Superimposing the HART signal influences the measurement signal and thus leads to reduced measurement accuracy.

With Ethernet-APL, measured process values can be transferred directly to the automation systems without loss of quality, since they are already available in digital form in the field devices. This provides additional measurement accuracy, available for optimized process control and increased safety. Transmission errors can be reliably detected and do not falsify the measurement result.

Increased Flexibility

As explained in this document, digital measuring points offer many advantages over analog measuring points. These are e.g. high accuracy, the transmission of several values or the automated evaluation of these measuring points.

It is a common procedure to perform new HAZOP studies during the life cycle of a plant. Based on the HAZOP findings, it may be necessary to convert operational measuring points into safety measuring points. This currently means a conversion from digital to analog interfaces (Figure 3). The described conversion does not only mean the physical exchange of the field devices necessary and a revision of the wiring level. The conversion also means that the optimization already implemented in the basic process control system by means of fieldbus technology is partly lost again. This disadvantage can be eliminated with Ethernet-APL as control measurements and safety measurements are based on the same communications technology (Figure 4).

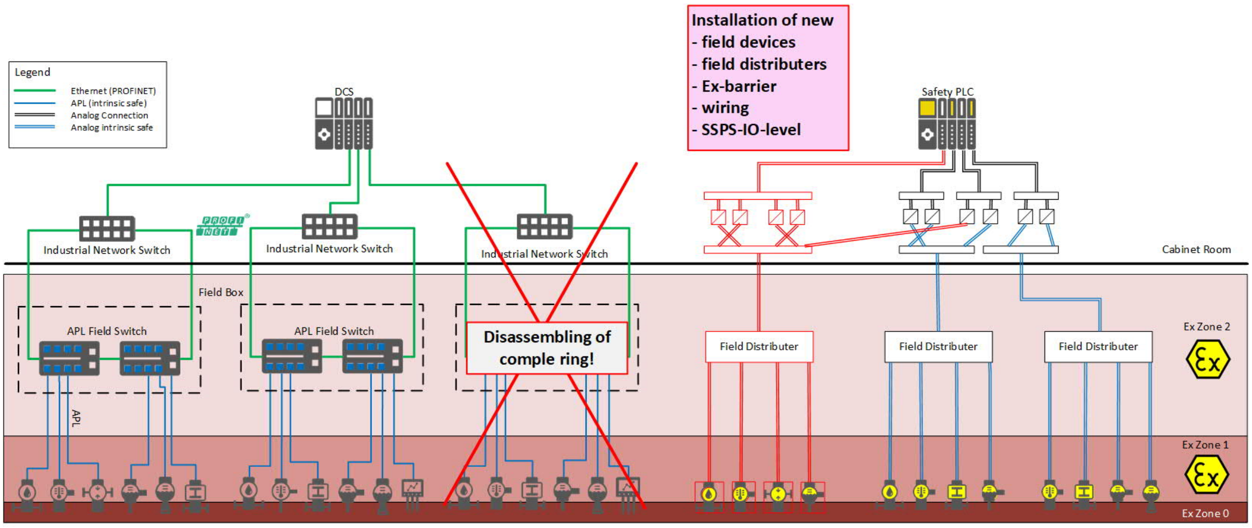

Figure 3: A mixed architecture Ethernet-APL and conventional safety application

A uniform design of future instrumentation with digital transmission would lead automation back to the original NAMUR approach, as with the introduction of the NE43 [9] signal as a transmission standard.

A new standard device, which is suitable for both operational automation and safety applications, is the basis for an integrated automation concept that can provide an answer to the increased requirements. The variety of devices and technologies in a production plant can be greatly reduced. Diagnostics and maintenance information are available where they can achieve the greatest savings in a plant: with the PCS safety devices.

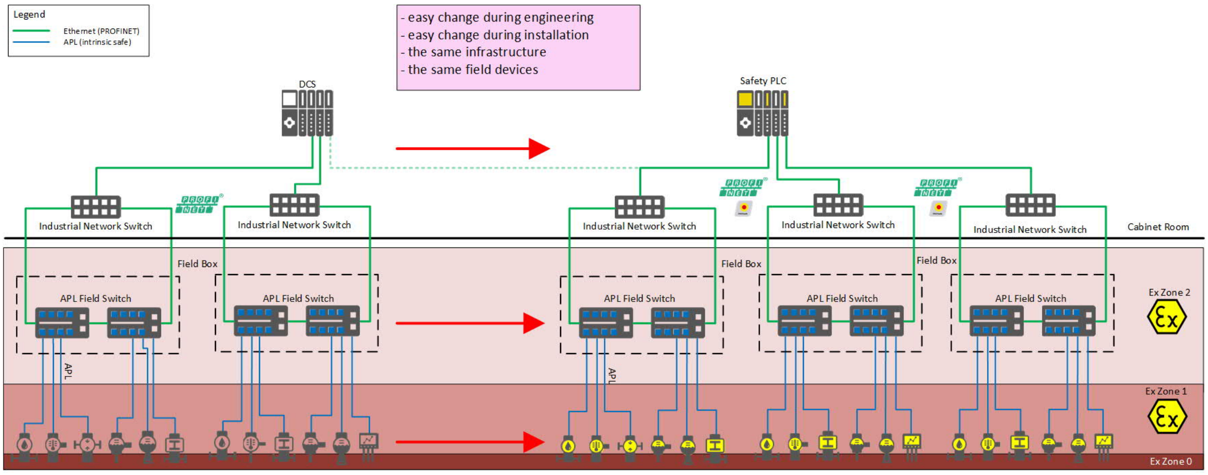

Figure 4: A uniform communication technology for process control and safety application

Optimized Diagnostics

A uniform infrastructure for safety and non-safety applications offers the possibility of implementing the same diagnostic concepts for field devices, network technology and automation systems.

With the pure 4-20 mA signals currently used in safety applications, diagnostic information can only be transmitted via a failure signal. This leads to the activation of the affected channel of the safety function. With Ethernet-APL, a differentiated evaluation and reaction to alarms without loss of measured values would be possible. In addition, an evaluation of maintenance messages with the aim of reducing the testing effort can also be realized with Ethernet-APL, allowing for regular and comprehensive inspection of the devices while the system is running.

For self-monitoring and diagnosis of field devices, it is recommended to use NE 107 [10] as a basis. The diagnostic data of this field device generation should be uniformly evaluated independent of the field device manufacturer. NE 131 [11] must also be followed and may have to be extended in this context.

With digitalization initiatives such as Industrie 4.0, the process industry has found ways to automate many time-consuming, manual evaluations by collecting diagnostic information and processing it.

The precise device information and the resulting more targeted action instructions will lead to simplified troubleshooting by maintenance personnel.

More Efficient Maintainability

The process industry has been striving to increase the use of automation for years. However, this increase leads to an overall increase in complexity, both for the network and in the functional and operating requirements of the field devices. At the same time, the industry is struggling with a growing shortage of skilled workers in maintenance units. For predictive maintenance, the transmission of digital additional information to the actual measurement signal is helpful. Support for the requirements of NE 107 has already been mentioned in the chapter Optimized Diagnostics . In addition, extended production runtimes of plants are made possible, since many tests can be performed without interruption during operation.

Efficient maintainability should include simple device management. Based on application profiles, devices can be replaced in the event of a fault without additional engineering. In addition to simplified device management, a uniform infrastructure also helps to reduce the effort required for maintenance and servicing.

Uniform Infrastructure

Plant operators expect the possibility of a uniform infrastructure with (almost) identical field devices, both for process control and for safety applications. Two separate field communication technologies should be a thing of the past. For this reason, plant operators can expect an applicable solution for safety communication via Ethernet-APL that should be provided from the very beginning.

High Availability

The unreliability of networks feared when Ethernet was introduced in industry has not been proven. As early as the beginning of the 2000 s, a 100 m long patch cable was laid several times around a welding transformer in a test setup at an automobile manufacturer in the vicinity of an active production facility. During the 16-day test 538,562,446 telegrams were exchanged (this corresponds to 389.5 telegrams/s). In total, only 15 messages were disturbed during this period. Although Ethernet was not originally developed for the industrial environment, it has proven its robustness during testing and since then in daily use. Ethernet-APL was developed from the outset for the industrial environment. This means that at least as much robustness can be expected.

The flexibility when implementing Ethernet architecture also contributes significantly to the availability of a system. This means that previously common star topologies can be selected where the failure of individual devices has no effect on the overall system. Alternatively, it is possible to construct ring topologies (see Figure 5), which often require less complex cabling, while providing a high level of protection for plant operations from negative of repercussions if one component fails.

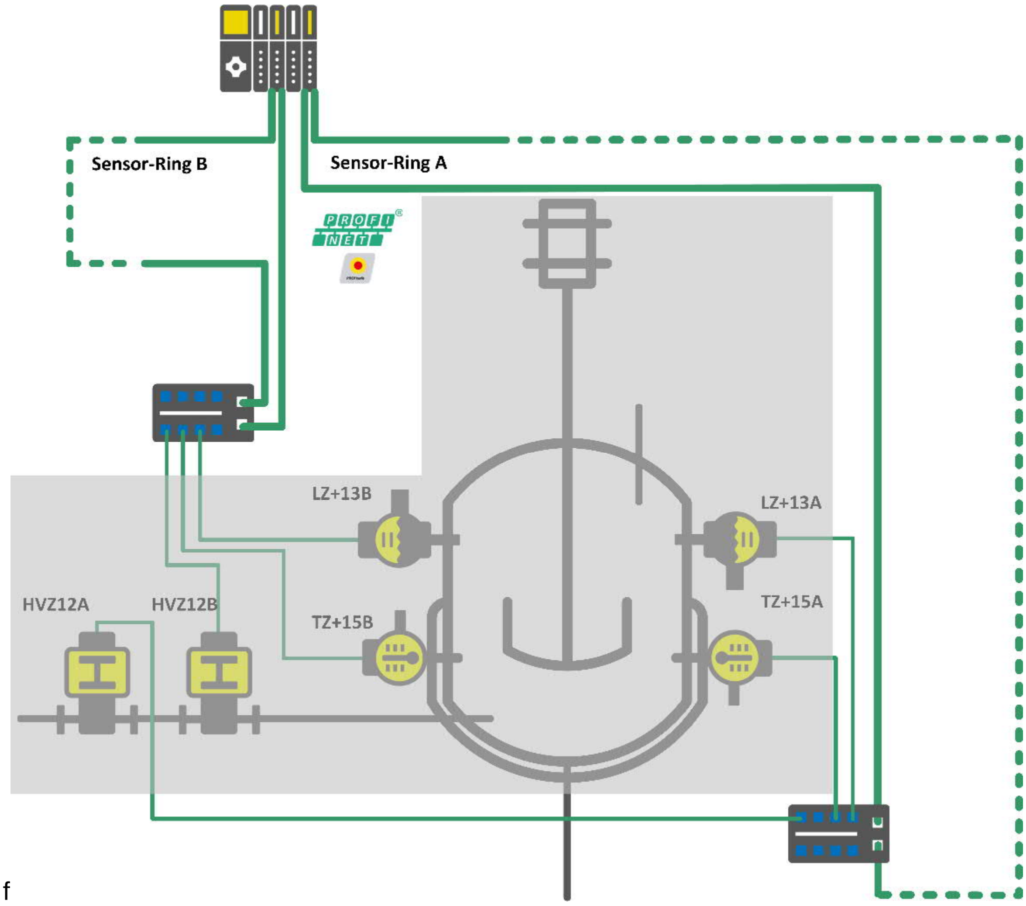

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Figure 5: High availability using ring topology

Ethernet-APL Future Proof

The introduction of Ethernet technology into automation and Ethernet-APL extending the same communication to the field within process plants, enables users to leverage all economic advantages of Ethernet everywhere. For example, only one type of infrastructure needs to be maintained and the number of costly point-to-point transmissions can be reduced. This is also guaranteed by high performance and high bandwidth.

Ethernet-APL constitutes a manufacturer-independent, open and expandable technology, which is based on IEEE and IEC standards and backed by major user organizations. This ensures the continuous further development and future-proofing of Ethernet-APL. For this reason, it can be expected that the number of available Ethernet-APL devices will also increase continuously. It is thus only logical to use these advantages for safety applications as well.

Simple Device Replacement and Monitoring

In case of a device exchange it is possible to parameterize it completely digitally, e.g. the setting of measuring spans for the analog measured value is no longer required. It is also possible to automatically detect field devices on the network, generate alarms if devices are used which are not intended for this measurement loop, or if devices are in simulation mode.

Flexible Planning and Reduced Commissioning Effort

Experience in existing fieldbus systems with a separate field communication technology and infrastructure for process control (fieldbus) and safety applications (4-20 mA) shows a considerable additional expenditure due to the double planning, maintenance and stock-keeping. It should be noted that these technologies no longer meet the requirements of modern automation solutions, while at the same time causing increased expenditure.

Ethernet-APL technology creates a uniform technological basis for safety and non-safety systems. This significantly simplifies and accelerates the activities associated with planning and commissioning because both, the field component itself and the experience gained from the non-safety infrastructure can be adopted identically for the safety systems.

4. Challenges when Applying Ethernet-APL

New Requirements for Devices

The field devices should be provided with write protection to prevent accidental or intentional manipulation of the parameters. Ideally, the device should have hardware and software write protection selectable. Acyclic diagnostic queries must be differentiated between pure diagnostics (without influencing the safety function) and test routines (with influence on safety function, e.g. brief freezing of the measured value, slight variation of the signals). Pure diagnostic functionalities should also be available with activated write protection, whereas test routines require deactivation of the write protection.

Unified Device Concept

Since plants have a longer useful lifetime compared to field devices, field devices are likely to be replaced during the life cycle of the plant. This can be an exchange with similar devices of a new generation. These devices must operate with parameterization that is compatible to the previous version. Users may wish or have the need to utilize different measurement methods or manufacturers. Ideally, similar devices can be used in DCS and safety loop. This makes conversion from DCS to SIS very simple. For the rededication of field devices already mentioned in the chapter: Increased Flexibility, only the application of the DCS and SIS would have to be adapted accordingly and the safety communication of the field device activated.

If this can be implemented economically, the procurement and warehousing of field devices throughout their entire life cycle will be significantly simplified.

Market Acceptance

The widespread use of Ethernet-APL field devices in both, operational and safety applications, requires that all common measuring principles are available with this technology. These include pressure, temperature, level and flow. To justify the investment in the Ethernet-APL infrastructure, at least 80-90% of the field devices in a plant must be connected via Ethernet-APL.

Furthermore, the components (Ethernet-APL field devices and Safety-PLC) must be developed and certified according to IEC 61508 for use in a safety application.

For a high acceptance of the solution on the market it is essential that it is easy to handle. Past experience has shown that a reduction in complexity leads to success and acceptance of new technologies.

Accompanying training opportunities for employees and additional information material (such as installation guidelines) are indispensable when new technologies are introduced. Appropriate commissioning and diagnostic tools facilitate handling of the new technology and thus contribute to increase in acceptance.

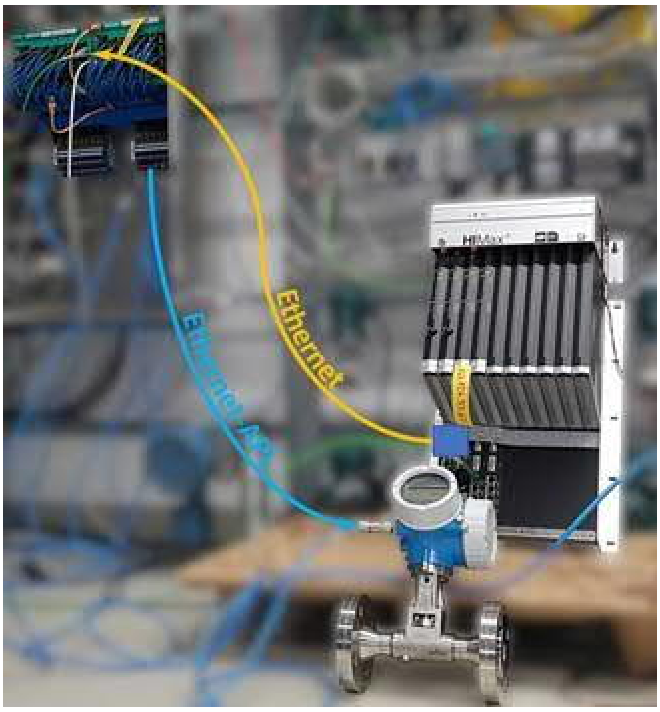

Figure 6: The world's first SIL 3 communication on Ethernet-APL: One infrastructure for safety and standard instrumentation

5. Conclusion

Ethernet-APL offers the potential of unifying the infrastructure of safety and non-safety. This is made possible while maintaining full physical separation of safety and process control networks and thus maximum availability and safety. And this is done consistently throughout the entire plant with full transparency of the data over the entire life cycle of the plant. In this way, future solutions in process automation can be created that enable minimum complexity with maximum cost-effectiveness.

A prerequisite for this is that users select Ethernet-APL as the infrastructure of choice across the board for integrating field devices in the plants and that the necessary portfolio for safety applications is also available.

This will arise when the described solution concept is adopted as an industry standard in process automation. A strong support for this would be a NAMUR recommendation, which must be developed afterwards.

6. References

[1] Ethernet-APL:
https://standards.ieee.org/standard/802_3cg-2019.html
https://www.profibus.com/download/apl-white-paper/

[2] IEC 61508 https://www.iec.ch/functionalsafety/
Functional safety of electrical/electronic/programmable electronic safety-related systems

[3] IEC 61511 https://webstore.iec.ch/publication/5527
Functional safety - Safety instrumented systems for the process industry sector

[4] NOA … Namur Open Architecture https://www.namur.net/fileadmin/media_www/fokusthemen/NOA_Homepage_DE_2018-06-20.pdf

[5] IEC TR 63069 https://webstore.iec.ch/publication/31421
Industrial-process measurement, control and automation - Framework for functional safety and security

[6] IEC 62443 https://webstore.iec.ch/searchform&q=62443
Industrial communication networks - Network and system security

[7] ISO/IEC 27000 https://webstore.iec.ch/searchform&q=270*
Information technology - Security techniques - Information security management systems

[8] IEC 61784-3: https://webstore.iec.ch/publication/61165

[9] NE 43 … Standardisation of the Signal Level for the Failure Information of Digital Transmitters

[10] NE 107 … Self-Monitoring and Diagnosis of Field Devices

[11] NE 131 … NAMUR standard device - Field devices for standard applications

[12] PROFINET Security Guideline
https://de.profibus.com/downloads/profinet-security-guideline/

[13] NA163 Security Risk Assessment of SIS

7. Glossar

APL	Advanced Physical Layer for Ethernet
BPCS	Basic Process Control System
DCS	Distributed Control System
Ethernet-APL	Ethernet Advanced Physical Layer
FF	Foundation Fieldbus
FPLC	Safety-related programmable logic controller
HART	Highway Addressable Remote Transducer
HAZOP	Hazard and Operability
NOA	Namur Open Architecture, see: https://www.namur.net/fileadmin/media_www/fokusthemen/NOA_Homepage_DE_2018-06-20.pdf
PA	Process Automation
PCS	Process control system
SIS	Safety Instrumented System

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