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APPLICATION EXAMPLE

Migration Guide for Tunnel Automation

from SIMATIC S7-400H with PROFIBUS to S7-1500H with PROFINET

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Table of contents

1. Introduction 4
1.1. Tunnel requirements 5
1.2. Scenario 6
1.2.1. Initial situation 7
1.2.2. Target state 8
1.3. PROFINET System Redundancy (informative) 9

2. Concepts 10
2.1. Controller swap first 10
2.2. Parallel operation 11
2.3. Distributed I/O swap only/first 13
2.4. Innovated legacy system with (PROFIBUS and) PROFINET 14

3. Technical aspects 15
3.1. Distributed I/O 15
3.1.1. Selection of successor products 15
3.1.2. I/O adapter 17
3.1.3. Exchange strategies 18
3.2. Field Topology 20
3.3. User program 22
3.4. PLC communication 23
3.5. Simulation 25
3.6. Cyber Security 26

4. Appendix 27
4.1. Service and Support 27
4.2. Application support 28
4.3. Links and literature 28
4.4. Change documentation 28

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1. Introduction

This document presents different concepts and approaches for the modernization of existing automation solutions in traffic tunnels, especially with a focus on the components of the PLC control and the distributed I/O periphery. It is primarily addressing planners and integrators at the beginning of the planning phase of such projects.

The modernization aims to maintain the performance and reliability of the systems used in the long term and to adapt them to modern requirements, e.g. with regard to data integration and cyber security.

Motivation: Product phase-out of I/O components

The reason for an overhaul is often the replacement of discontinued components, for which sufficient spare parts availability will no longer be guaranteed in the long term. In the SIMATIC portfolio, this currently applies above all to the I/O series ET 200S and ET 200M, whose life cycle is coming to an end.

It is important to emphasize that switching to newer generation products is essential to provide up-to-date functionality, reliability and security. These factors benefit the operator through lower maintenance costs, higher efficiency and higher availability, so that downtimes can be sustainably reduced.

On the other hand, it is also clear that such a switch can be associated with effort, costs and technical challenges. In all this, the disruption to ongoing operations must be as low as possible.

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1.1. Tunnel requirements

The main focus of automation solutions in the field of public transport infrastructure is on availability and smooth operation, ensuring the safety of all road users and infrastructure at all times. Continuous monitoring is just as important as protection against threats in the field of cyber security.



The operation of traffic tunnels entails special conditions that make it difficult to modernize the system components. This is because the impact on the local traffic flow is considerable in the event of an impairment or closure of the tunnel. In turn, they can result in serious losses for the economy and public acceptance. Functional safety must also not be endangered during the conversion process.

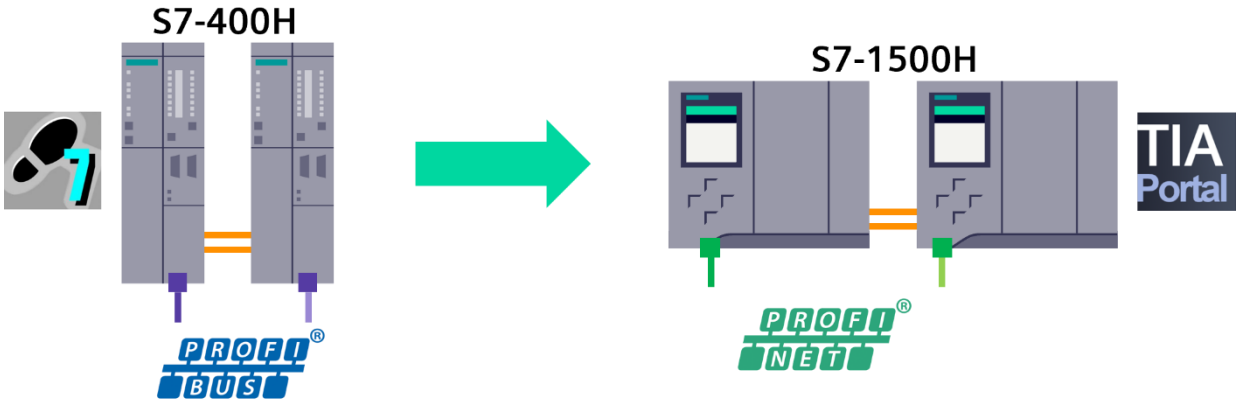
The migration of the automation hardware must therefore be carefully planned and prepared to minimize the downtime required to carry out the measures. Furthermore, it may be necessary to divide the implementation into several operations and to schedule it at times with lower traffic load. The concepts described below therefore take particular account of the possibility of a step-by-step approach. The number of devices and the size of such plants alone can require an approach in several stages. Also the costs for modernization are considerable for projects of this size.

It stands to reason that in the course of a major modernization, the technology of individual functions of tunnel automation will also be overhauled or replaced, e.g. for energy-saving LED lighting with modern control according to the DALI standard. Although such projects are not explicitly dealt with in this document, it is essential to consider them together in the course of a specific project.

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1.2. Scenario

This guide is primarily intended to serve as food for thought and a basis for discussion. In the following, a typical modernization scenario of tunnel automation will be discussed, which reduces the variety and complexity of real projects to a simple example:



	Initial situation	**Target state**
Controller	S7-400H	S7-1500H or S7-1500R
Topology	PROFIBUS, in redundant lines or rings	PROFINET with system redundancy R1 in redundant lines or rings PROFINET with System Redundancy S2 in line or ring
I/O Periphery	ET 200M	ET 200SP, ET 200MP (or ET 200SP HA)
Engineering	STEP 7 V5.x in SIMATIC Manager	STEP 7 Professional in TIA Portal

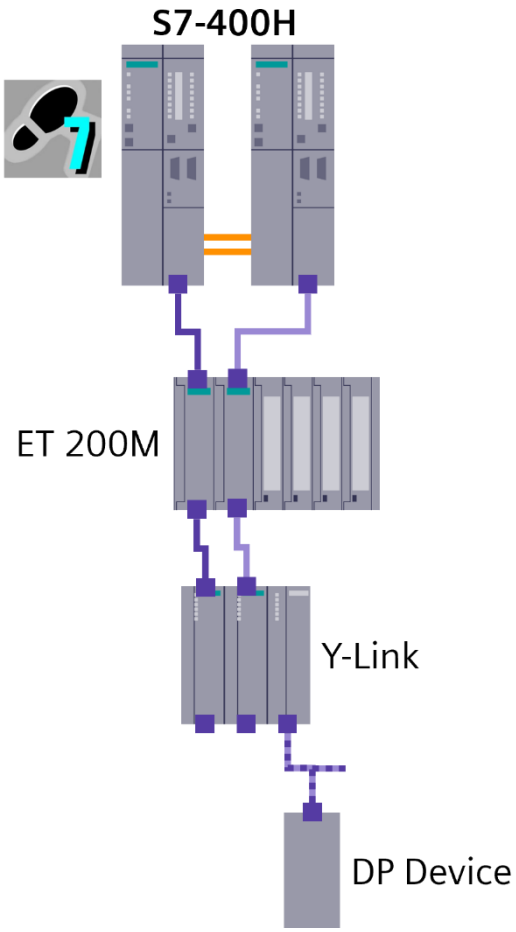
The initial situation and target state are explained in more detail in the following sections.

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1.2.1. Initial situation

In the past, controller redundancy was often covered by an H-System of the S7-400 family. The two CPUs of the system are each arranged on their own rack so that they can be distributed to geographically separated control cabinets, rooms or buildings. For the sake of clarity, the network topology towards the field devices is only indicated as a redundant line in the following. A design as redundant rings is common and is shown in combination with optical cables in chapter 3.2.

ET 200M stations are used as distributed I/O periphery – i.e. components whose availability is coming to an end in the foreseeable future. The configuration is carried out with STEP 7 V5.x using the SIMATIC Manager.



With a Y-Link, distributed I/O periphery stations that only have a single DP interface are connected to a redundant H-system of the S7-400 series. It represents a network transition from a redundant DP master system to a one-sided DP master system. A Y-Link consists of two IM153-2 interface modules and a Y-coupler.

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1.2.2. Target state

System Redundancy R1

For maximum availability, the PROFINET system redundancy R1 can be used in the target state, which is characterized by network and IM redundancy. This requires appropriate I/O stations with redundant head modules, which are currently available for the ET 200SP and ET 200SP HA series. Due to the smaller design and a large selection of special functions (e.g. DALI), the ET 200SP product family is being used in tunnel applications.

R1 redundancy is only supported by the S7-1500H system, not by the S7-1500R system. An H-system is not only more powerful anyway, but also offers higher availability due to synchronization via a dedicated fiber optic connection. This optical physics also allows a greater distance between the two controllers (of up to 40km).

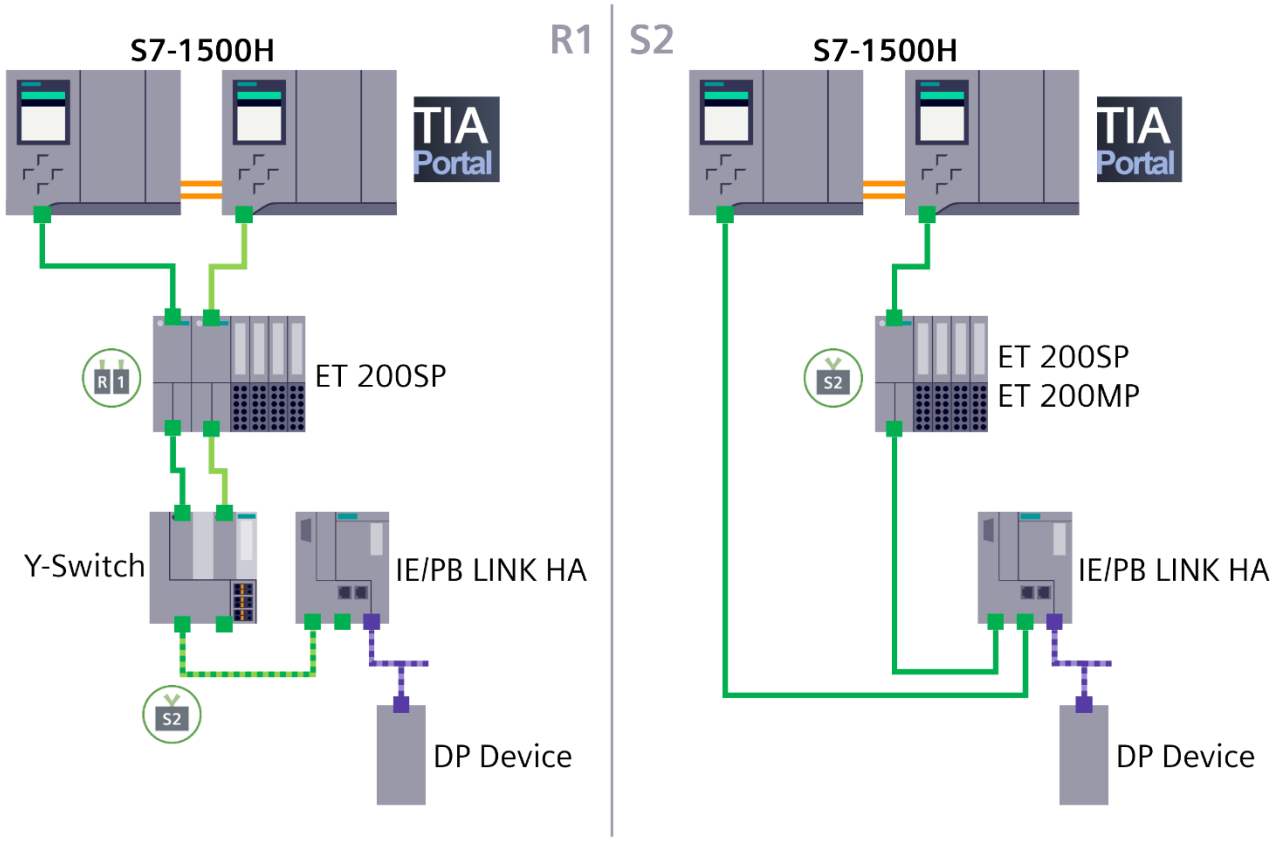
In the following target state, a line topology is indicated as an example, which starts at one of the two CPUs of the S7-1500H system and connects to one of the two interface modules of the ET 200SP stations (Interface Module "IM 155-6 PN R1"). It is equally conceivable and common to close the lines to form rings that provide additional media redundancy using the MRP protocol. For the sake of clarity, these topological variants are not differentiated or presented here. Chapter 3.2 shows a design in which the redundant rings are implemented by means of optical cables.

A Y-switch (officially "SCALANCE XF204-2BA DNA") enables the integration of S1 or S2 devices into an R1 topology by allowing a subordinate network to access both redundant networks. Even though it acts like a conventional network switch, a cross-connection between the two redundant networks remains blocked.

System Redundancy S2

The conecpts described in chapter 2 are also valid for an S2 topology, i.e. without redundant IMs and networks. In this variant, non-redundant interface modules are used, so that the use of ET 200MP stations is also an option.

Again, the topology can be designed in line or ring topologies (not shown in more detail). If a redundant S7-1500R system were to be used, the arrangement in an MRP ring would be technically mandatory.



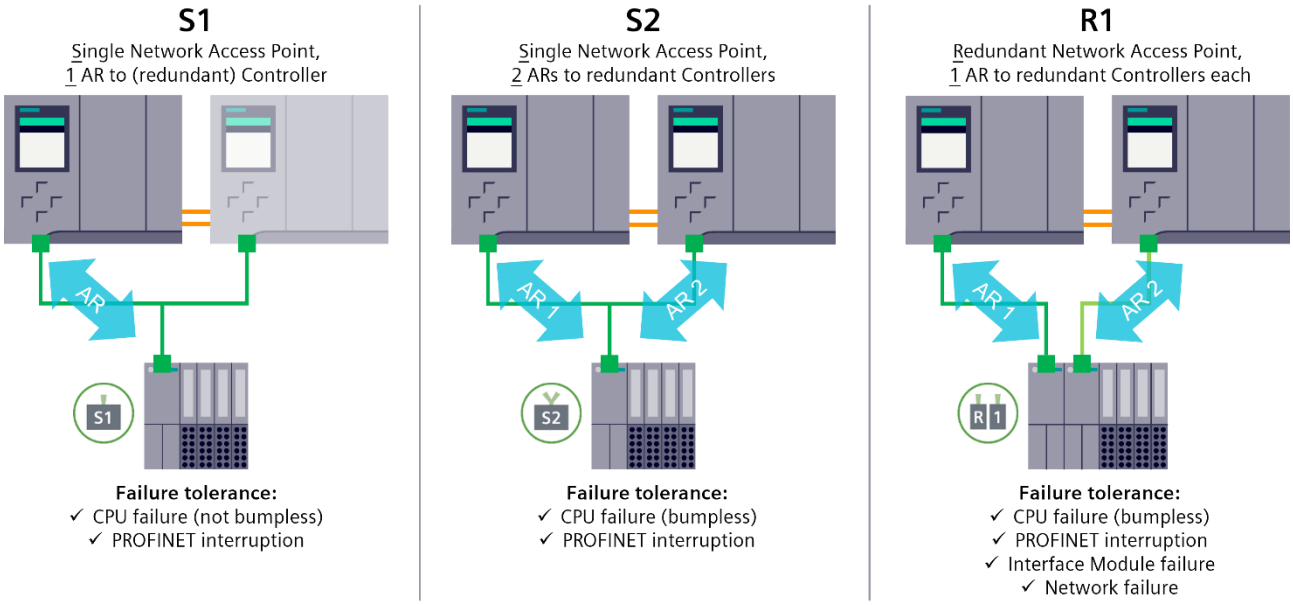
Transition to PROFIBUS

PROFIBUS subscribers who are not transferred to PROFINET must be operated behind an IE/PB LINK HA. This network gateway is used to connect PROFIBUS slaves to a PROFINET-IO system and enables the slaves to switch over without

bumps. All slaves are included in the total number of IO devices of the controller. The link itself acts as an S2 device. In the case of an R1 architecture, the link must be placed behind a Y-switch or a redundant Y-switch pair.

1.3. PROFINET System Redundancy (informative)

The following graphic compares the three main levels of PROFINET system redundancy:



An S1 device only has a single interface module through which it can establish a single Application Relation (AR). Operation on a redundant controller is possible with the "Switched S1" function. However, this switching is not bumpless because an alternative AR has to be rebuilt.

An S2 device, on the other hand, can simultaneously maintain two ARs via its single interface module – one each to each controller of a redundancy system such as the S7-1500R/H. During a switching procedure, the alternative AR becomes the new active AR without a process interruption.

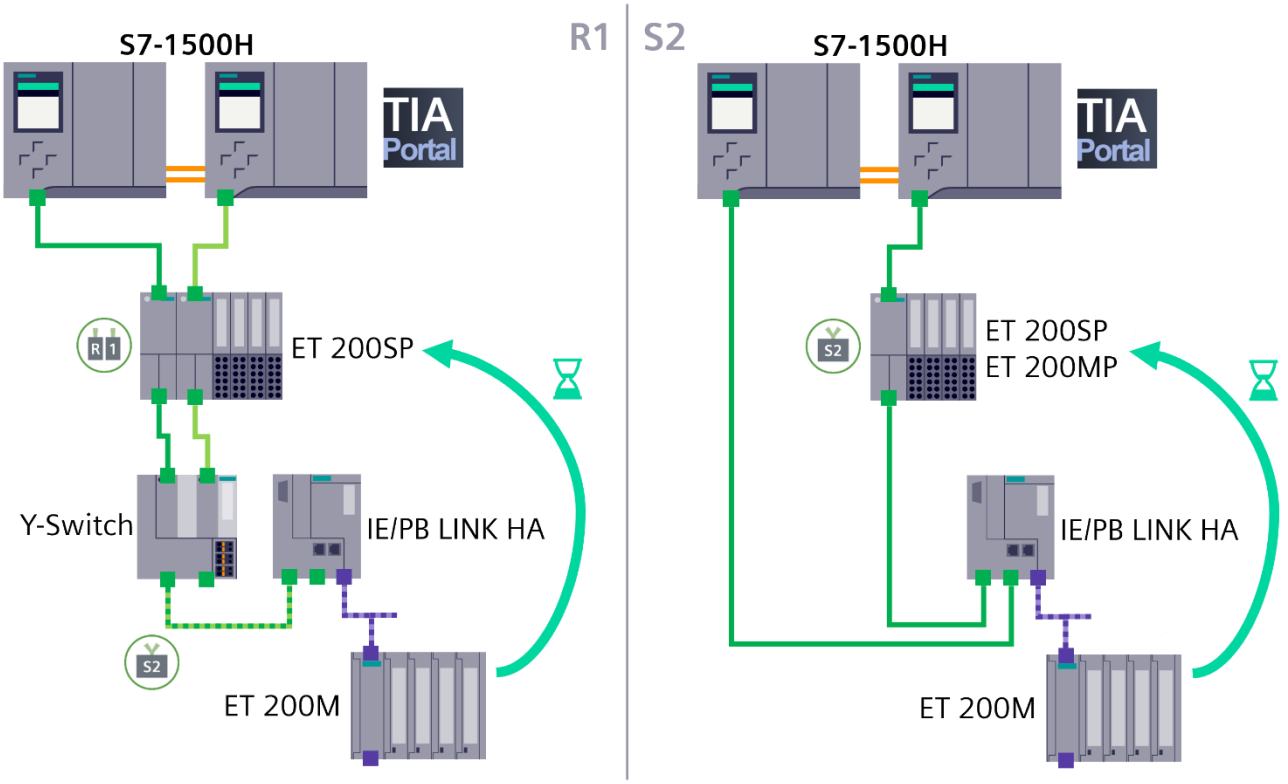
An R1 topology is characterized by additional network and IM redundancy. Availability is therefore increased because the failure of an interface module or a network can be absorbed. Each of the two interface modules of a device maintains a connection to one of the two controllers. When you switch, the alternate AR is activated or the alternate IM is used.

2. Concepts

This chapter deals with different concepts that can be followed for a gradual and orderly transition from the initial situation to the target state of the presented scenario. The ideal case of a complete migration is not explicitly presented.

2.1. Controller swap first

The idea of this variant is to switch from S7-400H to S7-1500H at the beginning, but to continue to operate the previous PROFIBUS subscribers as such on the new system for the time being. This requires an IE/PB LINK HA, behind which the slaves hang on a non-redundant PROFIBUS string:



With the initial switch of the controller, the migration of a participant initially only means a change of the project planning software from SIMATIC Manager to TIA Portal. The PROFIBUS stations are reduced to a single head and connected as slaves to the IE/PB LINK HA, which acts as an S2 device in the PROFINET-IO system.

The replacement of the I/O hardware from ET 200M to ET 200SP will then take place gradually with the move from the simple PROFIBUS string to PROFINET. In an S2-based target design, stations from the ET 200MP series can also be used. The use of Y-switches is no longer necessary.

Advantages

First of all, the migration of the controller system does not require the replacement and rewiring of the distributed I/O hardware.

Disadvantages

The initial effort for migration of the controller and the user program is considerable and affects all technologies of the tunnel. Even though the previous I/O stations can continue to be operated for the time being, they also have to be completely redesigned and programmed in the new controller system.

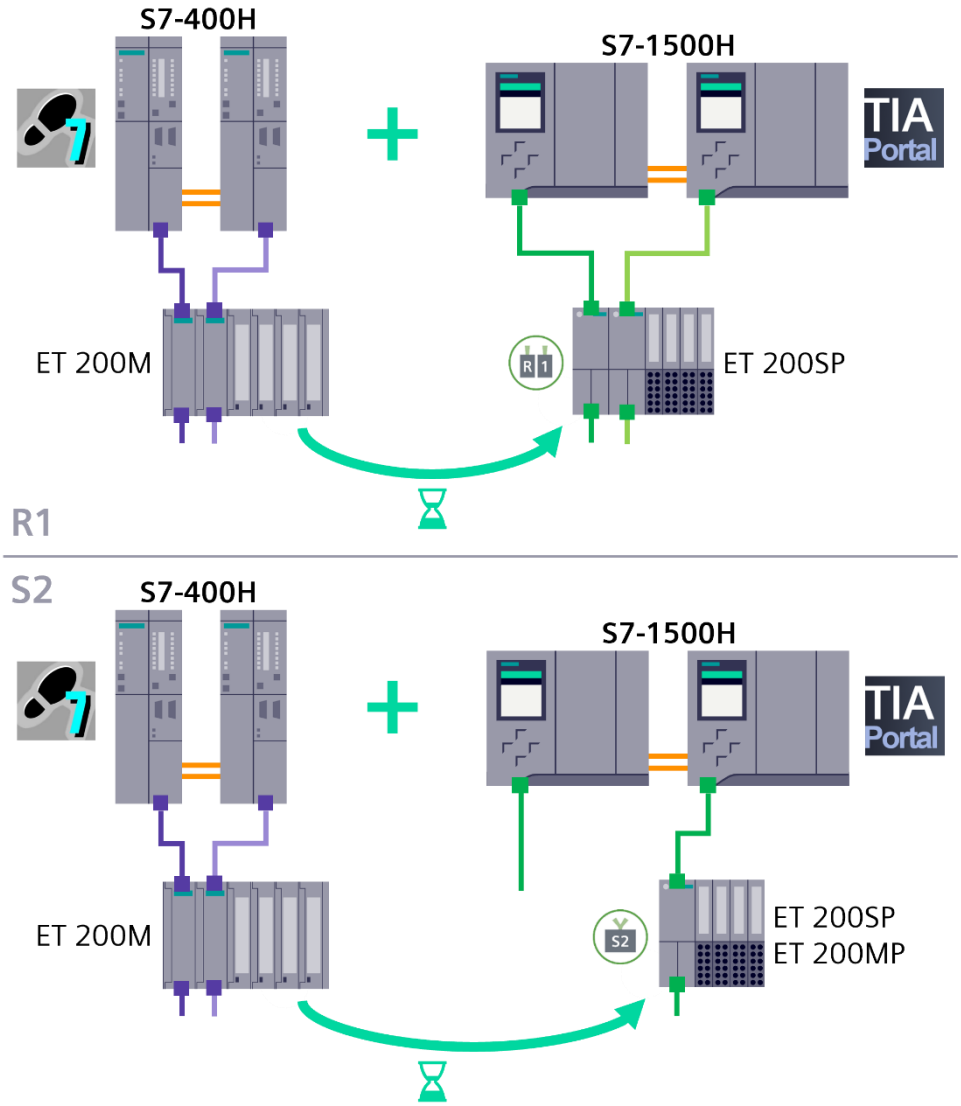
It is also not possible to set up a redundant PROFIBUS topology. The ET 200M stations must initially continue to be operated with a simple interface module. This could represent an unacceptable reduction in availability, even if it is only a temporary solution.

The replacement of the discontinued ET 200M hardware is one of the central reasons for the migration as a whole. Thus, it could be difficult to convey why these components of all components continue to be used for a transitional period and under a new controller.

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2.2. Parallel operation

The idea of this concept is to operate the old and new systems in parallel in a transitional phase. The old S7-400H system will remain in use until all functions and devices have been moved to the new S7-1500H system:



The migration of a station means at the same time a replacement of the hardware from ET 200M to ET 200SP or to ET 200MP (for S2) and a change from PROFIBUS to PROFINET. The gradual migration consists of replacing and moving the I/O stations one after each other – from the old S7-400H system to the new S7-1500H system.

The migration of engineering from SIMATIC Manager to TIA Portal can be carried out in different ways:

- The program logic moves to the S7-1500H system before the associated stations are migrated. The S7-400H system acts as an I/O gateway for the redesigned application in the S7-1500H system.
- The relocation of the program logic takes place synchronously with the migration of the associated I/O hardware.
- The user program remains in the S7-400H system even after the associated I/O stations have been migrated. The S7-1500H system provides the I/O data to the legacy S7-400H system.

Advantages

In the first step, with the installation of the new S7-1500H system and the PROFINET infrastructure, it is not necessary to migrate the user program or individual participants. The transition phase can therefore be entered without major risk or a long downtime.

Once the new controller hardware is ready for use and tested, the gradual relocation of the distributed I/O can begin. The old S7-400H system will remain as a fallback solution during the entire transition phase, i.e. even if the relocation of

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individual components or trades temporarily fails. It will only be removed when the conversion of all devices is completed. The risk of an unexpected outage due to migration issues is minimized.

The migration of the I/O hardware takes place together with the migration of the functionality from the old to the new user program or system.

Disadvantages

The parallel operation of both systems creates an increased space requirement in the central controller control cabinet during the transition phase.

The separation of processes on two systems can mean increased complexity and thus effort for programming, testing and acceptance. If individual functional units cannot be handled independently, even redundant PLC-PLC communication becomes necessary to exchange process states between the two systems. Chapter 3.4 presents possible solutions.

Special form "Hot Migration"

It would also be possible to provide the sensor signals to both systems. While the actuators are still controlled by the legacy system, the outputs of the new system could be compared to those of the legacy system.

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2.3. Distributed I/O swap only/first

Assuming that the replacement of the expiring ET 200M stations is the main reason for a migration, then the approach is to replace them first or even exclusively. I/O stations on the redundant PROFIBUS would therefore have to be adequately replaced. In the long term, a system change from S7-400H to S7-1500H could also be sought, but is not mandatory.

Redundant design

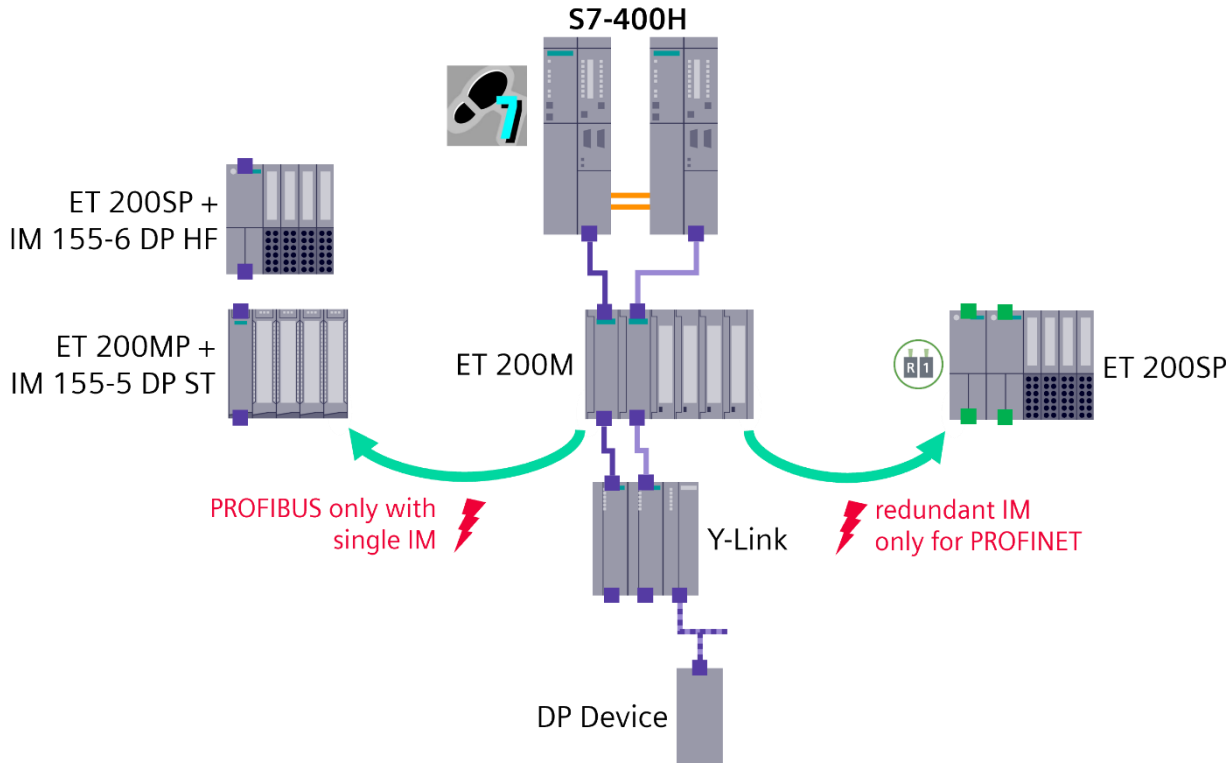
The main problem is that there is no direct successor to an ET 200M station that offers a PPROFIBUS interface in redundant design.

On the one hand, there would be the possibility of a connection with a redundant head for the ET 200SP or ET 200SP HA series, but not on the basis of PROFIBUS, but only with PROFINET and the R1 system redundancy.

On the other hand, there would be the possibility of a PROFIBUS-capable interface module for an ET 200SP station with the IM 155-6 DP HF, but not in a redundant design. Such a change would therefore only be possible if the new I/O station is arranged in a simple string behind a Y-Link. The loss of redundancy and the associated reduction in availability could be difficult to justify.

The same applies to the ET 200MP and its PROFIBUS-capable interface module IM 155-5 DP ST. If a switch to PROFINET in R1 topology and to the ET 200SP series is envisaged in the long term, then the ET 200MP as an interim solution is only a worthwhile investment to a limited extent anyway.

In principle, it should be borne in mind that the available PROFIBUS IMs are also likely to be discontinued in the long term.



Non-redundant design

If no redundant topology has been used so far or is no longer required, then the concept of I/O hardware exchange would be much easier to implement. ET 200M stations could be replaced 1:1 by comparable ET 200MP or ET 200SP devices with a simple PROFIBUS interface in order to solve the problem of product discontinuation. However, all components that are not natively available in the old configuration in STEP 7 V5.x would have to be integrated via GSD file.

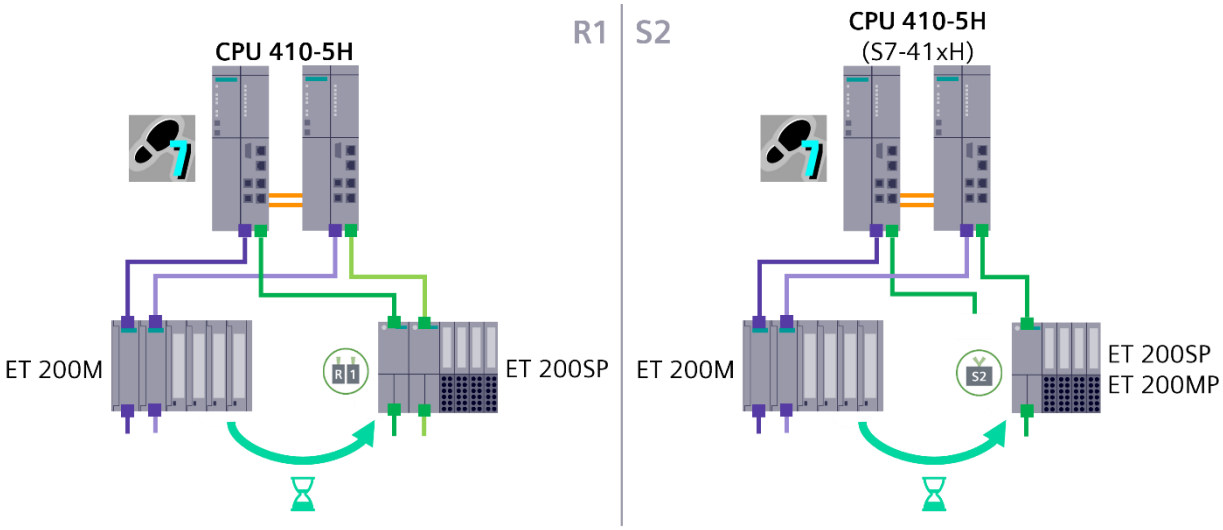
The use of PROFINET stations with a single interface would then also be possible and coincides with the S2-based concept in the following chapter 2.4 using the previous S7-400H system (not necessarily a CPU 410-5H).

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2.4. Innovated legacy system with (PROFIBUS and) PROFINET

The approach of this concept is the use of a CPU 410-5H controller that supports the use of PROFINET with system redundancy R1. For the goal of a PROFINET-S2 architecture, an S7-400H system is alternatively conceivable, extended by a simple PROFINET (if necessary by means of appropriate CPs). Compared to the CPU 410-5H, however, it is less future-proof.

In addition, the advantage that PROFIBUS and PROFINET devices can be operated in parallel on such a system can be used. The migration of the stations can therefore be carried out step-by-step:



The migration of a station means at the same time a replacement of the hardware from ET 200M to ET 200SP or to ET 200MP (for S2) and a switch from PROFIBUS to PROFINET – below the innovated legacy system CPU 410-5H or the extended legacy system S7-400H for S2. It is not necessary to change the engineering software from SIMATIC Manager to TIA Portal. The existing user program can continue to be used as far as possible.

It is also possible to replace all stations not step-by-step, but already with the installation of the innovated system CPU 410-5H. PROFIBUS would be replaced by PROFINET in one step.

As soon as the engineering project has been migrated to STEP 7 Professional in TIA Portal, the final controller exchange can take place to the redundant S7-1500H system.

Advantages

This variant has the advantage that the engineering platform and the user program could be retained (for the time being). Engineering and acceptance of a program created from scratch would represent a considerable effort and cost factor – especially when it comes to the retrofit of an existing tunnel and financial resources are comparatively scarce.

Disadvantages

To configure components outside the process automation portfolio, the import of the corresponding GSD file into STEP 7 V5.x is required. An ET 200SP station is also not natively available.

In order to do justice to the target state, namely the use of a controller of the S7-1500 family with configuration in TIA Portal, the system would have to be replaced with an S7-1500H after the complete relocation of the distributed I/O and the complete user program would have to be migrated. Just to serve as an interim solution, the purchase of a CPU 410-5H or S7-400H might not be justified.

It stands to reason that the final switch to an S7-1500H system could be dispensed with – especially if this change is accompanied by considerable effort for the acceptance of the user program, which was already invested in the hardware migration of the I/O stations. However, it should be noted that in the long term, the distribution and support of STEP 7 V5.x will also be phased out.

ATTENTION	The CPU 410-5H is a controller designed for process automation. Use with STEP 7 V5.x is possible, but requires special approval.

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3. Technical aspects

This chapter provides information on some technical topics that need to be considered in the course of a migration.

3.1. Distributed I/O

3.1.1. Selection of successor products

This section shows possible procedures for selecting distributed I/O components based on the discontinued products.

Collected information on the product phase-out schedule and recommended replacement products can be found in the following SIOS posts:

ET 200M : Product announcement 109809890 (see link \3\)
ET 200S : Product announcement 109767411 (see link \4\)

Excel list

In the case of the ET 200M, the product announcement offers an Excel list that refers specifically to the changeover to the ET 200SP and ET 200MP in the field of factory automation (and comparable fields of application). The column "Recommended Product" indicates the respective "functionally most likely / most suitable successor product".

The following example shows that an SM 321 DI module with 32 digital inputs can be replaced by a corresponding ET 200SP module:

	A	B	C	D	E	F	G	H
1	Phase out planning + Migration from S7-300 / ET 200M						to SIMATIC ET 200SP	
2	MLFB	Description	Beschreibung	Announcement of product phase-out (PM400) available as new part until PM410	Product cancellation (PM410) available only as spare part, delivery may be restricted	Product discontinuation (PM490) spare parts not available any more, only in case of warranty	MLFB	Description The technical properties of the respective component must always be checked for suitability for the intended use and application.
3	DI							DI - Recommended
7	6ES7321-1BL00-0AA0	SIMATIC S7-300, Digital input SM 321, Isolated 32 DI, 24 V DC, 1x 40-pole	SIMATIC S7-300, Digitaleingabe SM 321, potentialgetrennt 32DE, DC 24V, 1x 40-polig	01.10.2023	01.10.2025	not planned, but not before 01.10.2033	6ES7131-6BH01-0BA0	ET 200SP, DI 16x 24V DC ST, PU 1 SIMATIC ET 200SP, Digital input module, DI 16x 24V DC Standard, type 3 (IEC 61131), sink input, (PNP, P-reading), Packing unit: 1 Piece, fits to BU-type A0, Colour Code CC00, input delay time 0,05..20ms, diagnostics wire break, diagnostics supply voltage

Since the original module offers 32 channels, the successor product with its 16 modules may have to be used in duplicate.

List of I/O Adapters

In addition to the product number of the required adapter, the catalog of I/O adapters also indicates the respective replacement module:

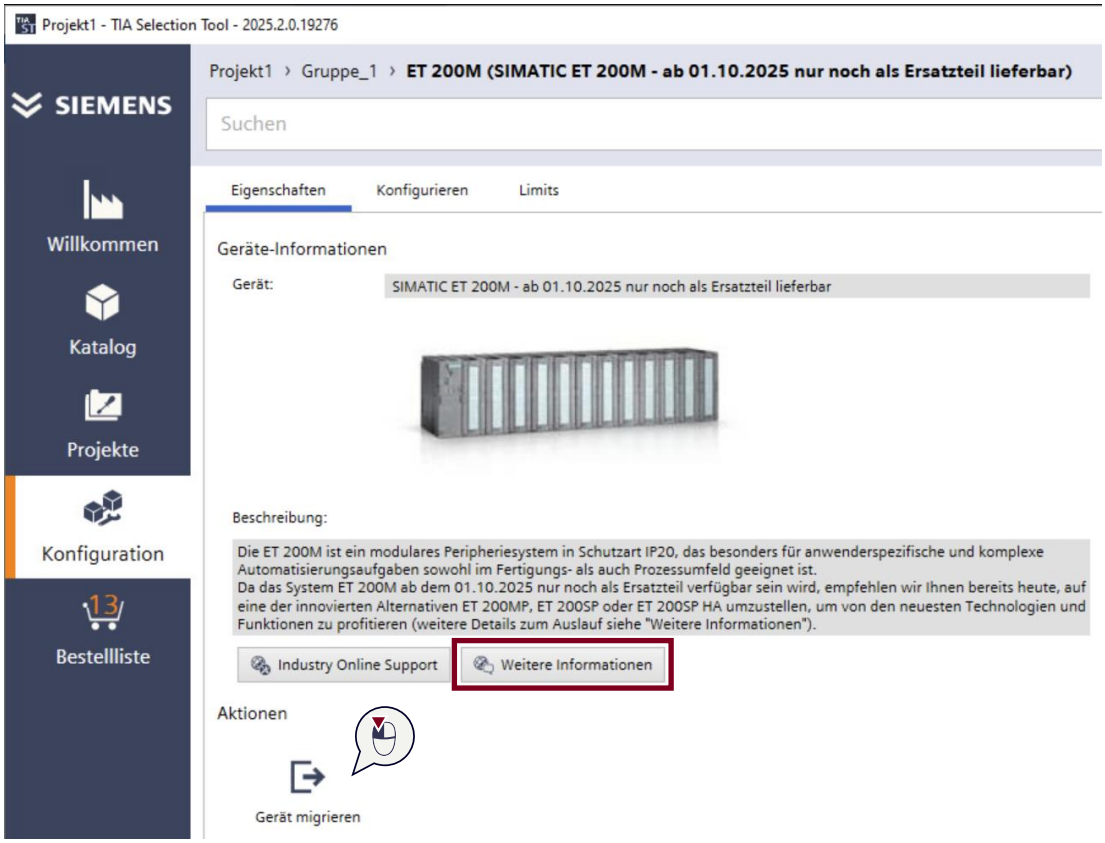
S7-300 (ET200M)			Adapter including BaseUnit		ET200SP		Comment
DI							
6ES7321-1BL00-0AA0	32 DI	24 VDC	6EZ2041-8HR42-0DE0	6ES7193-6BP00-0DA0	6ES7131-6BH01-0BA0	16DI /24VDC	rewire L+
				6ES7193-6BP00-0BA0	6ES7131-6BH01-0BA0	16DI /24VDC	

A description of the adapters can be found in the chapter 3.1.2.

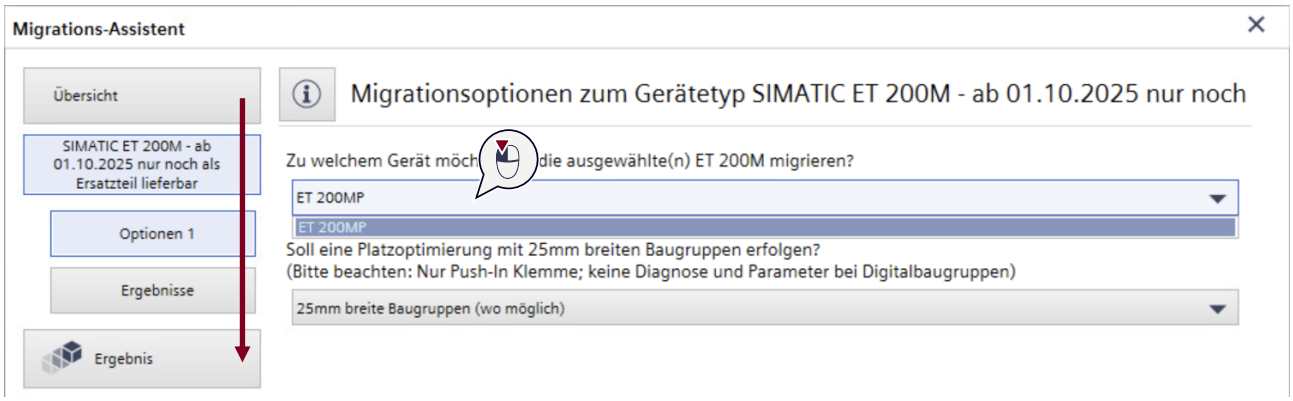
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TIA Selection Tool (only ET 200M → ET 200MP or ET 200S → ET 200SP)

When compiling an ET 200M or ET 200S station in the TIA Selection Tool, there is a reference to the discontinuation of affected components in several places, e.g. in the properties of the configured device. The "More information" button leads to the above-mentioned product announcement.



The desktop version of the TIA Selection Tool shown here has a "Migrate Devices" function. In this wizard, the components to be migrated as well as important constraints must first be selected:



After the dialog is complete, the migrated components could be transferred to the project.

HINT

The Migration Assistant only supports the conversion of an ET 200M into an ET 200MP station, not into an ET 200SP. This, in turn, is primarily considered the successor to the ET 200S series.

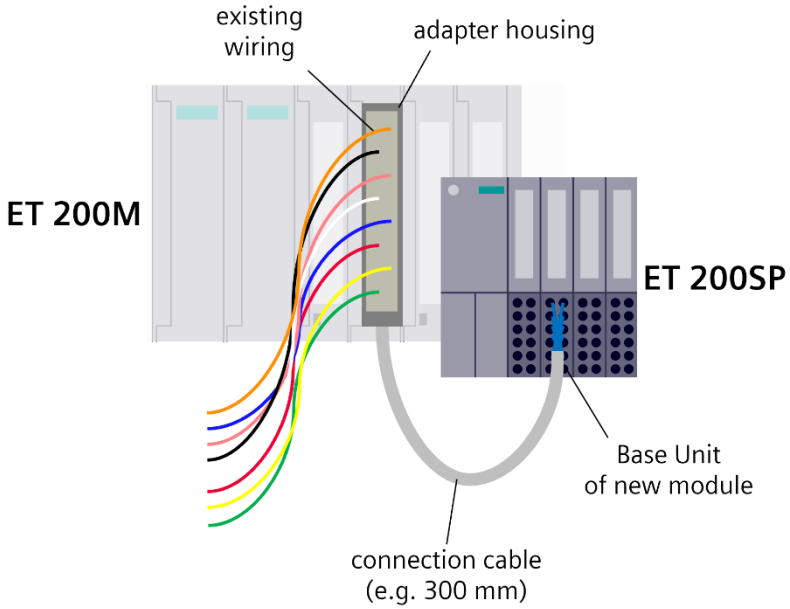
In addition, the Migration Assistant is only available in the desktop application of the TIA Selection Tool, not in the cloud-based version.

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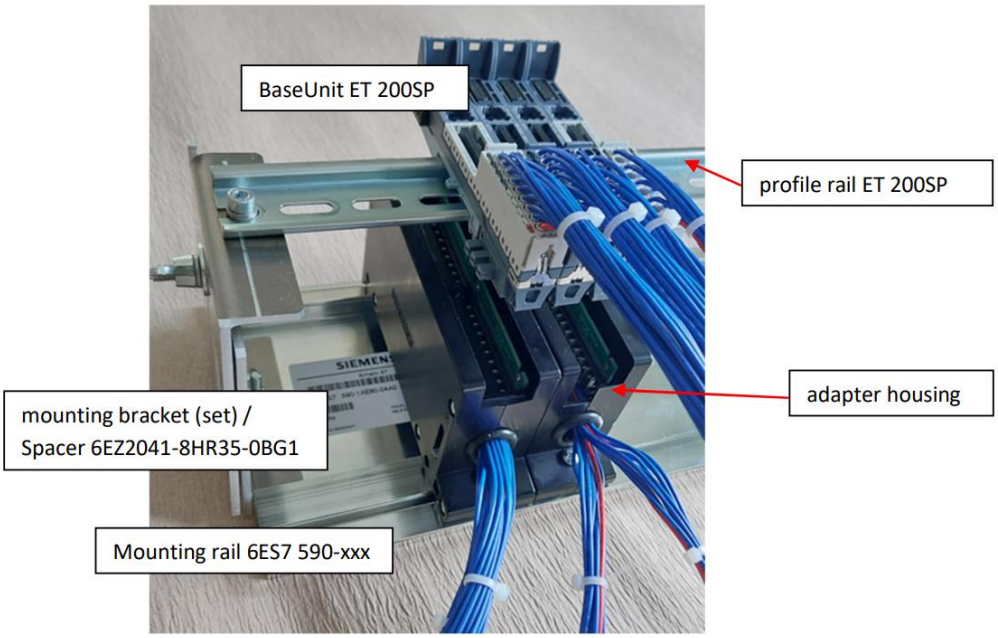
3.1.2. I/O adapter

Migrating sensor and actuator signals from one I/O module to another can be time-consuming and error-prone. In order to enable a quick and error-free changeover, simple adapters for all common system combinations have been developed. In the following, only the conversion from ET 200M to ET 200SP is shown. However, there are also solutions for the ET 200MP (S7-1500) or ET 200SP HA target platform.

The existing wiring is not moved cable-by-cable, but installed slot by slot in special adapter housings, which enable direct implementation to the base units of the new platform. This not only significantly reduces the effort required for planning and conversion, but also eliminates the need for time-consuming signal testing. The risk of signal errors is minimized.



The installation is carried out on standardised DIN rails, whereby the new system is usually mounted on an upstream rail in front of the old system:



Catalogue / Further information

The product catalogue is also available in the link collection on the subject of migration (link \5\, keyword "cabling adapter"). The regional expert advisors named in the report are available for advice.

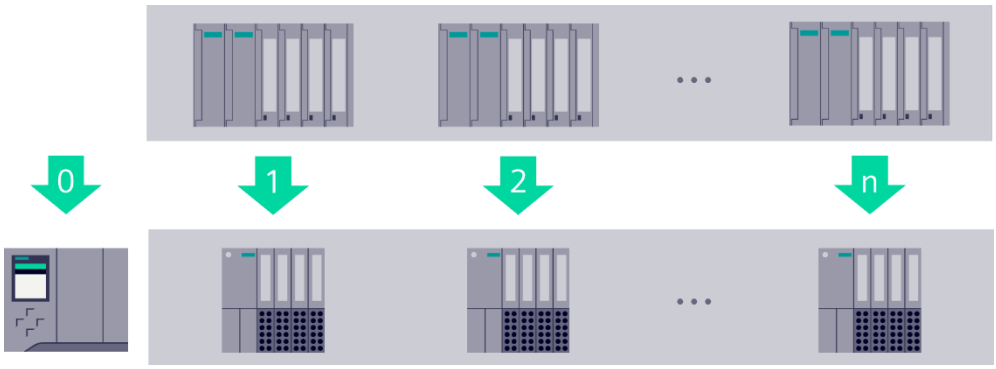
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3.1.3. Exchange strategies

This section illustrates two basic approaches that could be applied (or combined) in the incremental replacement of the I/O stations. With both strategies, it may be logistically necessary to first move all new decentralized control cabinets to the appropriate points in the tunnel in a single operation.

Niche by niche

This procedure involves tackling the individual sections of the tunnel one after the other, i.e. always dealing with the equipment in the control cabinet of a niche or cross-passage in its entirety:



As initial step 0, the migration of the controller is not specified in more detail here. The concepts from chapter 2 are applied.

In step 1, the control cabinet of the first niche is completely overhauled or even completely replaced. Only when this is completed, the same action is taken in the next niche. A single assignment could end with the completion of the conversion of a decentralized control cabinet. The migration is complete with the last niche.

Advantages

Each decentralised control cabinet can be converted or replaced as a whole. This enables fast implementation without the threat of a combination of old and new hardware in every decentralised control cabinet. In the case of a complete replacement, the new control cabinet can be assembled and tested in advance. The risk of wiring errors or functional problems on the day of installation or during on-site conversion is significantly reduced.

The feed-through at the first control cabinet should be used to confirm the circuit diagram and procedure. With the experience gained in this way, the following niches should be able to be migrated in a shorter time and without major difficulties.

Disadvantages

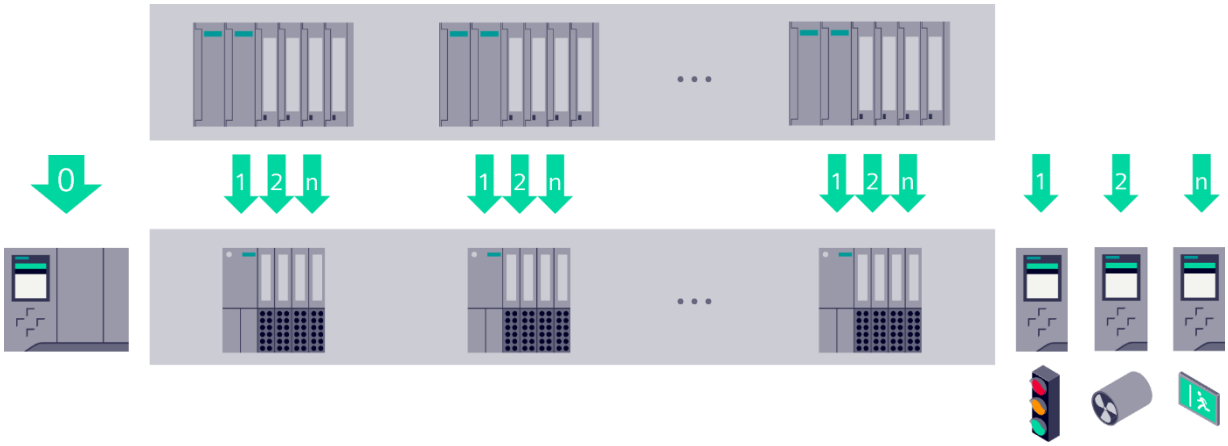
With the conversion of each decentralised control cabinet, all the technologies and trades contained in it may be affected. Accordingly, capacities must also be provided for suppliers and experts of all technologies for each operation. Especially when the conversion of each individual control cabinet entails a new acceptance of all technologies.

In addition, if the entire technology of a certain technology (e.g. ventilation, lighting, etc.) is to be overhauled at the same time, this procedure may be unsuitable.

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Trade by trade

A "trade" is a technology that concerns a specific automation task of tunnel equipment, e.g. traffic control or ventilation. In this procedure, the trades are considered independent and migrated one after the other:



As initial step 0, the migration of the controller is not specified in more detail here. The concepts from Chapter 2 are applied.

In phase 1, all signals and/or modules that belong to trade 1, e.g. traffic control, are migrated. The change can be made at all corresponding I/O stations of the tunnel at the same time (or in parts one after the other). Only when the migration of this automation task is completed and accepted is the next one tackled, e.g. ventilation. Only with the relocation of the last technology (here index "n") can the now empty ET 200M stations be finally eliminated.

Ideally, the individual I/O modules are only assigned to a single trade, so that one can also speak of a "module-wise" approach.

This procedure is all the more useful if a dedicated PLC is used for each of the individual trades.

Advantages

The individual technologies can be migrated and accepted as completed work packages. This makes sense if each technology is supported by different suppliers or experts. Especially if a technology is also overhauled in the course of the modernization measures and has to be converted at the same time anyway.

Disadvantages

In the time between the relocation of the first and the last modules, old and new I/O stations are needed simultaneously. This creates an increased space requirement in the decentralised control cabinets of the niches. No difficulties should be expected with regard to other factors as long as the old and new devices are moved from the old S7-400H system to the new S7-1500H system with a clean separation, e.g. with regard to the maximum number of IO devices and modules or the maximum I/O address range. The same logic applies to the expected network load if a switch from PROFIBUS to PROFINET (via Ethernet) is carried out with the device change.

A strong logical dependence between the different automation tasks could also make a step-by-step migration by trade much more complex. If necessary, PLC-PLC communication between the old and new systems would be necessary. If the different tasks are distributed among individual S7 controllers anyway, the dependencies could be fewer or at least implemented in a more structured way.

This procedure is also made more difficult if the technical trades share certain inputs or outputs or "share" I/O modules.

In the worst case, it is not possible to retrofit the control cabinet of each niche only partially without greater risk or effort. After all, the conversion of a decentralized control cabinet carries the risk that components that are not affected will also be involved or affected. The mere fact that a control cabinet is converted at the point of use and under time pressure increases the susceptibility to errors or unexpected difficulties.

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3.2. Field Topology

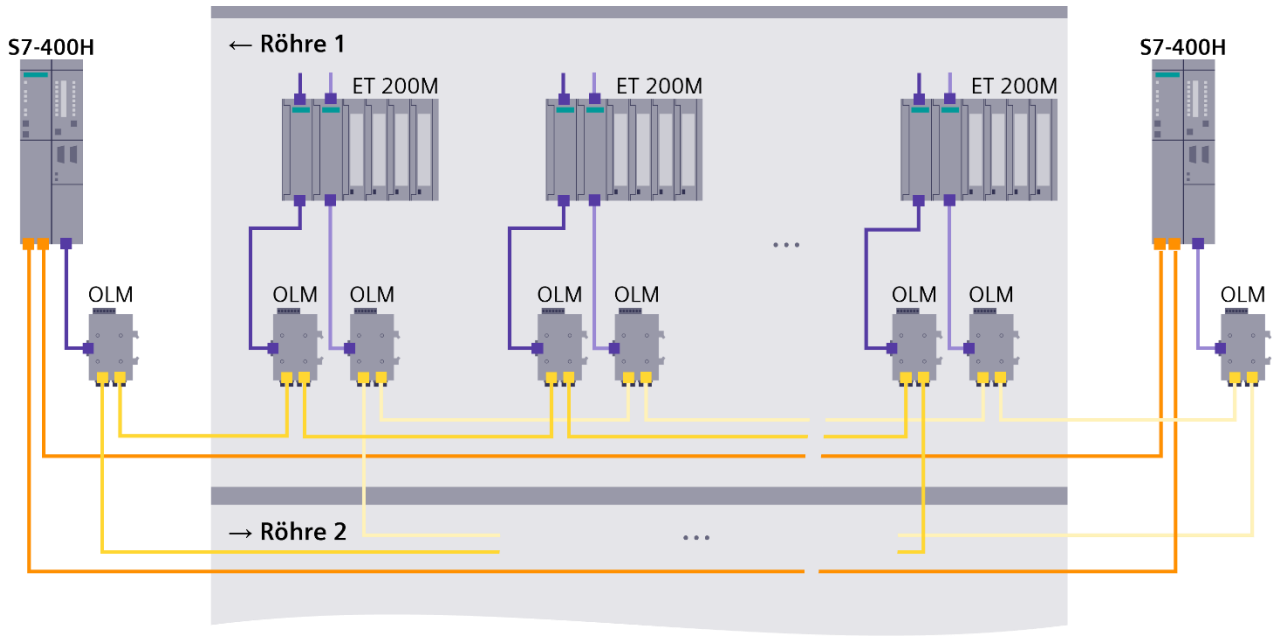
Due to the long distances within a tunnel, a combination of electrical and optical physics is usually chosen.

Starting situation

In a PROFIBUS-based architecture, so-called "Optical Link Modules", or "OLM" for short, were used for the transitions.

The following presentation shows an example in which two redundant optical rings have been formed. Each of the two rings connects all the OLMs that belong to a CPU of the S7-400H system. Usually, each of the two rings is routed there in one tunnel tube and back in the other. Slaves of the same CPU can be arranged on a ring in both tubes (not shown).

Each OLM has an electrical connection on which up to 32 bus subscribers can be operated.



The two optical synchronization lines of the H system are also divided between the two tubes.

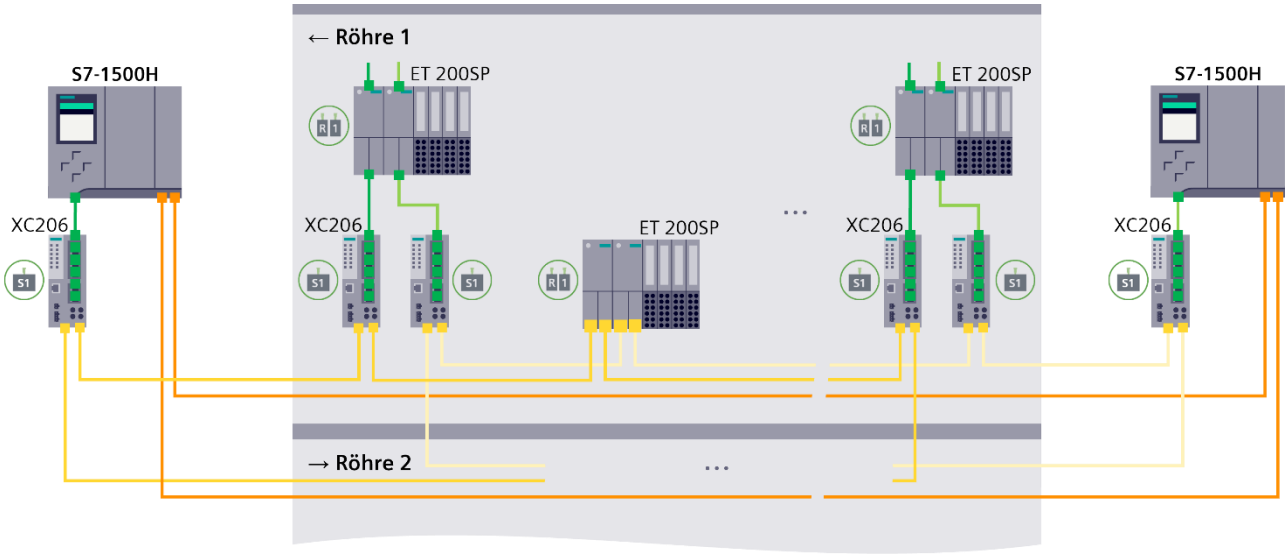
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Target state with system redundancy R1

A typical target layout in R1 layout logically differs only slightly from a PROFIBUS-based design.

SCALANCE switches can be used to form and connect to the optical ring, e.g. an XC206-2SFP with two integrated optical ports. Each of these switches with its six Ethernet ports can serve as the starting point for a star-shaped topology. If the switches are to be operated as IO devices in an R1 architecture, they are to be considered and configured as S1 devices. They only have access to one of the two separate networks and CPUs at a time.

Alternatively, an ET 200SP with optical bus adapters (e.g. BA 2x LC-LD) can also be placed directly in the optical ring, see middle station. However, it is then not possible to open an additional topology from the ET 200SP.



In this example, the two CPUs of the S7-1500H system are connected to the ring by a stitch line. It would also be possible to place them directly in the ring with the "MRP Auto-Manager" role. However, one section of the ring would then have to be formed with copper cables, as there are no optical ports available for the interfaces of the S7-1500.

In order to connect central technology, a separate MRP ring is often formed in each of the operating buildings, which is then coupled to the rings of the tunnel via MRP interconnection. So the infrastructure shown here is simplified anyway.

Reuse of optical cables

The similarity of the two layouts of the initial situation and the target state shown above is intended to express that a reuse of the existing optical fibers should be considered. However, due to the aging of optical fibers, replacement should be sought in the course of modernization measures in order to ensure long-term availability again.

Monitoring of optical connections in the ring

The Link Check feature allows adjacent XC206-2 and XC400 series switches to monitor the transmission quality of optical links within an MRP (or HRP) ring. Disrupted transmission links are switched off under certain conditions, so that the redundancy manager closes the ring and enables communication via an alternative route again.

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3.3. User program

The article (link \5\) summarizes information about the migration to S7-1500 controllers and TIA Portal.

In addition to the necessary requirements for migrating the user program (link \6\), the migration guide (link \7\ ) can be found there, i.e. a comprehensive document on the hardware and software-relevant aspects of migration. There it is confirmed that "*in general, all STEP 7 V5.x programs can be migrated to STEP 7 (TIA Portal). However, depending on the STEP 7 commands used, or special modules, adaptation work may be necessary after the migration.*

Nevertheless, it can make sense to create certain programs or program parts from scratch for various reasons. Example reasons:

- *Simpler code*
- *Additional features*
- *Better diagnostic options*
- *Creation of future-proof standard functions and libraries*
- *Same or higher migration effort as new build*
- *Achieving higher throughputs to increase performance*
- *Etc.*

Direct I/O access

With an S7-1500R/H, special attention should be paid to avoiding direct I/O access, as was common in programs of the S7-400H, e.g.

```
IW256:P
```

Each direct periphery access is synchronized in the RUN-Redundant system state and leads to a higher cycle time. Instead, it is recommended to access the inputs and outputs of the IO devices via the process image or the subprocess images.

SYNCUP

Other notes mainly concern the critical phase SYNCUP, in which the operating system synchronizes the backup CPU with the primary CPU. Here, the communication load and the use of cyclic interrupts should be reduced as much as possible. More detailed tips can be found in the system manual (\9\).

Note: S7-1500R/H compared to S7-1500

Basically, it should be mentioned that an S7-1500R/H can be programmed in TIA Portal like a standard S7-1500.

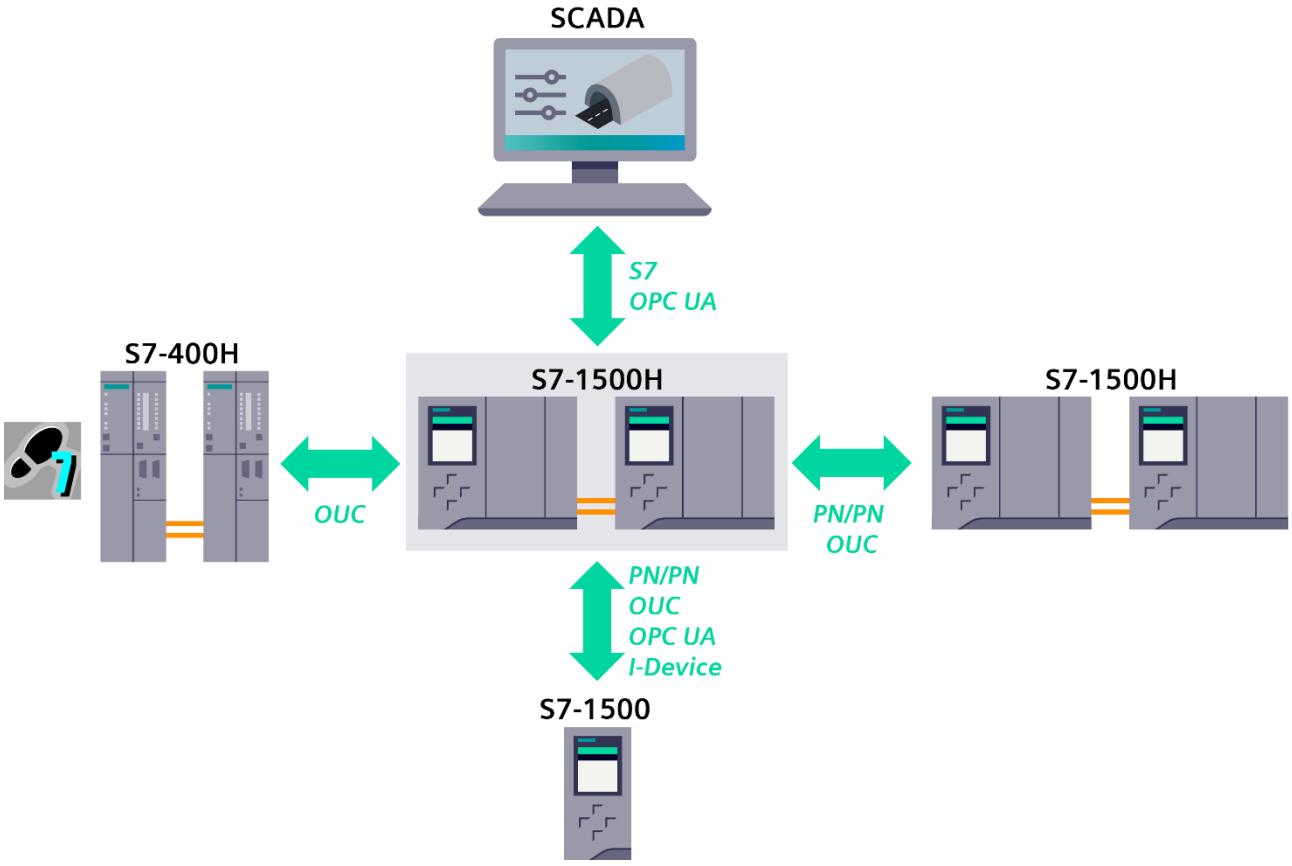
There are limitations to be aware of for an S7-1500R/H compared to a standard S7-1500 family CPU. For example, some system instructions and OBs are not available, e.g. for S7 communication (e.g. PUT/GET or BSEND/BRCV). A detailed list can be found in the System Manual, Chapter 10 (link \9\).

3.4. PLC communication

This section provides an overview of the possibilities of PLC communication that are commonly used. The data exchange between the old and new systems, which could be necessary especially in the concept of parallel operation, is also mentioned. Data exchange has the same availability requirements as the application's controller, so a redundant design may be necessary.

Overview

The following graphic shows which types of communication are available between an S7-1500H system and different partners:



Open User Communication (OUC) - LComRed

The "LComRed" library provides user program blocks for setting up redundant "Open User Communication", i.e. based on TCP or ISO-on-TCP. In addition to the up to four connections of the possible communication paths, a dedicated diagnostic connection is opened to monitor the availability of the active connection.

The library also provides a building block for use in STEP 7 V5.x, e.g. to set up a data exchange in parallel operation of the S7-400H and S7-1500H (see chapter 2.1). However, this requires the usability of Ethernet in the legacy system.

Due to the wide and simple applicability including redundancy switching, this type of redundant communication between controllers can be recommended, but without real-time capability and with switching only with interruption.

OPC UA

With its versatile possibilities, OPC UA is suitable for data exchange with SCADA or HMI applications, but in principle also between controllers. Communication can not only be designed to be high-performance and secure, but can also offer significant added value for integrators and operators through standardization and semantics.

The S7-1500R/H controllers support native use as OPC UA servers. The server redundancy can be used transparently by using the system IP as well as non-transparently. Then it is up to the OPC UA client to choose one of the possible failover modes, e.g. "Hot" or "HotAndMirrored". The range of functions is based on the standard CPUs of the S7-1500 family with few restrictions. However, it is not yet possible to use the S7-1500R/H as an OPC UA client.

Controllers of older generations do not support OPC UA or only to a very limited extent. This protocol is therefore conditionally suitable for PLC-PLC communication between old and new systems. Rather, it is particularly suitable for vertical communication between newer generation controllers or for SCADA applications at the control level. Compared to other protocols, however, the increased effort is only worthwhile if the advantages of OPC UA come into play.

I-Device

Neither an S7-400H nor an S7-1500R/H enable I-Device functionality. It is therefore out of the question for PLC-PLC communication between the old and new system.

If the tunnel is to be controlled by subordinate S7-1500 standard CPUs in addition to an S7-1500H system, then this real-time capable mechanism is a good choice. However, the I-Devices can only be connected to an S7-1500R/H via GSD file and only as an S1 device, i.e. with a non-bumpless switching.

PN/PN Coupler

For symmetrical communication between controllers, the use of a PN/PN coupler is possible, which functions as a real-time capable S2 device in PROFINET and thus enables bumpless switching. Another plus point of this device is the mains separation. In order to be able to cover a device failure, a redundant use of the coupler is also conceivable.

S7 Communication

A maxim for setting up a PLC-PLC communication could be to make as few changes as possible to the existing user program on the side of the old system. The communication would then only be possible to project one-sidedly, i.e. by means of special function blocks in the new system. However, since an S7-1500R/H does not enable S7 communication in the role of an active client (e.g. with PUT/GET or BSEND/BRCV), an implementation of data exchange is always explicitly necessary in the S7-400H program.

S7-based communication, on the other hand, remains a proven communication protocol between WinCC OA and S7 controllers.

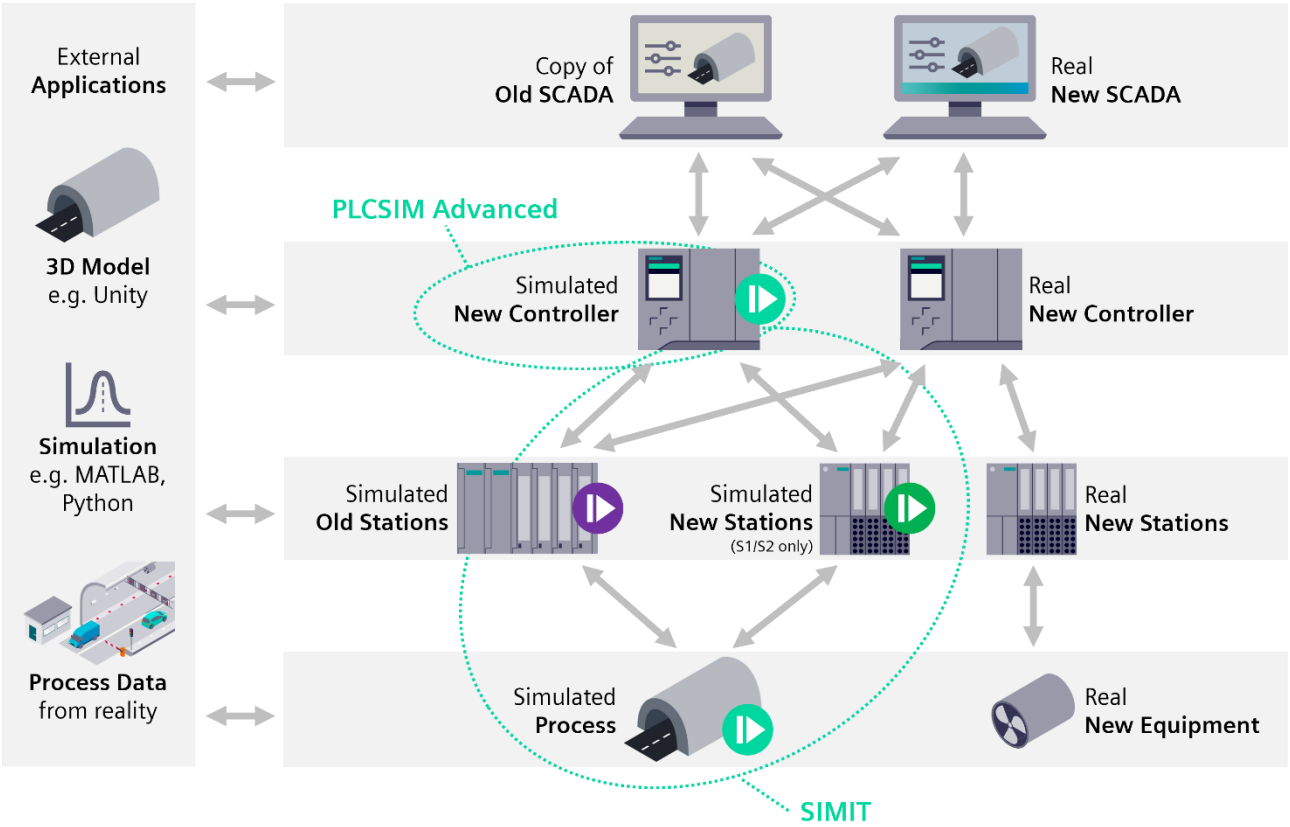
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3.5. Simulation

The virtual simulation of tunnel automation is becoming increasingly important in new construction projects. The potential of a digital twin during engineering, commissioning and operation is enormous – whether for design and planning, for optimizing and testing processes, for training personnel or for improving the monitoring and maintenance of a tunnel.

However, especially when modernizing existing systems, virtualization of individual aspects can be helpful or necessary. Because to be able to carry out a conversion quickly and smoothly, thorough and realistic preparation is essential. Furthermore, existing components cannot be used because they are still in operation until the conversion.

The following graphic illustrates which parts of tunnel automation could be simulated during a migration. From top to bottom, the hierarchical levels of automation are considered:



An existing **SCADA** application can be duplicated for the simulation process so as not to affect or even jeopardize the control of the real tunnel. If the SCADA system is also to be renewed in the course of modernization, it is already involved during the engineering phase. Such simulated applications are particularly suitable for training and training employees in specific scenarios (accident, fire, etc.).

The new **controller** to be installed, e.g. the high-availability S7-1500H system, can be included both as a new physical device or as a simulated instance. The user program of the control system to be developed can also be used in PLCSIM Advanced.

PROFIBUS or PROFINET-based **devices** can be virtualized with the help of a SIMIT unit – but system redundancy R1 is not supported. It is also conceivable to connect the new target hardware ET 200SP or ET 200MP to the new controller system, as it will be installed in the tunnel. In the course of this, the new stations can already be prepared for installation (name assignment, labeling, firmware, etc.) and tested (I/O test).

The **signals** from the field devices can be simulated in the SIMIT simulation platform using realistic behavioural models. SIMIT also offers the possibility of visualization, which can be used to represent or trigger certain situations of operation. New equipment to be installed can also be integrated directly into the engineering process in order to develop the correct control logic and test it in a proof-of-concept.

The simulation tools of the automation chain also offer different **interfaces** that are used to input or output data to other models. For example, external 3D visualizations based on a CAD or BIM model can be coupled. It is also conceivable to extract process data from real tunnel operation and feed it into the simulated environment.

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3.6. Cyber Security

Nowadays, the operation of a tunnel is not possible without meeting the requirements of modern cyber security.

It can be assumed that in the case of applications that are eligible for the modernization of individual components or technologies, the topic of cyber security must also be rethought and addressed. The real risks and dangers have developed steadily in recent years. At the same time, the legal framework has been adapted and in some cases drastically expanded.

However, a need for action can also arise solely or particularly from technical changes in the course of modernization, for example:

- New systems: TIA Portal, SIMATIC S7-1500, ET 200MP and ET 200SP are all systems that bring with them a range of technical possibilities and innovations, e.g. in terms of access management and certificate management. Integrators and operators must first become familiar with this.
- New Ethernet-based physics for PROFINET: The switch to Ethernet makes field devices easier to reach for attacks from the digital space and must be protected and hardened accordingly.
- New communication protocols: The use of OPC UA, Open User Communication or other protocols offers the possibility of consistent and standardized integration. However, this must be designed securely to avoid opportunities for attack.
- Incomplete protection during conversion or transition phases: As a supplier, SIEMENS provides solutions that offer a high degree of security, both in their configuration ex works and with the default settings of of engineering by the user. However, comprehensive protection only results from the interaction of many measures that could be integrated incompletely or with a time delay in the course of an overhaul. Example: new devices are installed and connected in the tunnel before the superimposed firewalls are available or set up.
- Increased risk from/for legacy systems: Older solutions may also contain components that are no longer considered secure according to the state of the art. They are now exposed to new dangers or pose an increased danger to other participants. Example: old operating computers with Windows XP operating system, which can only be completely dispensed with after all conversion measures have been completed.
- Limited interoperability between old and new systems: For example, it may be necessary to resort to solutions on a transitional or permanent basis that would otherwise no longer be used according to modern requirements. Example: For the data exchange between the old and new systems, PUT/GET-based S7 communication is used, which results in reduced access protection for the passive communication partner.
- Cost and time pressure: An existing tunnel often does not have the same financial and time leeway for modernization as a new one. This may also apply to acceptance and stress tests of the infrastructure.

Website

The SIEMENS website "Cybersecurity in Tunnels" (link \8\) outlines the approaches and solutions of the holistic "Defense in Depth" approach.

Among other things, a comprehensive white paper can be made available that explains the technical measures of the three fields of action tunnel security, network security and system integrity in more detail. An essential component is the blueprint of a system and network architecture, which illustrates the structured use of the available solutions. The offer is supplemented by competent support and consulting under the keyword "Industrial Security Consulting".

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4. Appendix

4.1. Service and Support

SiePortal

The integrated platform for product selection, purchasing and support - and connection of Industry Mall and Online support. The SiePortal home page replaces the previous home pages of the Industry Mall and the Online Support Portal (SIOS) and combines them.

- Products & Services
  In Products & Services, you can find all our offerings as previously available in Mall Catalog.
- Support
  In Support, you can find all information helpful for resolving technical issues with our products.
- mySieportal
  mySiePortal collects all your personal data and processes, from your account to current orders, service requests and more. You can only see the full range of functions here after you have logged in.

You can access SiePortal via this address: sieportal.siemens.com

Technical Support

The Technical Support of Siemens Industry provides you fast and competent support regarding all technical queries with numerous tailor-made offers – ranging from basic support to individual support contracts.
Please send queries to Technical Support via Web form: support.industry.siemens.com/cs/my/src

SITRAIN – Digital Industry Academy

We support you with our globally available training courses for industry with practical experience, innovative learning methods and a concept that's tailored to the customer's specific needs.
For more information on our offered trainings and courses, as well as their locations and dates, refer to our web page: siemens.com/sitrain

Industry Online Support app

You will receive optimum support wherever you are with the "Industry Online Support" app. The app is available for iOS and Android:





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4.2. Application support

Siemens AG

Digital Industries
SIMATIC PreSales Support
DI FA S SUP SPH

Gleiwitzer Str. 555
90475 Nuremberg, Germany

Contact: via support request from your regional specialist advice or your central contact person

4.3. Links and literature

No.	Topic
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Link to the contribution page of the application example https://support.industry.siemens.com/cs/ww/en/view/109983811
\3\	Product note on the phase-out of ET 200M components https://support.industry.siemens.com/cs/ww/en/view/109809890
\4\	Product note on the phase-out of ET 200S components https://support.industry.siemens.com/cs/ww/en/view/109767411
\5\	Link collection "Migration of systems with SIMATIC (TIA Portal) – Controllers" https://support.industry.siemens.com/cs/ww/en/view/83557459
\6\	FAQ "What are the requirements for migrating a STEP 7 V5.x project to STEP 7 Professional (TIA Portal)?" https://support.industry.siemens.com/cs/ww/en/view/62100731
\7\	Migration Guide: SIMATIC S7-300/S7-400 to SIMATIC S7-1500 https://support.industry.siemens.com/cs/ww/en/view/109478811
\8\	SIEMENS website "Cybersecurity in tunnel systems" https://www.siemens.com/global/en/products/automation/topic-areas/industrial-cybersecurity/cybersecurity-tunnel-systems.html
\9\	System Manual S7-1500R/H https://support.industry.siemens.com/cs/ww/en/view/109754833

4.4. Change documentation

Version	Date	Modification
V1.0	02/2025	First edition
V1.1	06/2025	Extension to S2-based target states, Extension of chapter "Simulation" (3.5)
V1.2	01/2026	Renaming and changes to chapter 2.4, minor changes

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