PROFINET-system redundancy with SINAMICS and S7-1500R/H system

SINAMICS / V1.2

https://support.industry.siemens.com/cs/ww/en/view/109744811

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1 Introduction

1.1 Overview

Introduction

With SINAMICS S120, G130, G150 and S150 PROFINET Control Units, the assembly of system-redundant systems (S2-system redundancy) is possible.

Precondition for system-redundant systems is a so-called H-system. The H-system consists of 2 fault-tolerant controls – master and reserve CPU – which are constantly synchronized via fiber-optic cables. If one controller fails, the other automatically takes on the job. This reduces system downtimes.

NOTE

PROFINET system redundancy is **not** supported by SINAMICS G115D or G120 Control units!

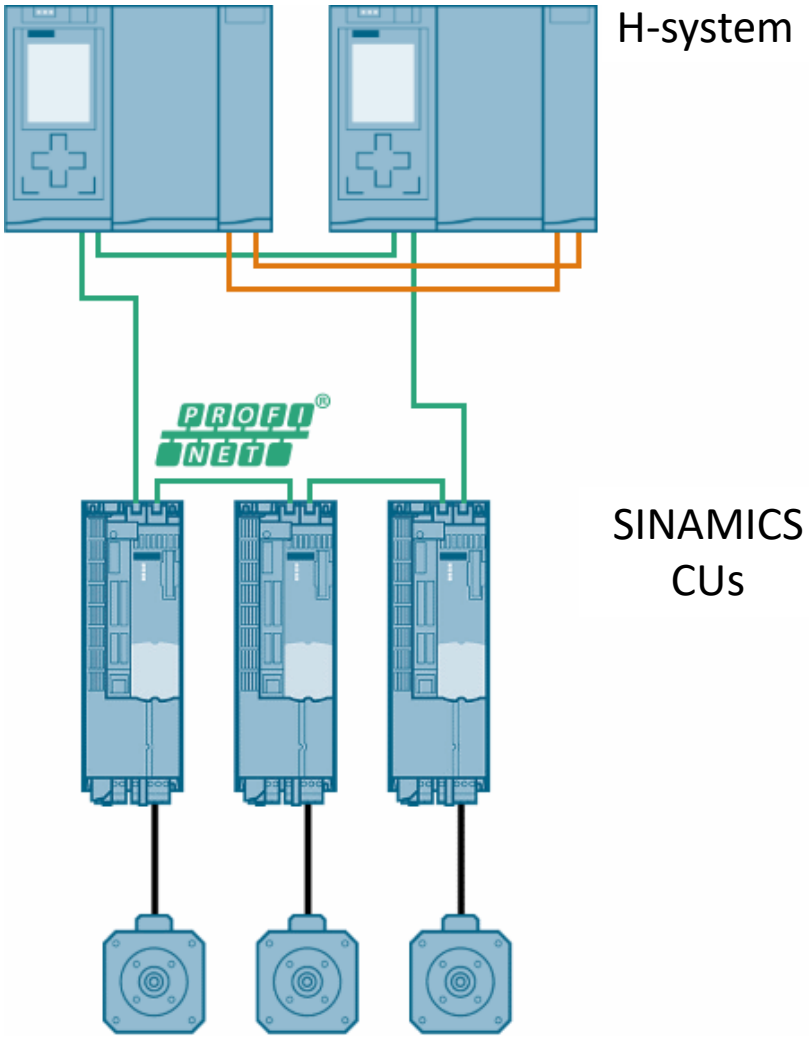
SINAMICS drives which do not support S2 system redundancy can be operated as switched S1-device with the redundant system (S7-1500R/H-system from FW V2.8). See chapter 3.2.3

For failsafe applications the H-system: S7-1518HF can be used, see chapter 3.2.4

Overview of the automation task

The figure below provides an overview of the automation task.

Figure 1-1 Task overview

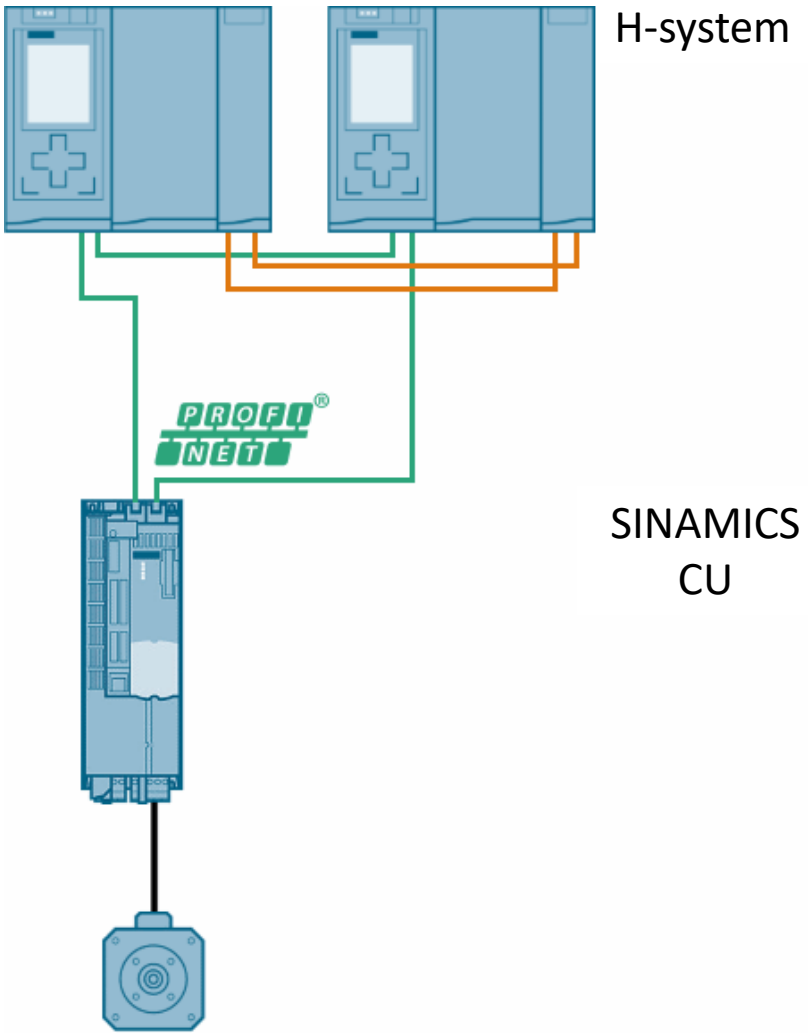


1.2 Mode of operation

Schema

The following figure displays the most important components of the solution:

Figure 1-2 Solution overview



Benefits

- No system downtime in the case of a controller failure
- Component replacement possible during ongoing operation
- Configuration changes possible during ongoing operation
- Automatic synchronization after replacing components

Restrictions SINAMICS

- PROFINET-IRT is not supported
- No simultaneous operation of Shared Device and Shared I-Device
- Maximum 2 cyclical PROFINET connections
- System redundancy only via the onboard interface of SINAMICS PROFINET Control Unit S120, G130, G150 and S150
- For the duration of switching from one controller to the other, the setpoints of the last connection remain frozen and valid.

Restrictions Engineering system

As Startdrive is not supported yet, GSD files must be used.

Restrictions H-system

For restrictions of the H-system please refer to the system manual:
https://support.industry.siemens.com/cs/ww/en/view/109754833

Knowledge required

Basic knowledge of SINAMICS drives and H-Systems is assumed.

1.3 Components used

This application example has been created with the following hardware and software components:

Table 1-1 Components

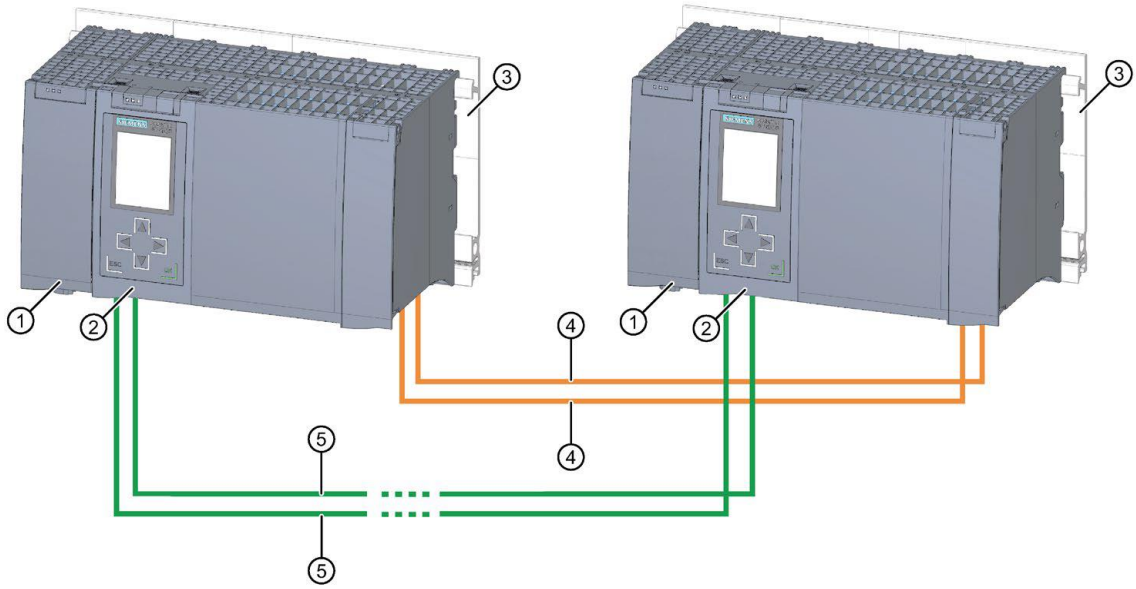
Component	Number	Article number	Note
CPU S7-1517H system bundle	1	6ES7500-0HP00-0AB0	with sync modules
SINAMICS S120 CU310-2 PN	1	6SL3040-1LA01-0AA0	Firmware V5.2 HF1
Training case	1	6ZB2480-0AD00	Servo motor with DRIVE-CLiQ
TIA Portal	1		V15.1
STARTER	1		V5.1 mit SSP V5.2 oder V5.3

2 Engineering

2.1 Installation of hardware

Following pictures show the hardware and the topology of the hardware.

Figure 2-1 Hardware



S7-1500H

The S7-1500H redundant system should be installed either on one shared mounting rail or on two separate mounting rails. You connect the two CPUs with fiber-optic cables to two synchronization modules in each CPU. You set up the PROFINET ring with the PROFINET interfaces X1 P1 R and X1 P2 R of the CPUs

Power supply

The load power supply (PM) supplies the system power supply (PS) and central modules (CPU) with 24 V DC. If you are using load power supplies, we recommend the devices from our SIMATIC series.

Synchronization modules (only S7-1500H)

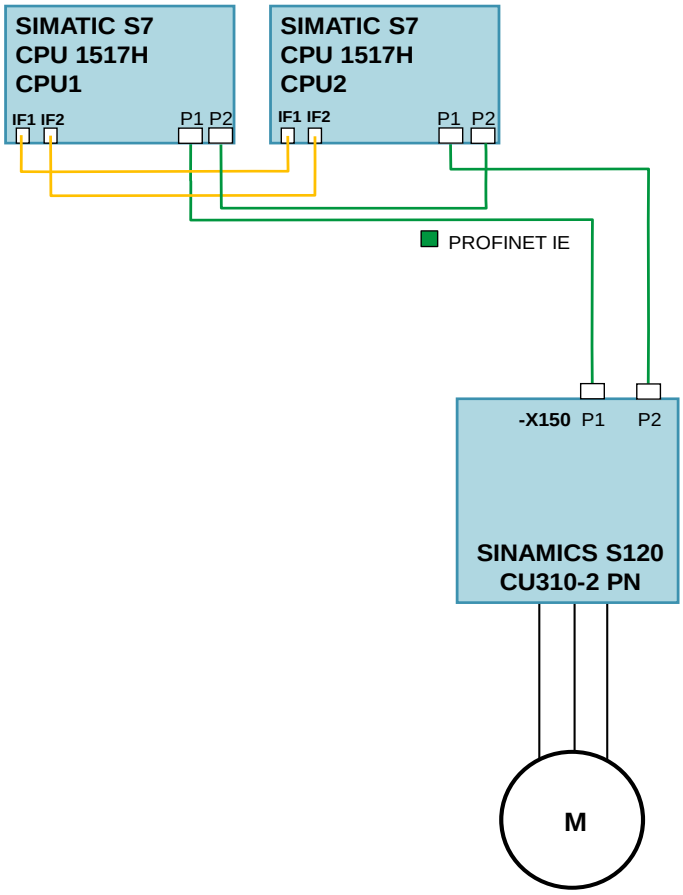
You create two redundancy connections between the H-CPUs with fiber-optic cables using a total of four synchronization modules

Fiber-optic cable (only S7-1500H)

You connect the two synchronization modules for each CPU in a pair with a fiber-optic cable

2.2 Topology

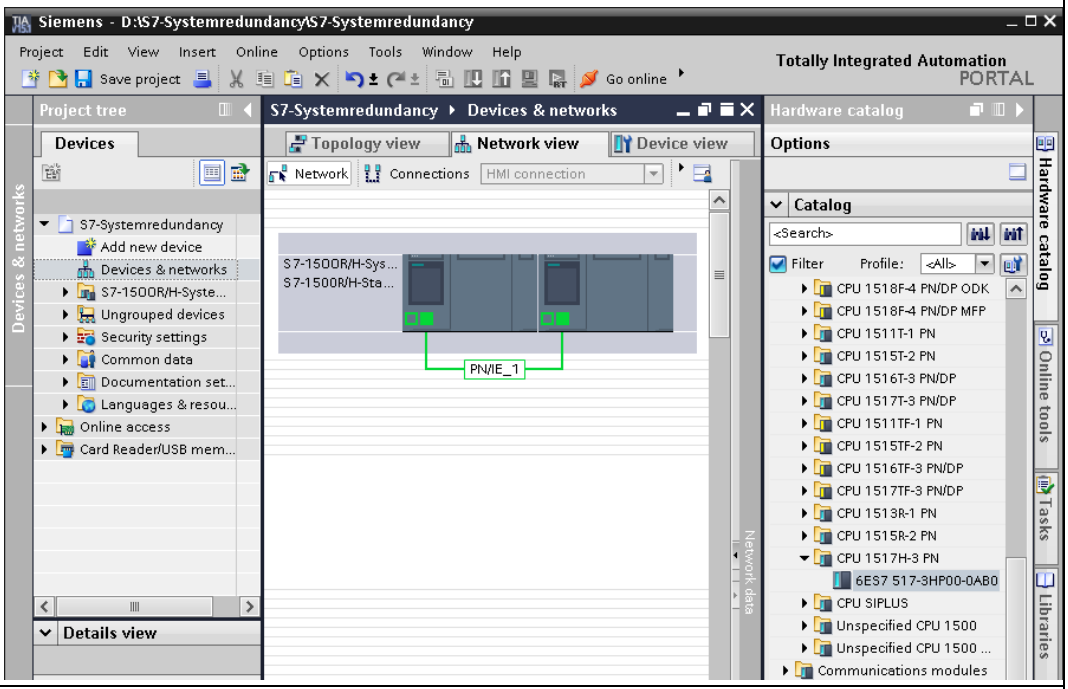
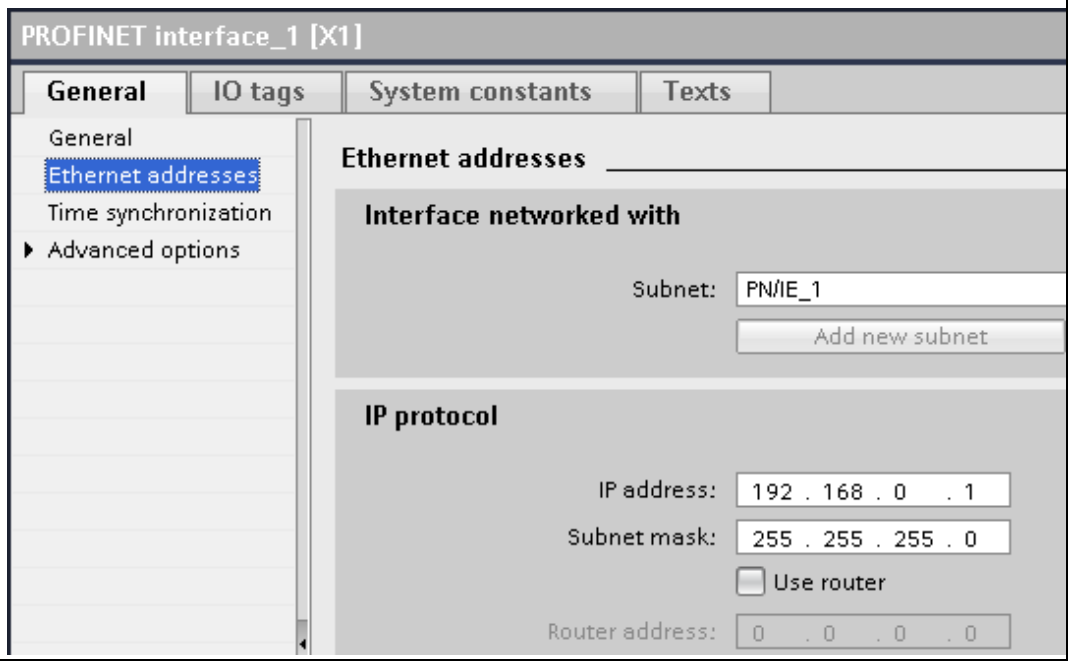
Figure 2-2 Interconnection

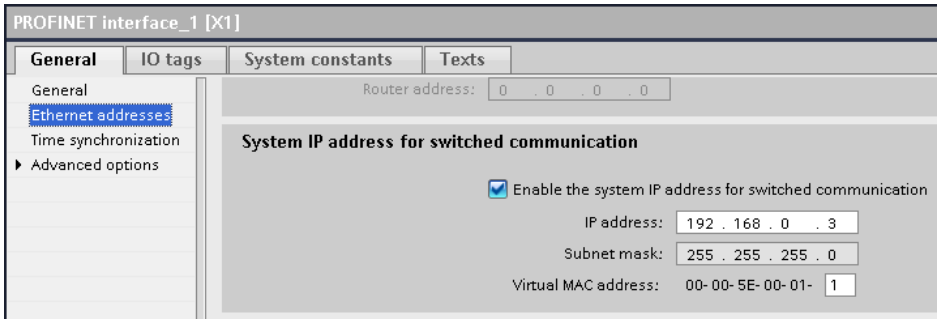


2.3 Configuration

2.3.1 Configuration of SIMATIC R/H-system

Table 2-1 Configuration with TIA portal

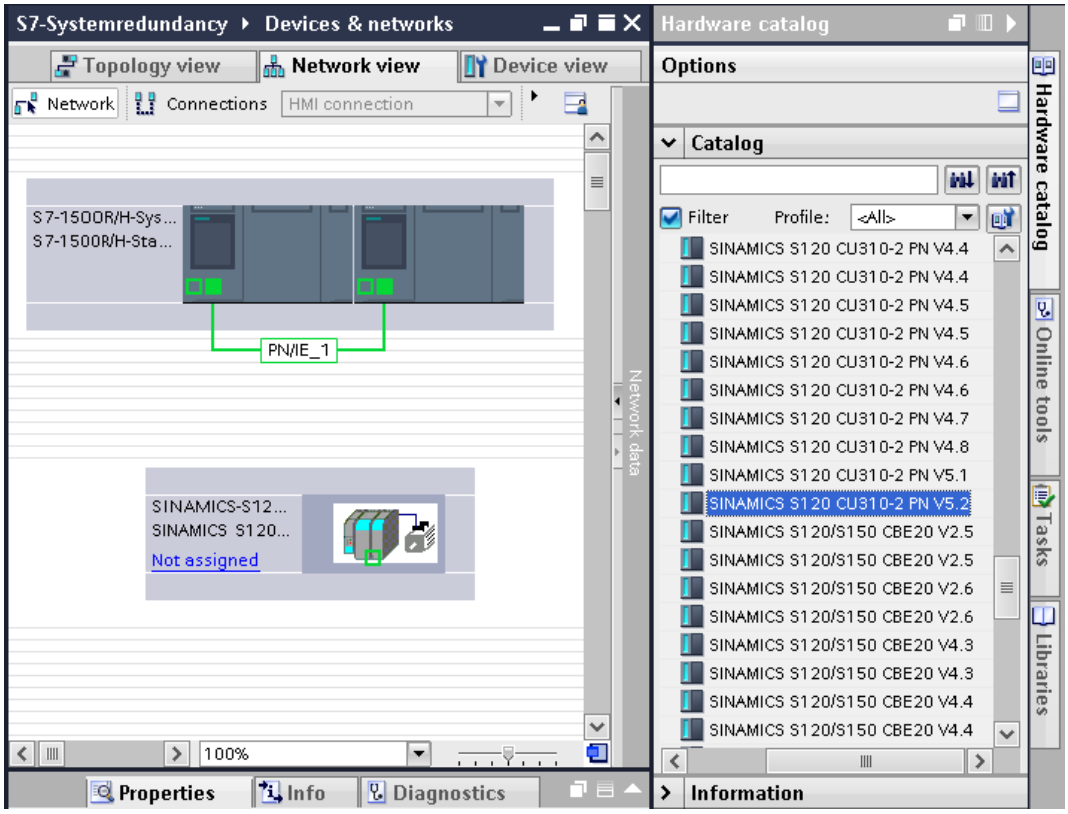
No	Action
1.	Create a new TIA Portal project.
2.	Insert a new `SIMATIC S7-1500R/H PLC` with the hardware catalog 
3.	Assign the IP addresses of the PLCs in the settings of the PLC respectively. e.g. default setting: PLC1: 192.168.0.1 PLC2: 192.168.0.2 

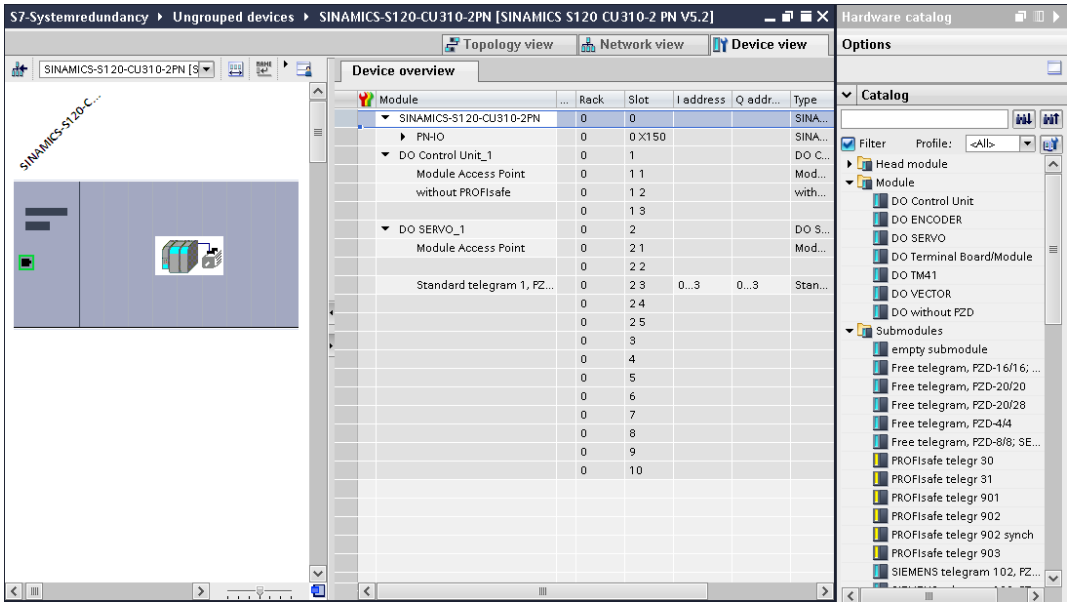
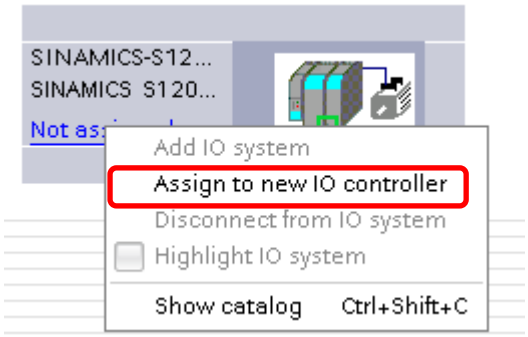
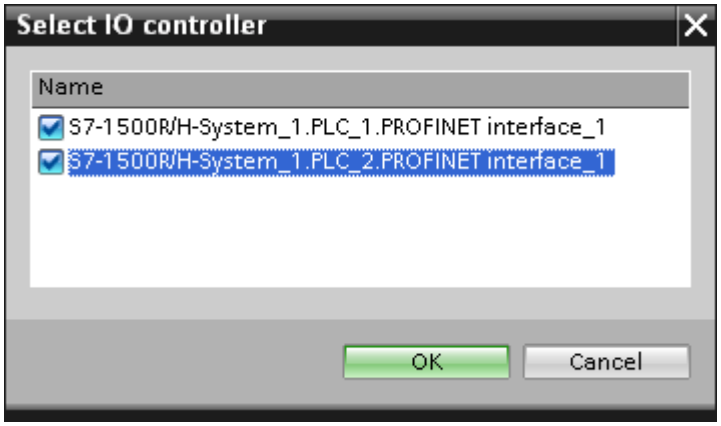
No	Action
4.	**Recommended:** Enable and assign the system IP address for the interfaces X1 and X2. **Advantages of system IP addresses over device IP addresses** • Targeted communication of the communication partner with the primary CPU. • The S7-1500R/H redundant system can continue to communicate over a system IP address even if the primary CPU fails. 

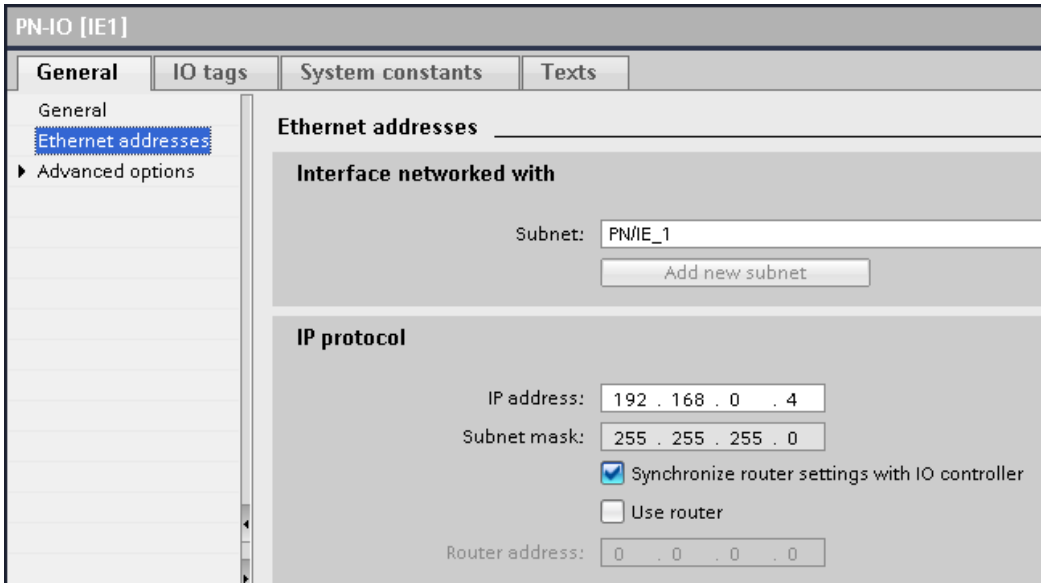
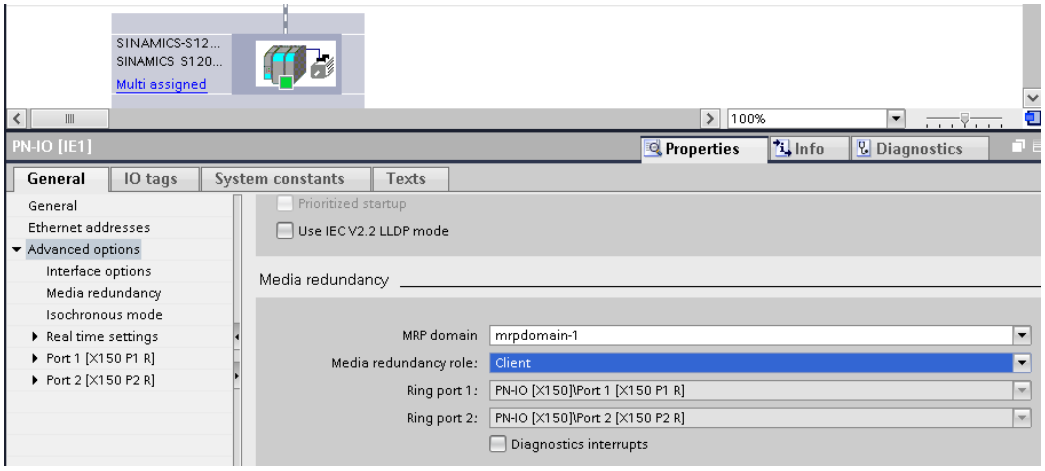
2.3.2 Configuration of the SINAMICS drive (GSD-file)

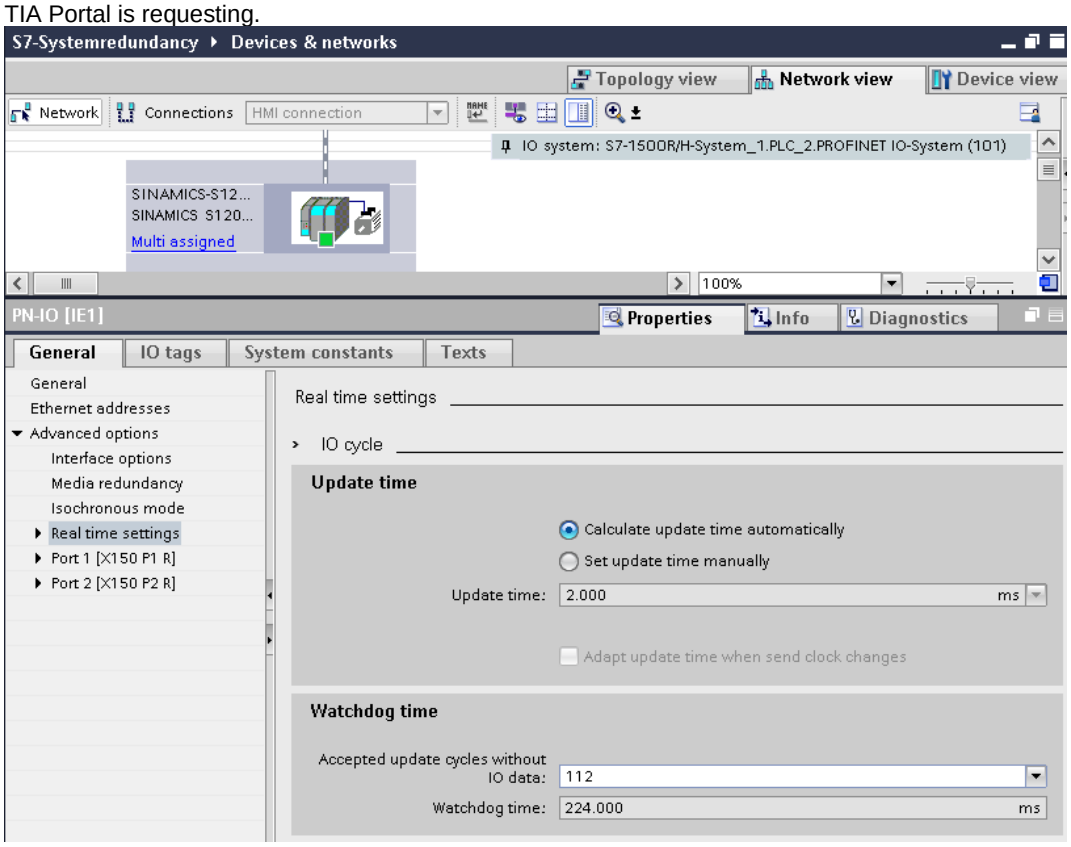
The SINAMICS drive can be configured with the hardware catalog.

Table 2-2 Configuration with GSD file

1.	Insert the SINAMICS S120 in the network view with the hardware catalog. 

2.	Configure the SINAMICS with the desired modules and submodules in the device view. 
3.	Right click “Not assigned” and click on “Assign to new IO controller” 
4.	Select both PLCs of the H-system: 

5.	Navigate to the properties of the interface and assign the desired IP address: e.g. default setting: 192.168.0.4 
6.	Navigate to “Advanced Options” → “Media redundancy” and set the media redundancy role to “Client”: 

7.	In „Advanced Options“ → „Real time settings“ set the accepted update cycles factor to the value TIA Portal is requesting. 

2.3.3 Download of the configuration

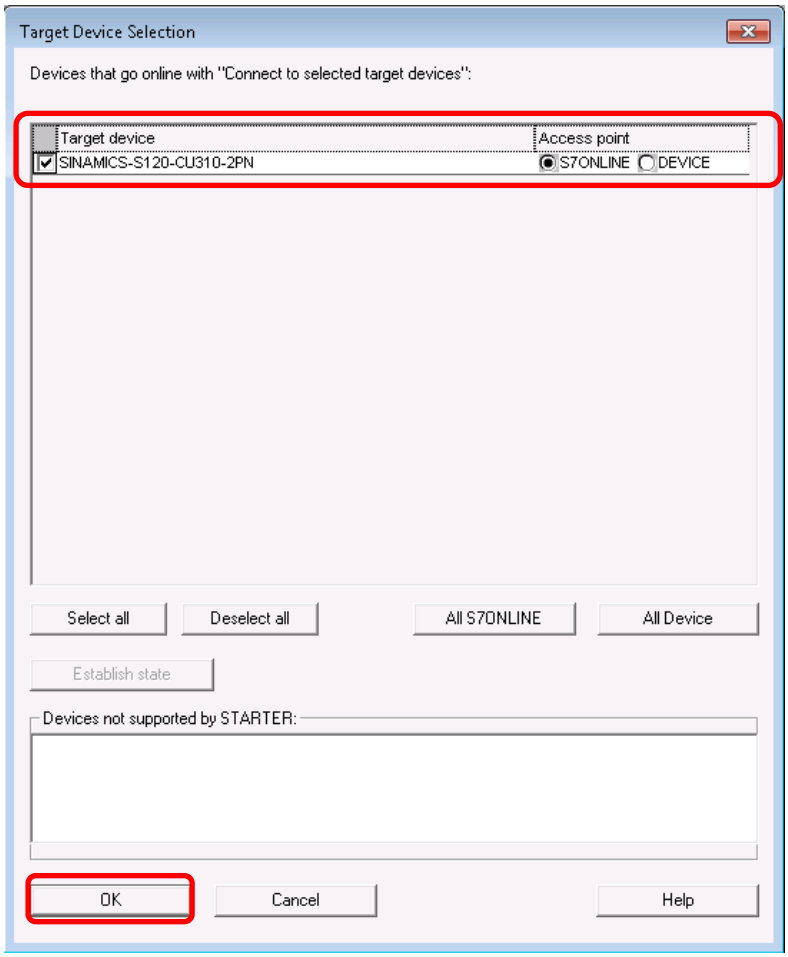
Table 2-3 Download of the configuration

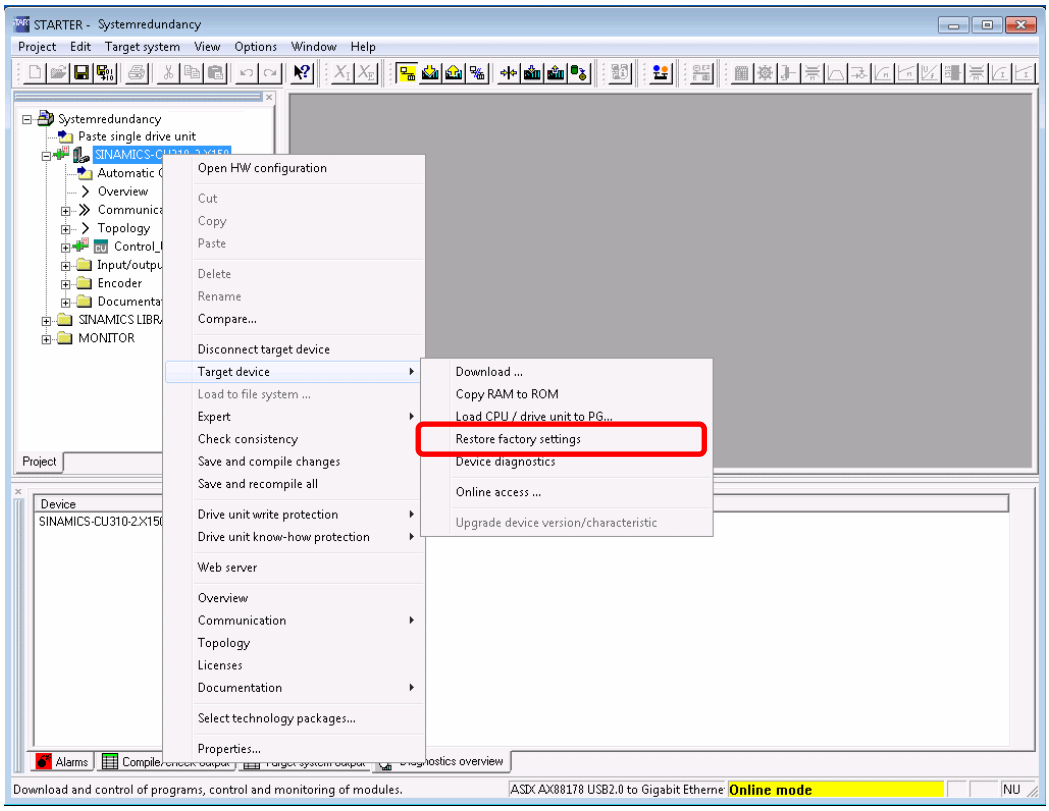
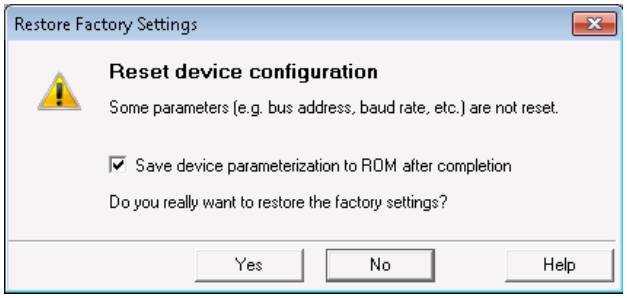
No.	Action
1.	Save and compile the project. 
2.	Download the project into the PLC. 
3.	Choose your PG/PC interface and search for the PLC. Select the primary PLC and click on “Load”.

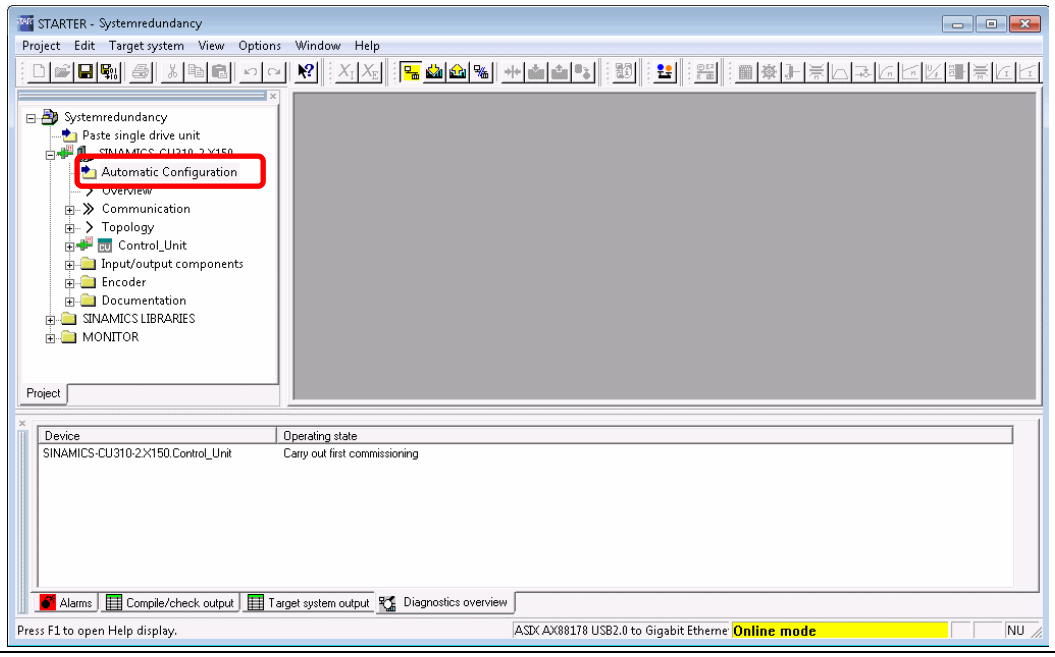
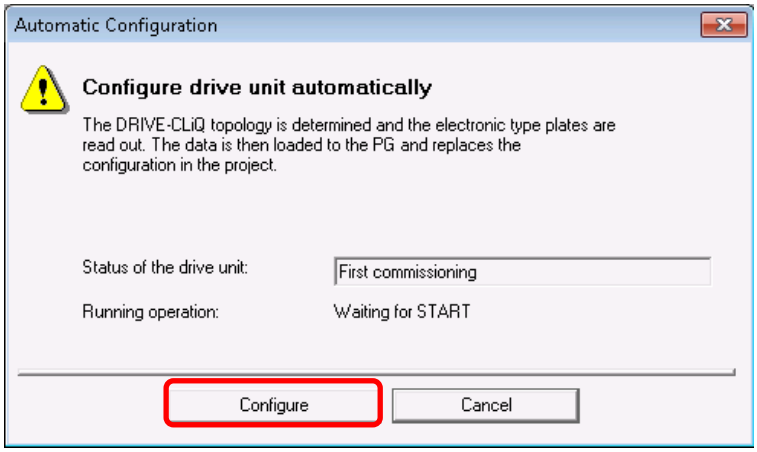
2.3.4 Commissioning of the SINAMICS drive

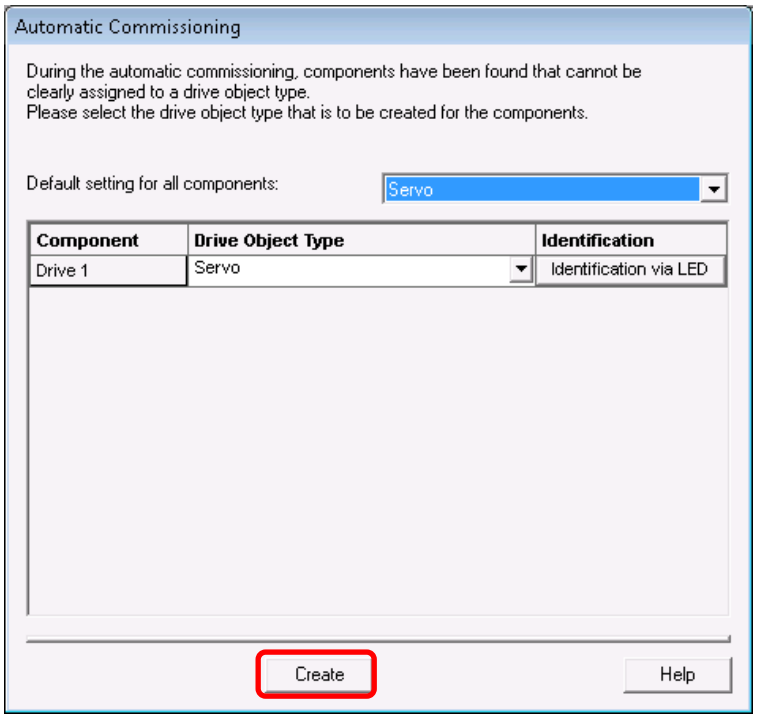
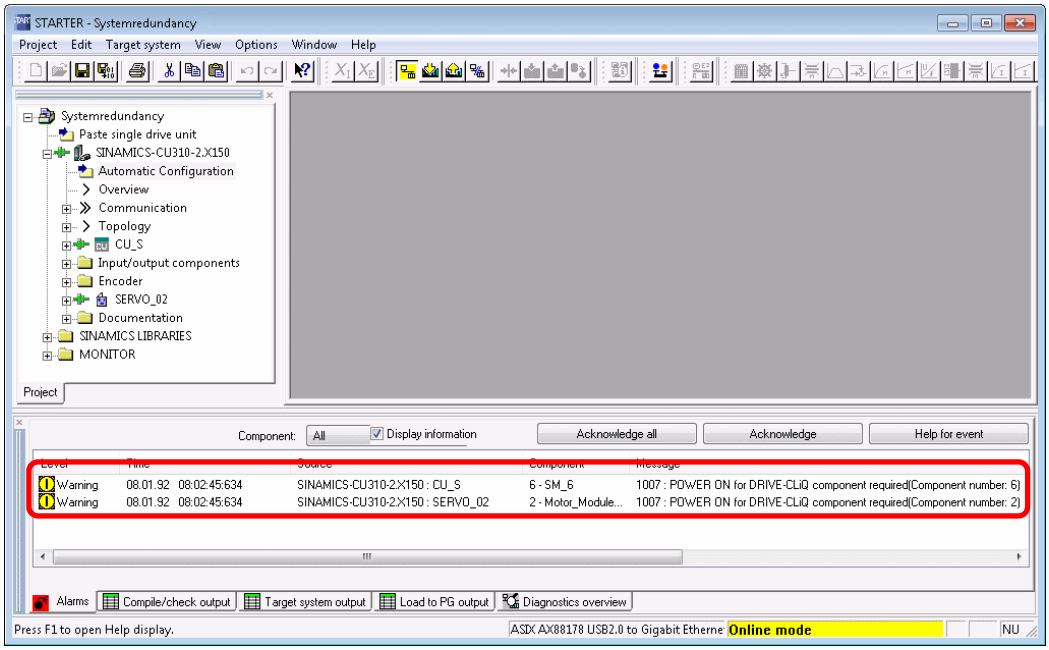
The standard configuration of the SINAMICS drive with the STARTER engineering system is shown below.

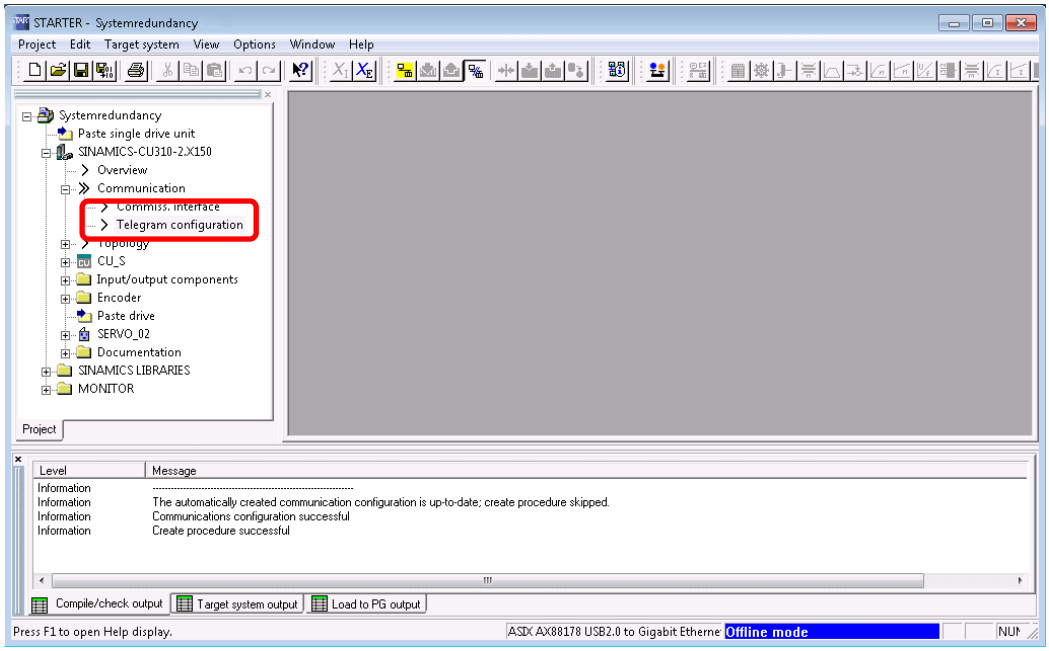
Table 2-4 Configuration SINAMICS drive

No.	Action
1.	Insert a single drive unit: SINAMICS S120 CU310-2PN Establish an online connection to the SINAMICS drive.  **Note** To establish an online connection, the network card of the engineering PC being used must be in the same IP subnet as the target device. Ensure that this precondition is complied with and if required adapt the IP configuration of your network card! Example • IP address of the target device `192.168.0.4` subnet mask `255.255.255.0` • IP address of the engineering PC `192.168.0.99` subnet mask `255.255.255.0`
2.	Select the configured SINAMICS drive (set the checkmark in the checkbox) and confirm your selection by pressing the "OK" button. 

No.	Action
3.	After this, restore the factory settings at the SINAMICS (if not already done). 
4.	Confirm the following message with "`Yes`". The drive is then reset to the factory settings. 

No.	Action
5.	Afterwards carry out the automatic configuration of the drive. 
6.	Start the configuration by pressing the "Configure" button. The DRIVE-CLiQ topology of the drive is read out. 

No.	Action
7.	A servo motor is used in the SINAMICS training case. 
8.	If the firmware version of the drive has changed compared to the last commissioning, after the automatic configuration it may be necessary to "`Power OFF/ON`" the drive to update the firmware of the DRIVE-CLiQ components  **Note** **Before** "`Power OFF/ON`" execute the "`RAM to ROM`" function at the drive to save the previous configuration in a non-volatile way.

No.	Action
9.	Go offline and open the drive telegram configuration using the menu item "Communication > Telegram configuration". 
10.	The following telegrams are used for cyclic communication between the controller and drive in the sample project: • CU_S Free telegram configuration with BICO, Length 0/0 • SERVO_02 Standard telegram 1, Length 2/2 Set these telegrams in the drive telegram configuration. IF1: PROFIdrive PZD telegrams Communication interface: PROFINET - ONBOARD (cyclic) The PROFIsafe communication is performed via this interface The PROFIdrive telegrams of the drive objects are transferred in the following order: **The input data corresponds to the send and the output data of the receive direction of the drive object.** **Master view:**

Object	Drive object	-No.	Telegram type		Input data Length	Output data Length
1	CU_S	1	Free telegram configuration with BICO		0	0
2	SERVO_02	2	Standard telegram 1, PZD-2/2		2	2
DOs that are not assigned to a slot. (No cyclic data exchange)						

11.	Save and compile the configuration 
12.	Establish an online connection with the drive. 
13.	Download to the SINAMICS drive. 
14.	Execute the "RAM to ROM" function in the drive to save its configuration in a non-volatile way. 
15.	The communication between the SIMATIC CPU and SINAMICS drive has therefore been configured.

2.4 Commissioning of the sample project

Overview

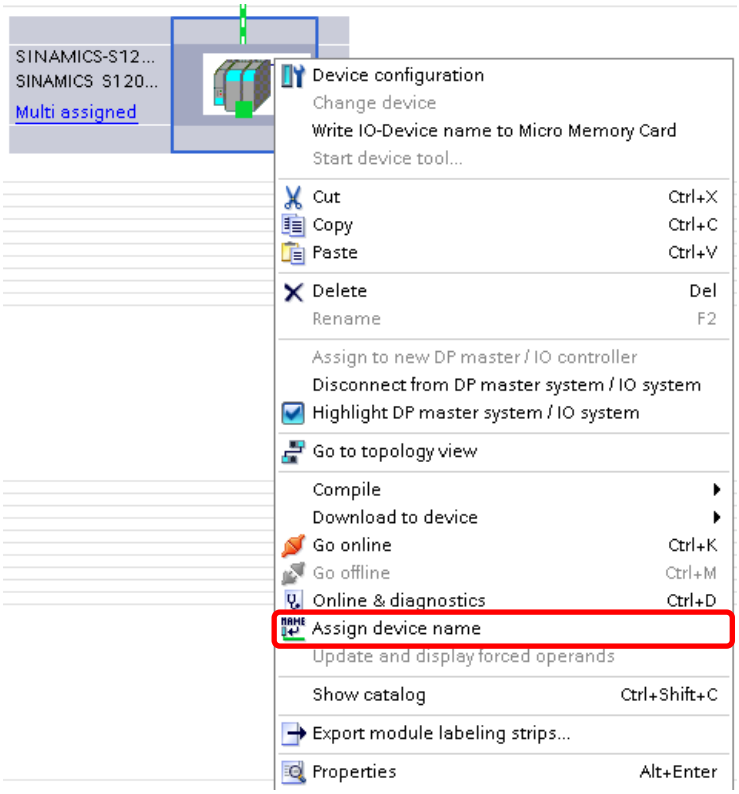
An executable sample project is included in the zip archive "109744811_Systemredundancy_S7-1500.zip".

NOTE The sample project is configured with a S7-1517 H-system. It can be changed with „Change device…" into a S7-1513R or S7-1515R. After changing the device, a PROFINET connection must be established between PLC1 and PLC2 in the topology view.

Commissioning of the sample project

The steps described in the following must be performed to commission the sample project.

Table 2-5 Commissioning

No.	Action
1.	All hardware components are available and interconnected.
2.	All PROFINET components are networked and accessible from the engineering system.
3.	The Ethernet interface of the engineering system is configured correctly and is working. Example IP address: `192.168.0.99` subnet mask: `255.255.255.0`
4.	Start TIA Portal V15.1.
5.	Open the TIA sample project from the zip archive "109744811_Systemredundancy_S7-1500.zip".
6.	Download the project into the PLC.
7.	Assign the SINAMICS drive the PROFINET device name. Navigate therefore to the network view and right click the SINAMICS > Assign device name 

No.	Action
8.	Search for the device, select it and click on “Assign name”
9.	As an alternative, PRONETA can also be used to assign the name. PRONETA can be downloaded at the following link. https://support.industry.siemens.com/cs/ww/en/view/67460624
10.	Start the STARTER engineering system and open the STARTER sample project
11.	Establish an online connection with the SINAMICS drive. 
12.	Download the configuration of the drive into the target device. 
13.	Then execute the "RAM to ROM" function. 
14.	The sample project is now ready for operation.

2.5 Controlling the SINAMICS

The H-system does not support technology objects and therefore the library DriveLib is used to control the SINAMICS:

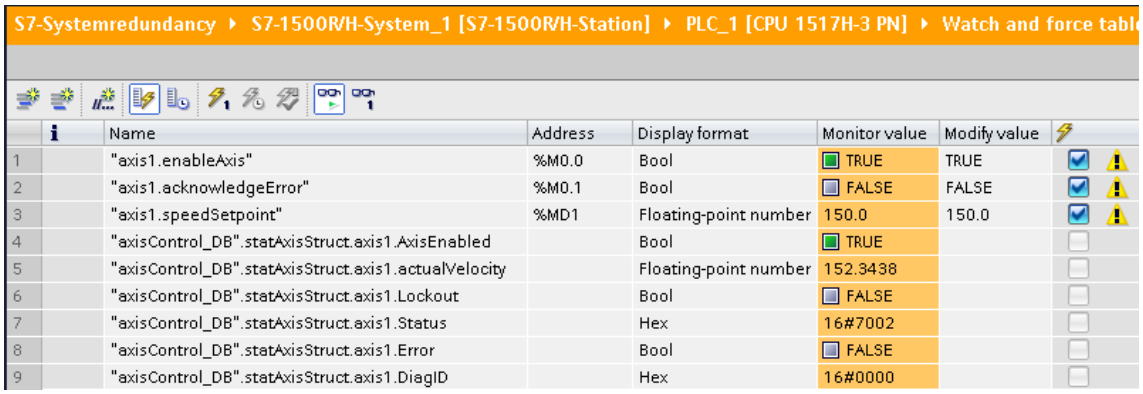
https://support.industry.siemens.com/cs/ww/en/view/109475044

2.6 Operation

The sample project can be operated with the watch table *axisControl*.

The user can define a speed setpoint and enable/disable the axis. Active faults can be acknowledged. Moreover, the current status of the FB is displayed.

Figure 2-3 Watch table axisControl



	i	Name	Address	Display format	Monitor value	Modify value	
1		"axis1.enableAxis"	%M0.0	Bool	TRUE	TRUE	☑ ⚠
2		"axis1.acknowledgeError"	%M0.1	Bool	FALSE	FALSE	☑ ⚠
3		"axis1.speedSetpoint"	%MD1	Floating-point number	150.0	150.0	☑ ⚠
4		"axisControl_DB".statAxisStruct.axis1.AxisEnabled		Bool	TRUE		☐
5		"axisControl_DB".statAxisStruct.axis1.actualVelocity		Floating-point number	152.3438		☐
6		"axisControl_DB".statAxisStruct.axis1.Lockout		Bool	FALSE		☐
7		"axisControl_DB".statAxisStruct.axis1.Status		Hex	16#7002		☐
8		"axisControl_DB".statAxisStruct.axis1.Error		Bool	FALSE		☐
9		"axisControl_DB".statAxisStruct.axis1.DiagID		Hex	16#0000		☐

3 Additional information

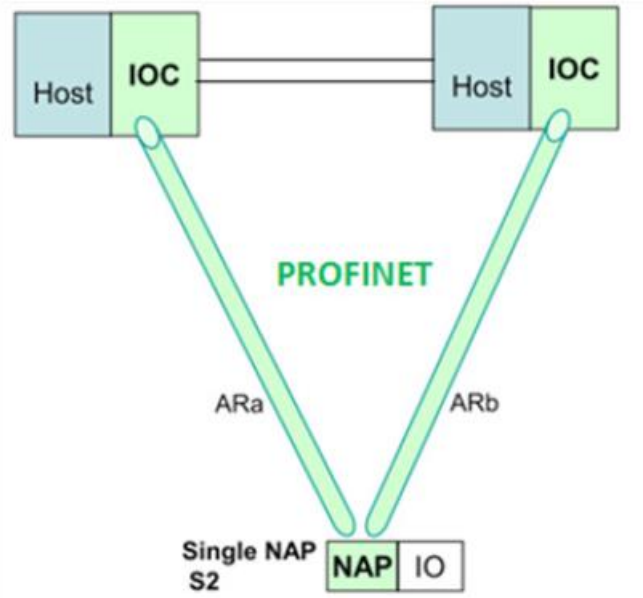
3.1 System and media redundancy

System redundancy

With system redundancy a PROFINET device is initiating more than one communication relation to a redundant controller. Thereby it is distinguished between different forms of system redundancy.

In this example only S2-system redundancy is used which describes a compact PROFINET device that can be operated with a highly available system without any additional hardware.

Figure 3-1 S2-system redundancy

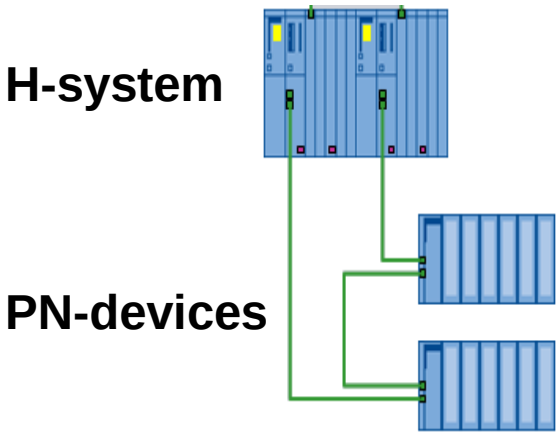


Requirement for realizing the system redundancy is the application of an H system.

The H system consists of two fault-tolerant controllers (master and reserve CPU). If one H-CPU fails, the other automatically takes over.

System redundancy is a connection of IO devices via PROFINET (PN devices), for which there is a communication connection between each PN device and each of both H-CPUs (see picture below).

Figure 3-2 System redundancy



The IO devices need to support the system redundancy; otherwise, they can be operated in the same network, however only one of both H-CPUs can be assigned (unilateral periphery).

The used topology (line, star, ring) plays no role for the system redundancy. This distinguishes the system redundancy from the media redundancy.

System redundant periphery is often also referred to as switched periphery. This does **not** refer to the fault tolerance between I/O groups or systems.

An example for switched periphery (system-redundant periphery) are PN devices, which support the system redundancy and can be assigned to an H system (e.g. ET 200M, SINAMICS CU320-2PN, etc..). In contrast, the ET 200S, for example, can only be assigned to an H-CPU unilaterally (no H system).

Media redundancy

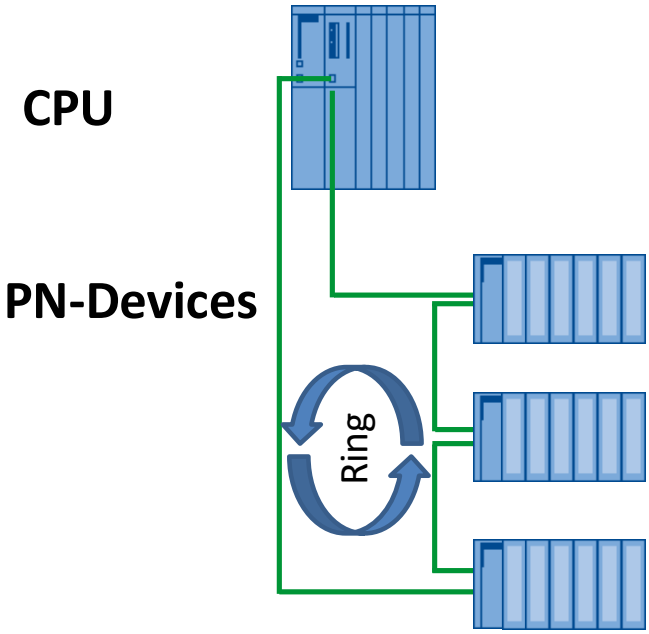
Media redundancy ensures the network availability and contributes to increasing the plant availability.

The ring topology is used here. The media redundancy protocol (MRP) ensures that when one transmission path fails, an alternative communication path is available.

For media redundancy with MRP, one device is the media redundancy manager (MRM), all other devices are redundancy clients. In the picture below, the CPU is the MRP-Manager.

In the case of a failed connection, the MRM selects the alternative communication path.

Figure 3-3 Media redundancy



Context

System and media redundancy have no mutual impact on each other.

3.2 Redundant system S7-1500R/H

3.2.1 System redundancy and media redundancy

All PROFINET IO devices assigned to the S7-1500R/H system must support system redundancy S2.

NOTE With the exception of Switches S1 devices. See chapter 3.2.3 Switched S1 device

These PROFINET IO devices can be located in the PROFINET ring or they can be separated with a switch.

All PROFINET devices in the PROFINET ring must support media redundancy (MRP). System redundancy S2 is not a requirement. For example, you can use switches and HMI devices without system redundancy S2.

The redundancy connections in an S7-1500R system are the PROFINET ring with MRP. The two CPUs must be directly connected to each other with a PROFINET cable. All nodes can still communicate with each other in the event of an interruption in the ring. PROFINET devices that do not support MRP must be separated from the ring with a switch.

3.2.2 PROFINET devices suitable for the redundant system

The table below shows the maximum number of PROFINET devices in the redundant system. The maximum number includes switches, S7-1500R/H CPUs, S7-1500 CPUs (V2.5 or later) and HMI devices. It does not include media converters.

Table 3-1 Number of devices

PROFINET devices	Maximum number S7-1500R	Maximum number S7-1500H
In the PROFINET ring	50 (Recommendation: 16) [1)]	50
In the PROFINET ring and separated with switches (line)	66	258

[1)]Recommendation: The number of devices in the PROFINET ring affects the availability of the S7-1500R system. You should therefore operate no more than 16 PROFINET devices (including R-PLCs) in the PROFINET ring. If you operate significantly more devices in the PROFINET ring, the availability of the IO devices and R-PLCs is reduced.

NOTE

Only with S7-1500R:

One of the two connections of the PROFINET ring between the two R-CPUs must not contain any other IO devices, switches or other PROFINET devices apart from transparent media converters
(The default setting is port 2 at PROFINET interface X1)

For more information see system manual:

https://support.industry.siemens.com/cs/ww/en/view/109754833

3.2.3 Switched S1 device

As of firmware version V2.8, the S7-1500R/H redundant system supports the "Switched S1 device" function.

The "Switched S1 device" function of the CPU enables operation of standard IO devices on the S7-1500R/H redundant system.

Standard IO devices are always assigned to both CPUs of the S7-1500R/H redundant system. In contrast to an IO device with S2 system redundancy, a standard IO device supports only one “Application Relation” (AR). The AR for the IO-device is only set up once by the primary CPU.

- Behavior in the RUN-Redundant system state:

  PROFINET communication runs on the AR between the primary CPU (IO controller) and the standard IO device. There is no AR between the backup CPU and the standard IO device. If the primary CPU fails or is switched to STOP, the S7-1500R/H redundant system responds as follows:

  - The AR between the primary CPU and the standard IO device is disconnected.
  - The previous backup CPU becomes the new primary CPU.
  - The S7-1500R/H redundant system temporarily has no access to the inputs and no control over the outputs of the standard IO device. The status of the outputs depends on the substitute value behavior of the respective channels.
  - The new primary CPU builds an AR to the standard IO device.
  - As soon as the new primary CPU has set up the AR, the S7-1500R/H redundant system has access to the inputs again and control over the outputs of the standard IO device.

- Behavior in the RUN-Solo system state:

  Only the primary CPU is the IO controller. PROFINET communication runs on the AR between the primary CPU (IO controller) and the standard IO device. There is no AR between the backup CPU and the standard IO device.

In STEP 7 you configure an IO device connected via the "Switched S1 device" function by assigning a standard IO device to both CPUs of the redundant S7-1500R/H system.

Main differences between IO device with S2 system redundancy and standard IO device

Table 3-2 Main differences between S2 system redundancy and standard IO device

Property	IO device with S2 system redundancy	Standard IO device
Requirement for IO device	Device supports S2 system redundancy	-
Maximum simultaneously supported ARs	2	1
Response to role change	Continuous connection with S7-1500R/H redundant system. Process data is transferred further.	Temporary disconnection from S7-1500R/H redundant system. No process data is transferred until the standard IO device is available again. The status of the outputs depends on the substitute value behavior of the respective channels.

3.2.4 Failsafe applications with 1518HF-4 PN

With the H-system 1518HF Safety applications can be realized and the Safety Integrated Functions of the SINAMICS drive family can be controlled.

NOTE

The library LDrvSafe is recommended to control the PROFIsafe functions of the SINAMICS: https://support.industry.siemens.com/cs/ww/en/view/109485794

When using Safety Integrated additionally to the watchdog time also the F-monitoring time of the respective devices have to be considered.

It is distinguished between following two scenarios:

- S2-Devices:

  The F-monitoring time must be at least higher than the MRP reconfiguration time. Thus, it is ensured that there will be no communication interruption in the case of switch over or failed connection.

- Switched S1-Devices:

  In this case the F-monitoring time cannot be exactly determined or calculated. There are three factors to be considered:

1. Watchdog time *
2. Take over time **
3. Restart time ***

Switched S1-devices can therefore already be online again after 600ms or only after > 1 second.

The F-monitoring time must be determined according to the respective application and be configured to make sure that PROFIsafe does not cause an undesired system-stop.

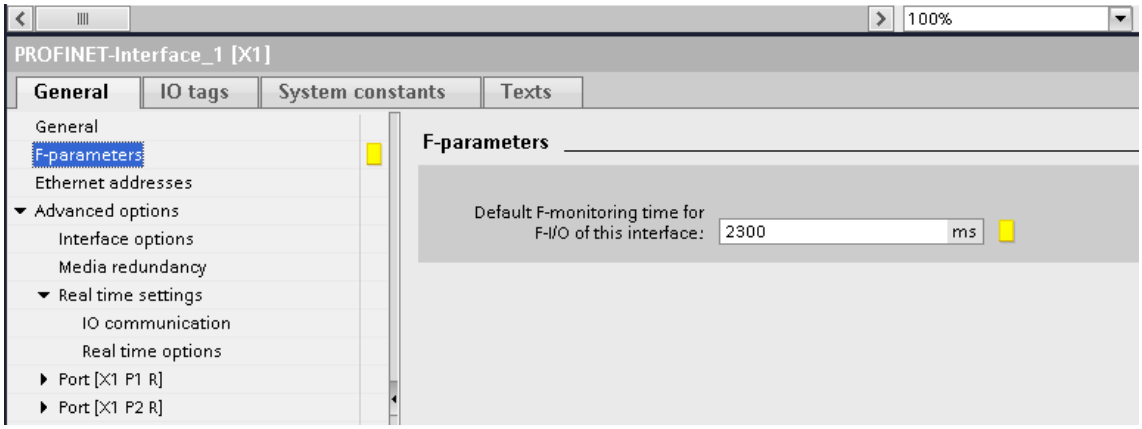
* Device is losing connection to the controller and waits this time to be ready for the new AR (default: 224ms)

** New primary PLC is taking over the ARs of the S1-devices and parameterizes them – always in blocks of 50 devices. The first 50 S1-devices are therefore faster online than devices 51-100, etc...

*** After parameterization IO-Devices have different restart times dependent on the device.

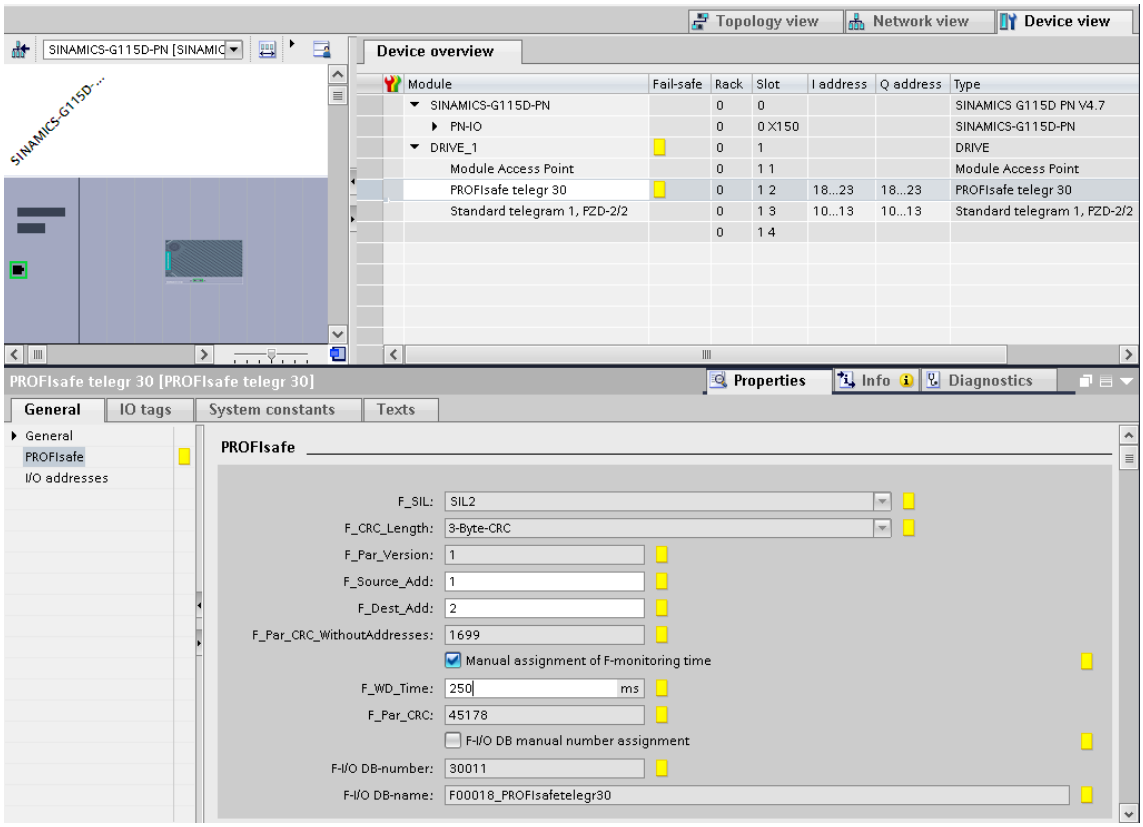
The default F-monitoring time for the H-system 1518HF is set to 2300ms:

Abbildung 3-4



The default F-monitoring time for the SINAMICS GSD file is set to 250ms. With deactivating the checkbox „Manual assignment of F-monitoring time" the global setting of the F-PLC can be used instead.

Abbildung 3-5



3.2.5 Specific instructions and blocks for S7-1500R/H

Specific instructions and OBs are available for the S7-1500R/H redundant system.

The "RH_CTRL" instruction is used to disable SYNCUP or to enable the running of the SYNCUP. The goal is to only permit the SYNCUP in less critical process phases.

The instruction "RH_GetPrimaryID" is used to read out which PLC is currently the primary PLC.

In addition to the OBs of the S7-1500 CPU, you can also use OB 72 (CPU redundancy error). OB 72 is called when the S7-1500R/H redundant system has reached or left the RUN redundant system state.

4 Appendix

4.1 Service and Support

Industry Online Support

Do you have any questions or need assistance?

Siemens Industry Online Support offers round the clock access to our entire service and support know-how and portfolio.

The Industry Online Support is the central address for information about our products, solutions and services.

Product information, manuals, downloads, FAQs, application examples and videos – all information is accessible with just a few mouse clicks at:
https://support.industry.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. You send queries to Technical Support via Web form:
www.siemens.com/industry/supportrequest

Service offer

Our range of services includes, inter alia, the following:

- Product trainings
- Plant data services
- Spare parts services
- Repair services
- On-site and maintenance services
- Retrofitting and modernization services
- Service programs and contracts

You can find detailed information on our range of services in the service catalog:
https://support.industry.siemens.com/cs/sc

Industry Online Support app

You will receive optimum support wherever you are with the "Siemens Industry Online Support" app. The app is available for Apple iOS, Android and Windows Phone:
https://support.industry.siemens.com/cs/ww/en/sc/2067

4.2 Contact

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4.3 Links and Literature

Table 4-1

No.	Topic
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Download page of this entry https://support.industry.siemens.com/cs/ww/en/view/109744811
\3\	SINAMICS S120 Function Manual Drive Functions https://support.industry.siemens.com/cs/ww/en/view/109763287
\4\	SIMATIC S7-1500 R/H redundant system https://support.industry.siemens.com/cs/ww/en/view/109754833
\5\	SIMATIC S7-1500R/H CPU 1518HF-4 PN https://support.industry.siemens.com/cs/ww/en/view/109784207

4.4 Change documentation

Table 4-2

Version	Date	Modifications
V1.0	06/2019	First version
V1.1	07/2020	Extension with “Switched S1 device”
V1.2	06/2022	Extension with 1518HF (failsafe applications)