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PROFINET-system redundancy with SINAMICS drives

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1 Task

Introduction

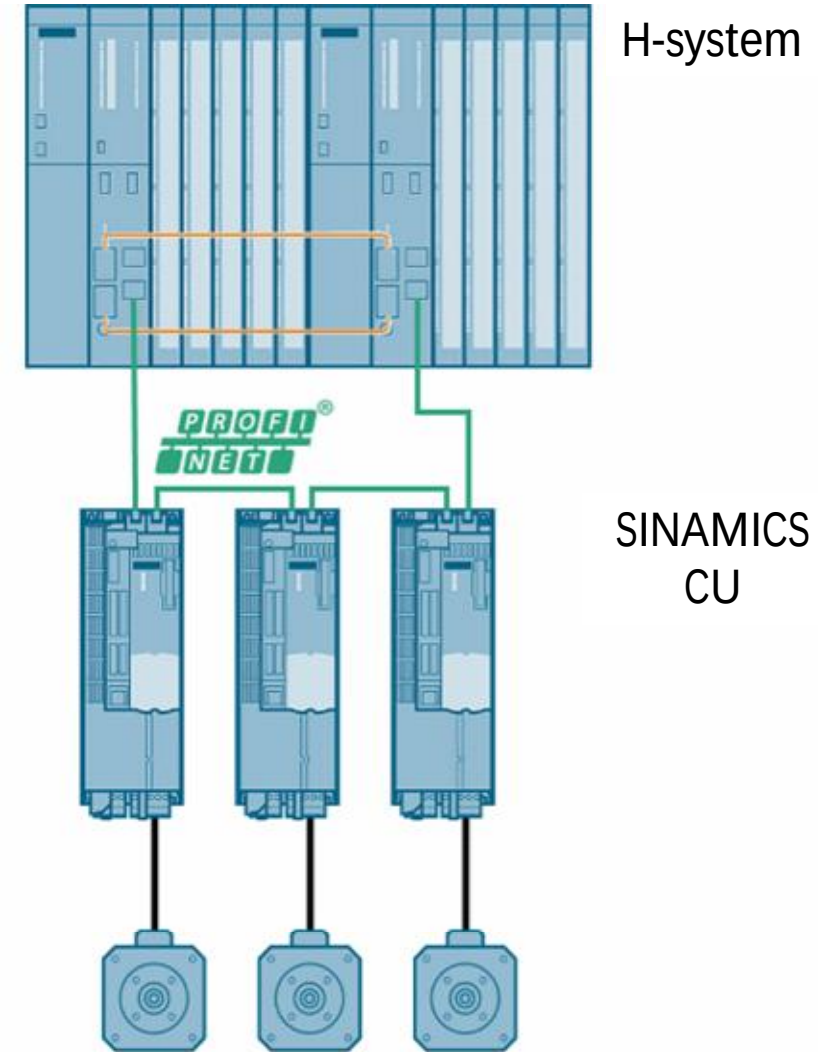
Thanks to SINAMICS S120, G130, G150 and S150 PROFINET Control Unit, the assembly of system-redundant systems (S2-system redundancy) is possible.

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.

Overview of the automation task

The figure below provides an overview of the automation task.

Figure 1-1 Task overview



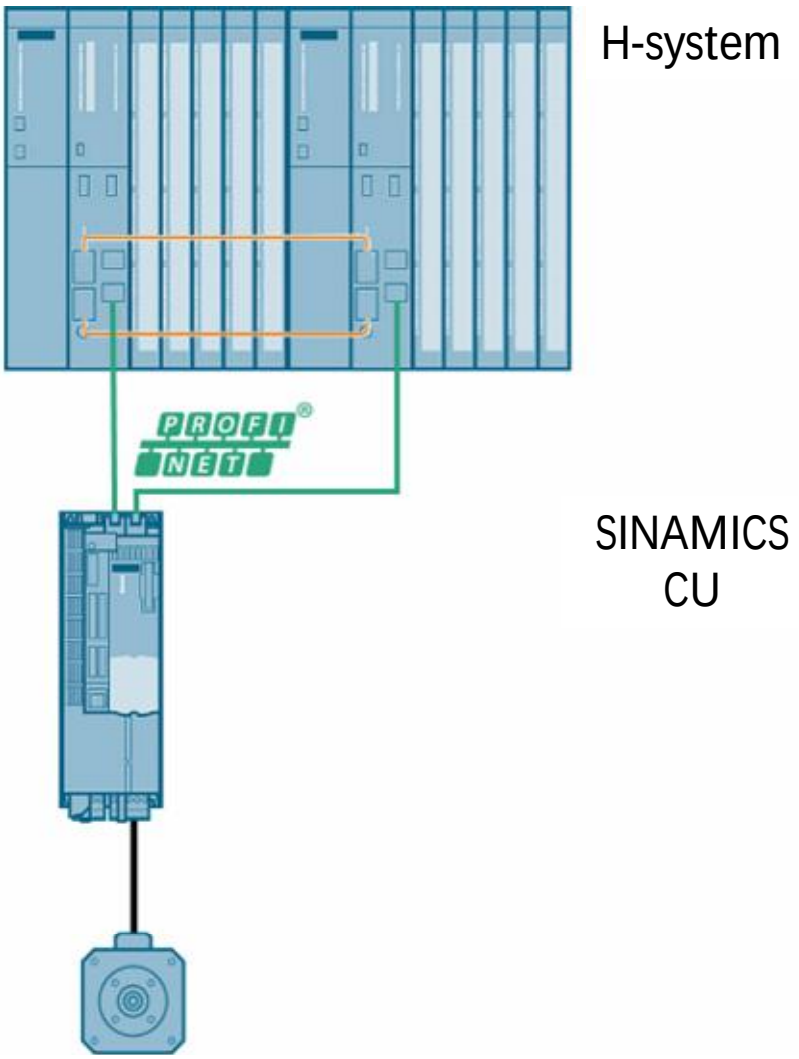
2 Solution

2.1 Solution overview

Schema

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

Figure 2-1 Solution overview



2.1 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

- 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 S120 PROFINET Control Unit
- For the duration of switching from one controller to the other, the setpoints of the last connection remain frozen and valid.

Knowledge required

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

2.2 Hardware and Software Components

2.2.1 Validity

This application example is valid for

- STEP 7 (where necessary a hardware update)
- SINAMICS S120 as of FW >= V4.8

2.2.2 Used components

The application was generated with the following components:

Hardware components

Table 2-1 Hardware components

Component	No.	Article number	Note
CPU 412-5H PN/DP	2	6ES7412-5HK06-0AB0	Rack: UR2-H
SINAMICS S120 CU310-2 PN/DP	1	6SL3040-1LA01-0AA0	Firmware V4.8
Training case	1	6ZB2480-0AD00	Servo motor with Drive-Cliq is used

Standard software components

Table 2-2 Software components

Component	No.	Article number	Note
STEP 7	1	-	-
STARTER	1	-	-

Sample files and projects

The following list includes all files and projects that are used in this example.

Table 2-3 Sample files

Component	Note
109744811_Systemredundancy_v10.zip	<This zip file includes the STEP 7 project.>
109744811_Systemredundancy_v10_en.pdf	This document.

3 Basics

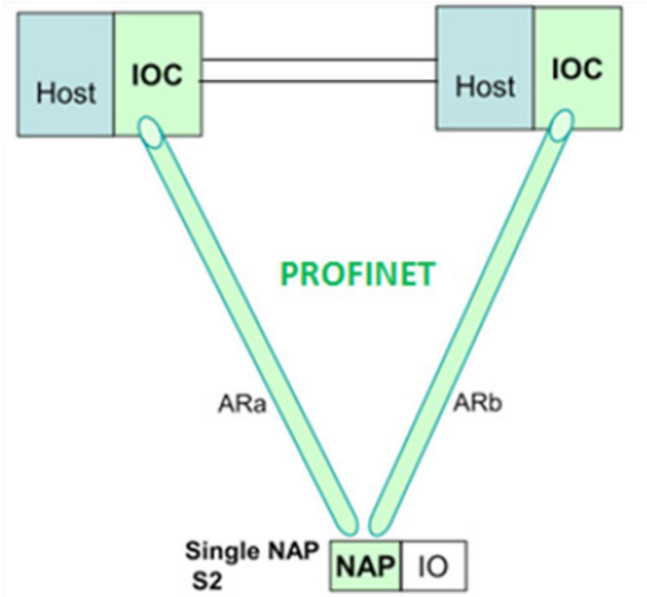
3.1 System and media redundancy

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

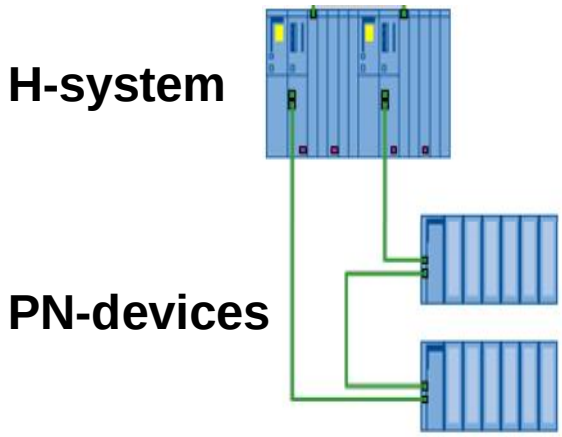


Requirement for realizing the system redundancy is the application of an H system.

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

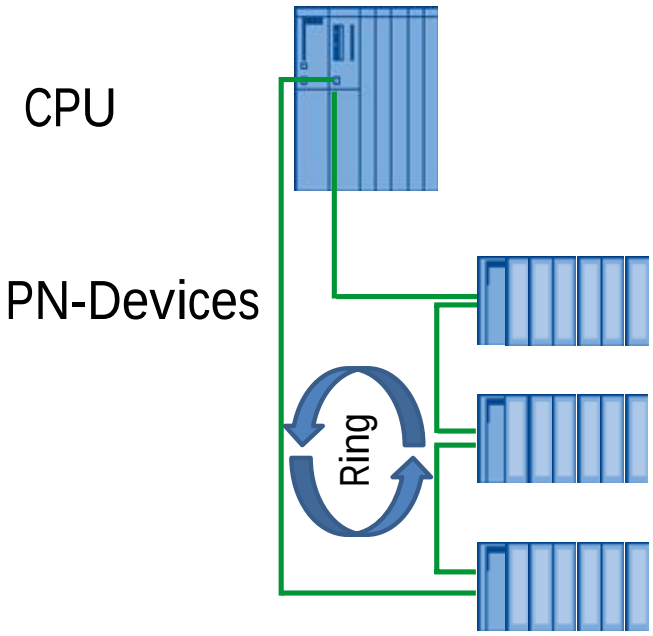
Media redundancy ensures the network availability and contributes to increasing the plant availability.

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 PN design versions

The following PN module design versions are available:

- Single-channel, one-sided configuration with standard availability

  With the single-channel, one-sided design, single PN devices are available. The PN devices are located in only one subsystem, and are only addressed by this subsystem.

  However, in redundant mode, both CPUs are interconnected via the redundant link and thus execute the user program identically.

- Single-channel, switched configuration with enhanced availability

  Switched single-channel distributed configurations contain only single PN devices, but they can be addressed by both subsystems.

- Redundant dual-channel configuration with maximum availability

  A redundant dual-channel configuration contains two sets of the I/O modules which can be addressed by both subsystems.

The SINAMICS S120 drive is realized as single-channel, switched configuration with enhanced availability in this application example.

3.3 Specific blocks for S7-400H

In addition to the blocks supported both in the S7-400 and S7-400H systems, the S7-400H software provides further blocks which you can use to influence the redundancy functions.

You can react to redundancy errors of the S7-400H using the following organization block:

- OB 70, I/O redundancy errors
- OB 72, CPU redundancy errors

SFC 90 "H_CTRL" can be used to influence fault-tolerant systems as follows:

- You can disable interfacing in the master CPU.
- You can disable updating in the master CPU.
- You can remove, resume or immediately start a test component of the cyclic self-test.
- You can execute a programmed master to standby changeover. The following changeovers are possible:
  - The current standby CPU becomes a master CPU.
  - The CPU in rack 0 becomes a master CPU.
  - The CPU in rack 1 becomes a master CPU.

Note

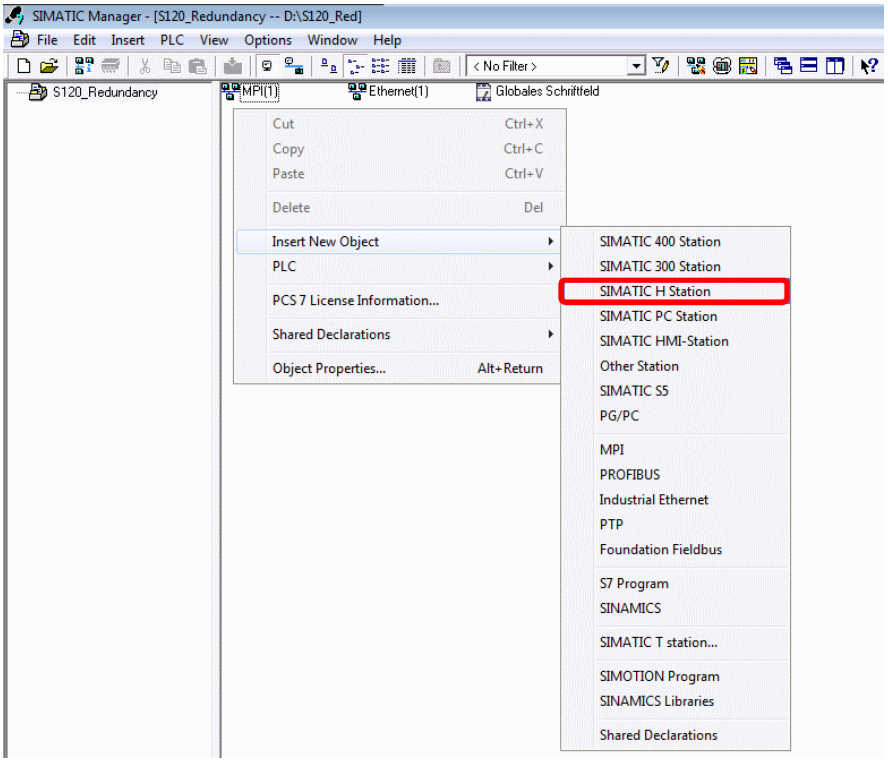
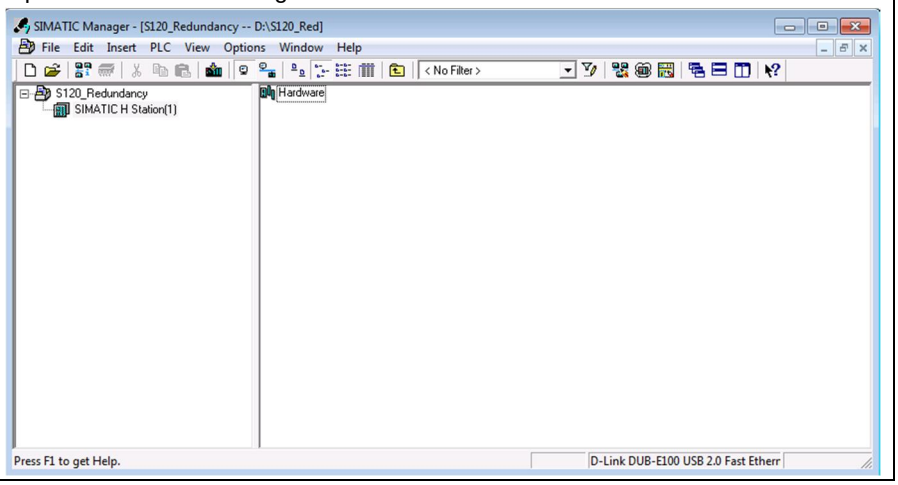
Always download these error OBs to the S7-400H CPU: OB 80, OB 82, OB 83, OB 85, OB 86, OB 88, OB 121 and OB 122.

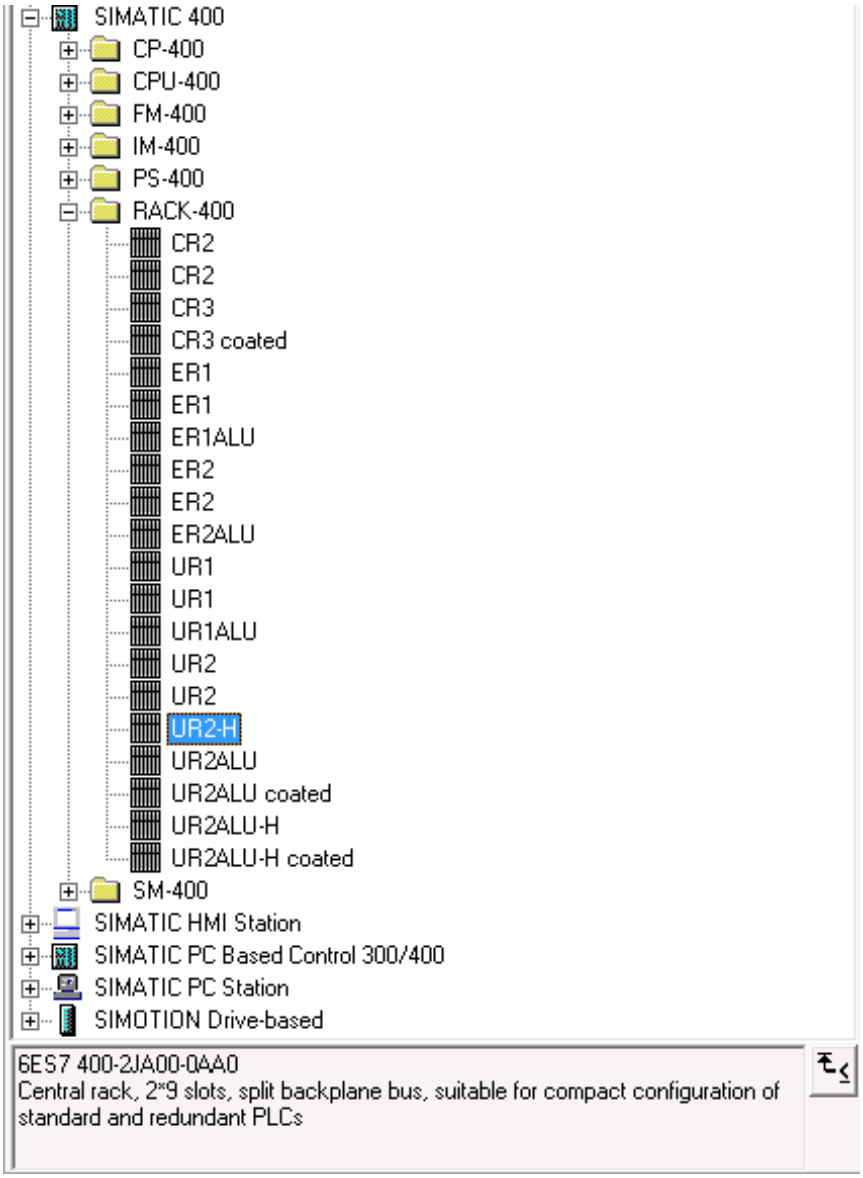
If you do not download these OBs, the fault-tolerant system goes into STOP when an error occurs.

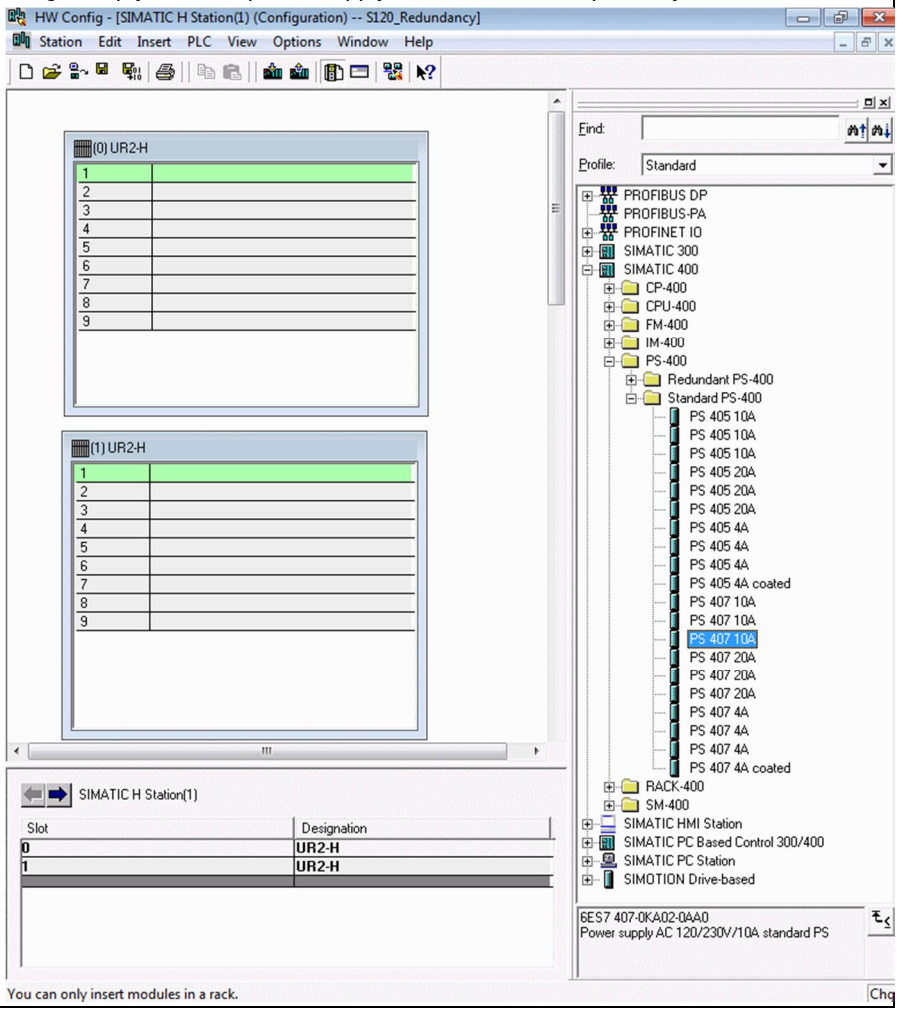
4 Configuration and Programming

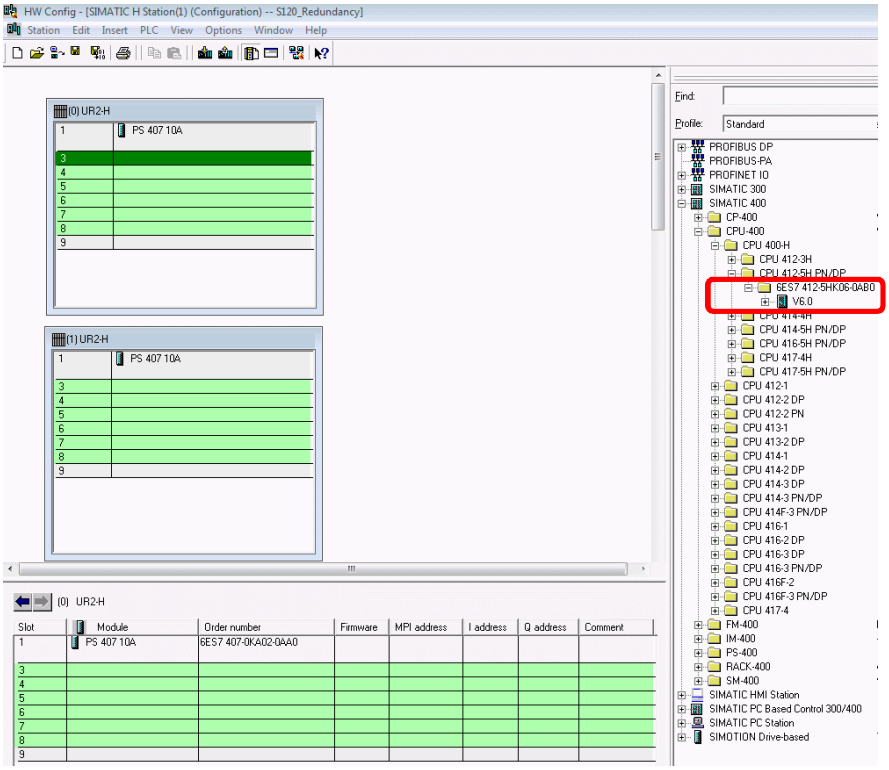
4.1 HW Config of SIMATIC H-CPUs

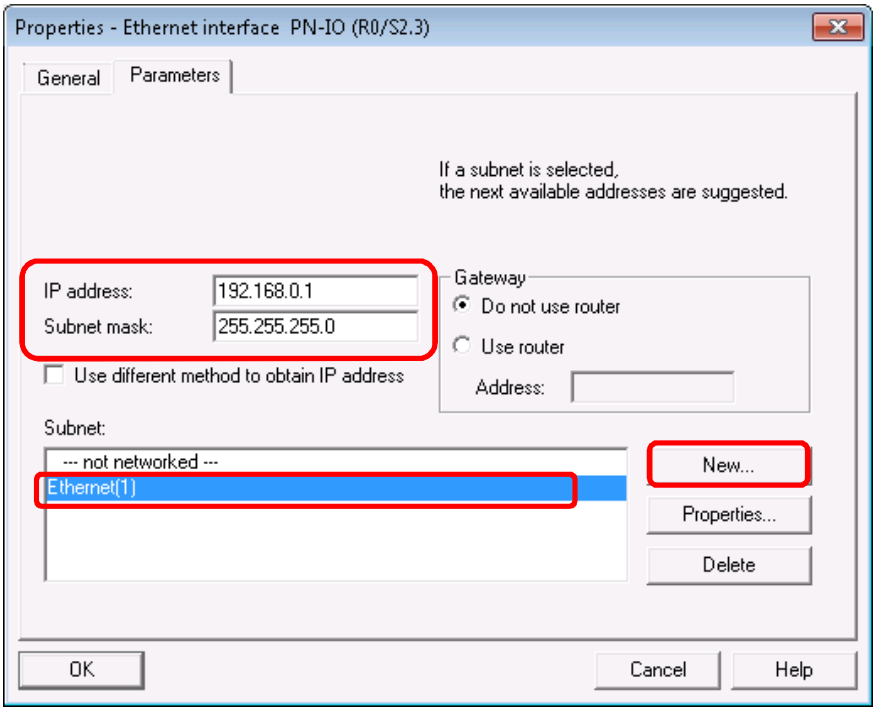
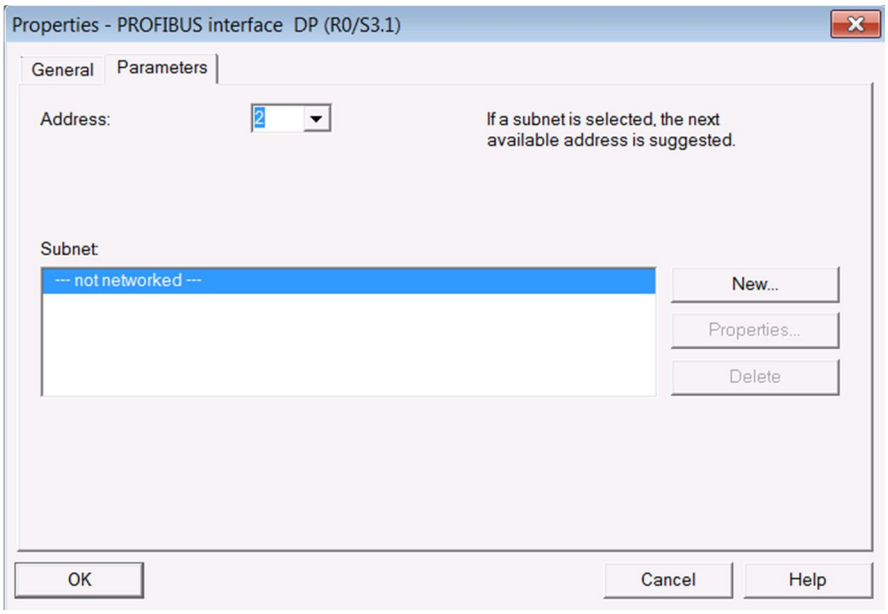
Table 4-1 Configuration SIMATIC H-CPU

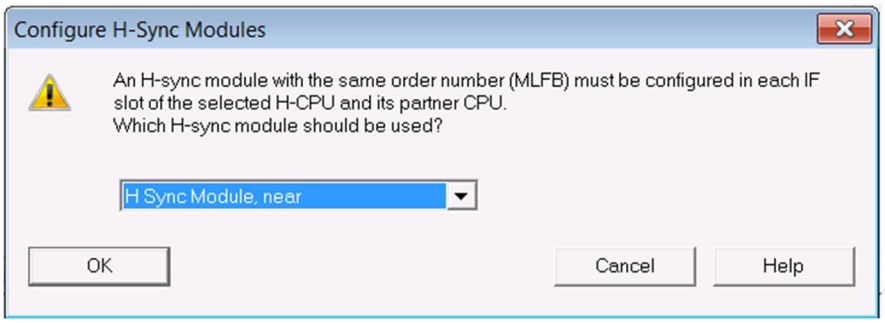
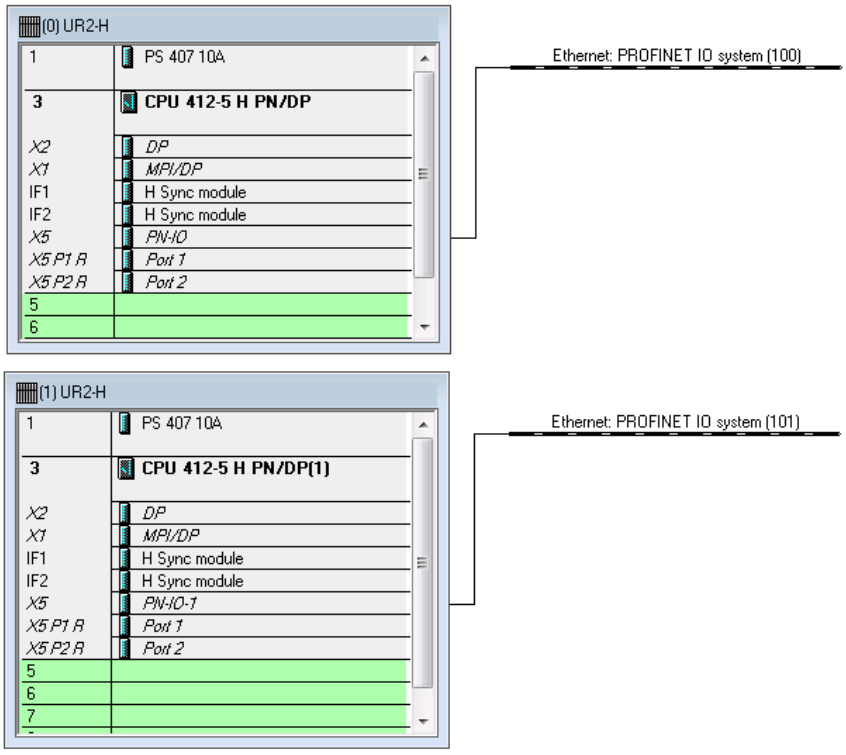
No.	Action
1.	Create a new STEP7 project.
2.	Insert a new `SIMATIC H Station`. 
3.	Open the Hardware-config. 

No.	Action
4.	Insert your used rack two times. 

No.	Action
5.	Drag &drop your used power supply into both racks respectively. 

No.	Action
6.	Afterwards insert your CPUs (here: `SIMATIC CPU 412-5H PN/DP V6.0`) into both racks. 

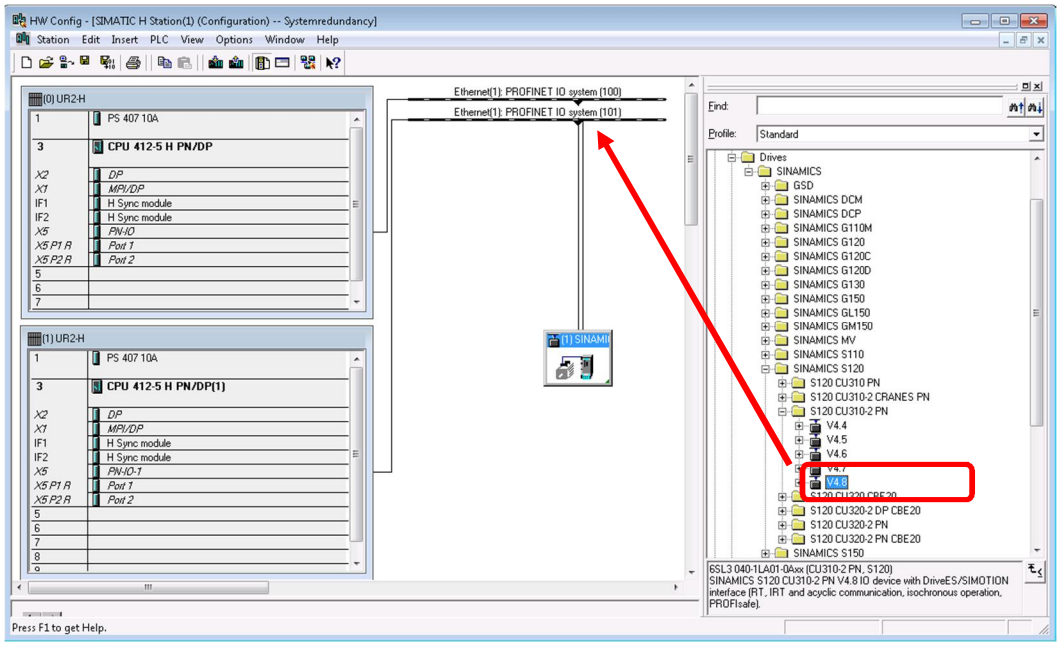
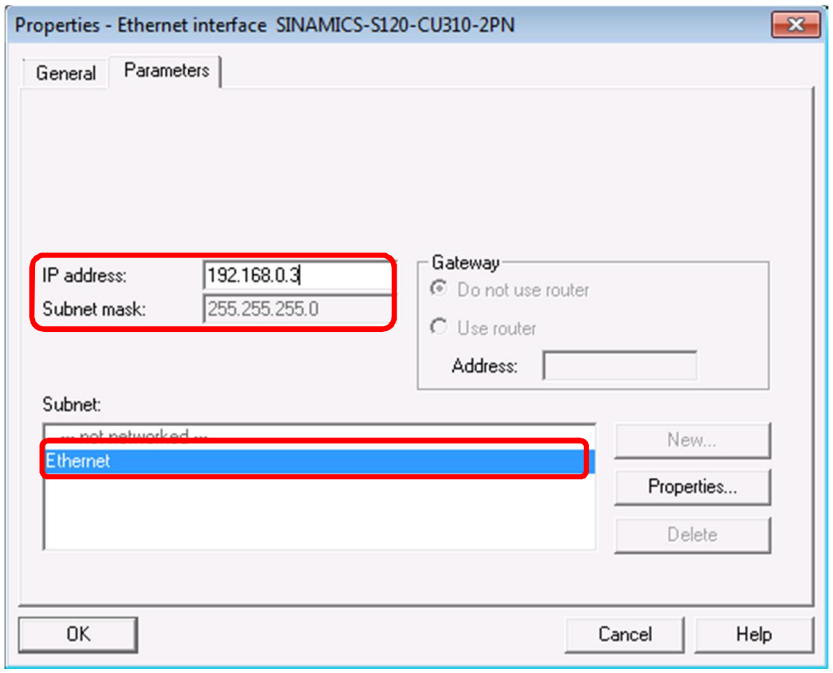
No.	Action
7.	Create a new Ethernet subnet and assign an IP address. (here: `192.168.0.1 / 255.255.255.0`).  PROFIBUS properties don't have to be parameterized. Confirm with OK. 

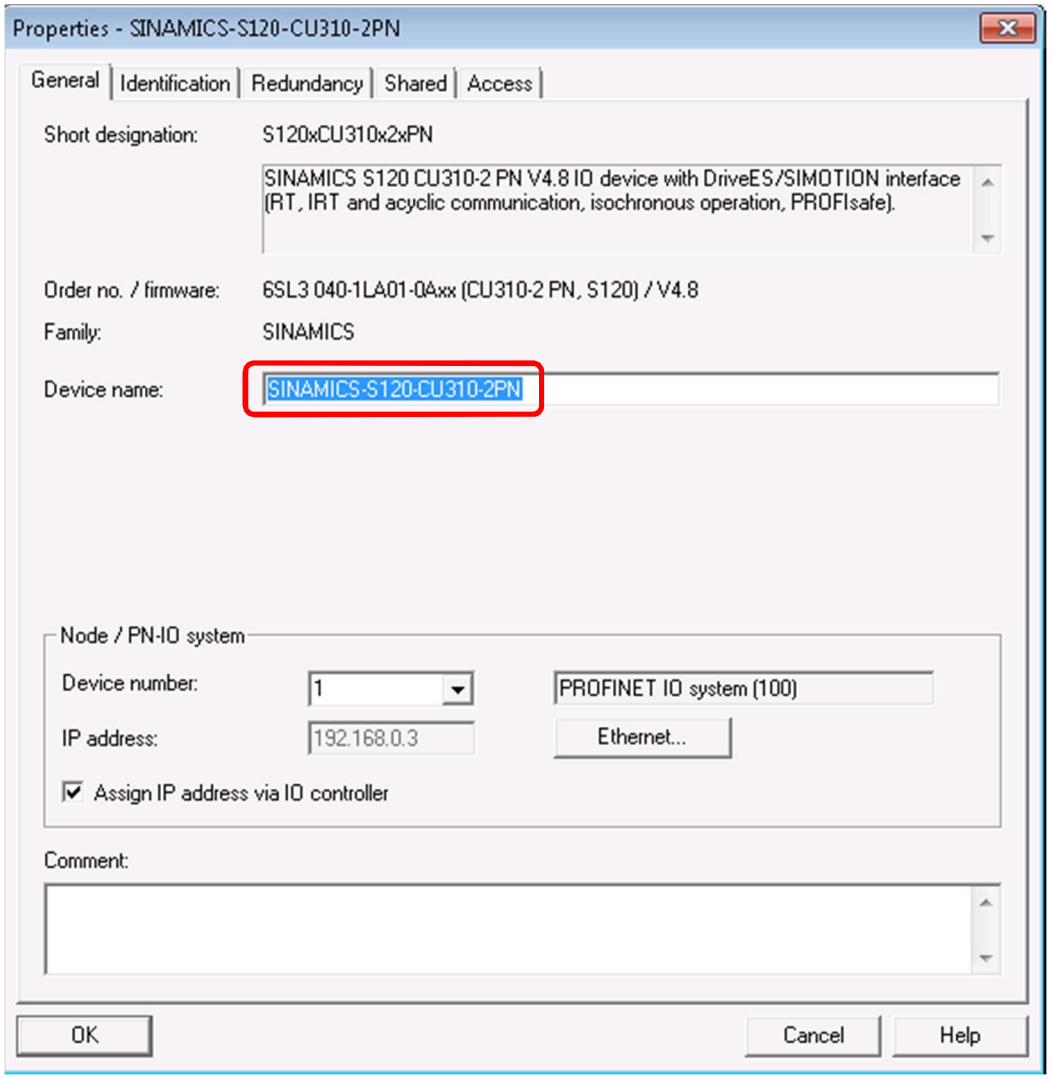
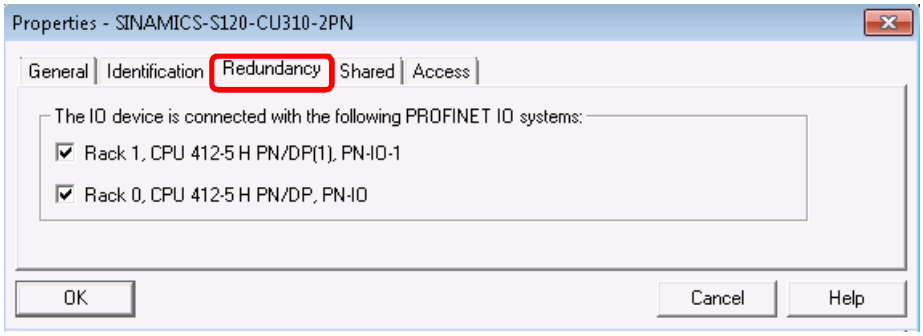
No.	Action
8.	Configure your H-Sync module:  Configure CPU1 respectively and assign an IP-address and subnet mask(here: `192.168.0.2 / 255.255.255.0`).
9.	Now there are two racks, two CPUs and two PROFINET systems configured. 

4.2 HW Config of SINAMICS drive

The SINAMICS drive can be configured with the OM (ObjectManager, Drive ES BASIC, hardware catalog) or with the help of a GSD file.
In the application example the drive is configured via the OM.

Table 4-2 HW Config SINAMICS drive

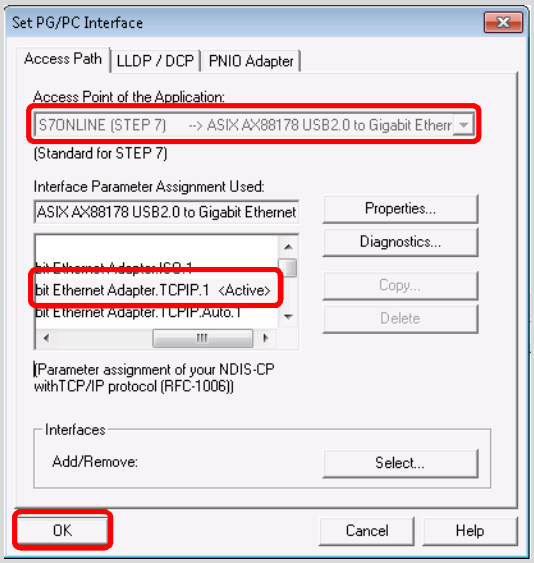
No.	Action
1.	Drag the SINAMICS drive `CU310-2 PN V4.8` to one of the existing PROFINET networks. 
2.	Select the existing Ethernet subnet and assign an IP address. (here: `192.168.0.3`). 

No.	Action
3.	Double-click the added SINAMICS drive to open the properties window. Define the device name (here: „SINAMICS-S120-CU310-2PN“).  Check in the tab „Redundancy“, if the SINAMICS is connected with both PROFINET systems. 

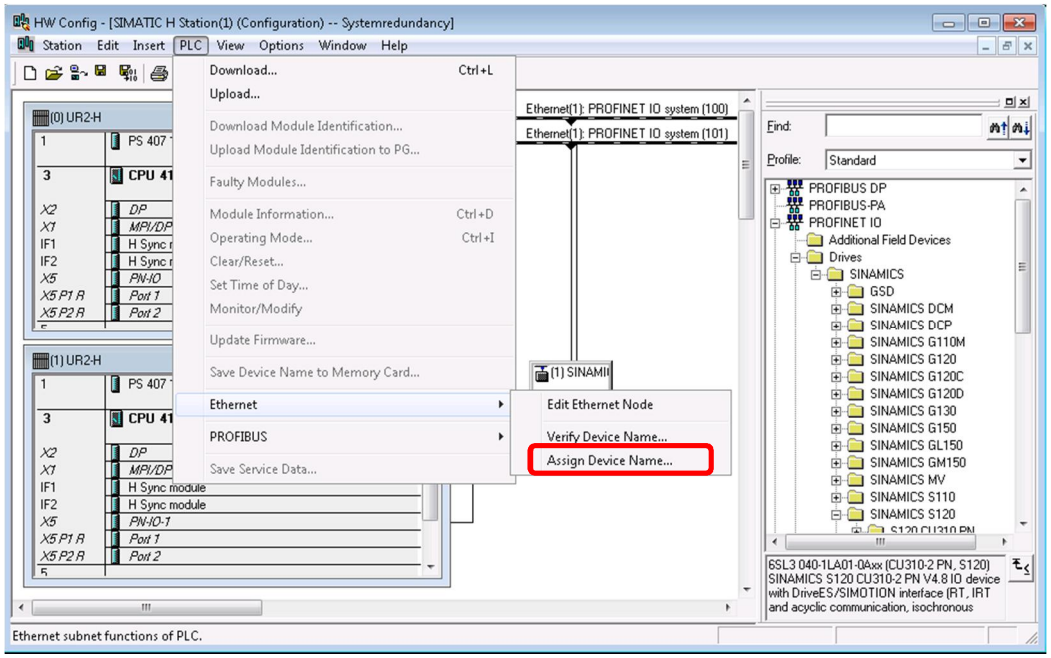
Note

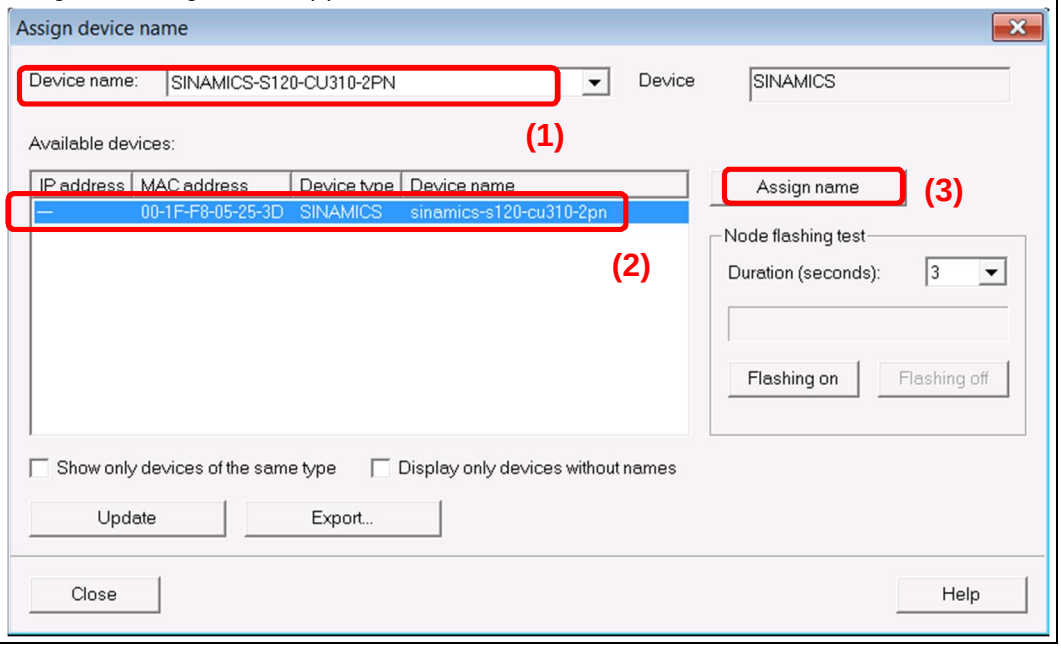
For the steps described in the following, a functional connection is required between the engineering PC and the hardware being used!

In SIMATIC Manager, using the menu item "`Options > Set PG/PC Interface…`" open the window to set the PG/PC interface. There, for the access point "`S7ONLINE`", select the network card of your engineering PC that you are using with the supplement "`TCPIP.1`" (not "`TCPIP.Auto.1`").



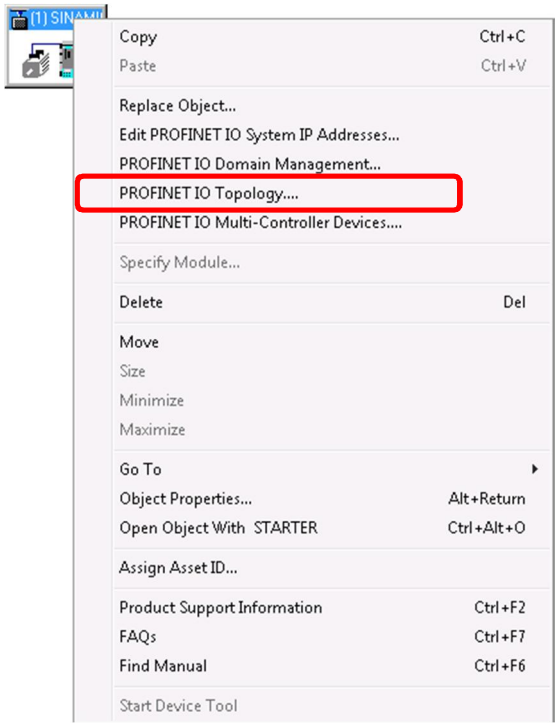
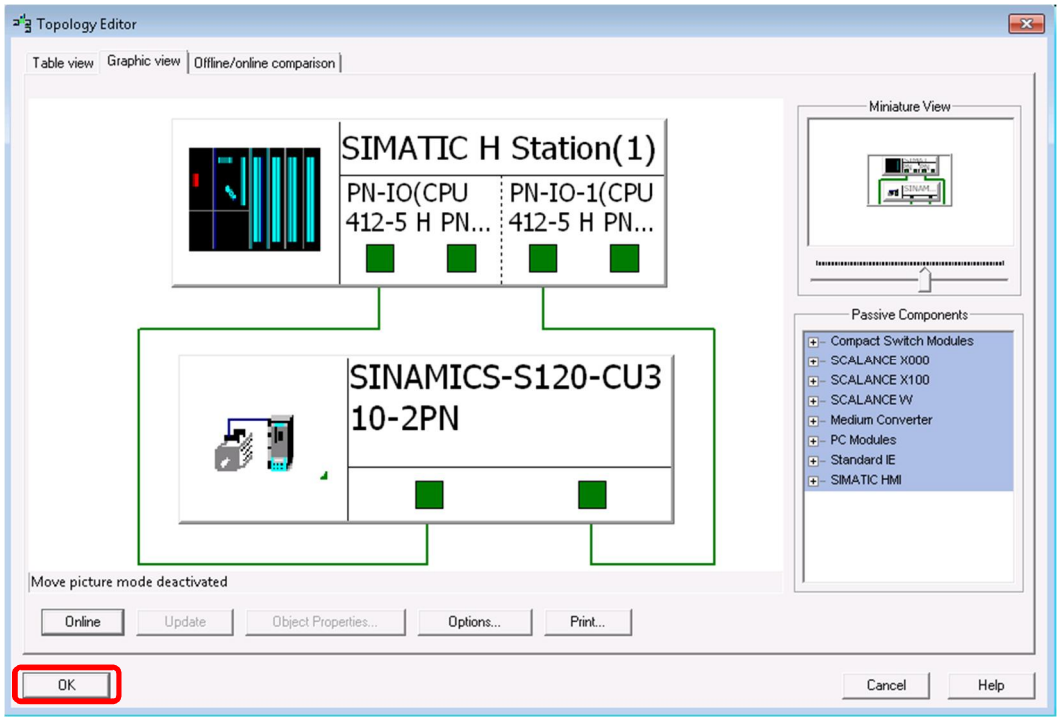
No.	Action
4.	The device name must then be assigned to the SINAMICS drive. For this purpose mark the PROFINET IO system. Open the window for the name assignment with "`PLC > Ethernet > Assign Device Name`".



5.	Select the device name configured in HW config using the drop-down menu (1). Then select the SINAMICS drive from the list of available devices (2) and assign the device name using the "Assign name" (3) button. 

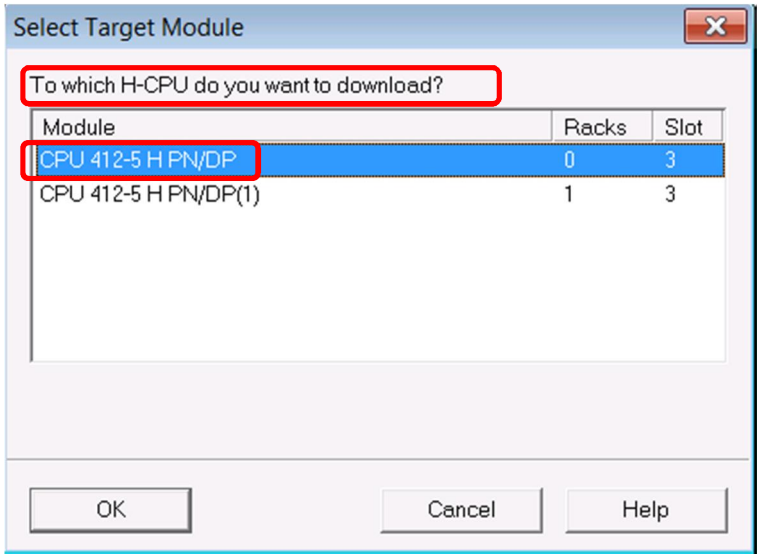
4.3 Configuration of topology

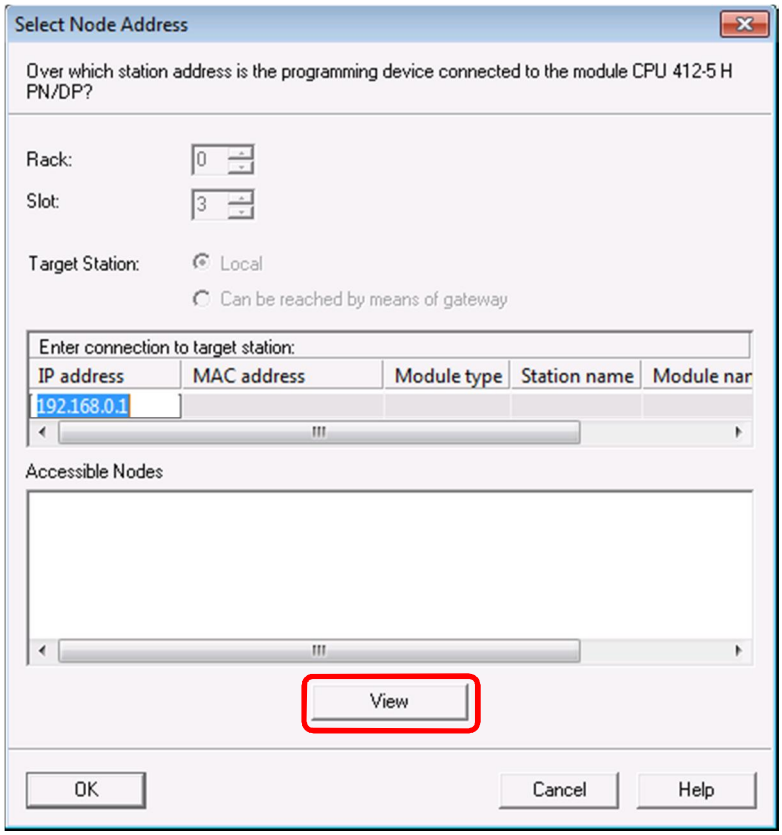
Table 4-3 Configuration of topology

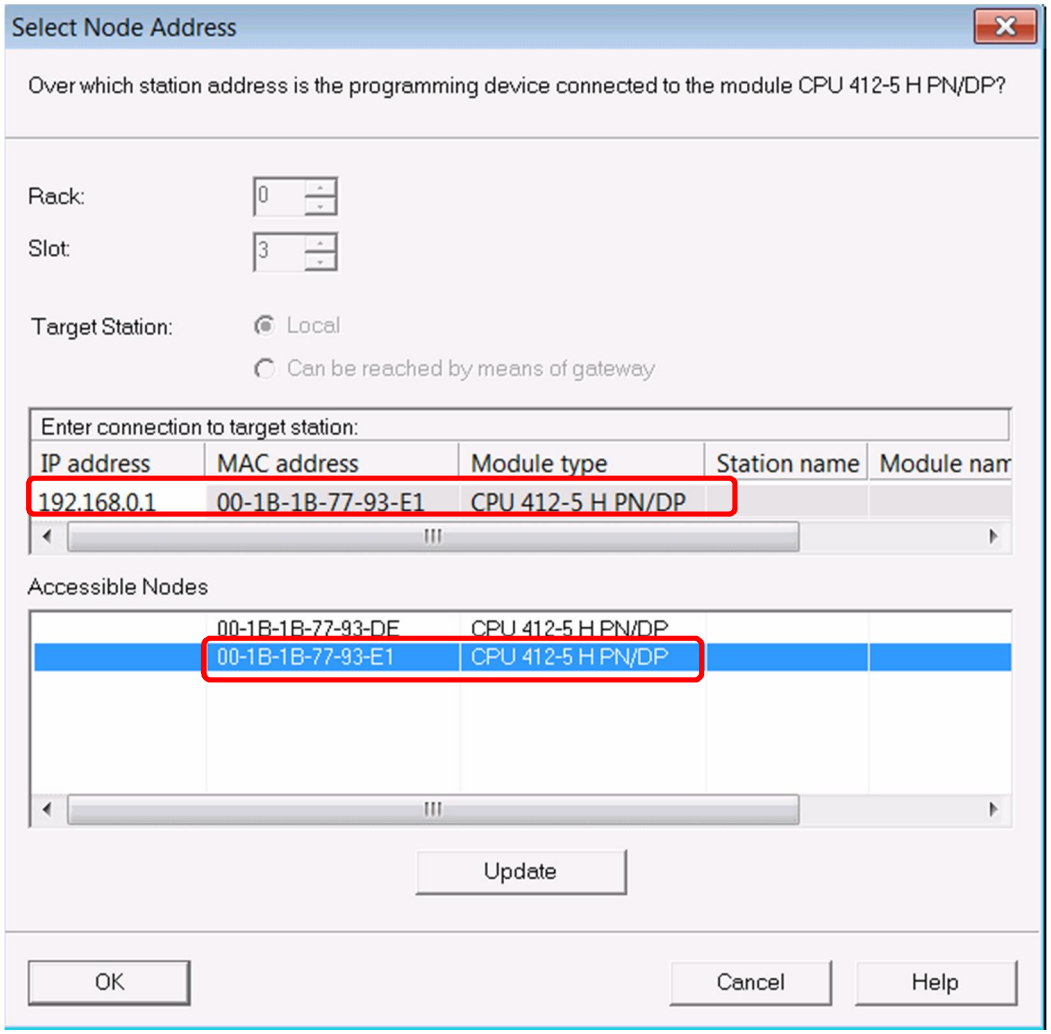
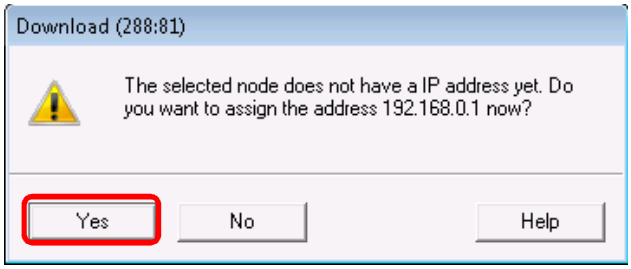
No.	Action
1.	Open the topology via rightclick on the SINAMICS in HW-config. 
2.	Connect both ports 1 of the H-CPUs with port 1 and port 2 of your SINAMICS CU.  Confirm with OK.

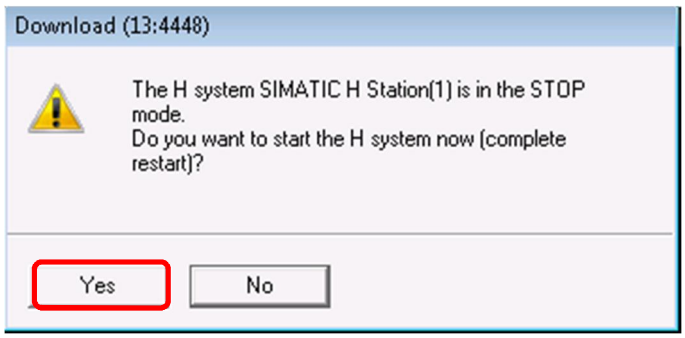
4.4 Download of HW-Config

Table 4-4 Download of HW-Config

No.	Action
1.	Save and compile the HW Config. 
2.	Download it into the SIMATIC CPU. 
3.	To do this, select the corresponding target device, and confirm your selection using the "OK" button. 

No.	Action
4.	If the SIMATIC CPU is still in the factory setting (i.e. the IP address is `0.0.0.0`), a download is only possible after assigning the IP address configured in HW Config. Browse through the network for controllers that can be accessed by pressing the `"View"` button. 

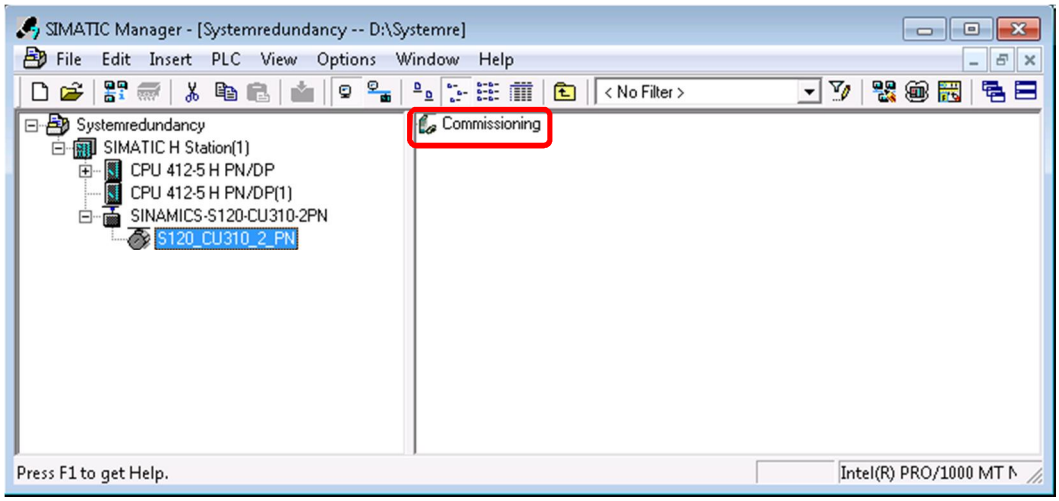
No.	Action
	All of the controllers that can be accessed are displayed. Select the corresponding controller by identifying it based on its MAC address and confirm your selection by pressing the "OK" button.  **Note** First reset the interface of the controller to the factory settings, if the SIMATIC CPU already has an IP address, which does not match the IP address configured in HW Config! **("PLC > Ethernet > Edit Ethernet Node > Browse > Select CPU > OK > Reset")**
5.	Confirm the following message with "Yes", to assign the IP address configured in HW Config to the controller (192.168.0.1) (permanent IP address!). 

No.	Action
6.	Then switch the SIMATIC CPU back into the "RUN" operating state. 

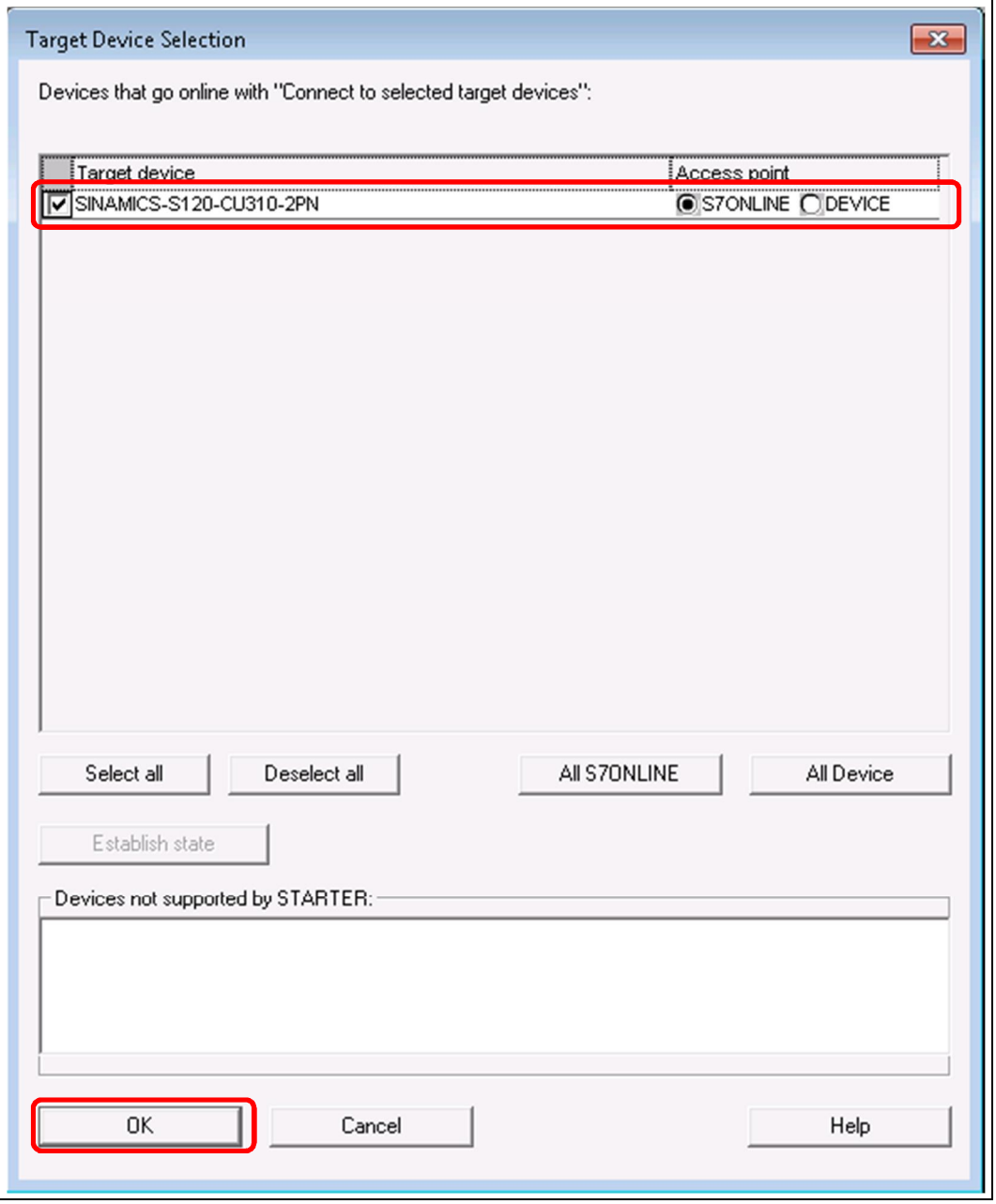
4.5 Configuration of SINAMICS drive

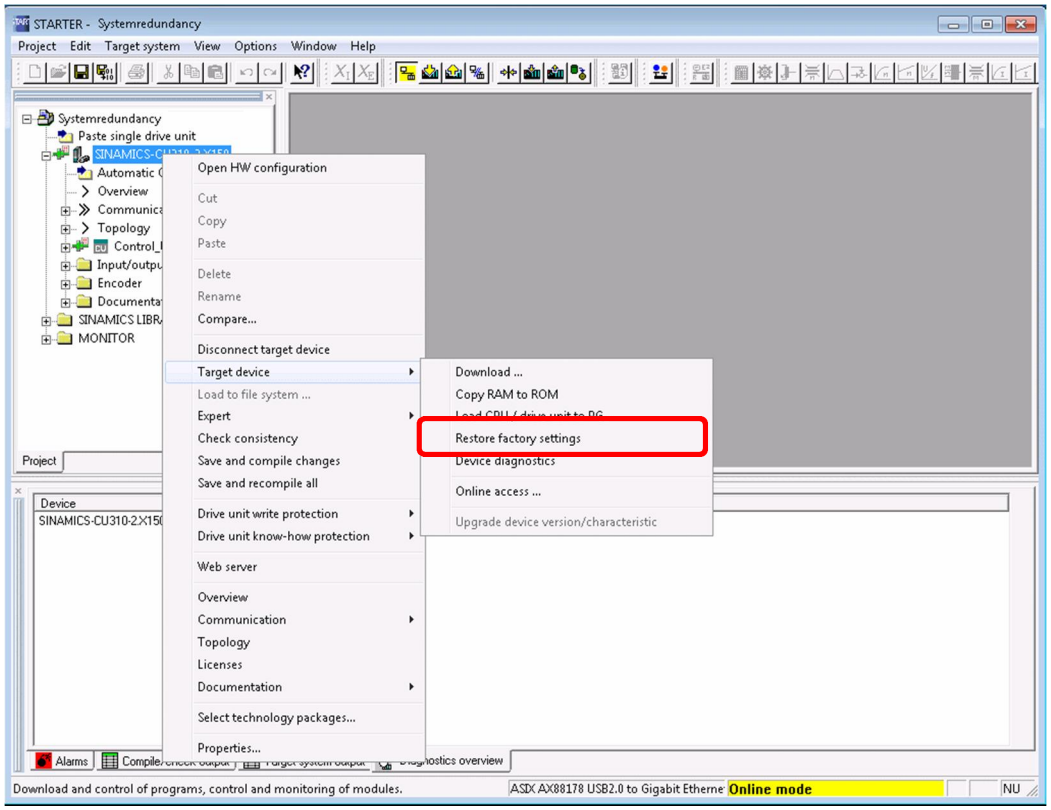
The standard configuration of the SINAMICS drive with the STARTER engineering system is shown below.

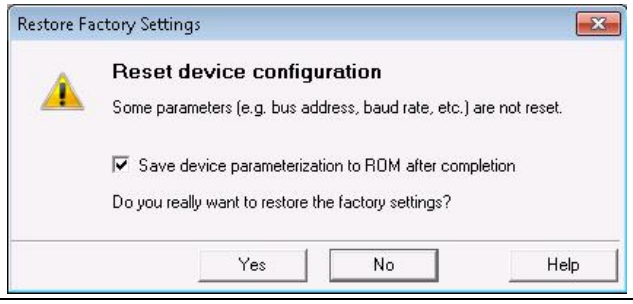
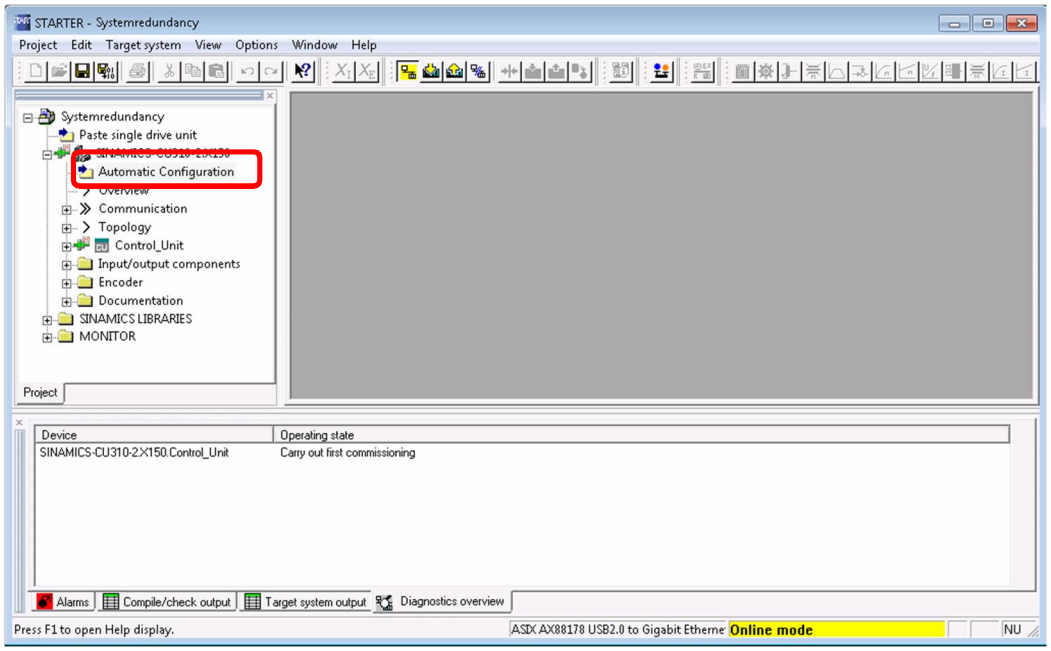
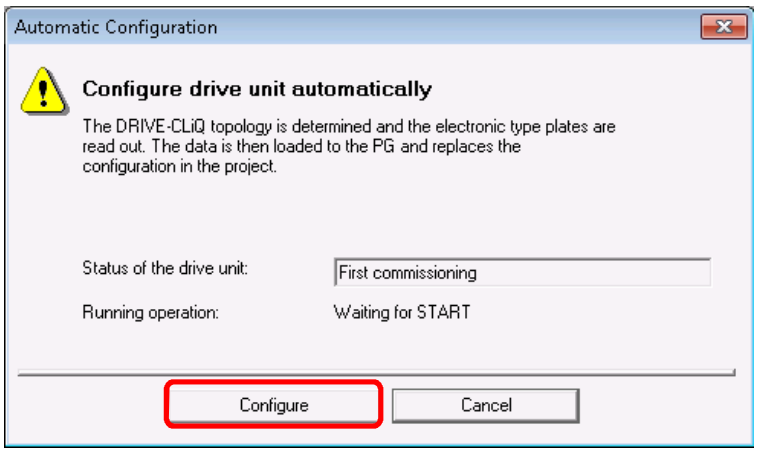
Table 4-5 Configuration SINAMICS drive

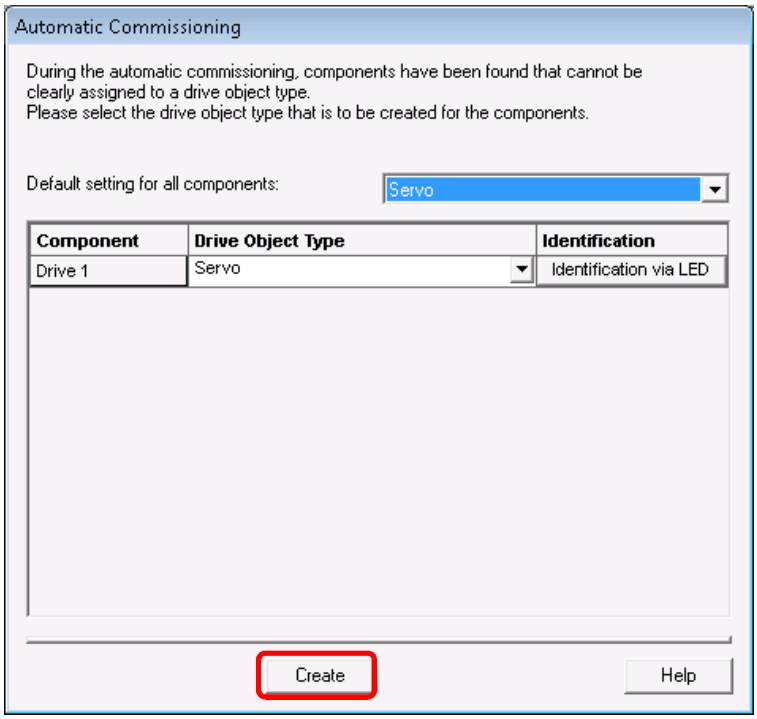
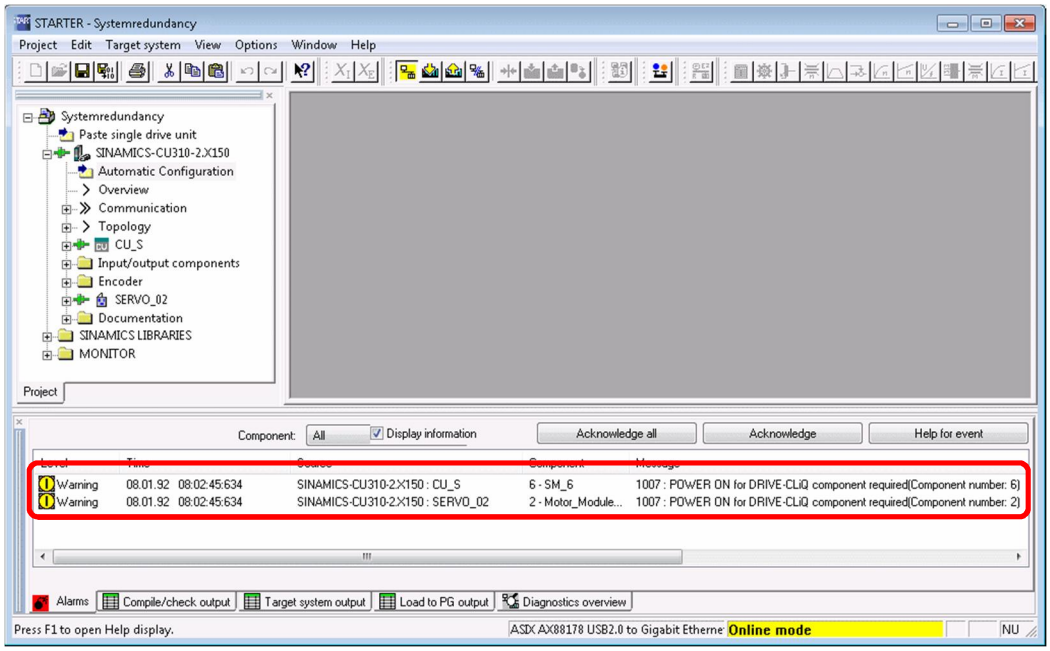
No.	Action
1.	Open the current project in the STARTER engineering system from the SIMATIC Manager. 
2.	Establish an online connection to the SINAMICS drive.  **Note** To establish an online connection, the network card of the engineering PC being used must be in the same IP subnet as the target device. 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 `192.168.0.2` subnet mask `255.255.255.0` • IP address of the engineering PC `192.168.0.99` subnet mask `255.255.255.0`

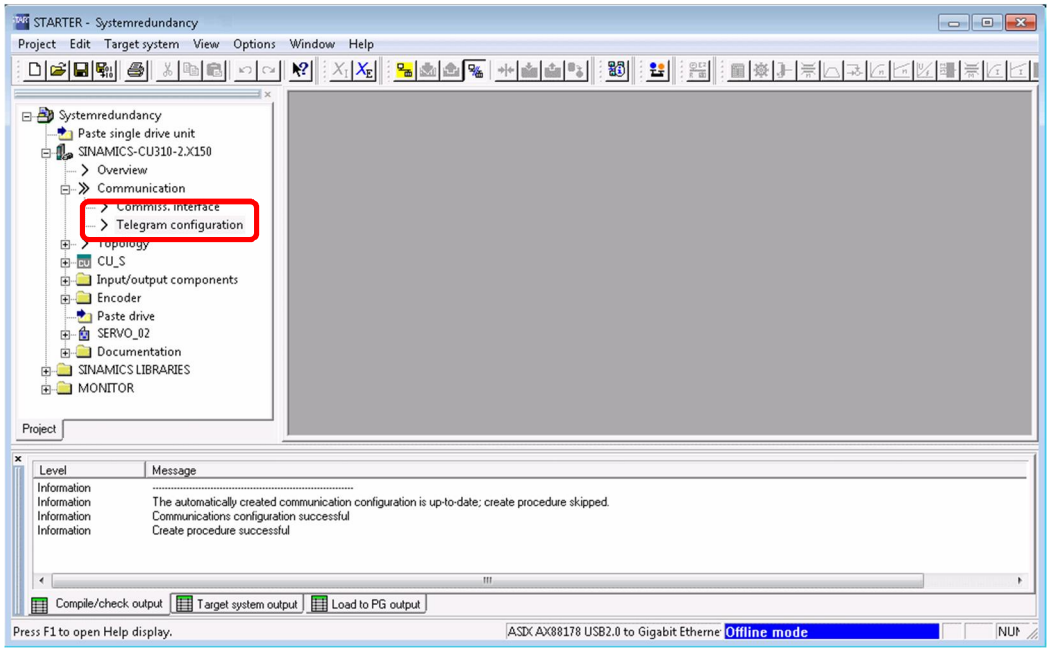
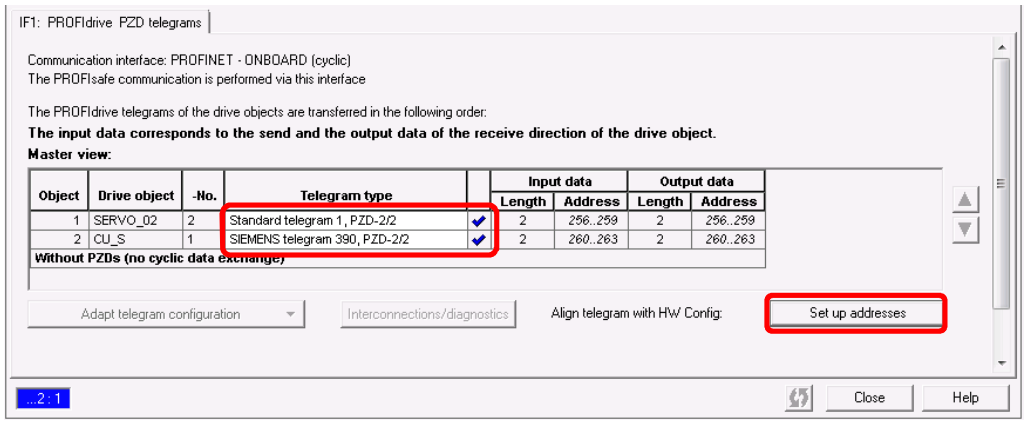
No.	Action
3.	Select the configured SINAMICS drive (set the checkmark in the checkbox) and confirm your selection by pressing the "OK" button.

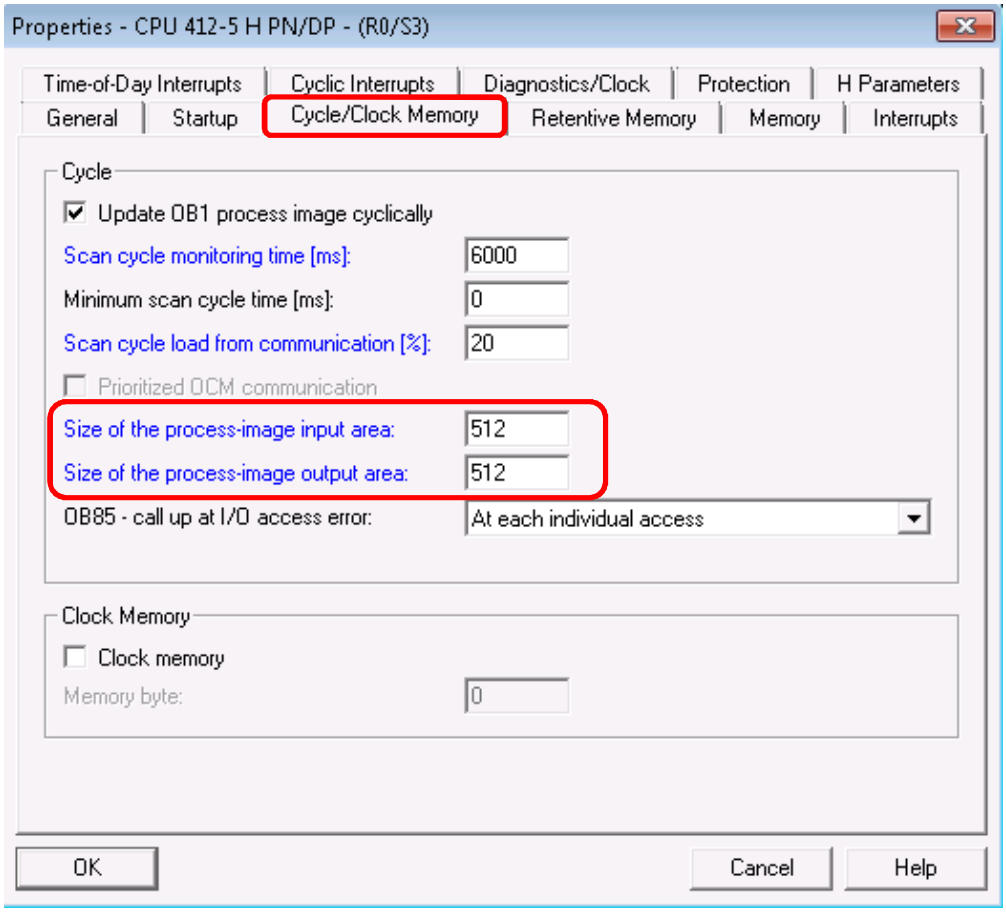


No.	Action
4.	After this, restore the factory settings at the SINAMICS (if this has still not been done). 

No.	Action
5.	Confirm the following message with "Yes". The drive is then reset to the factory settings. 
6.	Afterwards carry out the automatic configuration of the drive. 
7.	Start the configuration by pressing the "Configure" button. The Drive-CliQ topology of the drive is read out. 

No.	Action
8.	A servo motor is used in the SINAMICS training case. 
9.	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  **ote** **Before** "Power OFF/ON" execute the "RAM to ROM" function at the drive to save the previous configuration in a non-volatile way. 

10.	Open the drive telegram configuration using the menu item "Communication > Telegram configuration".  **Note** Carry out the following steps that are described offline!
11.	The following telegrams are used for cyclic communication between the controller and drive in the sample project: • SERVO_02 Standard telegram 1, PZD-2/2 • CU_S SIEMENS telegram 390, PZD-2/2 Set these telegrams in the drive telegram configuration and align the telegram configuration with HW Config ("Set up addresses").  **Note** Confirm the message that follows with "Yes". A blue tick after the telegrams indicates that the telegram configuration has been successfully aligned with HW Config.

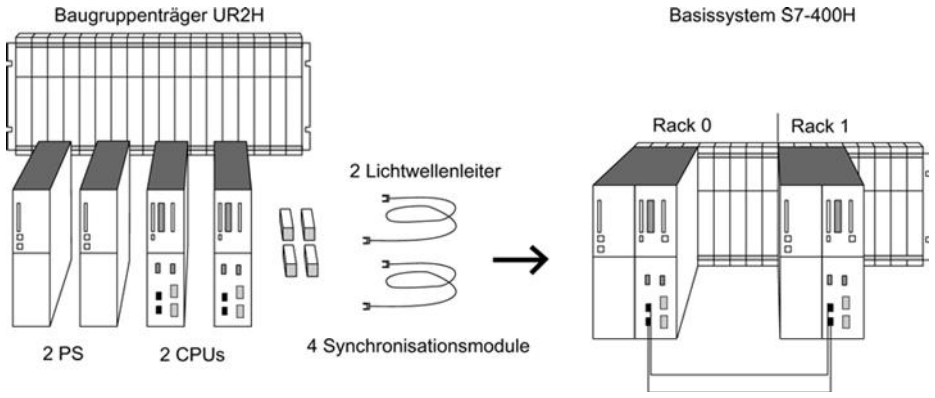
No.	Action
12.	Change to the HW Config of the SIMATIC CPU, and check the size of the process image of the controller (double click on the CPU > tab "Cycle/Clock Memory").  **Note** If required, adapt the size of the process image of the inputs and outputs so that the input and output data of the SINAMICS drive telegrams are completely inside of the process image of the controller!
13.	Save and compile the configuration of the SINAMICS drive in STARTER and in the HW Config of the SIMATIC CPU. 
14.	Establish an online connection with the drive. 
15.	Download to the SINAMICS drive and load HW Config into the controller. 
16.	Execute the "RAM to ROM" function in the drive to save its configuration in a non-volatile way. 
17.	The communication between the SIMATIC CPU and SINAMICS drive has therefore been configured.

5 Installation and Commissioning

5.1 Installation of hardware

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

Figure 5-1 Hardware



Central processing units

The two CPUs are the heart of the S7-400H. Use the switch on the rear of the CPU to set the rack numbers. In the following sections, we will refer to the CPU in rack 0 as CPU 0, and to the CPU in rack 1 as CPU 1.

Note

An incorrectly set rack number prevents online access and the CPU might not start up

Rack for S7-400H

The UR2-H rack supports the installation of two separate subsystems with nine slots each, and is suitable for installation in 19" cabinets.

You can also set up the S7-400H in two separate racks. The racks UR1 and UR2 are available for this purpose.

Power supply

You require one power supply module from the standard range of the S7-400 for each HCPU, or to be more precise, for each of the two subsystems of the S7-400H.

To increase availability of the power supply, you can also use two redundant power supplies in each subsystem.

Synchronization modules

The synchronization modules are used to link the two CPUs. They are installed in the CPUs and interconnected by means of fiber-optic cables.

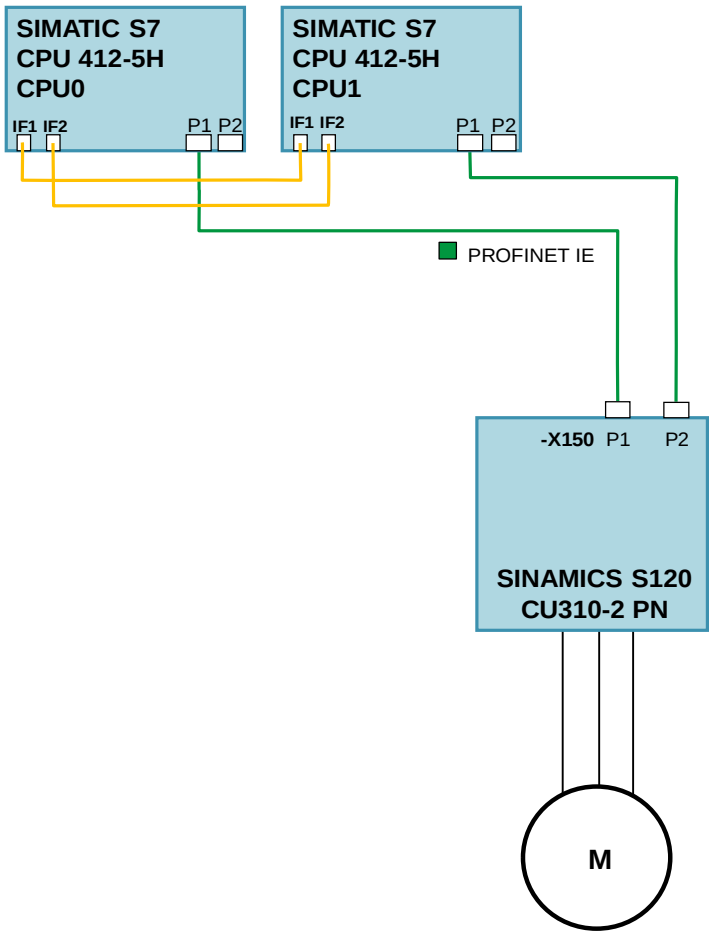
There are two types of synchronization modules: one for distances up to 10 meters, and one for distances up to 10 km between the CPUs.

A fault-tolerant system requires 4 synchronization modules of the same type.

Fiber-optic cable

The fiber-optic cables are used to interconnect the synchronization modules for the redundant link between the two CPUs. They interconnect the upper and lower synchronization modules in pairs.

Figure 5-2 Interconnection



Note The port interconnection must correspond to your STEP7 configuration.

5.2 Commissioning

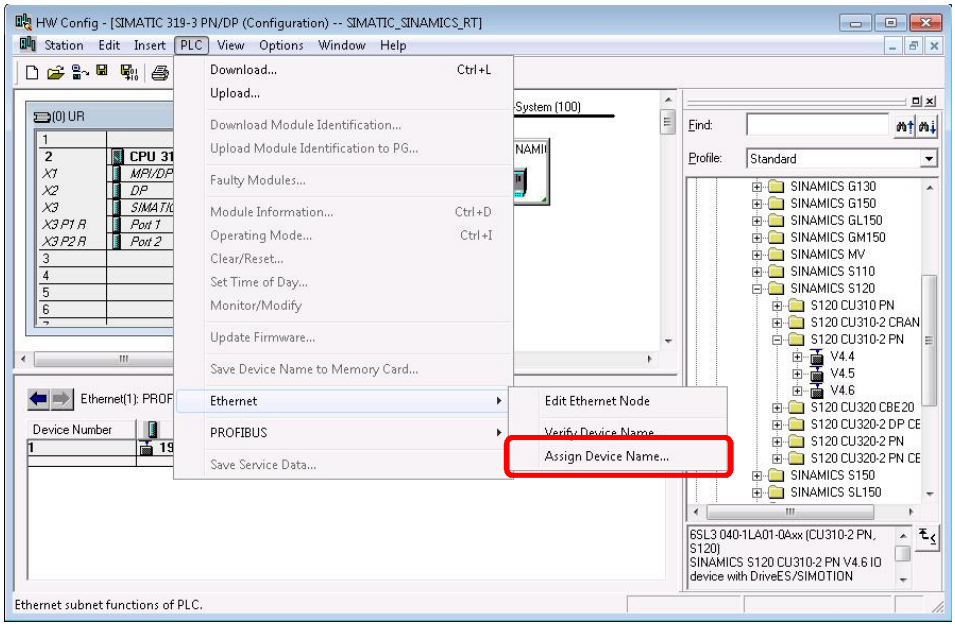
Overview

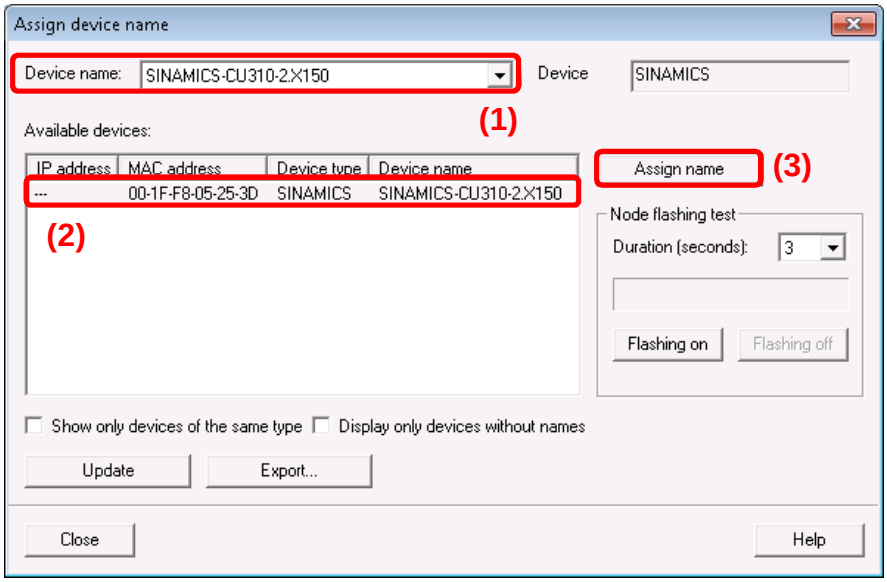
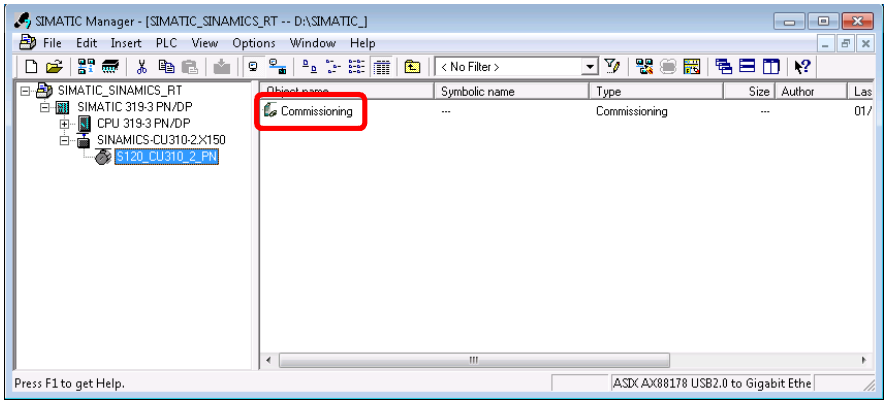
An executable sample project is included in the zip archive "109744811_Systemredundancy_v10.zip".

Commissioning of the sample project

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

Table 5-1 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 the STEP 7 SIMATIC Manager engineering system.
5.	Retrieve the sample project "109744811_Systemredundancy_v10.zip".
6.	Open the HW Config of the SIMATIC CPU.
7.	Download the HW Config and all blocks from the block container into the controller.
8.	Carry out a node initialization of the SINAMICS drive. To do this, change to HW Config of the controller and select the PROFINET network. Using the menu item "`PLC > Ethernet > Assign Device Name`..." open the window to assign a name. 

No.	Action
9.	Select the device name configured in HW Config using the drop-down menu (1). Then select the SINAMICS drive from the list of available devices (2) and assign the device name using the "Assign name" (3) button.  **Note** Only IO devices are listed here. IO controllers receive their device name by downloading the HW Config.
10.	As an alternative, the Primary Setup Tool (PST) can also be used to perform the node initialization. The PST can be downloaded at the following link. http://support.automation.siemens.com/WW/view/en/19440762
11.	Start the STARTER engineering system from the project in the SIMATIC Manager. 
12.	Establish an online connection with the SINAMICS drive. 
13.	Download the configuration of the drive into the target device. 
14.	Then execute the "RAM to ROM" function. 
15.	The sample project is now ready for operation.

6 Operating the sample project

6.1 Controlling the servo motor

In the sample project, the cyclic communication between SIMATIC CPU and SINAMICS drive is implemented in OB1. The OB1 contains the user program subsequently described.

Table 6-1 Control of the servo motor

No.	Action
1.	Network 1: User program Speed calculation, drive control and failure reset // speed calculation L "N_SOLL_USER" MD100 L 6.000000e+003 /R L 1.638400e+004 → W#16#4000 *R TRUNC T "N_SOLL" MW110 U "boMove" M0.0 SPBN S002 The user must specify the speed setpoint used to operate the servo motor ("N_SOLL_USER"). The calculation of the speed setpoint is based on the specified definitions of the PROFIdrive profile. 6000 rpm corresponds to the value "W#16#4000". The calculated speed is then buffered so that it can be further accessed ("N_SOLL"). The servo motor is operated with the calculated speed and is stopped again by setting the "boMove" flag. **Note** The rated speed of the servo motor installed in the training case is 6000 rpm. The maximum speed is 10000 rpm.

<table>
<tr><th>No.</th><th>Action</th></tr>
<tr><td>2.</td><td>

```
// drive control
      L     W#16#47E                  2#0000_0100_0111_1110

      T     MW    10

      L     "N_SOLL"                  MW110
      T     "N_SOLL_Drive"            AW258

      L     "ZSW1_Drive"              EW256

      L     W#16#211                  2#0000_0010_0001_0001

      UW
      L     W#16#211
      ==I
      SPBN  S001

      L     W#16#47F                  2#0000_0100_0111_1111

      T     MW    10

S001: L     MW    10
      T     "STW1_Drive"              AW256

      SPA   S003
```

If flag "boMove" is controlled to a value of "1", then the required releases are set in control word 1("STW1") of the servo motor (**W#16#47E**), so that it can be moved.
To ensure that the motor is only moved when all releases required are actually present, its status word 1 ("ZSW1") is compared with a constant word that represents the required releases (**W#16#211**).
Only when status word 1 ("ZSW1") matches this value, the bit in control word 1 ("STW1") is set, that switches on the servo motor (**W#16#47F**). The servo motor is then moved with the speed setpoint entered by the user.

</td></tr>
<tr><td>3.</td><td>

```
S002: L     0
      T     "N_SOLL_Drive"            AW258

      L     W#16#400                  2#0000_0100_0000_0000

      T     "STW1_Drive"              AW256

// failure reset
      U     "boReset"                 M1.0
      SPBN  S003

      L     W#16#480                  2#0000_0100_1000_0000

      T     "STW1_Drive"              AW256

S003: NOP   0
```

The speed setpoint of the servo motor is 0 rpm as long as the "boMove" flag is not controlled to a value of "1".
In control word 1 ("STW1"), only bit 10 ("Control by PLC") is set (**W#16#400**).
If faults are active, flag "boReset" can be controlled to a value of "1".
As a consequence, in control word 1 ("STW1") of the servo motor additionally bit 7 ("Acknowledge faults") is set, which acknowledges the fault (**W#16#480**). In this case, flag "boMove" must have the value "0"!

</td></tr>
</table>

Note

The structure of the relevant (standard) telegram (i.e. STW1, NSOLL_B, etc.) is defined in the PROFIdrive profile. You can find further information about this at the following link:

SINAMICS S120 / S150 List Manual (Chapter 2.9)

Note

The following addresses are used in the sample project to control the SINAMICS drive:

- AW 256 Control word 1 ("STW1")
- AW 258 Speed setpoint ("NSOLL_B")
- EW 256 Status word 1 ("ZSW1")

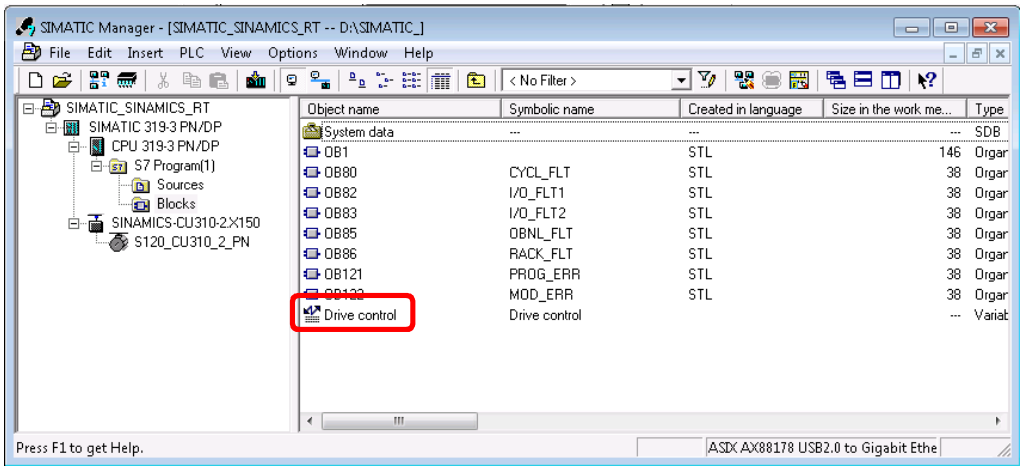
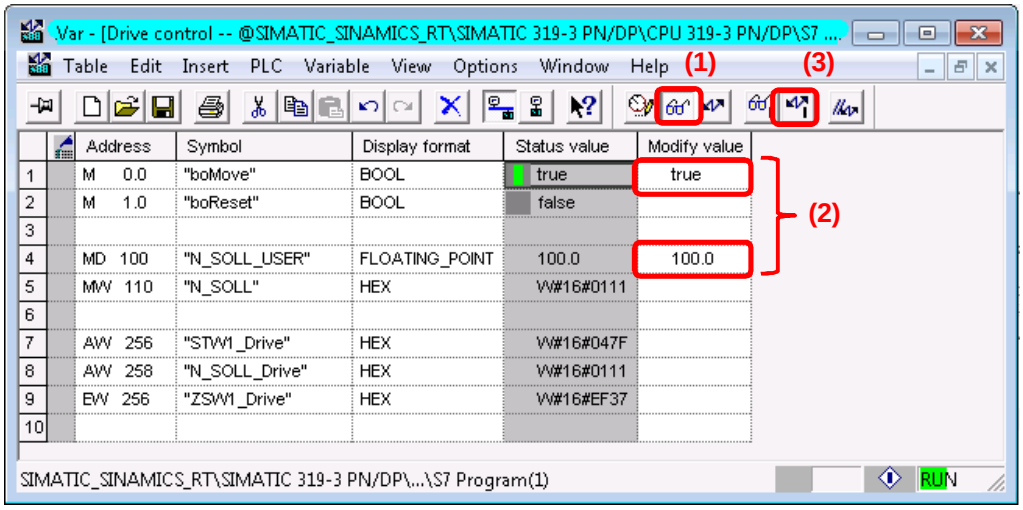
Slot	Module	Order number	I Address	Q address	Diagnostic Address
0	*SINAMICS-S120-CU310-2PN*	*6SL3 040-1LA01-0AAx*			*8175**
X150	*PN-IO*				*8174**
X150 P1 R	*Port 1*				*8173**
X150 P2 R	*Port 2*				*8172**
1	**DO SERVO**				**8171***
1.1	*Module Access Point*				*8171**
1.2					
1.3	Standard Telegramm 1, P~		256...259	256...259	
1.4					
2	**DO Control Unit**				**8170***
2.1	*Module Access Point*				*8170**
2.2	*ohne PROFIsafe*				*8169**
2.3	SIEMENS Telegramm 390, ~		260...263	260...263	

6.2 Operation

The sample project is operated using the variable table "Drive control" of the SIMATIC CPU in the SIMATIC Manager.

Here, the user can enter the set point speed for the servo motor as well as switching the motor on and off. Possibly upcoming faults of the servo motor can also be acknowledged.

Table 6-2 Operation

No.	Action
1.	Open the variable table "Drive control", which is located in the block container of the SIMATIC CPU. 
2.	In the variable table, switch to the online view using button "Monitor variable" (1). Then enter the required speed setpoint in column "Modify value" into flag double word MD100 (unit: rpm) and the value "true" or "1" into flag M0.0 (2). Activate the values by using the button "Activate modify values" (3). 

No.	Action
3.	The speed "N_SOLL_USER" entered by the user is scaled according to the definitions of the PROFIdrive profile and entered at the servo motor as speed setpoint. Further, the required releases are set in control word 1 ("STW1") of the drive to move it. **Note** The speed setpoint can also be changed if the servo motor is already in operation, i.e. flag "boMove" is set.
4.	By setting flag "boReset", possible faults present at the servomotor can be acknowledged. **Note** Pending faults can be acknowledged only when the servomotor is not operational, i.e. the "boMove" flag must not be set! Further it should be noted that flag "boReset" is not automatically reset to the value "0". This must be done manually after the acknowledgement of the faults!

7 Further notes, tips and tricks, etc.

Further information

Further information about PROFINET System redundancy can be found in following manuals in SIOS:

- System manual "SIMATIC Fault-tolerant systems S7-400H" (https://support.industry.siemens.com/cs/ww/en/view/82478488)
- Configuration Examples for S7-400H with PROFINET SIMATIC S7-400H as of V6.0 (https://support.industry.siemens.com/cs/ww/en/view/90885106)
- SINAMICS S120 Function Manual Drive Functions (https://support.industry.siemens.com/cs/ww/en/view/109740020)

8 Related literature

Table 8-1

	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/109740020
\4\	Configuration Examples for S7-400H with PROFINET SIMATIC S7-400H as of V6.0 https://support.industry.siemens.com/cs/ww/en/view/90885106
\5\	System manual "SIMATIC Fault-tolerant systems S7-400H" https://support.industry.siemens.com/cs/ww/en/view/82478488

9 Contact

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10 History

Table 10-1

Version	Date	Modifications
V1.0	03/2017	First version