ACTEA-project

Bachelor Elektromechanica
Afstudeerrichting: Automatisering
Academiejaar: 2020-2021

Panis Matthias
AP-Hogeschool
Stage begeleider: Van Grieken Geert

Eerste examenkans

ARTESIS PLANTIJN
HOGESCHOOL ANTWERPEN

Inhoud

1 Projectdefinitie

Mijn project zal gaan over het schrijven van een cursus in automatisatie.
Het project is een internationaal Erasmusproject, genaamd ACTEA project waarbij Mr. Van Grieken ontwikkelaar
is van cursusmateriaal en didactisch materiaal en levert hij technische
ondersteuning op vlak van PLC-uitrusting. Hij heeft mij als hulp ingeschakeld om een cursus rond Advanced PLC te
vervolledigen. Het project heeft als doel om de bevolking in Oost-Afrikaanse landen op te leiden in STEM technieken op het niveau van een professionele bachelor.

Om de levensstandaard in Oost-Afrikaanse landen te verbeteren bied dit project een zekere meerwaarde. Bovendien is er een grote vraag naar technici van investeerders, ngo's en de opkomende middenklasse. Om aan deze vraag te kunnen voldoen, is er behoefte aan bekwame mensen, opgeleid in relevante technische beroepen, maar die zijn moeilijk te vinden vanwege de sterke theoretische benadering aan de universiteiten in plaats van praktijkgericht competentiegericht onderwijs.

Het ACTEA-project heeft tot doel te voldoen aan de specifieke behoeften op het gebied van engineering, betere afstemming van vaardigheden te bieden, cursusmateriaal te leveren in 2 specialisaties, computerondersteunde fabricagetechnologie en elektrotechniek & automatisering, en technologische laboratoria op te richten met virtuele en externe toegankelijkheid, leermiddelen opzetten, academisch personeel aanvullende opleiding over technologie en in het ontwikkelen van technologisch cursusmateriaal volgens EU-normen.

Zoals eerder vermeld is Mr. Van Grieken ontwikkelaar in cursusmateriaal en didactisch materiaal. Hierbij zal ik mee helpen en hier zal mijn bachelor proef dan ook over gaan.

2 Voorwoord

Ik studeer op het departement Wetenschap & Techniek van AP-Hogeschool Welke zicht bevindt in de campus Spoor Noord - Ellermanstraat 33 in Antwerpen. Ik volg hier de opleiding Elektromechanica

met de afstudeerrichting Automatisatie. Hier doe ik ook mijn bachelorproef voor het ACTEA-project welke een samenwerking is van de volgende universiteiten en hogescholen:

- Hogeschool West-Vlaanderen
- Fachhochschule Dortmund
- Technological Educational Institute of Crete
- Mekelle University Ethiopia
- Jimma University (Jimma Institute of Technology)
- Mbarara University of Science and Technology
- Muni University
- Mzumbe University
- Ardhi University
- Research and Education Network for Uganda
- Tanzania Education and Research Network

Hierbij worden er STEM-cursussen ingericht voor gebruik in Oost-Afrikaanse landen waaronder, Ethiopië, Oeganda en Tanzania. Deze cursussen bestaan uit 2 grote modules, module 1: "Computer Aided Manufacturing Technology", module 2 "Electrical Engineering & Automation" en ten slotte module 3 : "Labor Market Skills".
Ik zit in de groep die verantwoordelijk is over module 2 "Computer Aided Manufacturing Technology" en bevat volgende cursussen.

- Electrical Installations
- Electrical Motors & Drives
- Basic PLC Programming
- Advanced PLC & Motion
- Sensor Technology
- Process Simulation & Control
- Renewable Energy
- Embedded Measurement and Control

Waaruit "Advanced PLC & Motion" mijn verantwoordelijkheid zijn.

3 Omschrijving Bachelorproef

Ik zal bestaande cursusmateriaal omzetten naar het Engels. Dit cursus materiaal bevatten ook schema's en oefening die ik zal hermaken / hernoemen naar de correcte engelse benamingen. De oefening zal ik zelf allemaal moeten uittesten en naar de correcte engelse benamingen omzetten. Ik maak gebruik van Atom om deze cursus in Markdown [1] te schrijven en heb ook in Atom mijn PDB

geschreven. Atom is een tekst editor vooral gemaakt voor bv. markdown bestanden mee te schrijven. Verder gebruik ik ook GitHub om de cursusses en mijn aanpassingen te uploaden en downloaden. Mensen met de juiste link hiernaar kunnen dan deze cursussen en bestanden online bekijken.

De PDB zelf heb ik dan ook in een .md bestandformaat geschreven gebruik makend van Atom. Deze is dan geexport naar een HTML pagina die dan in een PDF versie gepresenteerd wordt. Dit PDB staat ook op een persoonlijke repository op Github

4 IST-Situatie

- Advanced PLC boek is nog niet vervolledigen
- ADD01[2] Electrical drawings
- ADD02 TAG Name

5 SOLL-Situatie

- Elektonische Advanced PLC boek geschreven
- EX01[3] Industrial Networks
- EX02 ANSI/ISA S88
- EX03 Sequential controllers
- EX04 Continue controllers
- EX05 HMI displays
- ADD03 HMI
- ADD04 GRAFCET
- ADD05 controllers
- ADD06 S88

6 ACTEA Team

Via Microsoft Teams worden er meetings georganiseerd. Hier gaat ook alle communicatie door. Als er een hoofdstuk klaar is voor controle communiceer ik via deze weg met het team.

6-1 Van Grieken Geert

Lector en onderzoek van de AP Hogeschool Antwepen verbonden aan de opleiding professionele bachelor Elektromechanica van het departement Wetenschap en Techniek.
Gespecialiseerd in industriële automatisatie voor de maakindustrie en interne logistieke transporten.

Is binnen het ACTEA-project verantwoordelijk voor de cursussen “M2C3 Basic PLC programming” en “M2C4 Advanced PLC programming”. In zijn functie als cursusverantwoordelijke verzorgt hij de aansturing van de internationale “writing teams” inclusief de uitwerking, opvolging en ondersteuning van het technisch didactisch materiaal voor deze cursussen.

6-2 Panis Matthias

Student (ik) die verantwoordelijk is voor de uitwerking van de cursus "Advanced PLC & Motion"

6-3

Van de andere personen heb ik momenteel nog geen aantwoord gekregen.

7 Software vereisten

In de cursus is er gebruik gemaakt van Siemens TIA Portal V16 en Real Games Factory IO 2.4.X. TIA Portal is een computerprogramma dat gebruikt wordt om de oefeningen die aan bod zullen komen te programmeren en uit te voeren op een PLC. FactoryIO is een simulatie programma dat waarin je verschillende scénes kunt maken van echte machine's. Deze scènes en machines die gebouwd zijn in FactoryIO kunnen gesimuleerd worden om met een PLC te communiceren. Hiermee kan een student zijn programmatie controleren zonder effectief de machine voor hun te hoeven hebben. Dit is geweldig makkelijk voor studenten omdat ze het live kunnen controleren met de simulatie van een "echte" machine.

Om deze programma's uit te kunnen voeren zal je PC tenminste met deze specificaties moeten voldoen.

7-1 Tia Portal

Hardware/Software	Requirement
Processor	Intel® Core ™ i5-6440EQ (up to 3.4 GHz)

Hardware/Software	Requirement
RAM	16 GB (min. 8 GB, 32 GB for large projects)
Hard disk	SSD with 50 GB free storage space
Network	1 Gbit (for multi-user) Laptops need WiFi
Monitor	15.6 "full HD display (1920 x 1080 or more)
Operating system	Windows 7 (64-bit) ** ▪ Windows 7 Home Premium SP1 * ▪ Windows 7 Professional SP1 ▪ Windows 7 Enterprise SP1 ▪ Windows 7 Ultimate SP1 Windows 10 (64-bit) ▪ Windows 10 Home Version 1809, 1903 * ▪ Windows 10 Professional Version 1809, 1903 ▪ Windows 10 Enterprise Version 1809, 1903 ▪ Windows 10 IoT Enterprise 2015 LTSB ▪ Windows 10 IoT Enterprise 2016 LTSB ▪ Windows 10 IoT Enterprise 2019 LTSB Windows Server (64 bit) ▪ Windows Server 2012 R2 StdE (full installation) ▪ Windows Server 2016 Standard (full installation) ▪ Windows Server 2019 Standard (full installation) * only for Basic Edition ** not for "STEP 7 Basic / Professional and WinCC Professional", only for "STEP 7 Basic / Professional incl. Safety and WinCC Basic / Comfort / Advanced and WinCC Unified"

7-2 FactoryIO

Hardware/Software	Requirement
Processor	CPU with SSE2 instruction set support
GPU/ Video Card	NVIDIA since 2006 (GeForce 8), AMD since 2006 (Radeon HD 2000), Intel since 2012 (HD 4000 / IvyBridge)
RAM	8 GB

Hardware/Software	Requirement
Hard disk	SSD with 10 GB free storage space
Network	1 Gbit (for multi-user) Laptops need WiFi
Monitor	15.6 "full HD display (1920 x 1080 or more)
Operating system	Windows 7 SP1+ or higher

8 Cursus

Ik behandel het gedeelte M2C4 wat de advanced cursus is van automatisatie cursus.
Deze cursus bevat volgende hoofdstukken:

- Addendum 3 **HMI**
- Addendum 4 **GRAFCET**
- Addendum 5 **Controllers**
- Addendum 6 **Software model following S88**
- Exercise 1 **Industrial networks**
- Exercise 2 **ANSI/ISA S88**
- Exercise 3 **Sequential controllers**
- Exercise 4 **Continue controllers**
- Exercise 5 **HMI displays**

Link naar Github repository van ACTEA

De hele cursus is in het engels geschreven, gebruik makend van Atom. Deze is te vinden in de Bijlagen

8-1 Addendum 3 HMI

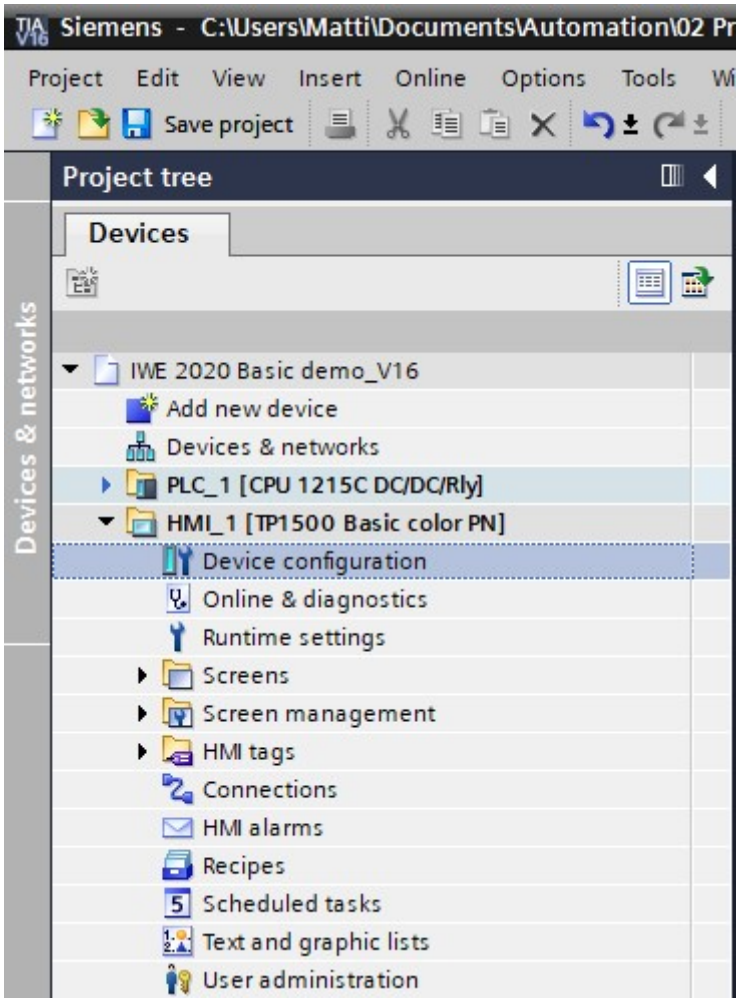
Dit addendum heb ik met hulp van Siemens pdf's zelf samen gesteld (HMI Tutorial). Dit is ook in het engels geschreven maar heb het terug naar nederlands vertaald hier.

Engelse volledige versie Bijlagen

In dit hoofdstuk wordt het HMI en hoe men deze gebruikt in TIA portal besproken.
Men legt uit hoe je de HMI toevoegd via TIA portal. Dit kan zowel via het portal view of project view.

Vervolgens wordt men door de device selectie geleid. Als de juiste HMI geselecteerd is zal de HMI wizard tevoorschijn komen. Hierin wordt elke opties uitgelegd en de functies ervan.

Als dit allemaal geconfigureerd is kunnen we verder naar de "Device configuration". Hierbij zullen we eerste de HMI moeten configureren.



In de device configuratie wordt uitgelegd waar men de juiste IP instellingen ingegeven wordt. Als dit ingesteld is zal de CPU en het HMI Paneel worden gecompiled. Als er geen errors zijn kunnen we verder naar het ontwerpen van de schermen.
In dit hoofdstuk legt men uit hoe je een scherm aanpast met verschillende elementen. Deze elementen kunnen via de Toolbox van TIA Portal worden geselecteerd. Vervolgens bespreekt men the "Basic objects", "Elements", "Events" en "Animations".

Onder de **basic objects** zitten de volgende voorwerpen;

- Text box
- Rectangle
- Circle
- Line

- Ellipse
- Graphic view

Deze delen ongeveer dezelfde eigenschappen (hun lay-out en de make-up ervan).
Dit kan aangepast worden in de properties tab.
Het speciale aan een **Graphic view** is dat men custom afbeeldingen in het HMI schermen kan steken.
Dit is uitgelegd hoe men het doet in de cursus.

De **"elements"** zijn figuren die kunnen gelinked worden met PLC data. Deze bestaan uit;

- I/O-Field
- Button
- Symbolic I/O-Field
- Graphical I/O-Field
- Date/Time Field
- Bar
- Switch

Een I/O-Field kan dus ingesteld worden om bv. een integer waarde vanuit de plc te lezen en/of wegschrijven. Deze functionaliteit wordt in de properties veranderd onder "General".

De **events** kunnen toegepast worden op elk object of figuur op een HMI scherm.
Deze events kunnen verschillende functies doen bv.

In de cursus leg ik het gebruik van "SetBitWhileKeyPressed" dit zal de functionaliteit van een drukknop nabootsen.

De **animations** bestaat onder 2 verschillende toepassingen die men kan kiezen.
Deze zijnde ;

- Display
- Movements

Het display zal de optie geven om de "visibility" aan te passen. Hierdoor kan je voorwerpen tevoorschijn of verbergen aan de hand van een waarde.

De movements bestaan onder 4 verschillende sub categoriëen;

- Direct movement
- Diagonal movement
- Horizontal movement
- Vertical movement

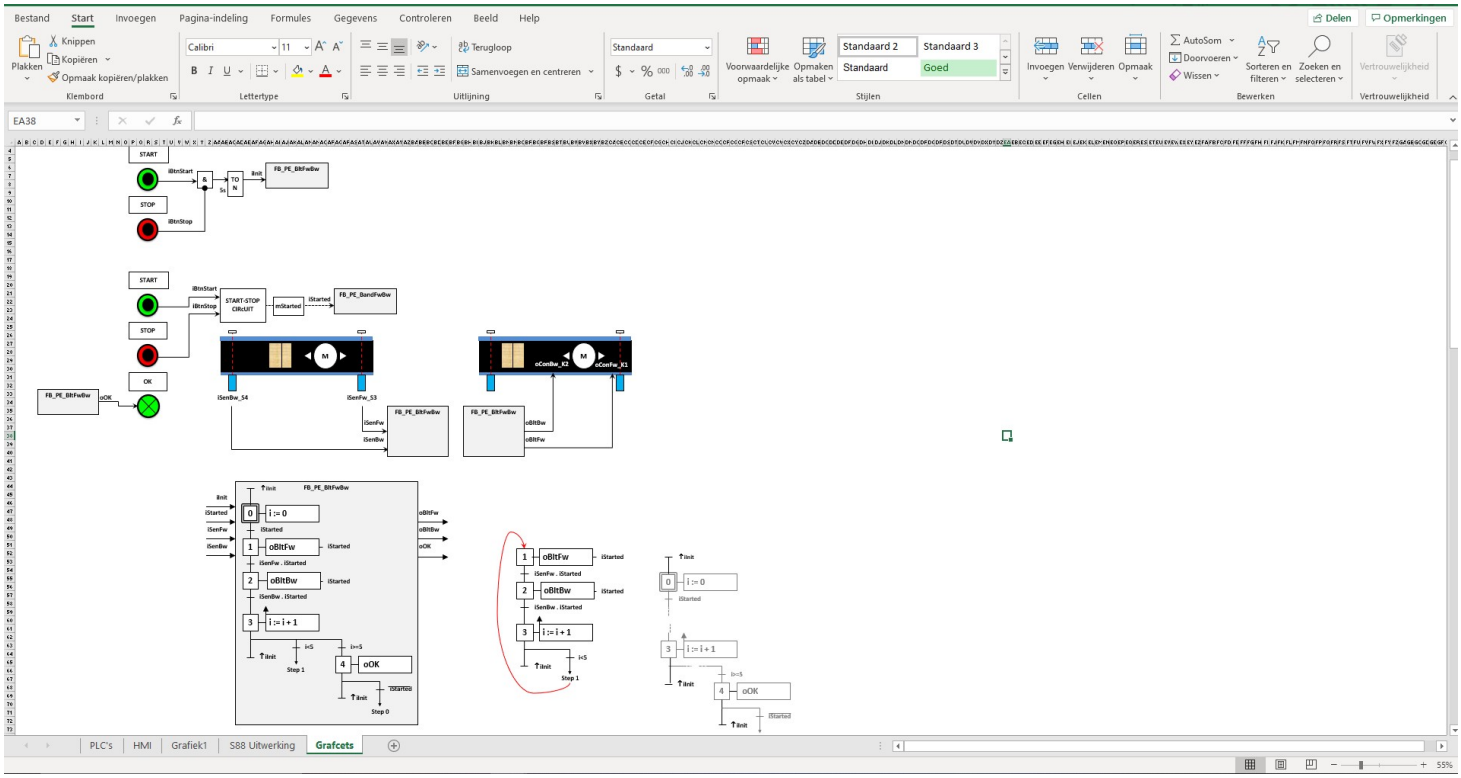
Deze bepalen hoe het object zal bewegen. Dit is ook weer linkbaar met een variabel.

8-2 Addendum 4 GRAFCET

In dit hoofdstuk wordt een GRAFCET uitgelegd. Hiervan was al een Nederlandse cursus door Mr. Van Grieken geschreven. Deze heb ik dan volledig omgezet van Nederlands naar Engels. Afbeeldingen die eerst in het Nederlands stonden zijn dus ook in Ms Excel aangepast naar de correcte Engelse benamingen. Hier had Mr. Van Grieken ook al een Ms Excel file van met al de correcte Nederlandse benamingen.

Engelse volledige versie Bijlagen

Een voorbeeld van de afbeeldingen in Ms Excel :



In Ms Excel kan je de rasterlijnen laten verdwijnen door "Pagina-indeling" > "Uitlijnen" > "Rasterlijnen weergeven" af te vinken. Hierdoor verdwijnen de rasterlijnen. Hierna gebruik makend van de snipping tool in Ms Windows kan de gewenste afbeelding worden geselecteerd.

Verder is deze addendum ook opgedeeld in 5 subchapters:

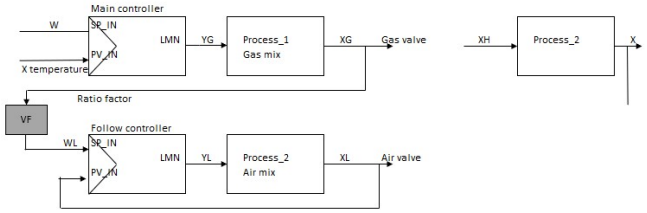
- Subchapter01 zal gaan over de algemene uitleg
- Subchapter02 zal gaan over het ontwerpen van een GRAFCET
- Subchapter03 zal gaan over de GRAFCET taal geprogrammeerd in TIA Portal (Bool)
- Subchapter04 zal gaan over de GRAFCET taal geprogrammeerd in TIA Portal (INT)
- Subchapter05 zal gaan over de GRAFCET taal geprogrammeerd in TIA Portal (ST)

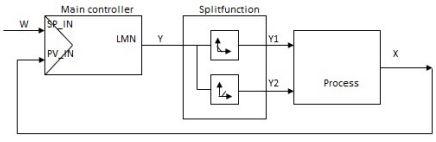
Voor subchapter 3 tot 5 komt er ook TIA Portal programmatie voor. Deze zijn ook vertaald naar het Engels. Gebruik makend van de Nederlandse voorbeelden in de bestaande cursussen heb ik dan in TIA Portal deze bouwstenen nagemaakt maar dan met de Engelse benamingen.

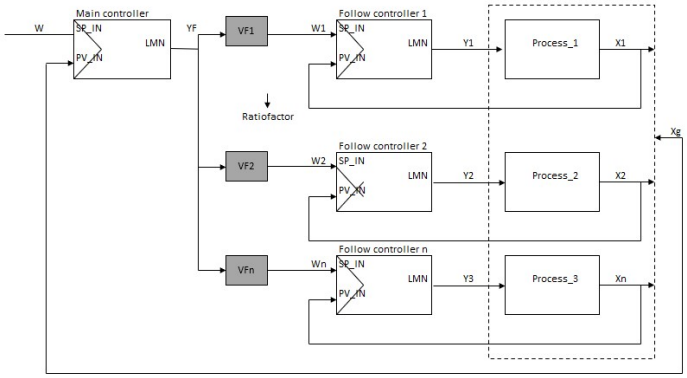
8-3 Addendum 5 Controllers

In dit hoofdstuk worden de verschillende controllers uitgelegd. Hiervan was al een Nederlandse cursus door Mr. Van Grieken geschreven. Deze heb ik dan volledig omgezet van Nederlands naar Engels. Afbeeldingen die eerst in het Nederlands stonden zijn dus ook in Ms Excel aangepast naar de correcte Engelse benamingen. Deze heb ik zelf nagetekent in Ms Excel.

Door middel van de kolombreedte op 2 en de rijhoogte op 15 krijg je een mooi vierkant. Hiermee kunnen we nu zelf de sturing na tekenen. Om het makkelijker te makken om de lijnen en vormen uit te lijnen activeren we de optie "Uitlijnen op raster". De optie kan terug gevonden worden onder "Pagin-indeling" > "Uitlijnen".
Met behulp van deze functies zijn de sturing getekent in Ms Excel:







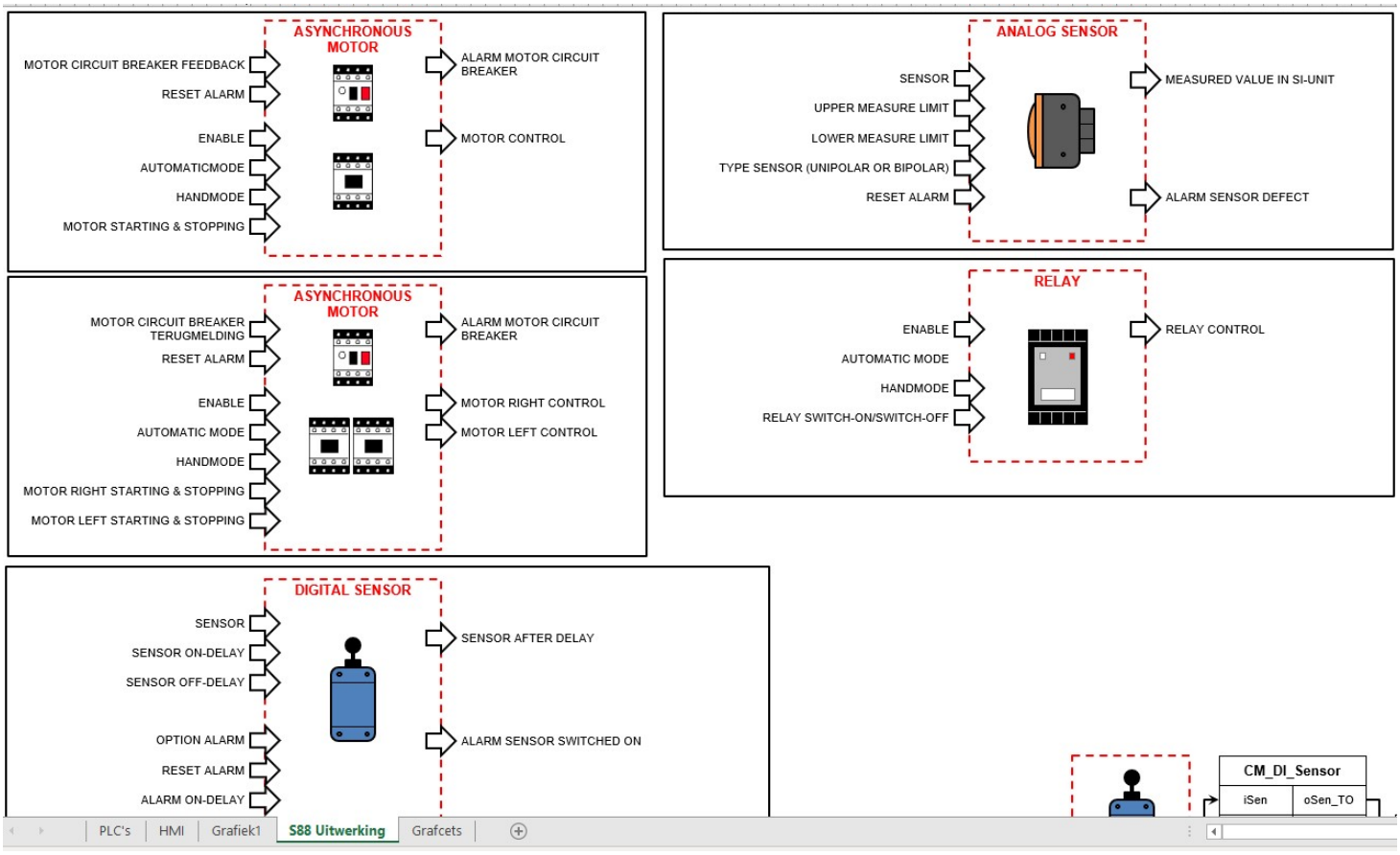
Verder is deze addendum ook opgedeeld in 5 subchapters:

- Subchapter01 zal gaan over de eigenschappen en begrippen
- Subchapter02 zal gaan over een aan-uit controller
- Subchapter03 zal gaan over een PID controller
- Subchapter04 zal gaan over regelkring structuren

8-4 Addendum 6 S88

In dit hoofdstuk bespreken we het S88 software model. Hierbij is er een standaard AP library gebruikt. Ook deze zal omgezet worden van Nederlands naar Engels, later worden de library gebruikt om oefeningen mee te maken. Deze heb ik dan volledig omgezet van Nederlands naar Engels. Afbeeldingen die eerst in het Nederlands stonden zijn dus ook in Ms Excel aangepast naar de correcte Engelse benamingen. Hier had Mr. Van Grieken ook al een Ms Excel file van met al de correcte Nederlandse benamingen.

Een voorbeeld van de afbeeldingen in Ms Excel :



CM_DI_Sensor	
iSen	oSen_TO
iReset	oAL_Sen
iAL_Option	
iAL_Time	
iTON_Time	
iTOF_Time	

CM_AI_Sensor	
iSen	oX
iReset	oAL_Sen
iHiLim	
iLoLim	
iUniOpt	

CM_DOL	
iEnable	oCon
iReset	
iMcb	oAL_Mcb
iModeHand	
iHandOn	
iHandOff	
iAut	
iTON_Time	
iTOF_Time	

CM_Relay	
iEnable	oRel
iModeHand	
iHandOn	
iHandOff	
iAut	
iTON_Time	
iTOF_Time	

CM_DOLRev	
iEnable	oConR
iReset	oConL
iMcb	oAL_Mbv
iModeHand	
iHandR	
iHandL	
iHandOff	
iAutR	
iAutL	
iTOF_Time	

CM_Lamp	
iHandTest	oLmp
iAut	
iAut_1Hz	
iAut_2Hz	

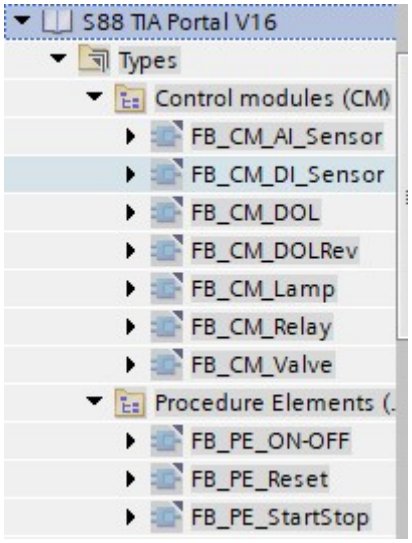
CM_Valve	
Release	oVen_1
iReset	oVen_0
iModeHand	
iHand_1	
iHand_0	
iAut_1	
iAut_0	

PE_StartStop	
iBtnStart	oStarted
iBtnStop	oStopped
iTON_Time	oStarted_TO
iTOF_Time	

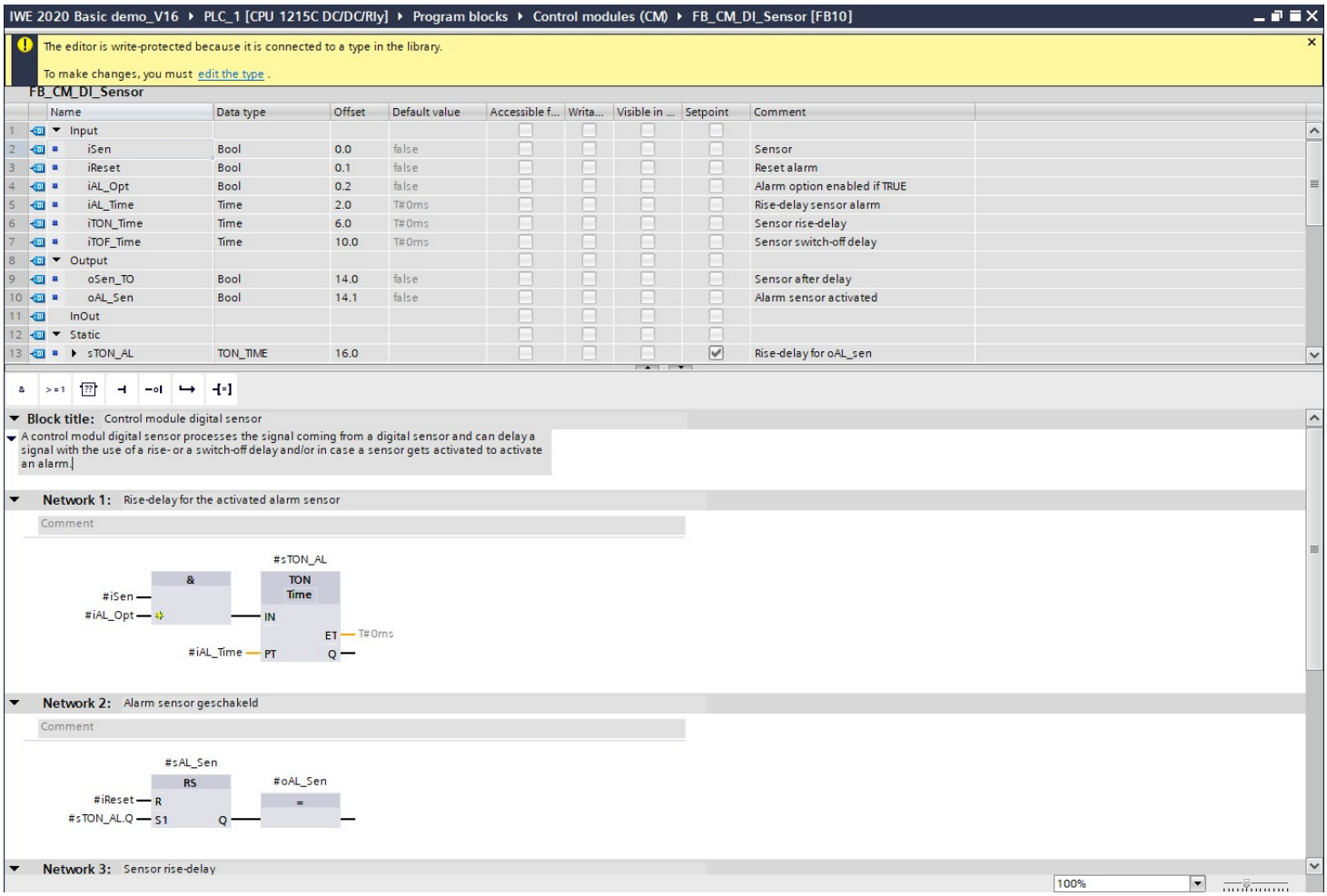
PE_Reset	
iBtnReset	oReset
	oReset_1s

PE_ON-OFF	
iOn	oY
iX	oY_NOT
iW	
iH	

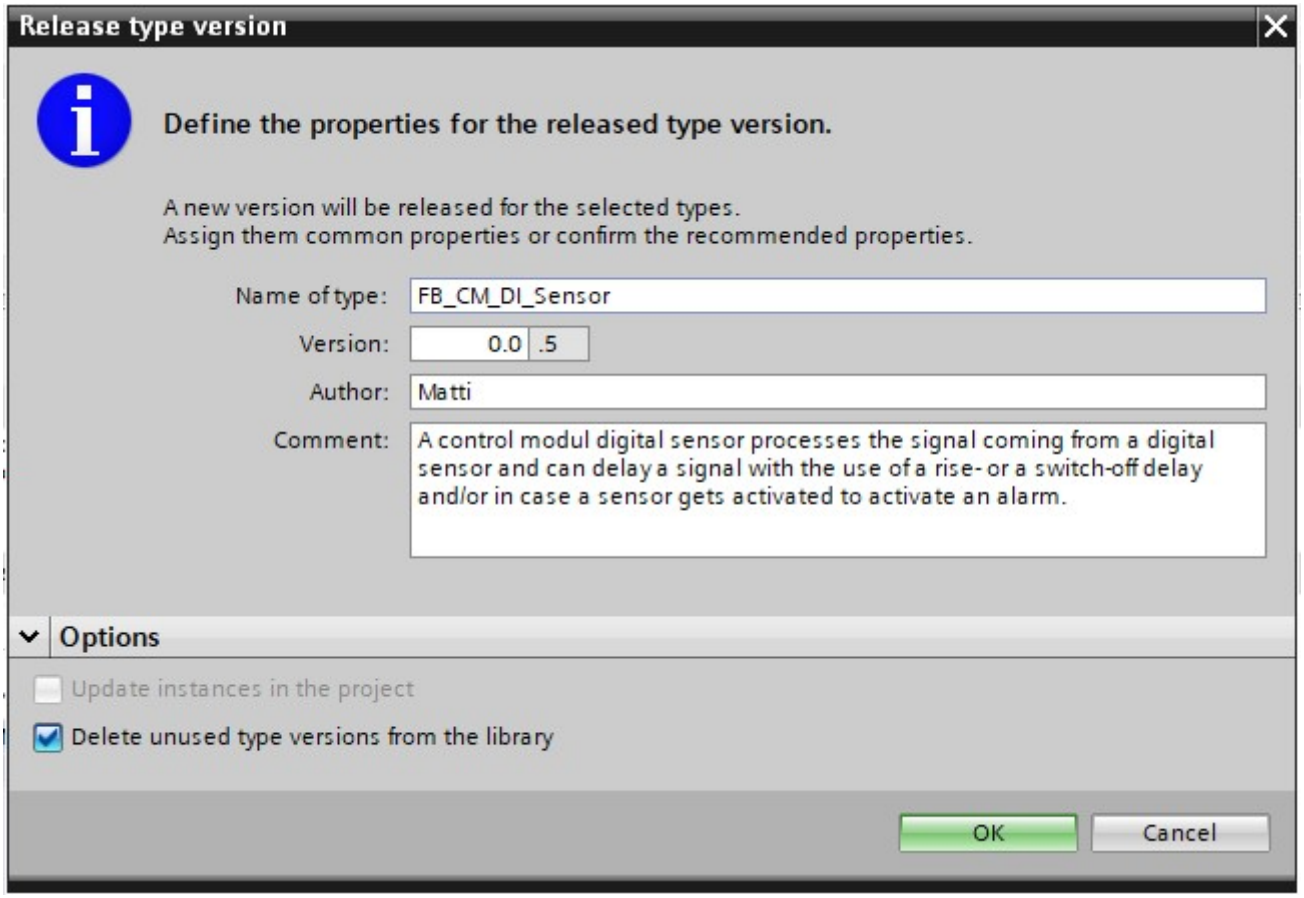
De engelse library ziet er als vogt uit:



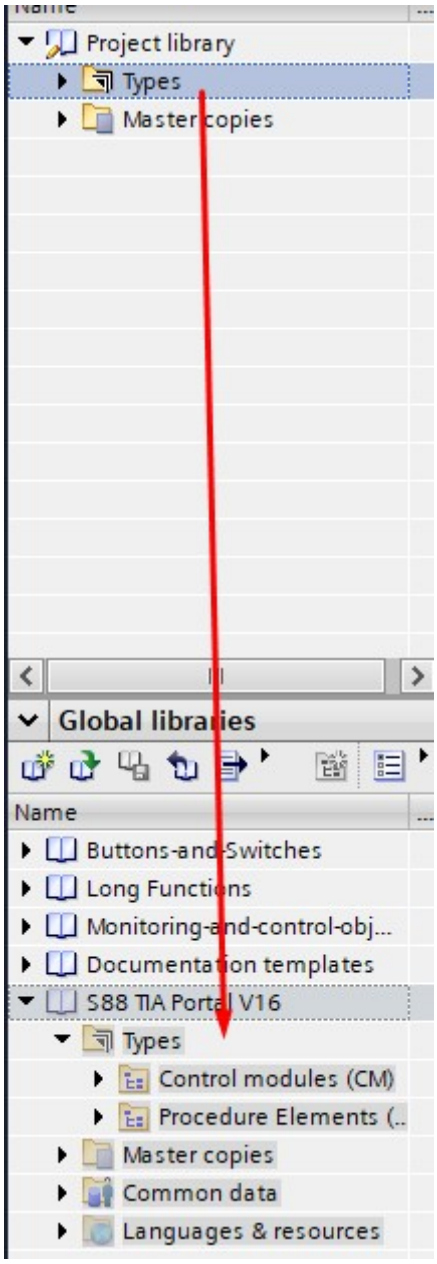
Om in TIA Portal de Nederlandse library aan te passen moet je de functie blok in TIA portal slepen. Dan pas je deze aan door op "edit the type" te klikken nadat je de functie blok hebt geopend.



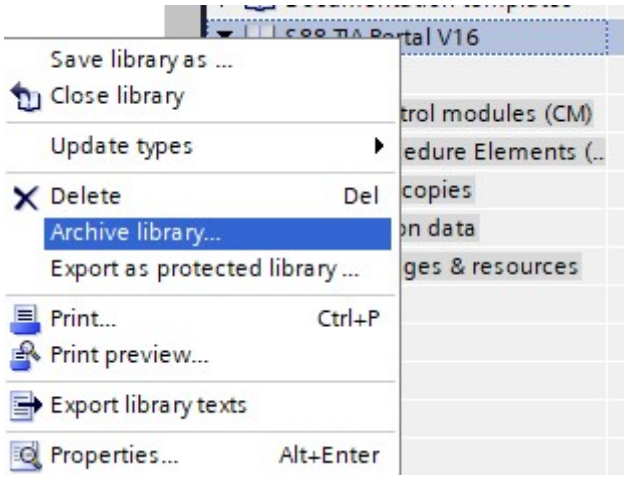
Als dan alles correct is aangepast zal deze blok als een nieuwe versie worden "gereleased". Dit ziet er als volgt uit:



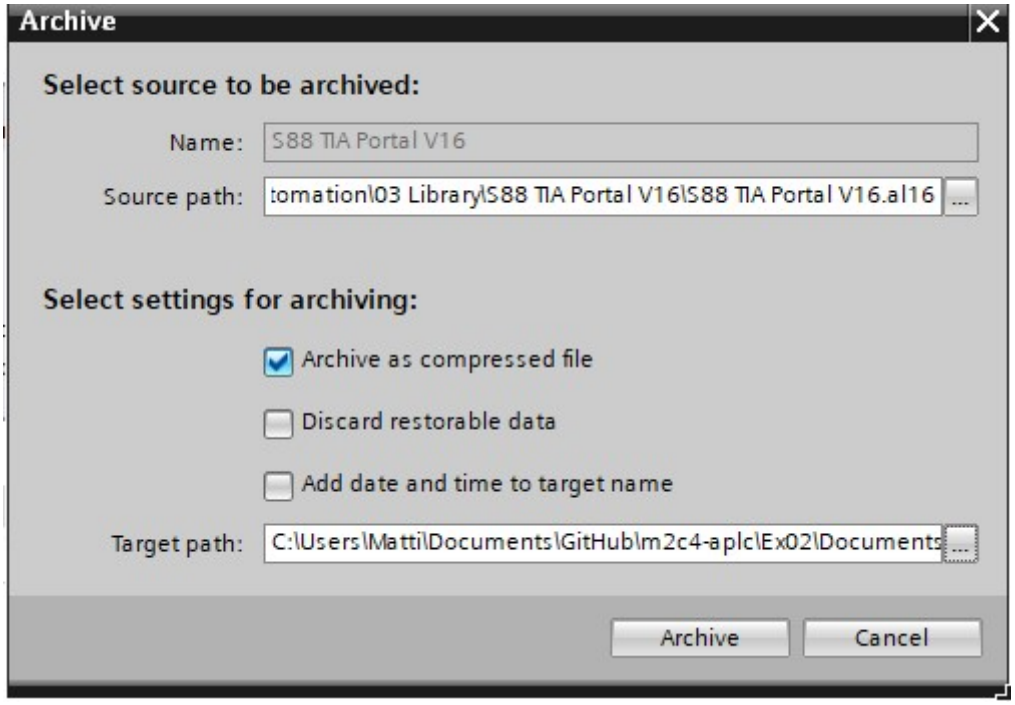
Dit is gedaan voor elk controle module en process element. Om dit bruikbaar te maken voor later gebruik zal er een nieuwe library aangemaakt moeten worden in de "Global Library" tab. Deze library is genoemd "S88 TIA Portal V16"



Volgende stap is er een archive van te maken. Dit gebeurd door te rechtsklikken op "S88 TIA Portal V16", wat een menu opent met de optie "Archive library..."



De archived library wordt opgeslagen bij oefening 2 onder "Documents"



De archived library zal gebruikt worden in oefening 2.

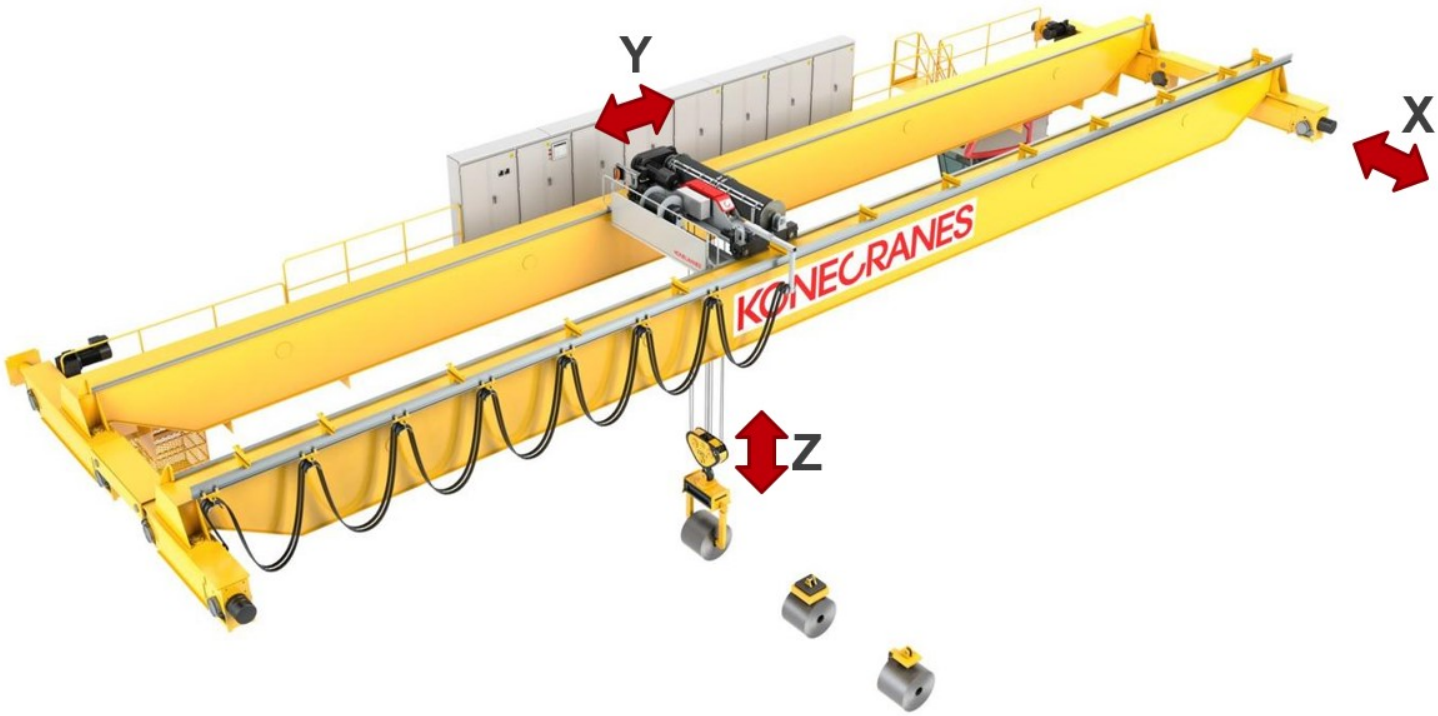
Verder is deze addendum ook opgedeeld in 5 subchapters:

- Subchapter01 zal gaan over de algemene uitleg
- Subchapter02 zal gaan over sensoren
- Subchapter03 zal gaan over het aansturen van motoren door een controle module
- Subchapter04 zal gaan over de controle module voor een ventiel en contactor
- Subchapter05 zal gaan over geeft voorbeelden

8-5 Exercise 1

Bijlagen

Oefening 1 zal de student een uitgebreid netwerk configuratie moeten maken. Deze bevat ProfiNET & Profibus apparaten maar ook gewone IO.
De hardware configuratie wordt gemaakt voor een kraan:

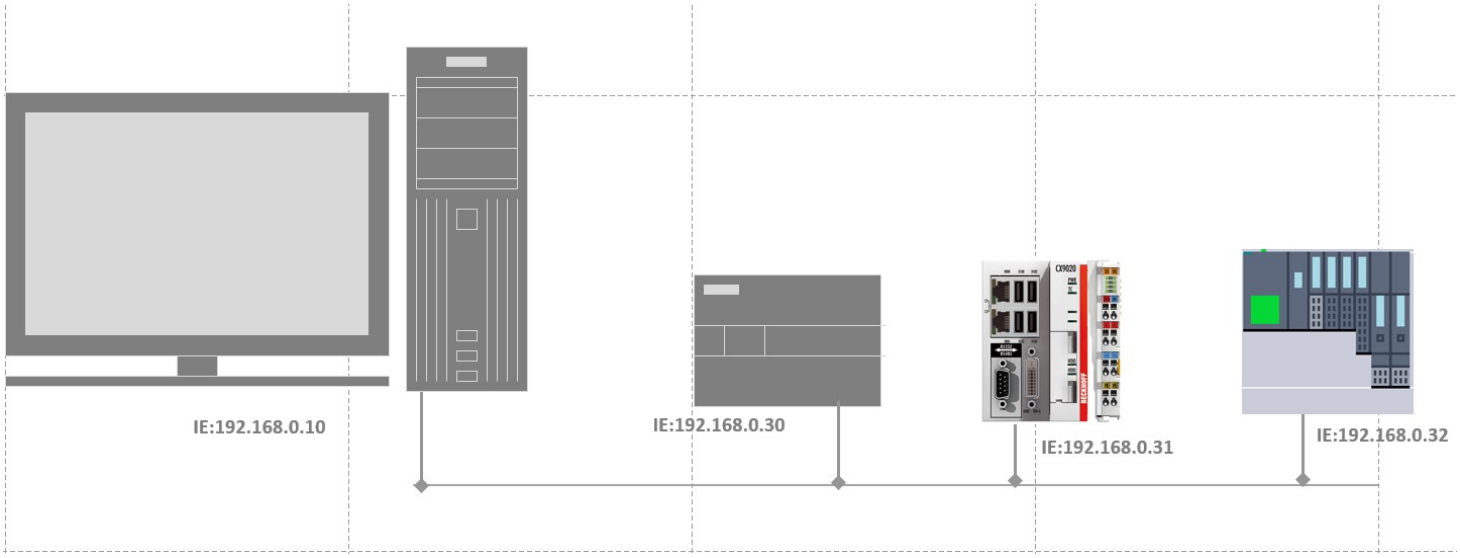


Om alle apparaten in de netwerkconfiguratie te krijgen zijn er GSD bestanden nodig. Deze moeten ze zelfs zoeken aan de hand van modelnummers van de apparaten. Als ze geen internet ter beschiking hebben zijn alle GSD bestanden toegevoegd onder "Ex01/Documents/GSD files"

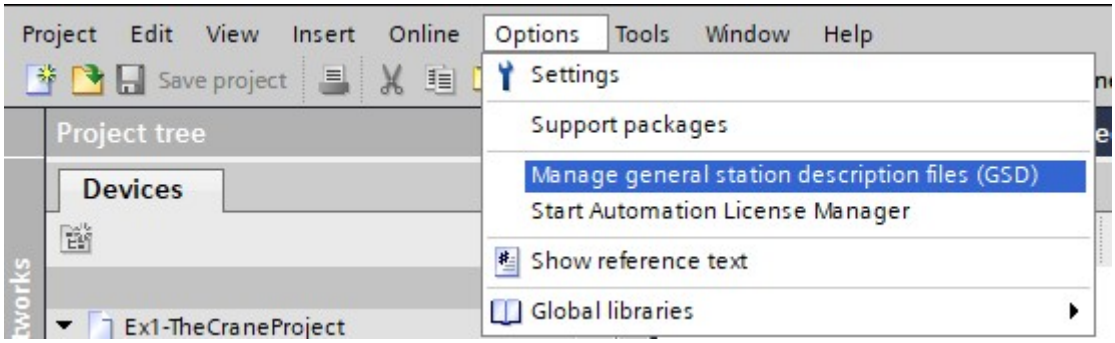
Eerste doel zal zijn om ProfiNET apparaten toe te voegen met de juiste configuratie en IP adressen:

```
Beckhoff CX8093 island (IO on bridge)
-       3x digital sensor (grabber open, rabber closed, grabber on top)
-       2x digital sensor (eindeloop left, eindeloop right)

Siemens ET200S island 1  (pumps)
-       3x motorstarter (supply- & drainpump & heating)
-       2x analog measurement (level and temperature)
-       1x digital levelmeasurement (overflow)
```

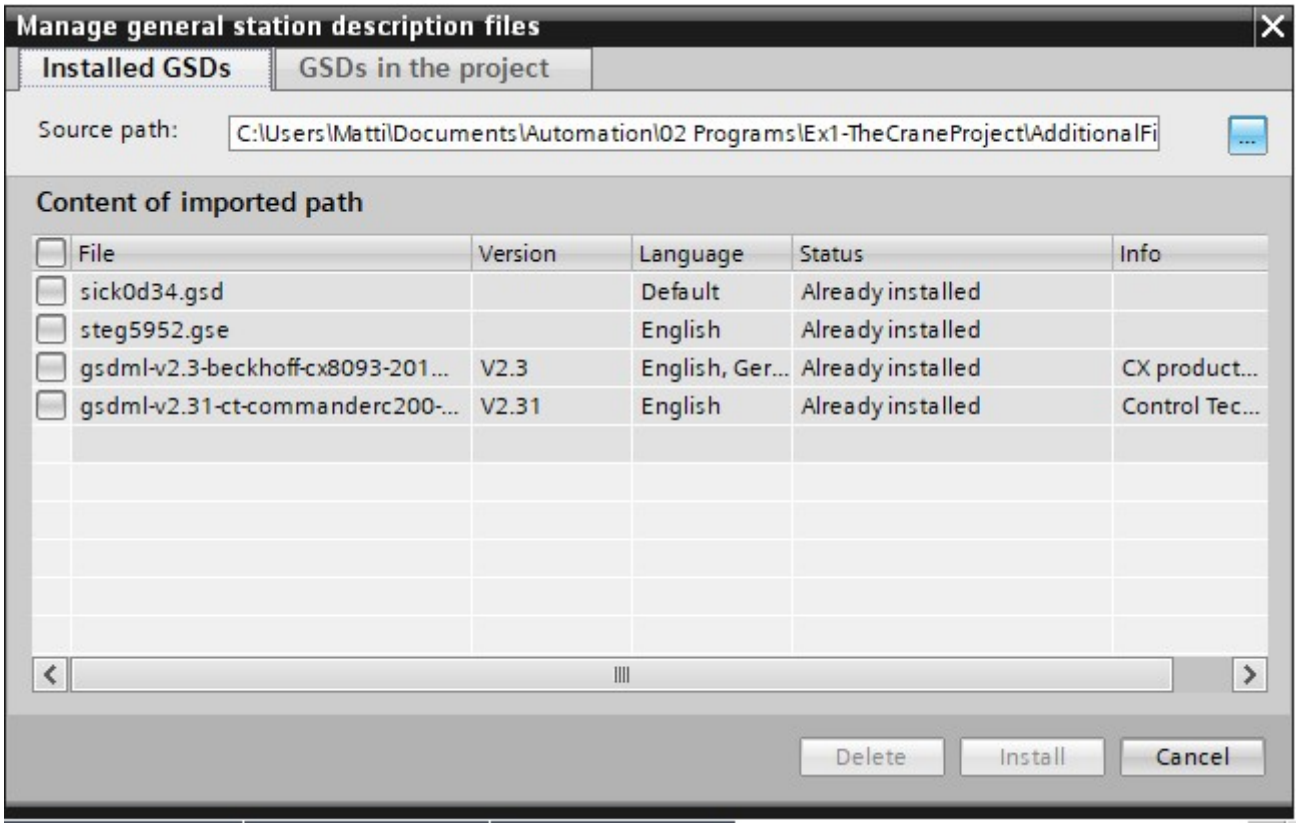
Netwerkoverzicht



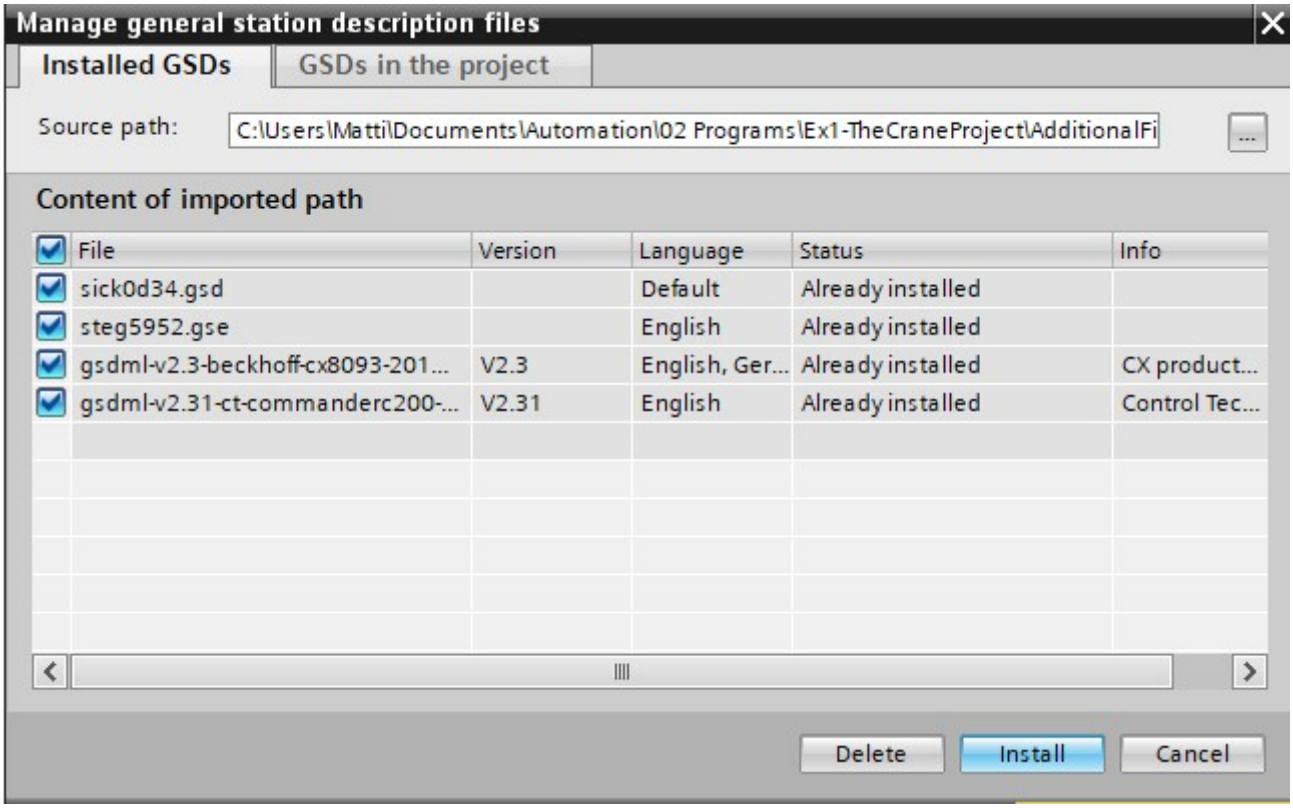
Om GSD bestanden correct toe te voegen aan TIA Portal moet het volgende gebeuren:
"Options" > "Manage general station description files":



Selecteren van de GSD bestanden:



Installeren van de GSD bestanden:

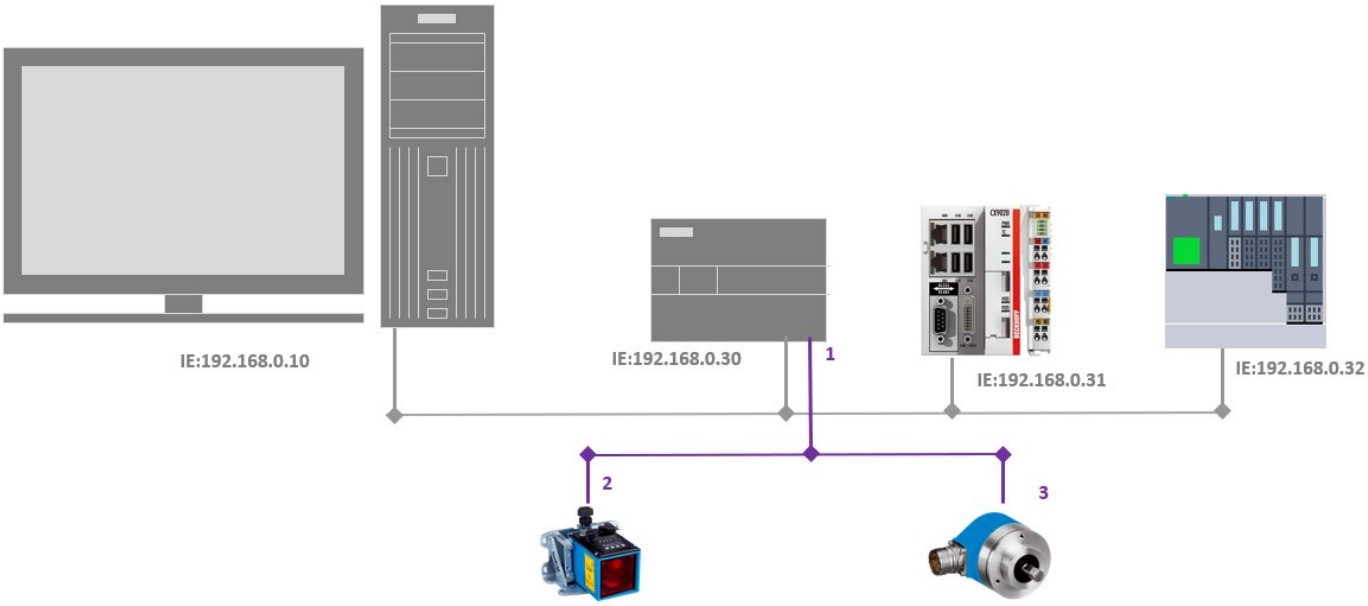


Als de juiste apparaten zijn toe gevoegd aan het project moet de juiste IO nog geconfigureerd worden. Modulen per apparaat inslepen volgens de opgegeven in en uitgangen(functies).

Profibus apparaten die toegevoegd moeten worden:

- Sick Long-range-sensor DX100
- Sick wire-encoder ATM60

Netwerkoverzicht

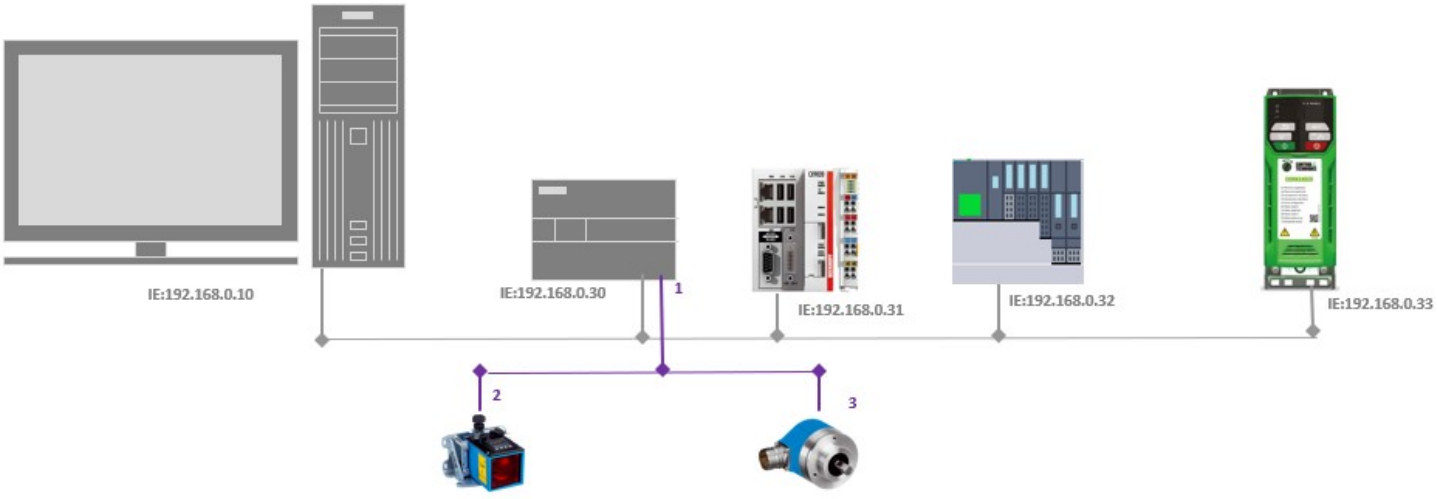


Ten laatste moet een Control Techniques drive worden toegevoegd:

Step 1: Search for the correct GSD file for the following device:

```
Control Techniques Commander C300
```

Netwerkoverzicht



Als dit allemaal gedaan is zal het project moeten gecompileerd worden en nakijken op errors.

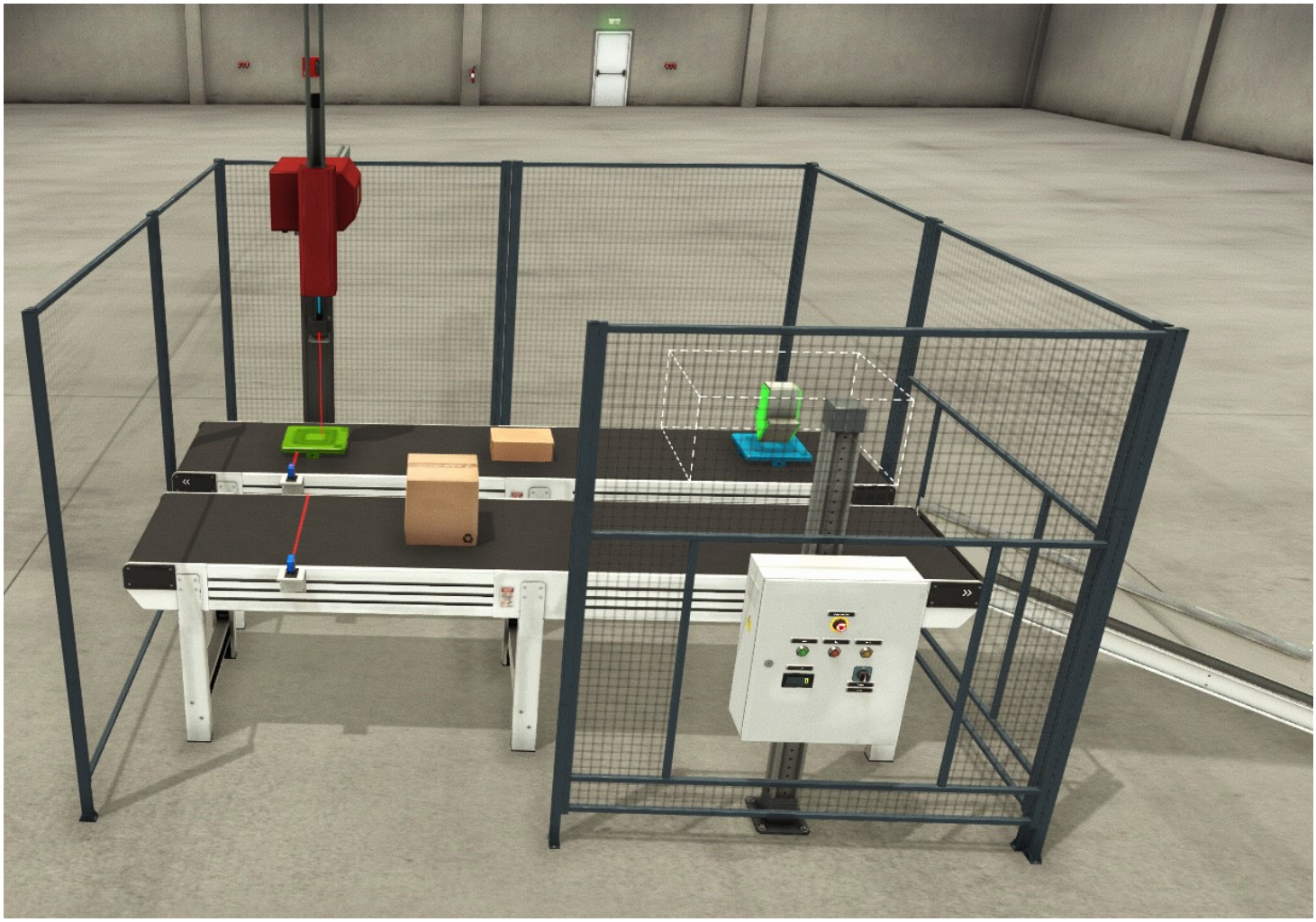
8-6 Exercise 2

Bijlagen

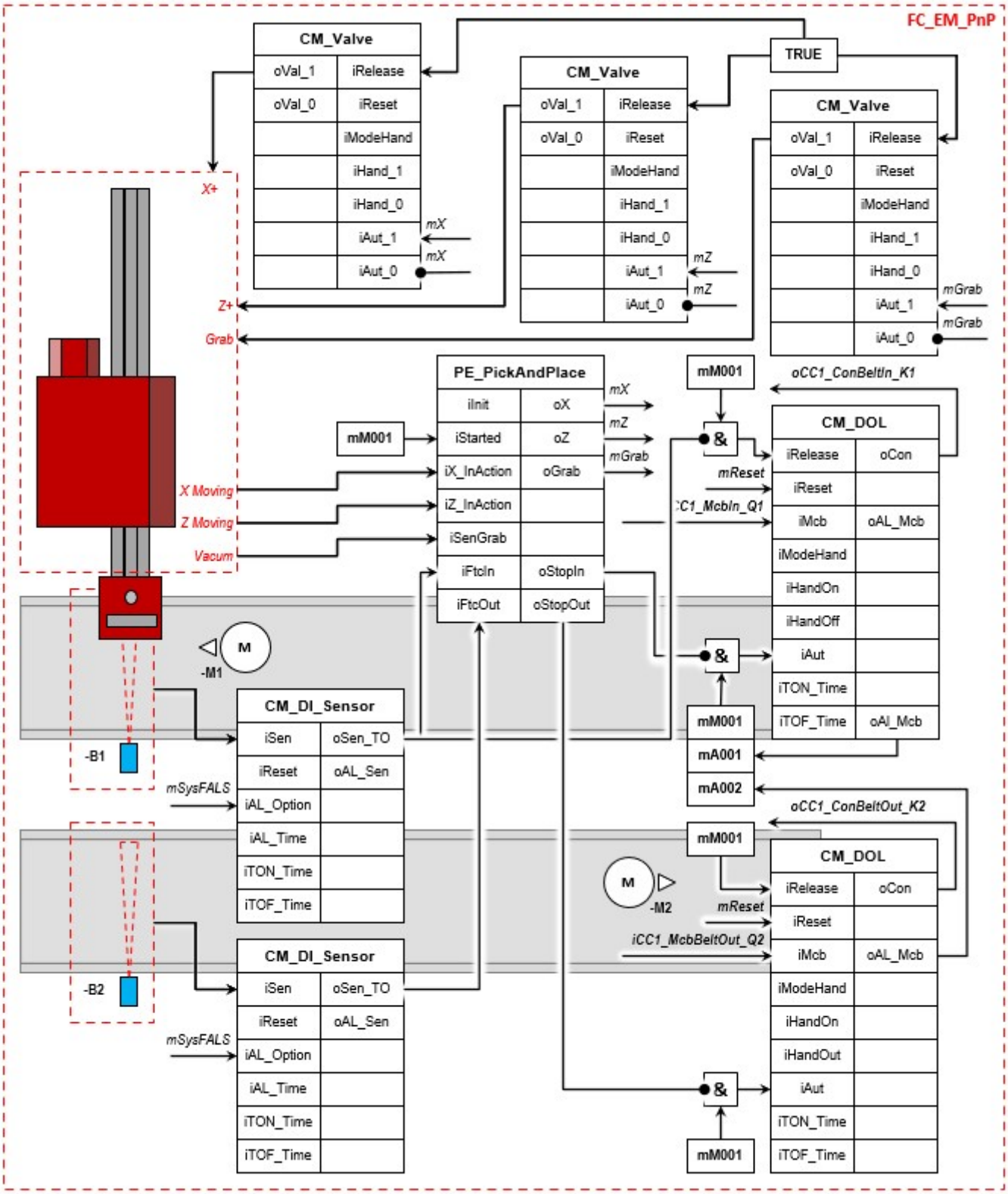
Oefening 2 is een toepassing op S88. De student leert een S88 ontwerp om te zetten naar een software design. Ook zullen ze leren om de volgende functies uit te voeren in TIA Portal:

- Het retrieven van een archived programma
- Het retrieve van een archived library
- Het importen van een external source file

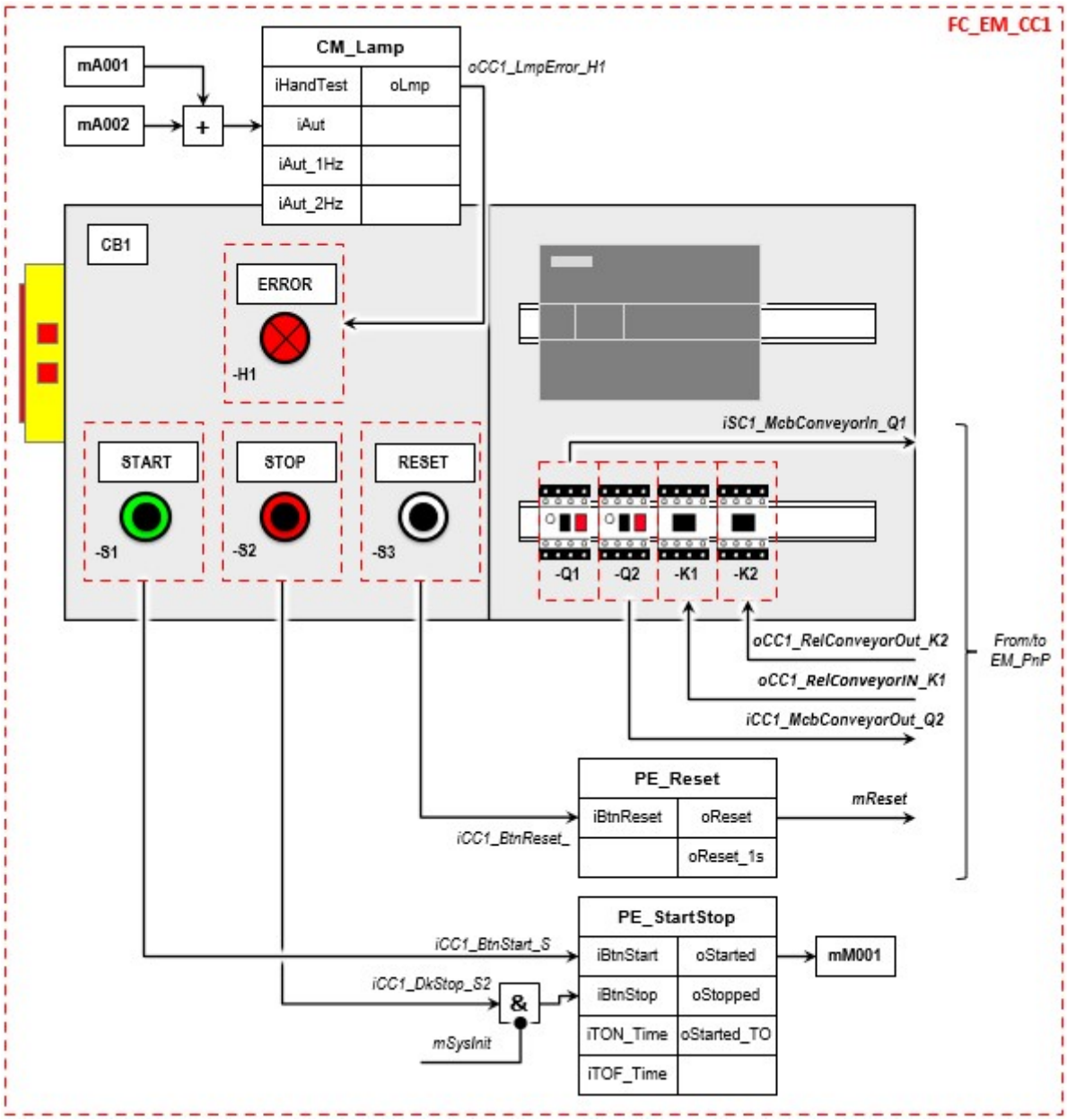
De oefening is opgebouwd rond de FactoryIO scene Pick And Place.



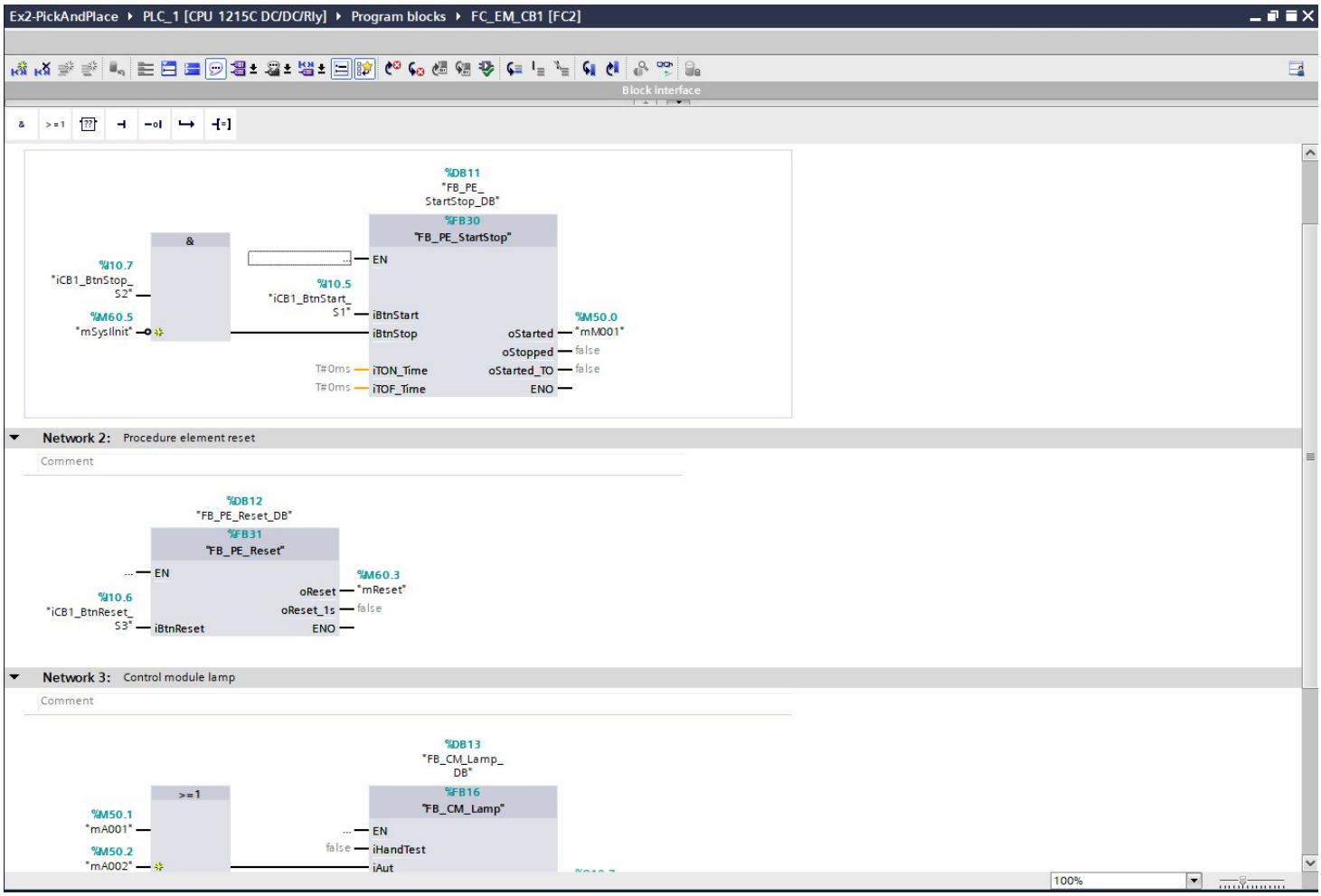
De robot arm zal dozen van de input transportband naar de output transportband verplaatsen. Hiervoor is een S88 software model gemaakt in het Nederlands, dit is vertaald naar het Engels in Ms Excel. Het is een beetje aangepast voor een veiligere werking van de ventielen. De originele werking zou als je op stop duwt de robot arm naar zijn rust positie gaan en de dozen weggooien. Door de ventielen altijd te bekrachtigen zal de robot arm tot stilstand komen op die momentele positie.



De bedoeling zal zijn dat de student deze S88 zal programmeren. Alvorens ze dit kunnen doen zullen ze een archived programma moeten retrieven. Deze heb ik zelf gemaakt en bevat het S88 gedeelte met de drukknoppen, motor beveiligingen en contactors:



Deze heb ik geprogrammeerd in TIA Portal:



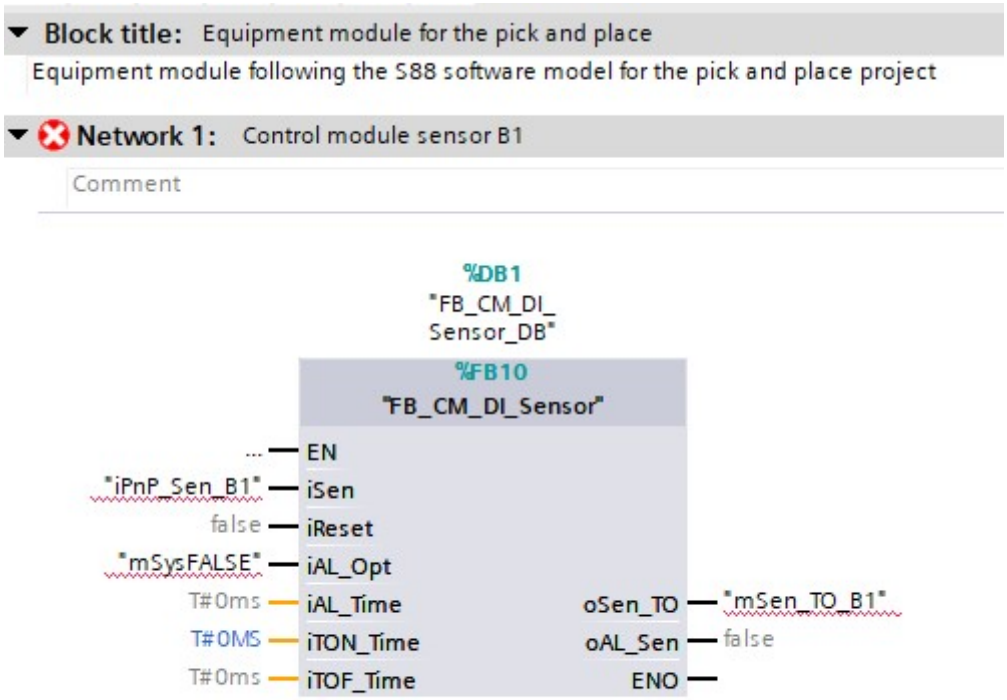
Dit hoeft de student dus niet meer programmeren, wel zijn er de instructies om het archived project te downloaden / kopiëeren naar de juiste bestandslocatie. Hierna zijn er nog instructies om het programma te openen.

De volgende stap zal zijn om de library die gemaakt is in 8-3 Addendum 06 te retrieven. Deze bevat al de nodige controle modules om de oefening correct te laten werken.

Er is een tag lijst aangemaakt in de opgaven van de oefening die ze zelf moeten overnemen.

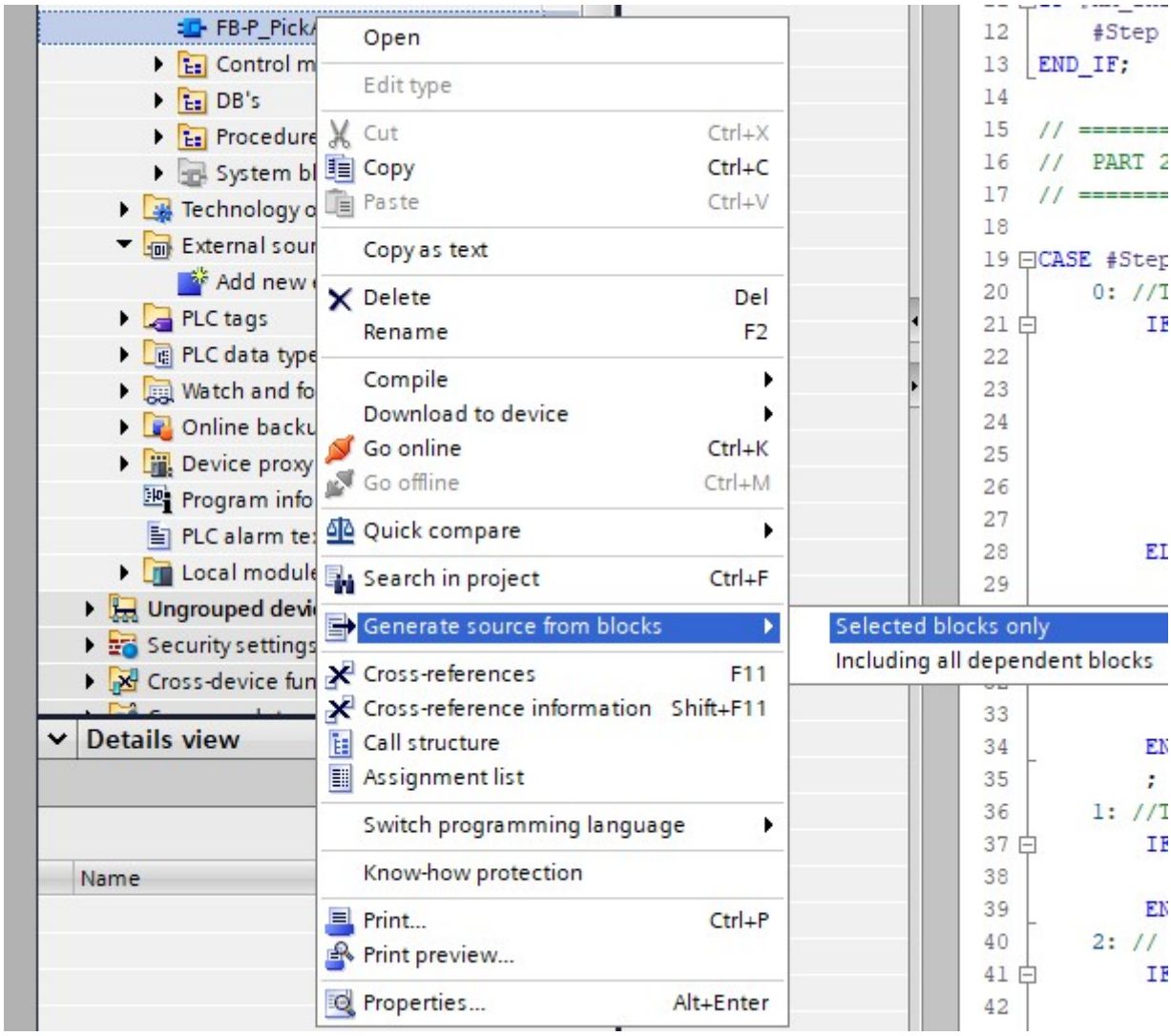
```
//Inputs
iCC1_McbConveyorIn_Q1 - BOOL - %I 0.0 - Motor circuit breaker for conveyor belt entry
iCC1_McbConveyorOut_Q2 - BOOL - %I0.1   - Motor circuit breaker for conveyor belt exit
iPnP_Sen_B1 -   BOOL - %I10.0 - Sensor item at entry
iPnP_Sen_B2 - BOOL - %I10.1 - Sensor item at exit
Moving X - BOOL - %I10.2 - Robot is moving in the X axis
Moving Z - BOOL - %I10.3 - is moving in the Z axis
Vacuum - BOOL - %I10.4 - The vacuum of the robot is active
iCC1_BtnStart_S1 - BOOL - %I10.5 - Start button
iCC1_BtnReset_S3 - BOOL - %I10.6 - Reset button
iCC1_BtnStop_S2 - BOOL - %I10.7 - Stop button
iCC1_BtnEms_S4  - BOOL - %I11.0 - Emergency stop button


//Outputs
iCC1_McbConveryorIn_K1 - BOOL - %Q10.0 - Contactor conveyor belt entry
iCC1_McbConveyorOut_K2 - BOOL - %Q10.1 - Contactor conveyor belt exit
Move X - BOOL - %Q10.2 - Moves the robot in the X axis
Move Z -  BOOL - %Q10.3 - Moves the robot in the Z axis
Grab - BOOL - %Q10.4 - Grabs an item
oCB1_LmpError_H1 - BOOL - %Q10.7 - Error lamp


//Flags
mM001 - BOOL - %M50.0 - System started
mA001 - BOOL - %M50.1 - Motor circuit breaker conveyot belt entry alarm
mA002 - BOOL - %M50.2 - Motor circuit breaker coneyor belt exit alarm

mZ - BOOL - %M60.1 - Flag move Z-axis of the robot
mGrab - BOOL - %M60.2 - Flag grab item
mReset - BOOL - %M60.3 - Flag reset
mSysFALSE - BOOL - %M60.4 - Flag FALSE
mStopIn - BOOL - %M60.6 - Flag stop conveyor belt entry
mStopOut - BOOL - %M60.7 - Flag stop conveyor belt exit
mSen_TO_B1 - BOOL - %M61.0 - Flag sensor B1
mSen_TO_B2 - BOOL - %M61.1 - Flag sensor B2
mSysIlnit       - BOOL - %M60.5 - Flag initilization
```

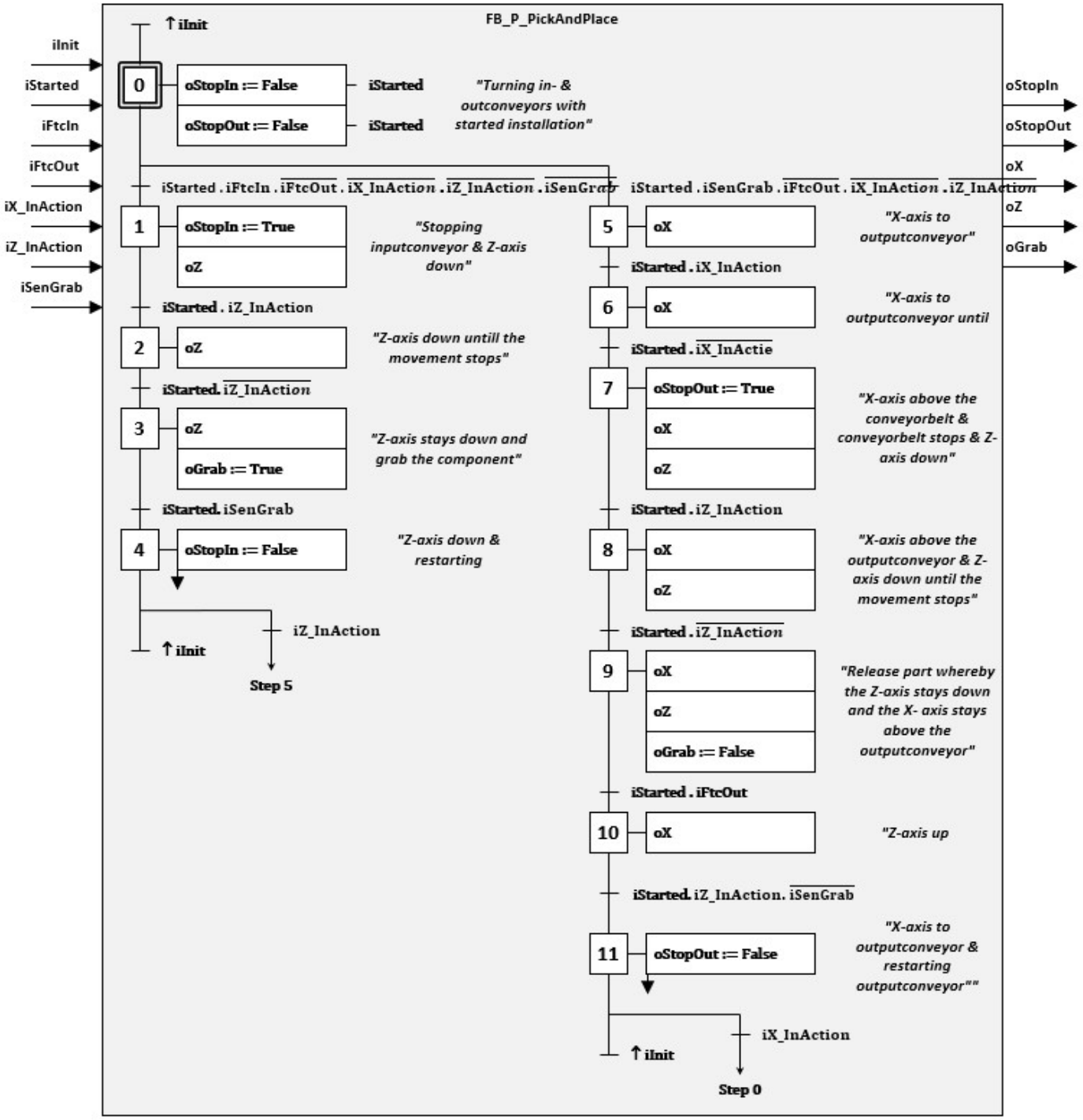
Om de student wat te helpen is er nog 1 controle module over namelijk:



Verder zullen ze de S88 zelf moeten programmeren aan de hand van de gegeven S88 software model.

Om hun software te testen moeten ze de GRAFCET importeren via een external source file. Deze is meegeleverd in de oefening en noemt "FB-P_PickAndPlace.scl" als ze dit correct importeren via "External source files", hebben ze een werkende GRAFCET en kunnen ze de oefening testen. Het bestand "FB-P_PickAndPlace.scl" heb ik gegenereerd uit een zelf geschreven scl block. Die de volgende GRAFCET volgt:


FB-P_Pick/
Control m
DB's
Procedure
System bl
Technology o
External sour
Add new
PLC tags
PLC data type
Watch and fo
Online backu
Device proxy
Program info
PLC alarm te
Local module
Ungrouped devi
Security settings
Cross-device fun
Details view
Name
Open
Edit type
Cut Ctrl+X
Copy Ctrl+C
Paste Ctrl+V
Copy as text
Delete Del
Rename F2
Compile
Download to device
Go online Ctrl+K
Go offline Ctrl+M
Quick compare
Search in project Ctrl+F
Generate source from blocks
Cross-references F11
Cross-reference information Shift+F11
Call structure
Assignment list
Switch programming language
Know-how protection
Print... Ctrl+P
Print preview...
Properties... Alt+Enter
Selected blocks only
Including all dependent blocks
#Step
END_IF;
// =======
// PART 2
// =======
CASE #Step
0: //T
IF
EI
EN
;
1: //T
IF
EN
2: //
IF



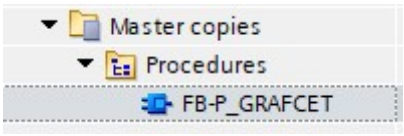
De GRAFCET is vertaald in Ms Excel. Origineel was dit een Nederlandse versie gemaakt door Mr. Van Grieken.

Heel deze oefening is gearchived voor de lectoren om de verwarchte werking mee te controleren.

8-7 Exercise 3

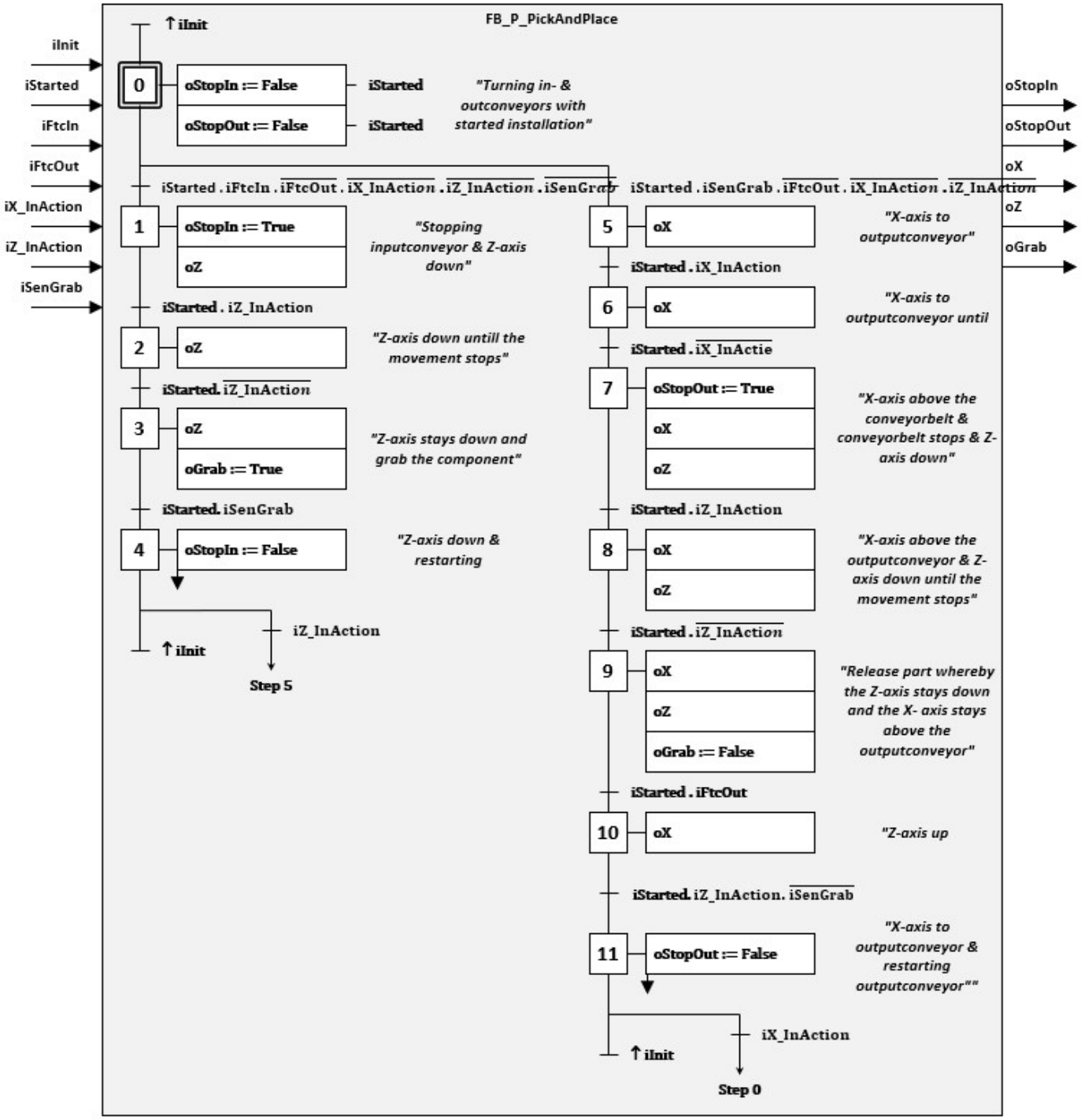
Bijlagen

Bij deze oefening zal het de bedoeling zijn om een GRAFCET en een Flowchart correct te programmeren. De vorige oefening zal op worden verder gebouwd. Nu zullen ze zelfs de GRAFCET moeten programmeren aan de hand van het GRAFCET voorbeeld. Dit zal gebeuren in de FBD programmeer taal. Om de student een start te geven heb ik een extra library gemaakt dat een GRAFCET voorbeeld bevat.



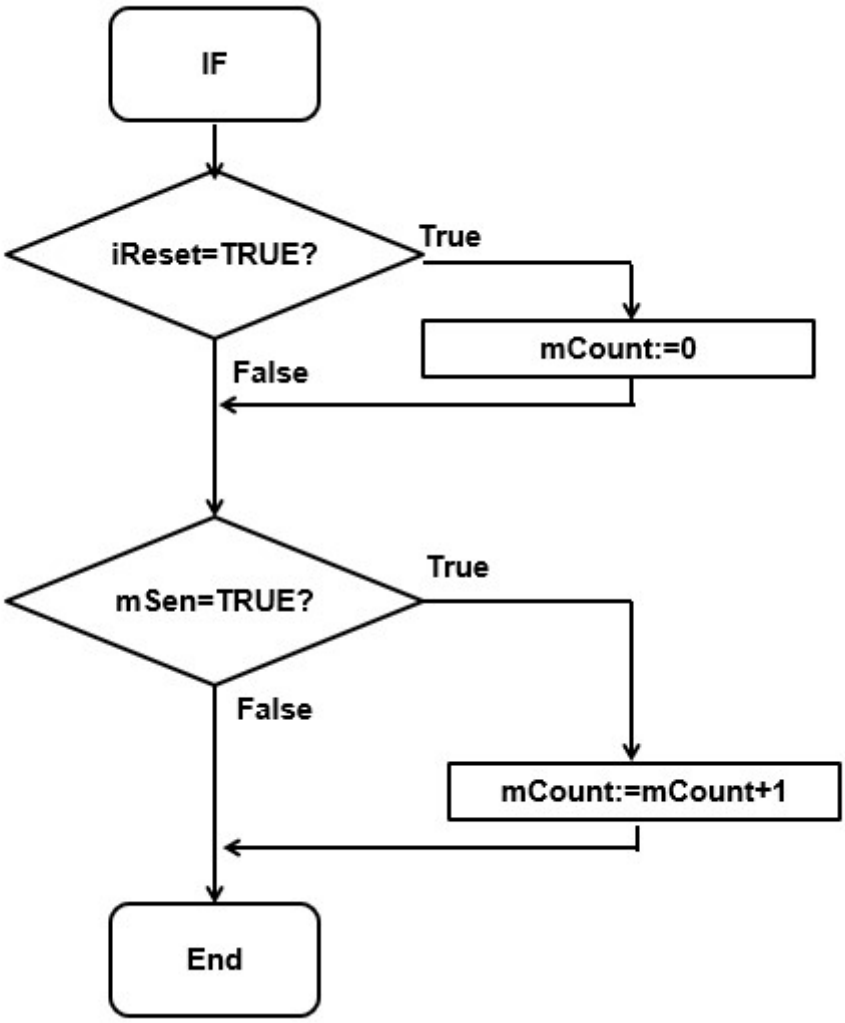
Het ziet er als volgt uit:

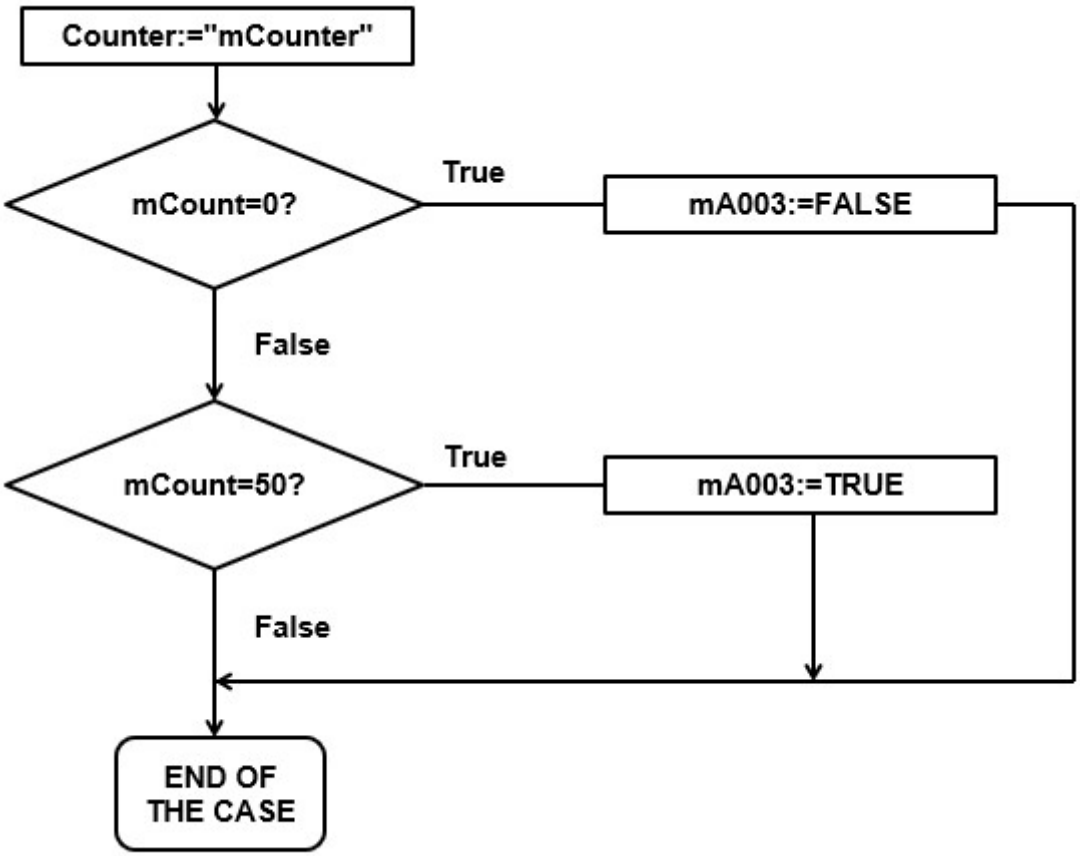
Deze blok zal de voorgeprogrammeerde block "FB_P_PickAndPlace" vervangen. Deze had ik ze gegeven voor de vorige oefening te testen. Nu moeten ze die blok verwijderen omdan zelf de GRAFCET te programmeren. De GRAFCET ziet er ook weer uit zoals in oefening 2:



Als dit dan werkt zoals beschreven kunnen ze een Flowchart programmeren. Deze flowchart is een simpele controle van de hoeveelheid boxen dat verwerkt zijn. Als dit boven 50 geraakt zal er een lamp branden om aan te duiden dat de machine een inspectie nodig heeft. De machine zal niet stoppen maar de operator zal wel de reset knop moeten induwen om dit alarm weg te krijgen.

De Flowchart wordt in SCL geprogrammeerd en ziet er als volgt uit :





Omdat de counter maar 1 keer mag optellen zal de output sensor worden voorzien met een flank detectie (die de student zelf moet programmeren). De actuele verwerkte dozen zullen ook op een numeriek display in FactoryIO komen te staan.
De programmatie :

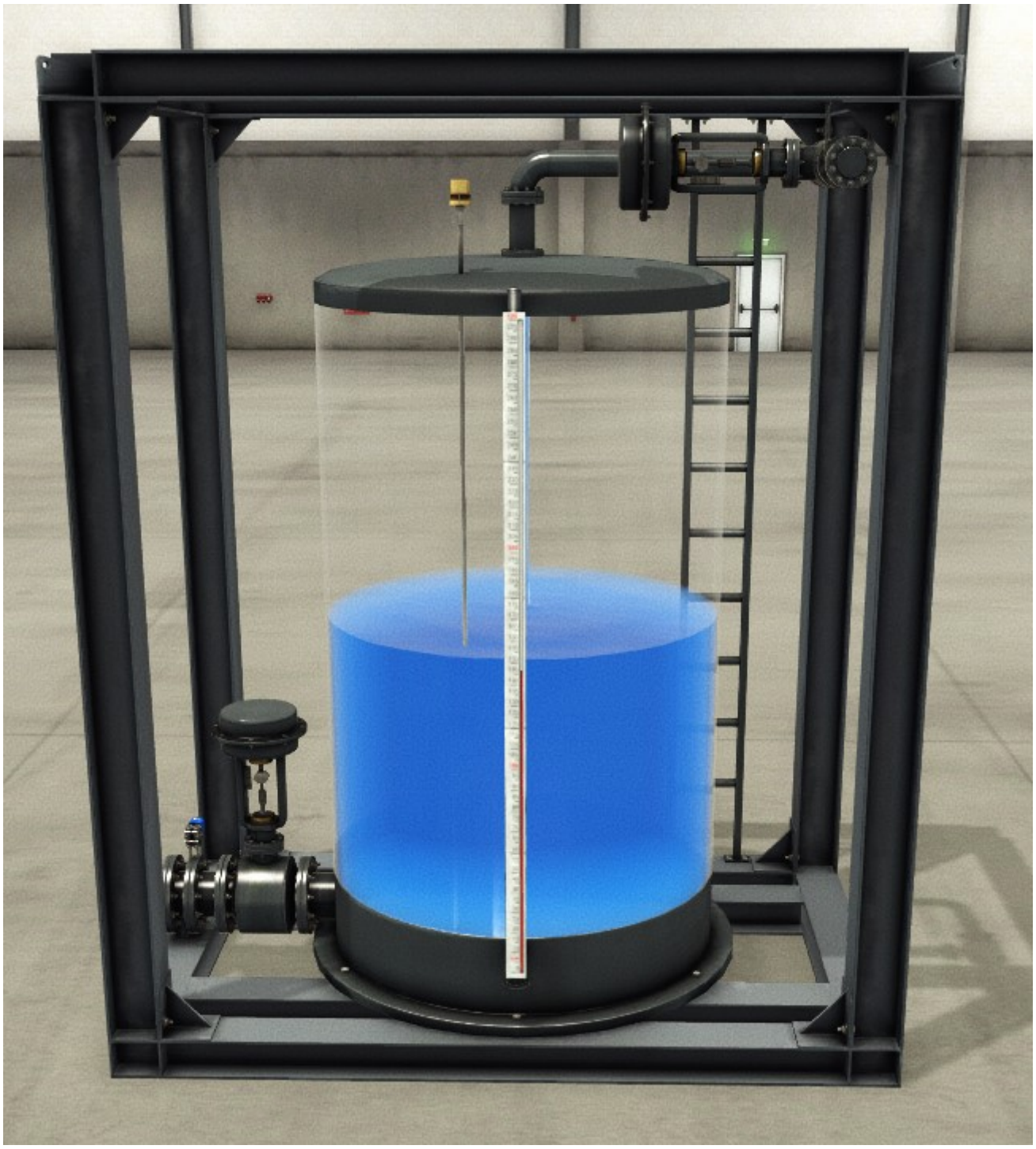
```
// Rising edge detecting for the sensor on the output conveyorbelt
"R_TRIG_DB"(CLK:="mSen_TO_B2",
            Q=>#mSen);

// Reset the counter variable if system gets resetted
IF "mReset" = TRUE THEN
    "mCounter" := 0;
END_IF;

// If the sensor detects an item, mCounter +1
IF #mSen = TRUE THEN
    "mCounter" := "mCounter" + 1;
END_IF;
// Moving the counter data to an output
"Counter" := "mCounter";

CASE "mCounter" OF
    0: // Reset alarm
        "mA003" := FALSE;
    50:// Set alarm for maintenance
        "mA003" := TRUE;
END_CASE;
```

Nu kan het programma gecompileerd en getest worden.
Heel deze oefening is gearchived voor de lectoren om de verwarchte werking mee te controleren.

8-8 Exercise 4

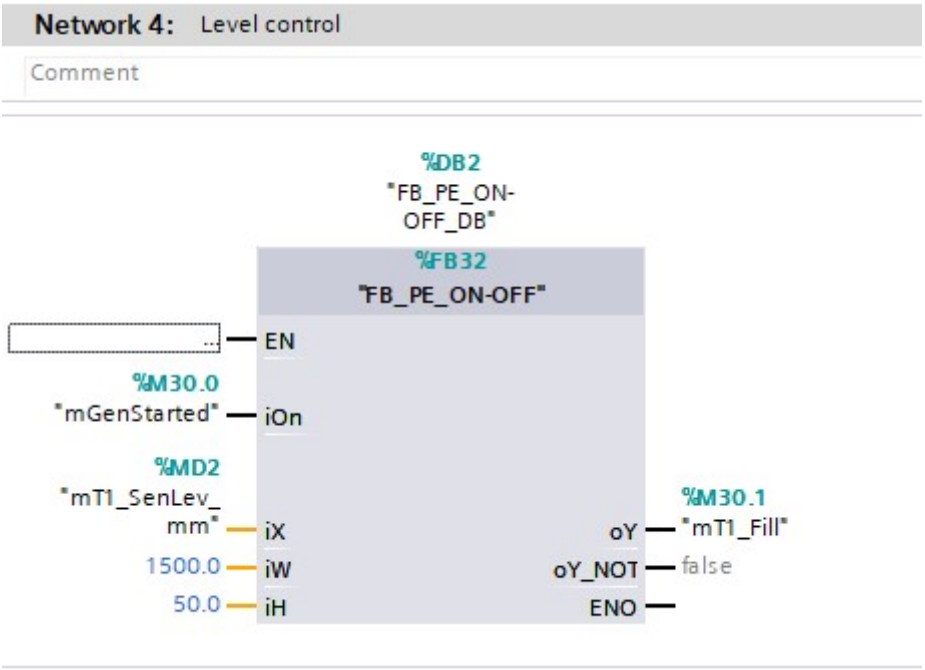
Bijlagen

Bij deze oefening gaan we een tank met een on-off(twph) controller en PID controller regelen. Via FactoryIO simuleren we de tank en niveau meting. Deze scene is door Mr. Van Grieken opgesteld in oefening 7 van de basis cursus. Er is ook een archived programma dat in oefening 7 van de basis cursus is gemaakt (de complete versie).



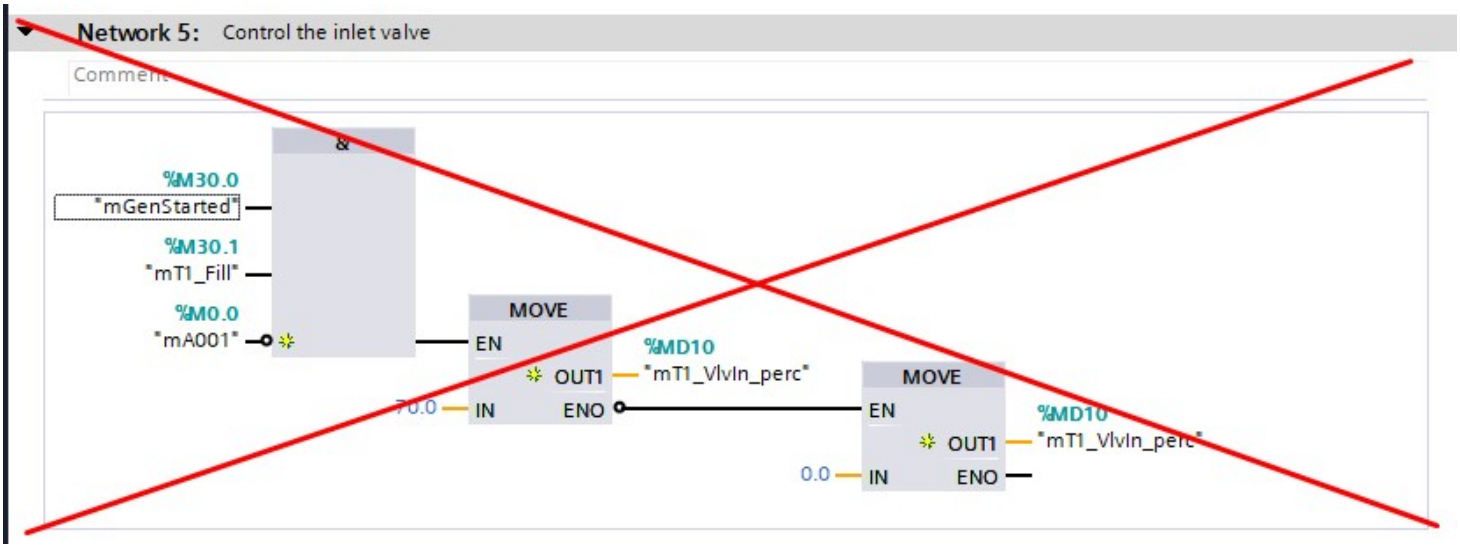
De archived programma moet de student openen om verder te kunnen. Als hij dit gedaan heeft moet hij in de fucntion "FC_T1" netwerk 4 level control verwijderen. Hierin moet de on-off controller geplaatst worden. In de library S88 TIA Portal V16 zit een voorgeprogrammeerde on-off controller. Dit moet dus in netwerk 4 geslepen worden.

Dan verbind men "mT1_SenLev_mm" met de iX ingang, "mGenStarted" wordt verbonden met de ingang "iOn", "mT1_Fill zal worden verbonden met output "oY".

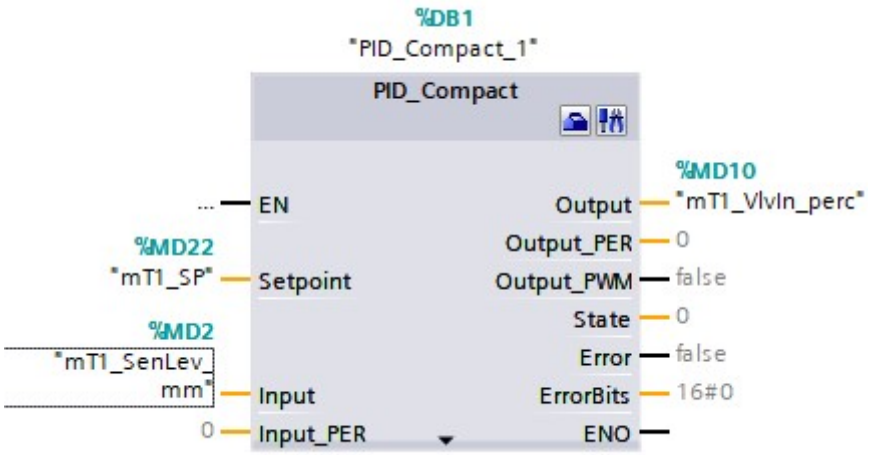


Met iW en iH kan je nu experimenteren wat het exact doet. iW is het setpoint, hiermee kan je het gewenste niveau van de tank ingeven. iH is de hysteresis, hiertussen zal de on en off controller in en uit schakelen. Kleine hysteresis betekent dat hij veel zal in en uitschakelen. Een grote hysteresis betekent dat dit trager zal gaan, hierdoor zal de tank ook leger lopen en voller lopen vanwege de output die altijd op 50% open staat.

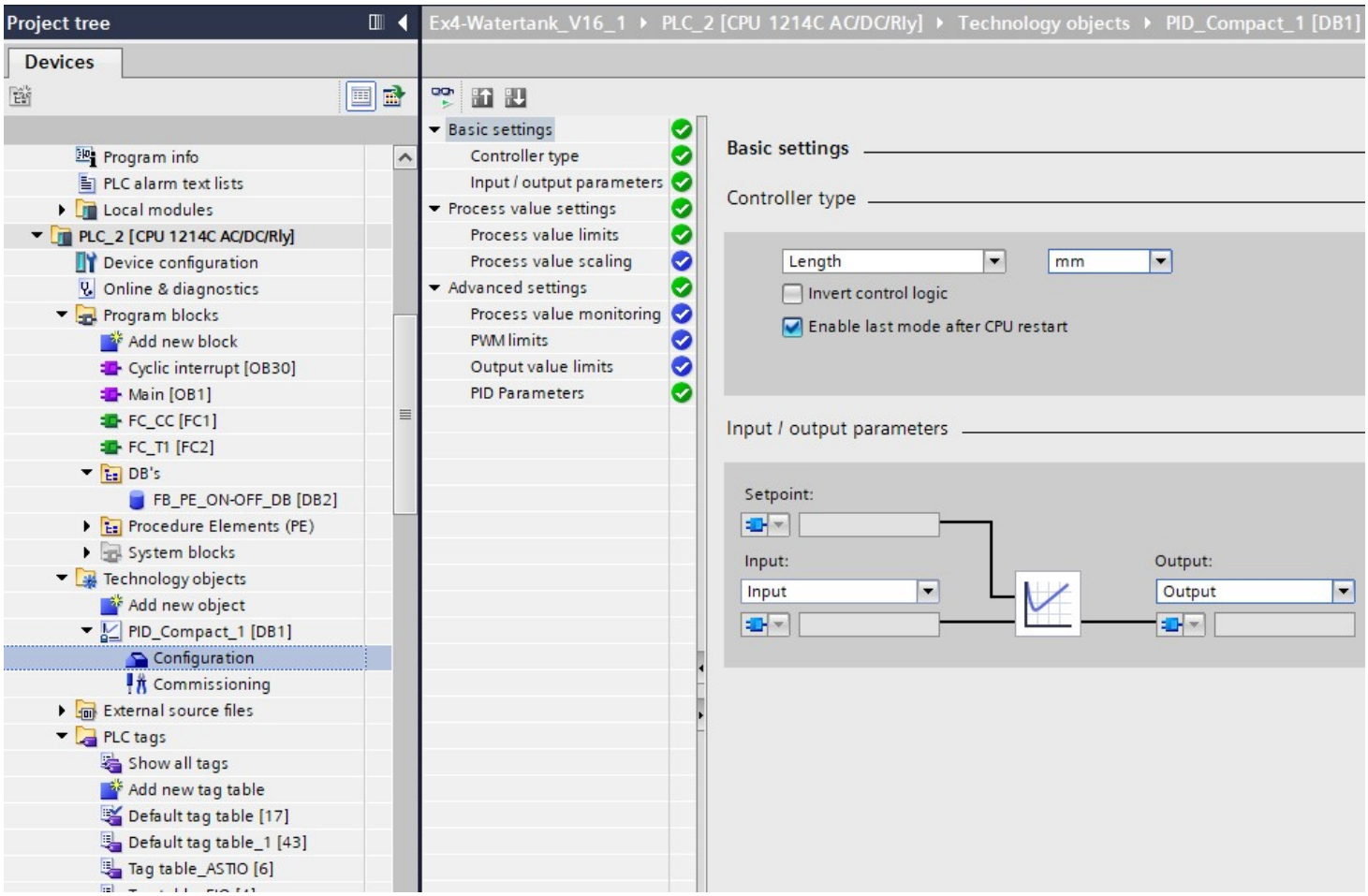
Het volgende deel van de oefening zal de on-off controller vervangen met een PID_Compact regeling. Deze bouwsteen zit standaard in TIA portal en heeft een cyclicinterrupt organization block nodig om deftig te werken. De on off controller en netwerk 5 wat de regeling van de inlaat bevat, verwijderen we uit het programma. Dit wordt vervangen met de PID_Compact uitgang die zelf tussen 0 en 100 % zal regelen.



De PID_Compact wordt dan met de volgende tags aangesloten.



PID_Compact zal ook correct geconfigureerd worden om de watertank te controleren. "PLC_1" > "Technology objects" > "PIC_Compact" > "Configuration"



Als dit correct is ingesteld kan het getest worden via een HMI. Dit is de 5de en laatste oefening in deze cursus.

8-9 Exercise 5

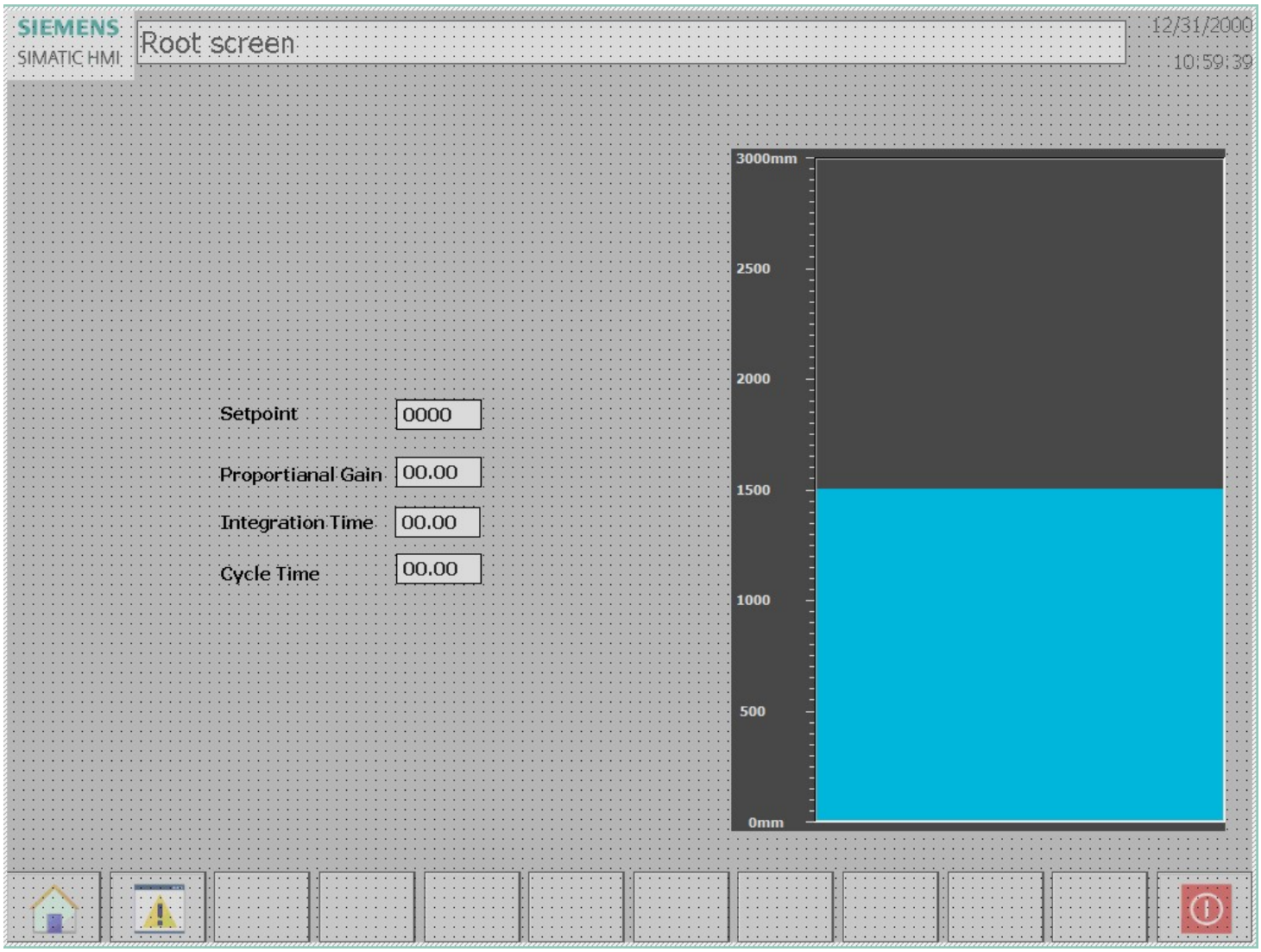
Bijlagen

In deze oefening zal er een HMI scherm moeten worden opgebouwd en gebruikt worden om oefening 4 correct te testen. Op dit HMI scherm zal de student de PID paramaters moeten zetten om deze dan via HMI aan te passen en uit te testen wat het doet.

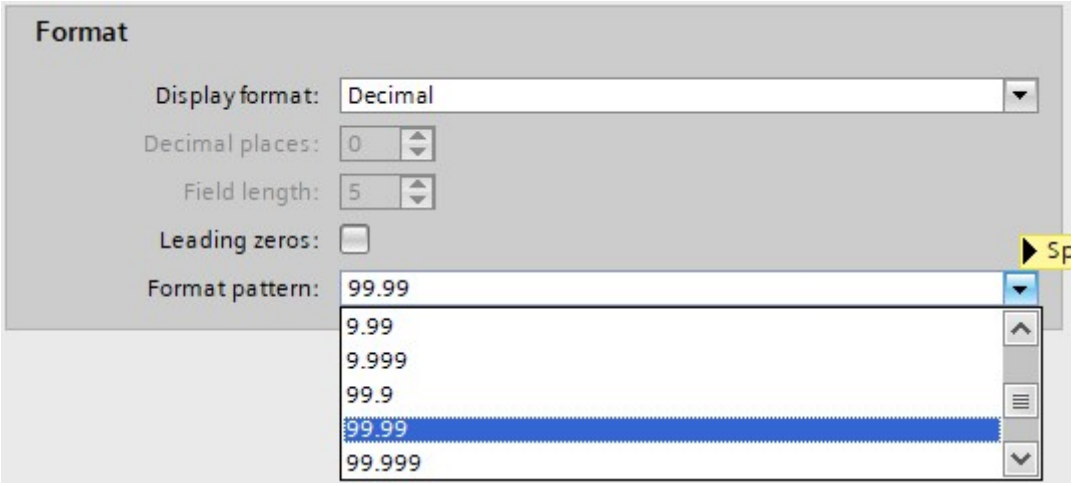
In TIA voegen we het grootste HMI paneel beschikbaar toe. We werken via de HMI simulator, voeg TP1500 Basic color PN toe. Deze wordt gelinked met PLC_1 in de HMI setup wizzard. De netwerkconfiguratie voor de HMI is:

```
IP-address                    : 192.168.0.31
IP-address subnet mask        : 255.255.255.0
```

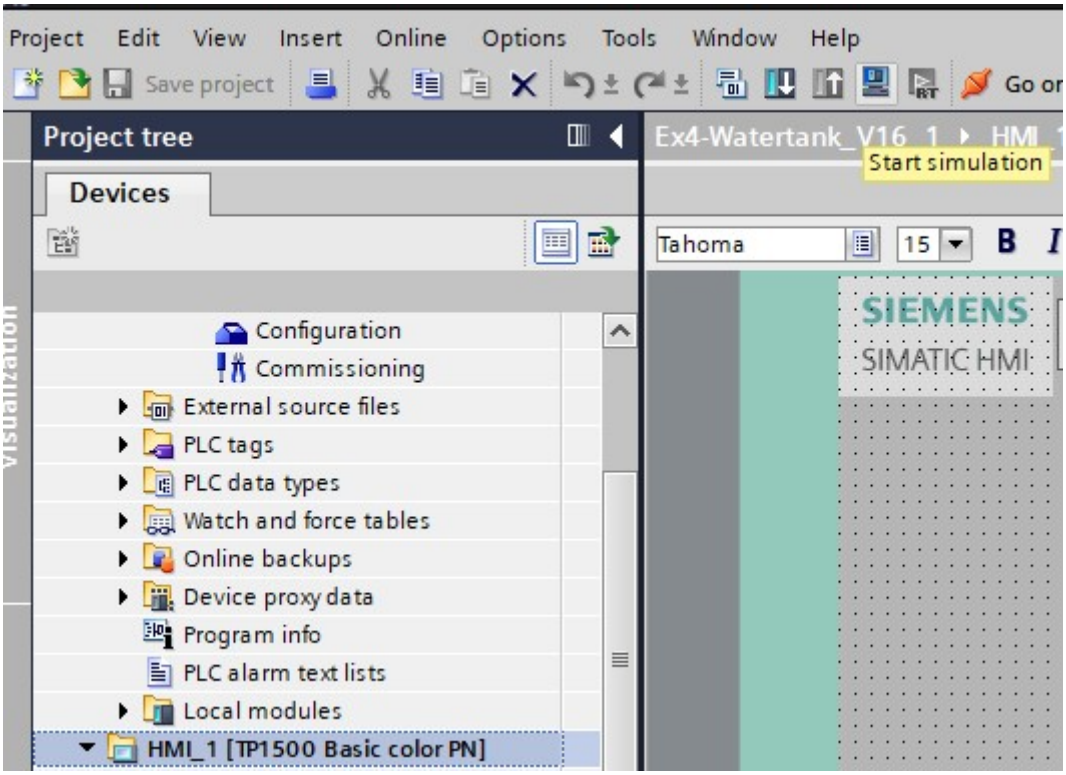
Het volgende scherm heb ik zelf opgesteld via IO-fields en een bar dat de actuele waarde zal uitlezen vanuit FactoryIO



Let op: om parameters in een IO field 00.00 waardes te laten zien pas je format pattern aan;



Via de HMI simulatie kan de student de PID correct configureren door het live te testen samen met de FactoryIO scene "Level_Control.factoryio"



Als de hmi simulatie de PLC niet vind zal je het volgende programma moeten uitvoeren

```
"C:\Program Files\Common Files\Siemens\CommunicationSettings"
```

Acces point > S7ONLINE > "Your networkcard"

Nu kunnen we via de HMI simulatie de parameters zo aanpassen dat als het setpunt wordt aangepast het niveau in de tank langzaam naar dit punt zal stijgen of dalen.

9 Bibliografie

HMI Tutorial
FactoryIO minimum requirements
TIA Portal minimum requirements

10 Bijlagen

10-1 Cursus

HMI programming in Siemens TIA Portal V16

Introduction

Due to production processes are becoming more and more complex and requirements for machine and plant functionality are increasing, operators need a powerful tool for controlling and monitoring production plants. An HMI system (human-machine interface) represents the interface between man (operator) and process (machine/plant). It is the controller that actually controls the process. Hence, there is an interface between the operator and WinCC (at the HMI device) and an interface between WinCC and the controller.

Device description

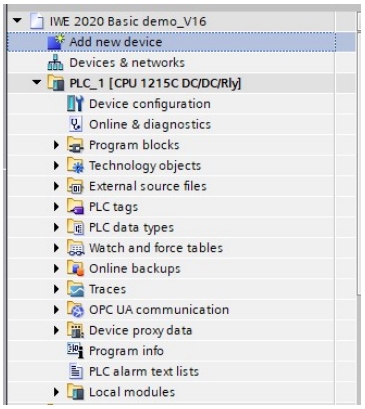
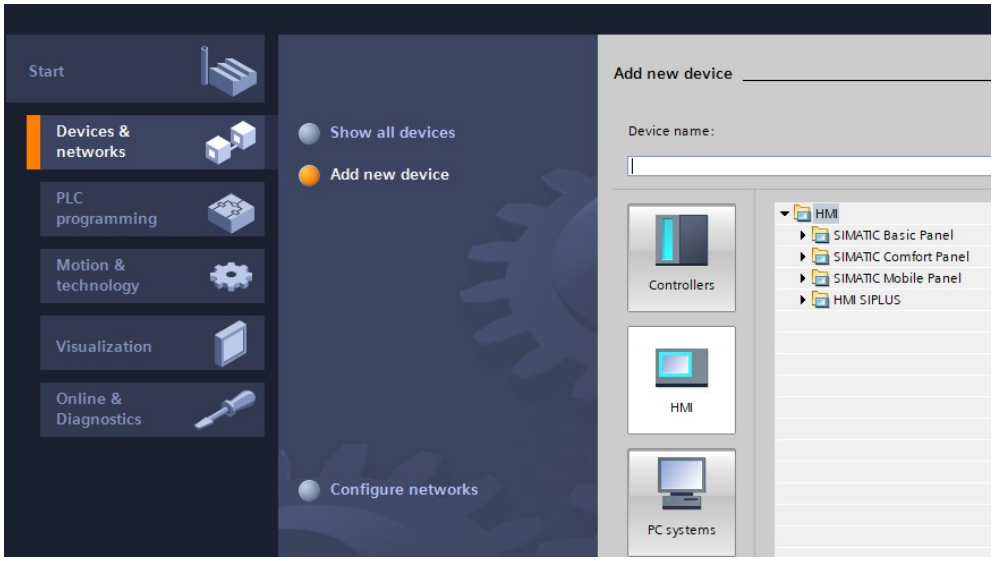
The SIMATIC HMI Basic Panels product line features key and touch panels (operator input via keyboard and touch screen)
SIMATIC HMI Basic Panels cover all requirements described in the previous section.

Hardware configuration

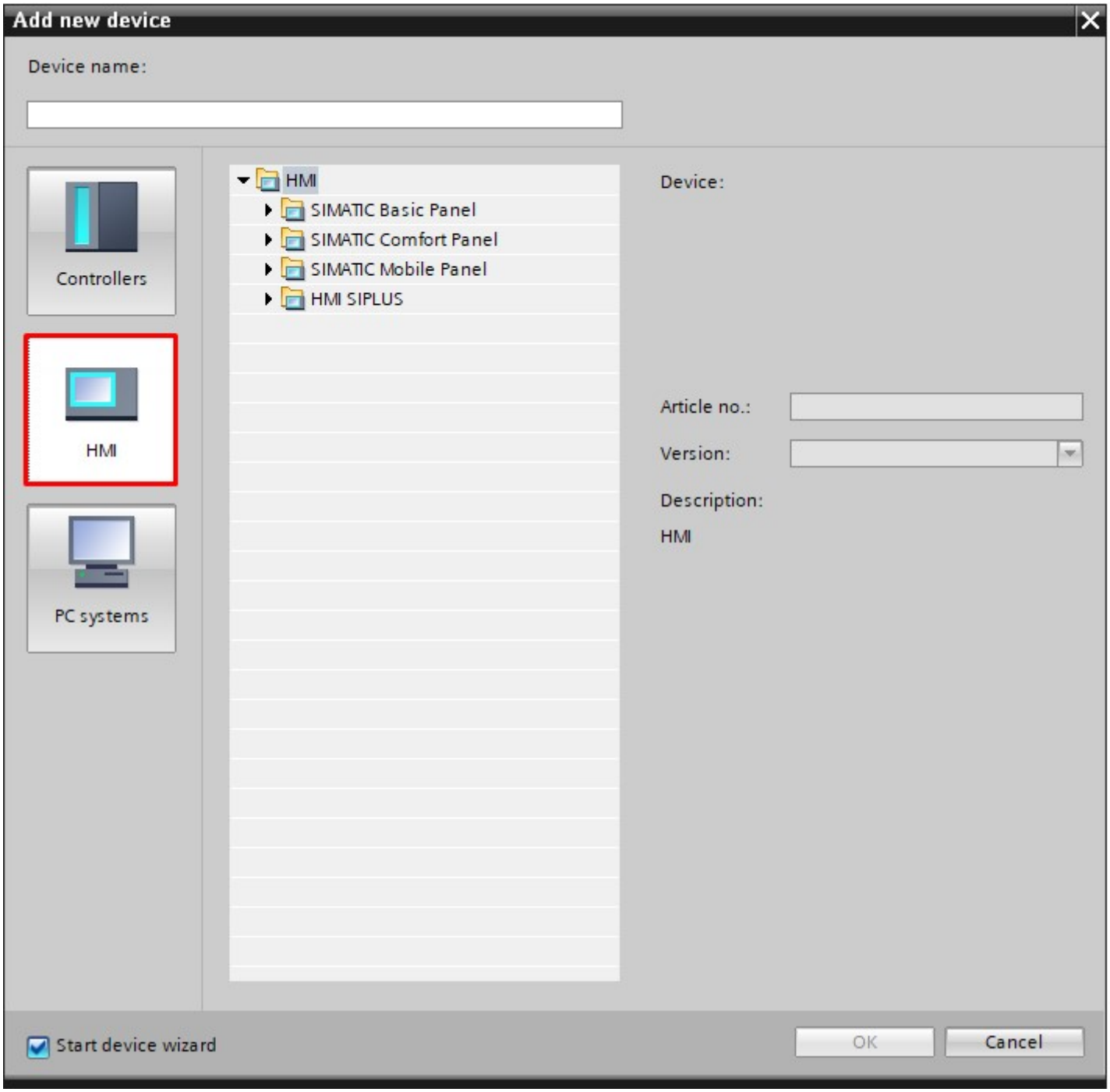
For a HMI to be correctly used in TIA Portal V16, one will need to make the right hardware configuration. For this to be correct you will need a correct CPU configuration mentioned in M2C3-

ADD03.

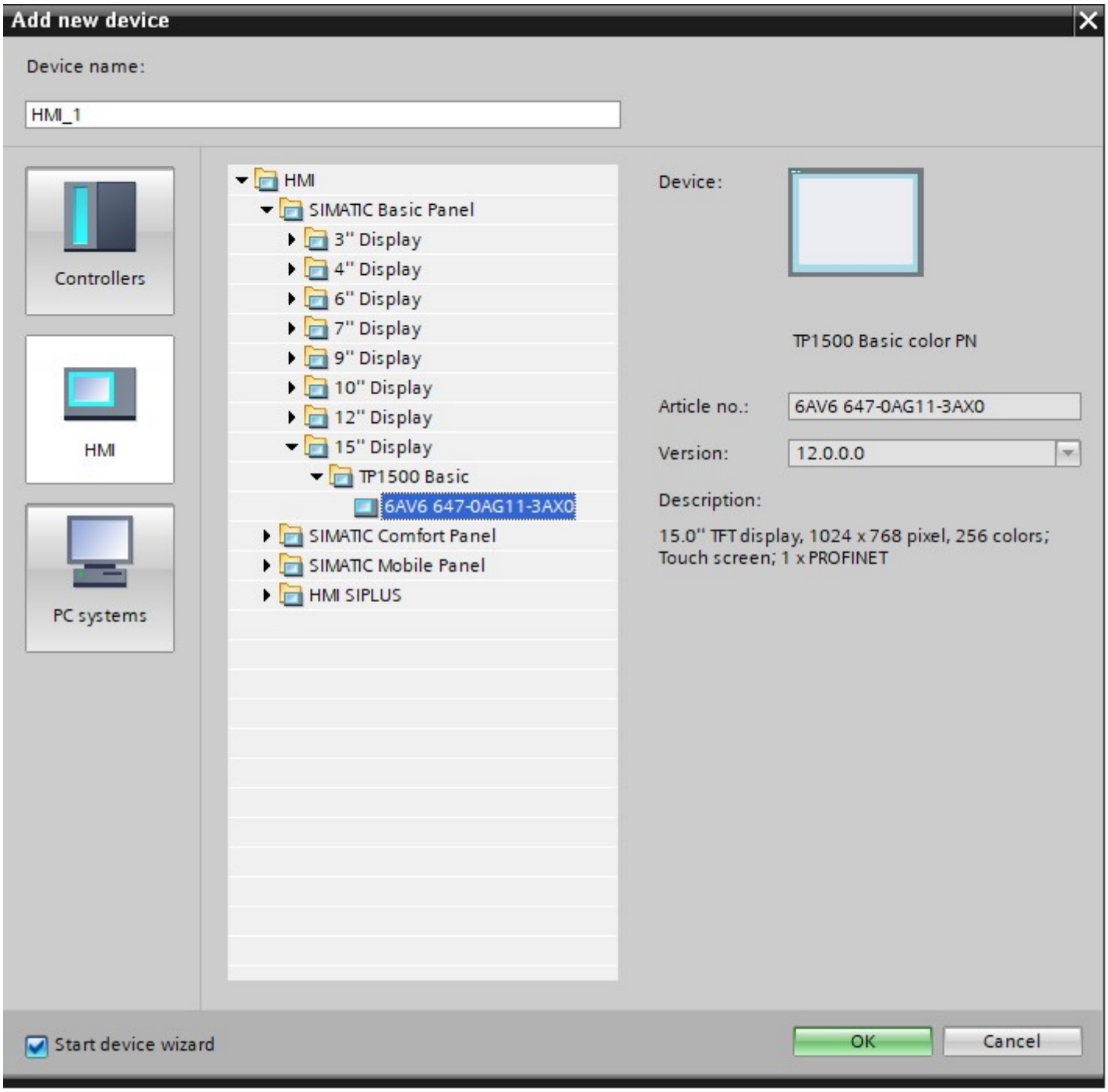
To add a HMI to a current project you will have to add a new device. This can be done through the 2 views within TIA portal.

Project View	Portal View
"New Device"	"Devices & network > Add new device"
	

The menu that pops up has 3 main options to select between Controllers / HMI / PC systems. For our example we'll be needing the HMI tab:



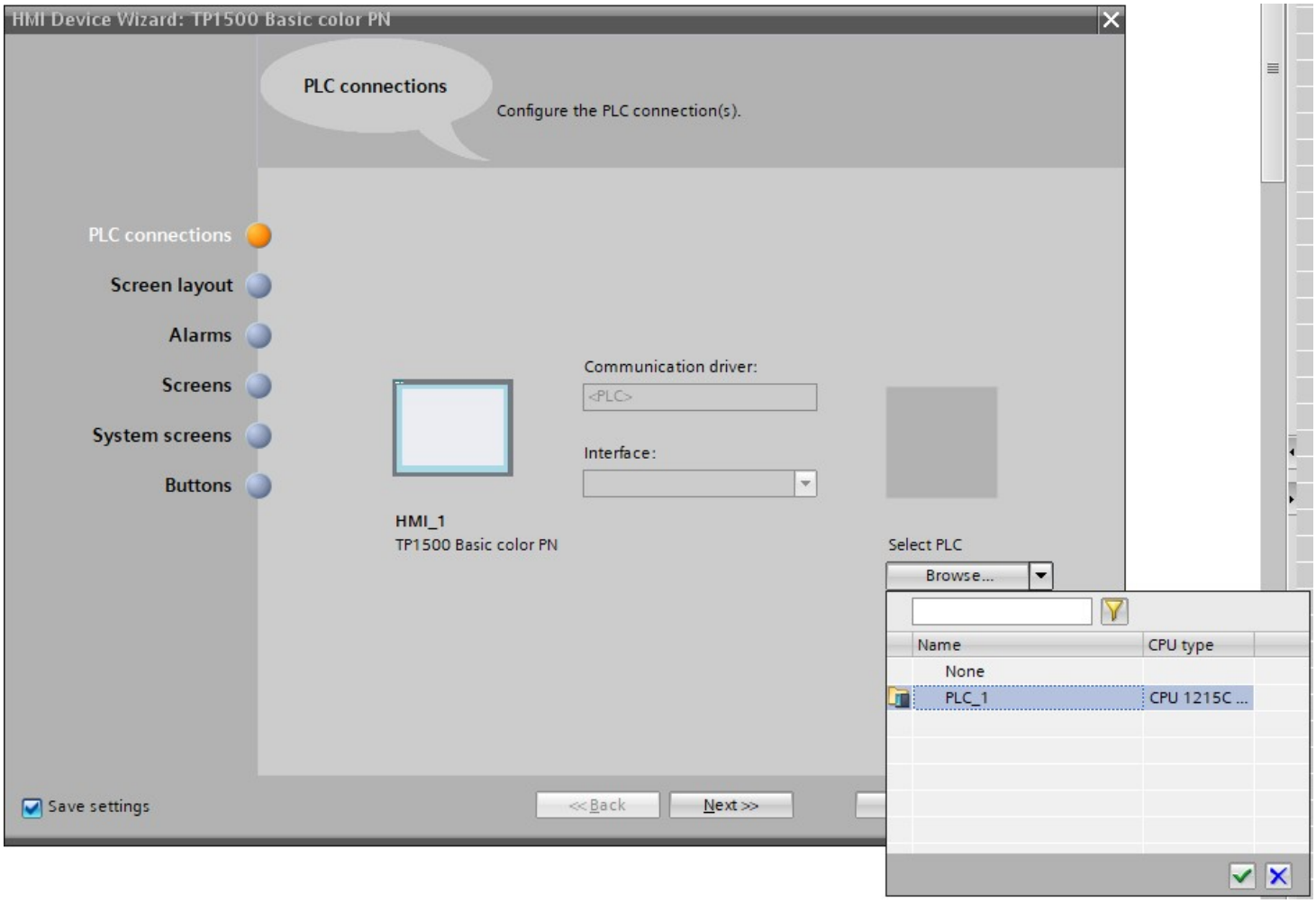
After which you select the desired HMI. HMI > SIMATIC Basic Panel (we'll be using the simulator of TIA Portal, for this example i took the KTP1500 Basic):



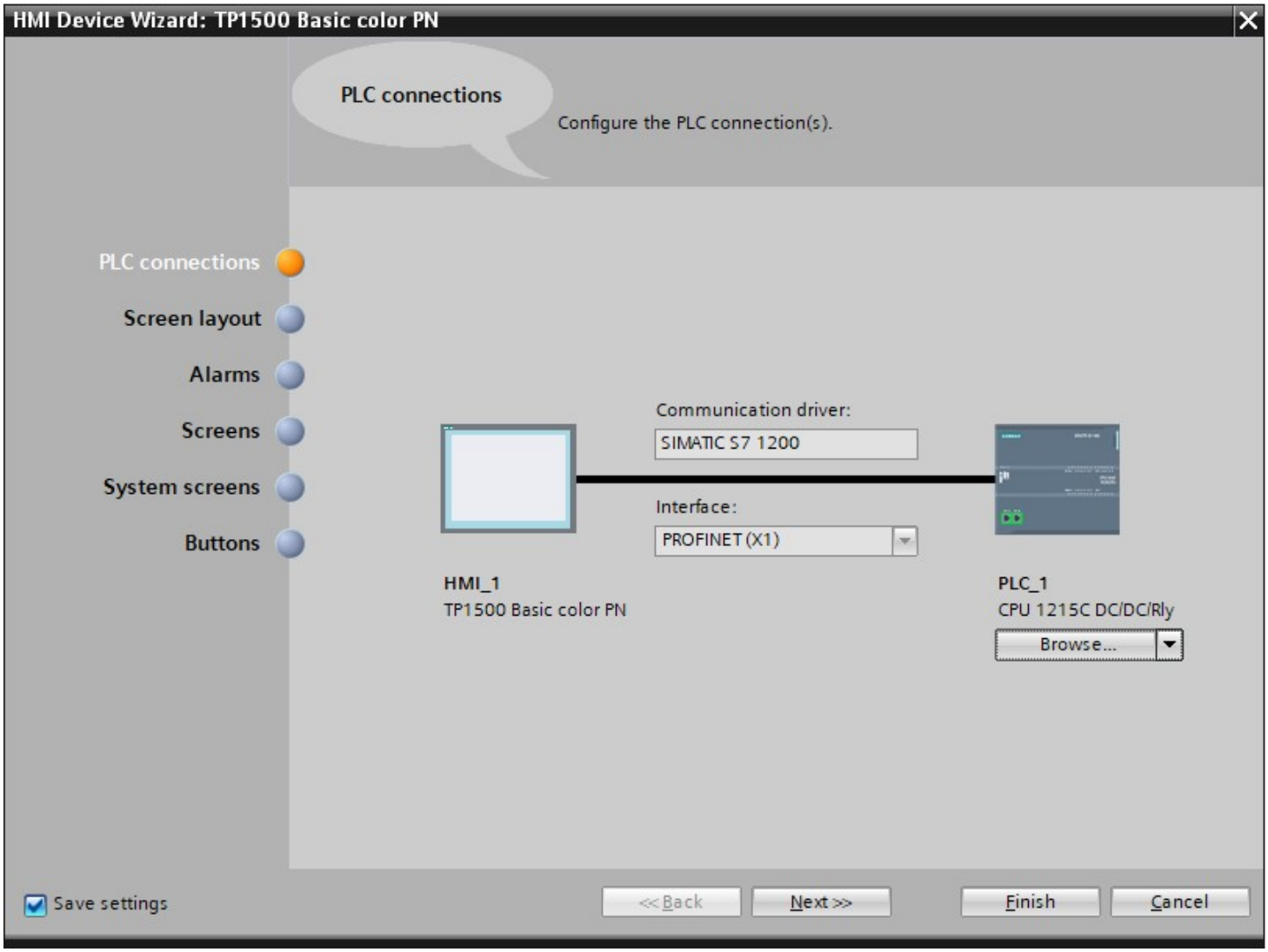
HMI wizard

When you selected the correct/desired HMI you get the following screen presented:

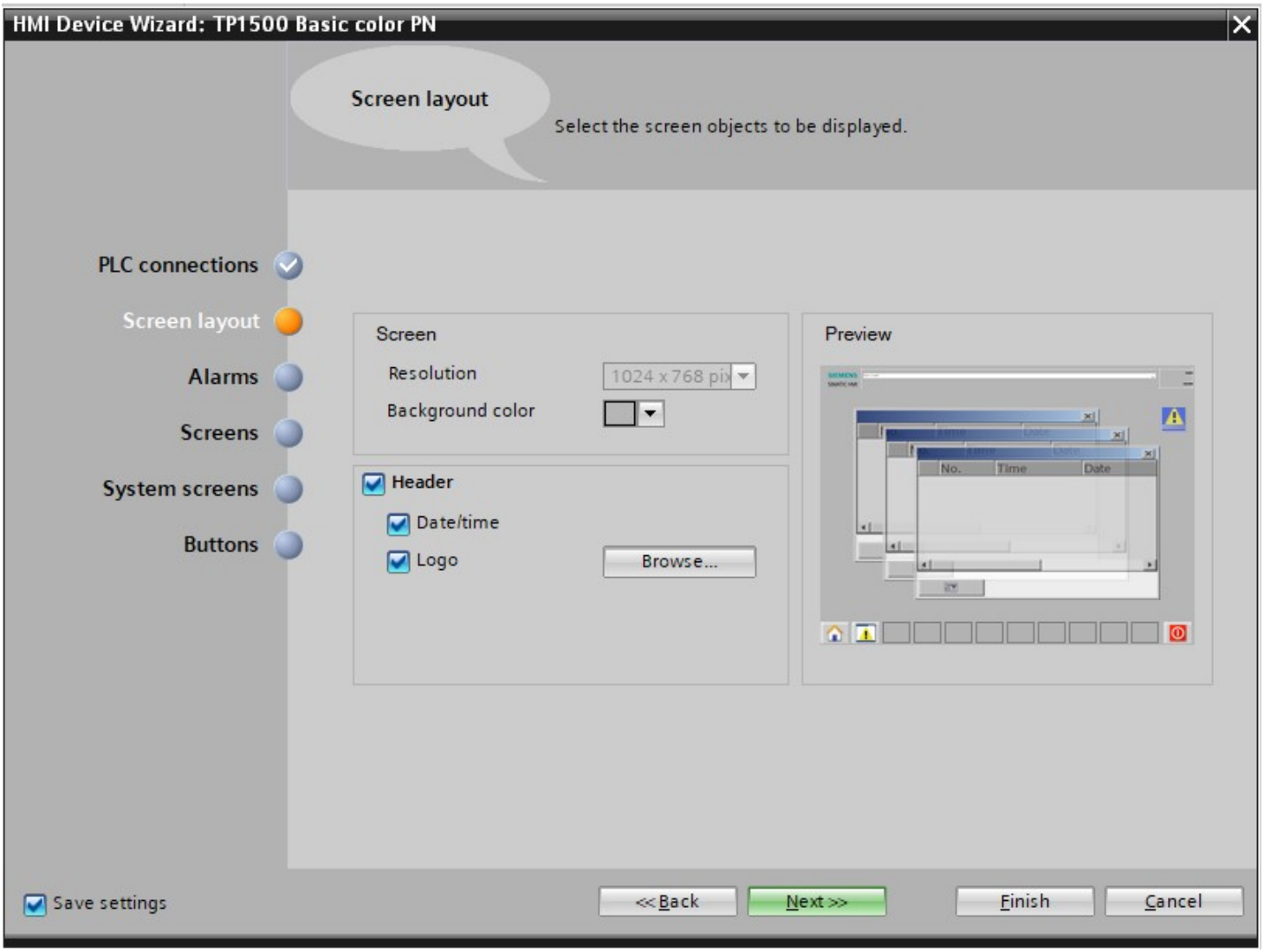
Here you need to link the HMI to the correct PLC, this is done by selecting the right PLC under Select PLC -> PLC_1



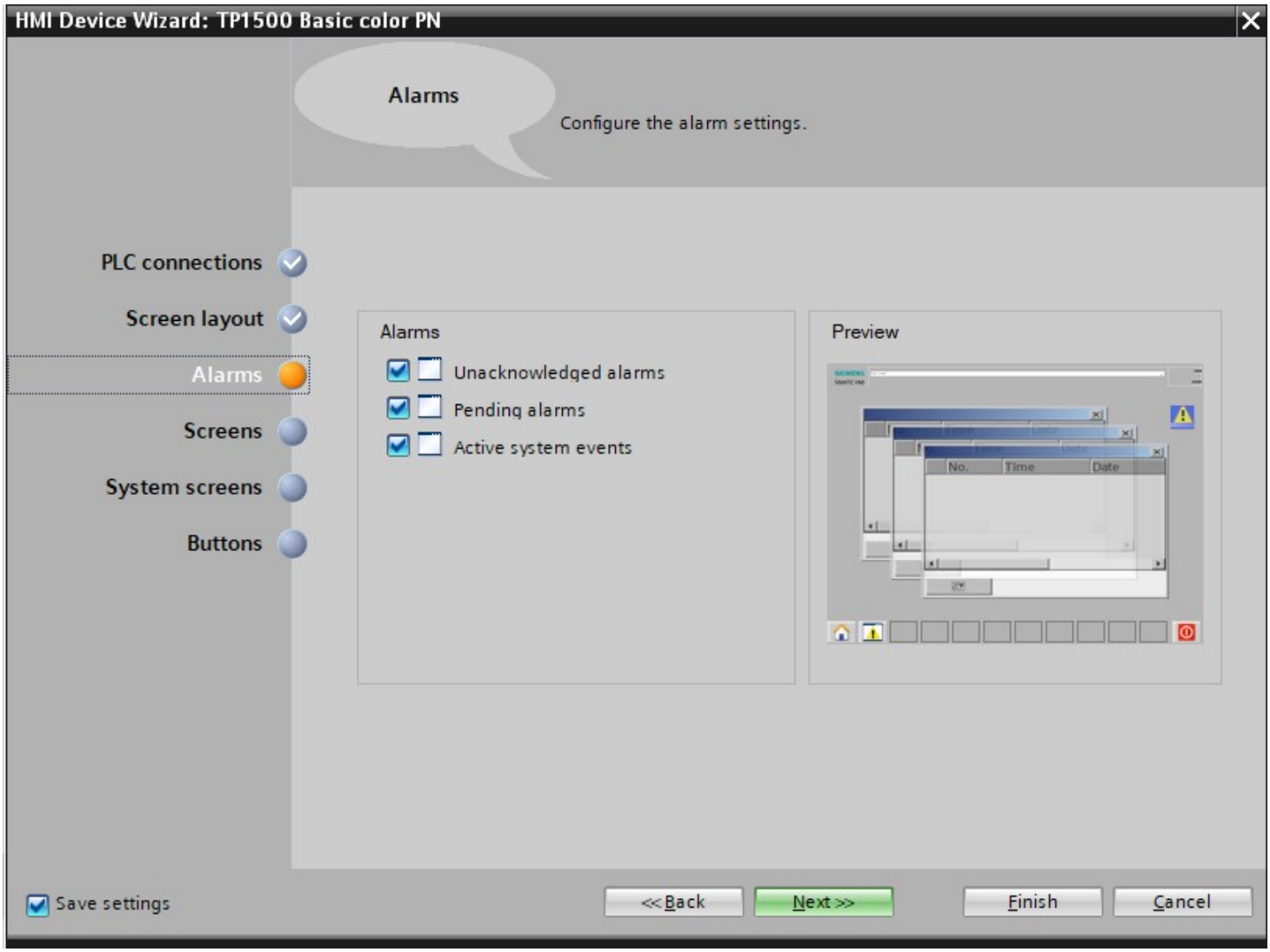
If the correct PLC is selected it should automatically link the HMI to the PLC through ProfiNET. Now proceed to the next screen by pressing "Next".



You can change the default background color of your panel under "Screen layout".
Select the "Header", "Date/time" and "Logo" check boxes. Confirm your selection by clicking on "Next ".



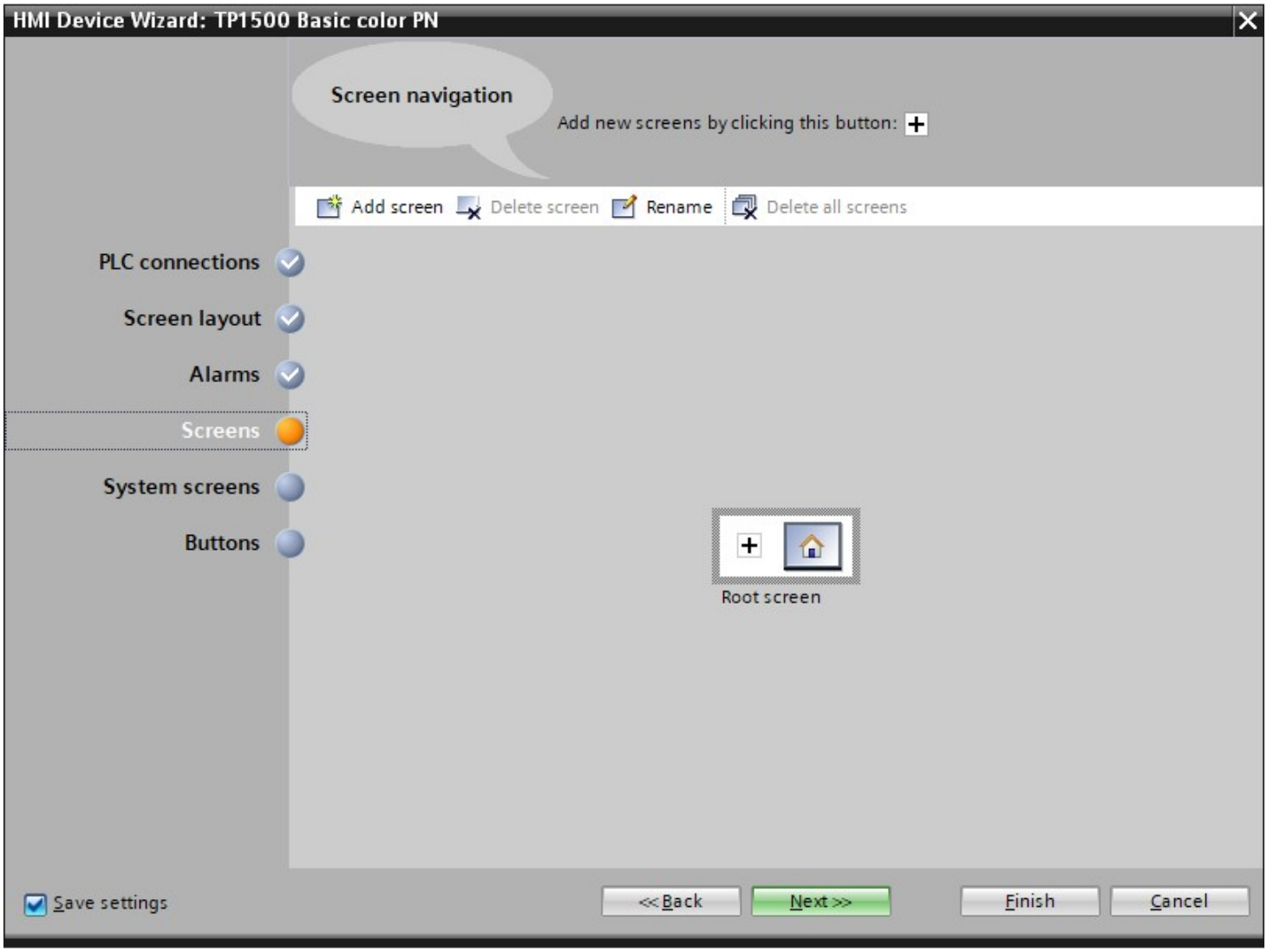
In the "Alarms" section, you can specify which of the alarms are to be displayed in a window. Select all three alarm types. Confirm your selection by clicking on
"Next".



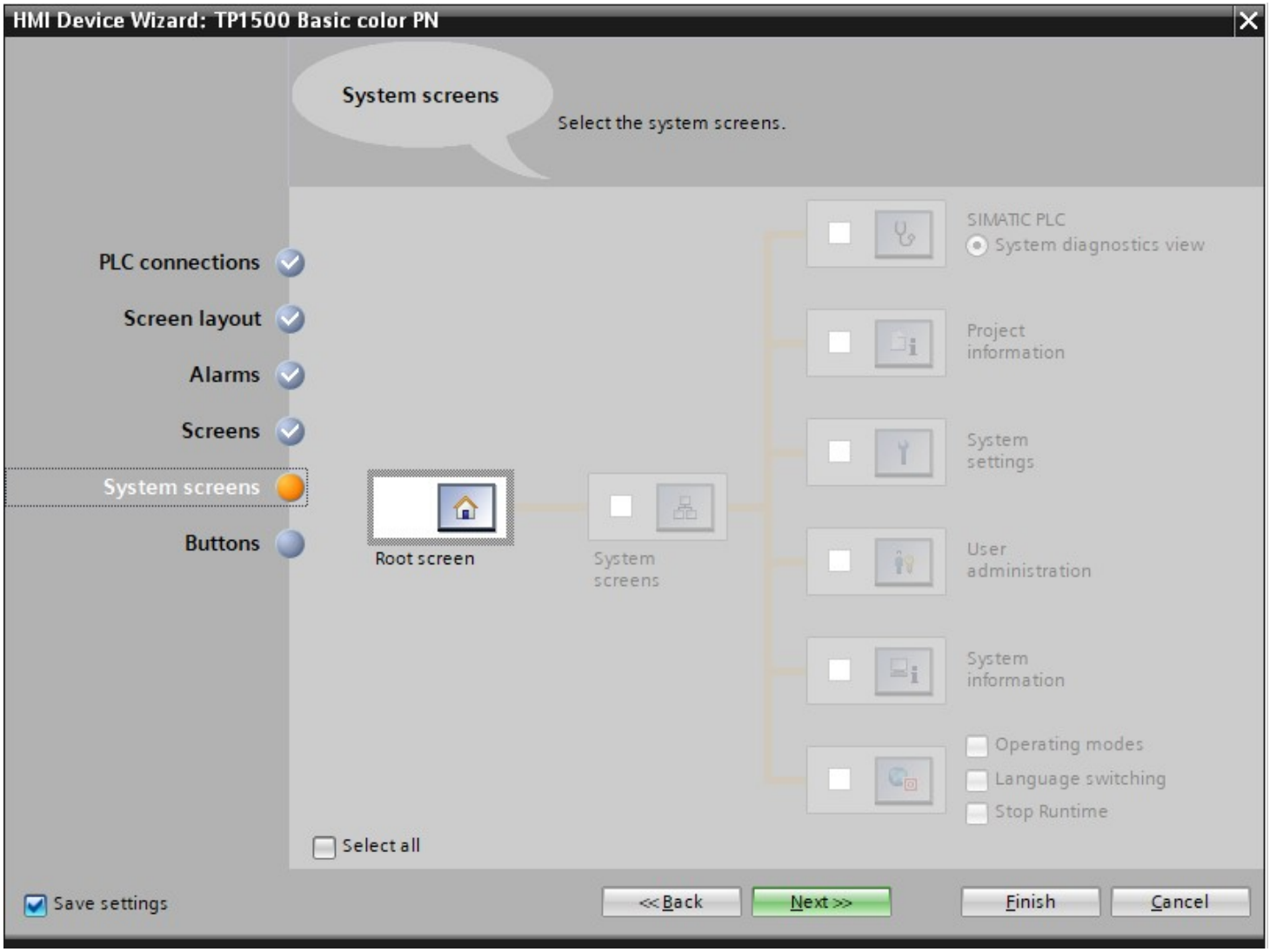
In the "Screen navigation" section, the screen structure is displayed with the screen name of the last created project, starting with the root screen on the far left. A new name can be assigned simply by clicking on a screen name.

If you click on + you can insert new screens in the hierarchy ® and delete selected screens by clicking on "Delete screen".

Confirm your selection by clicking on "Next".

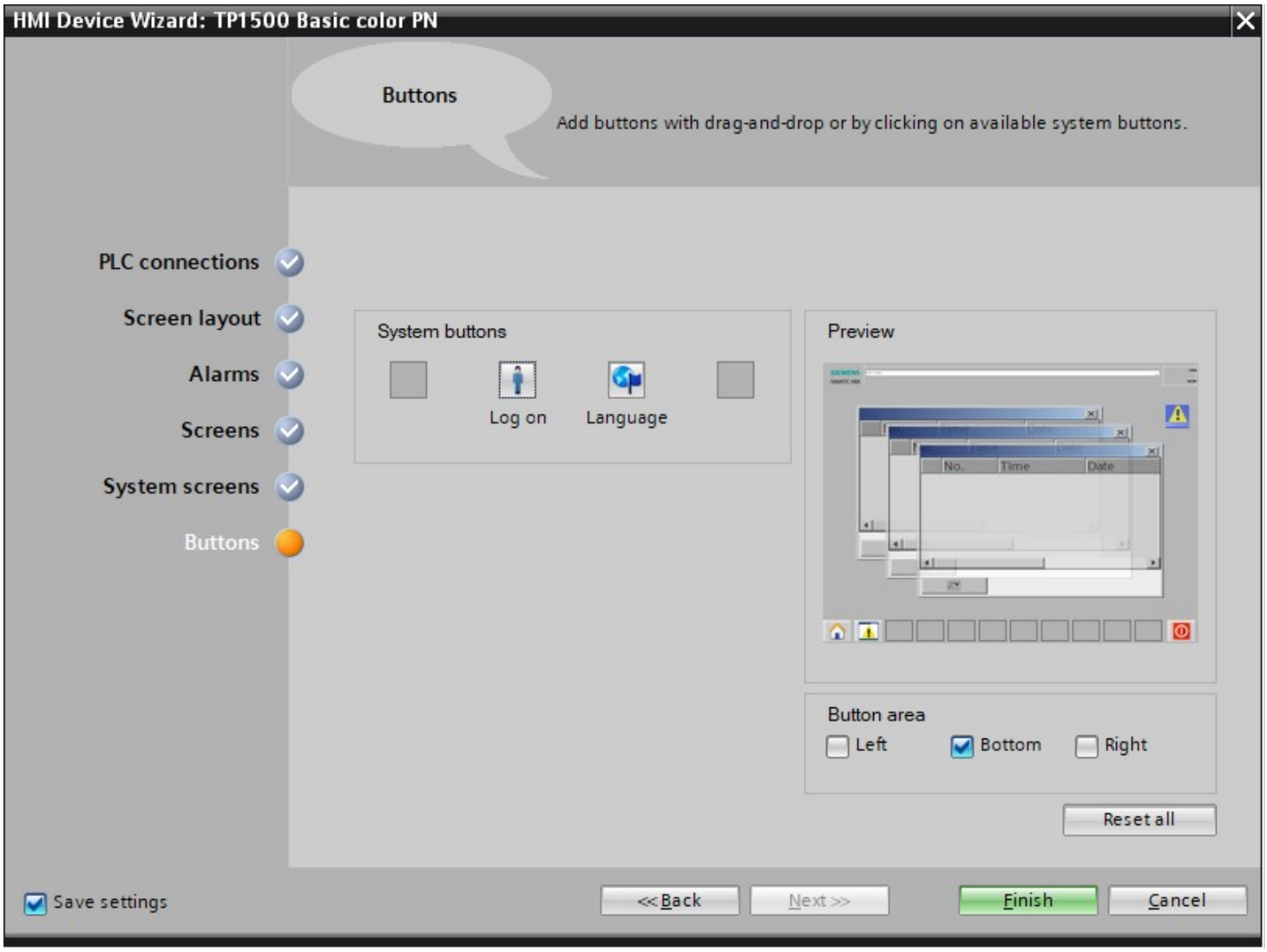


In the System screens section, you can select previously preset views for system functions and have them automatically added. Select all system screens by clicking "Select all". Confirm your selection by clicking on "Next".



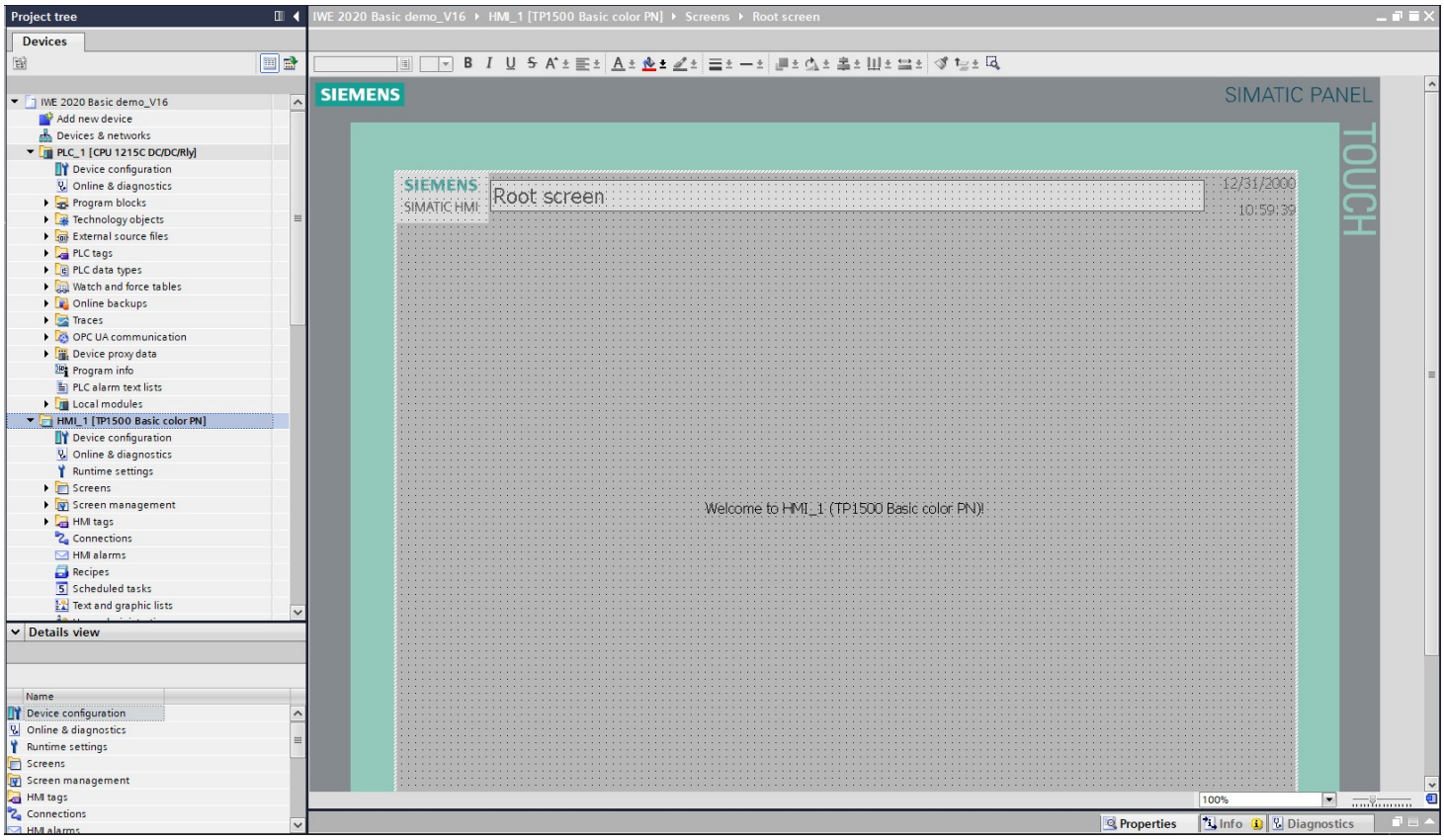
In the System buttons section, you will find four user-selectable buttons for Exit(Runtime), Log on, Language and Root screen. You can place these buttons on the provided button areas "Left", "Bottom" or "Right" as desired. An "Open alarm window" button is already created.

Select only the "Button area", "Bottom".Insert the button for the "Root screen" on the left and the button for "Exit" Runtime on the right. Confirm your selection by clicking on "Finish".

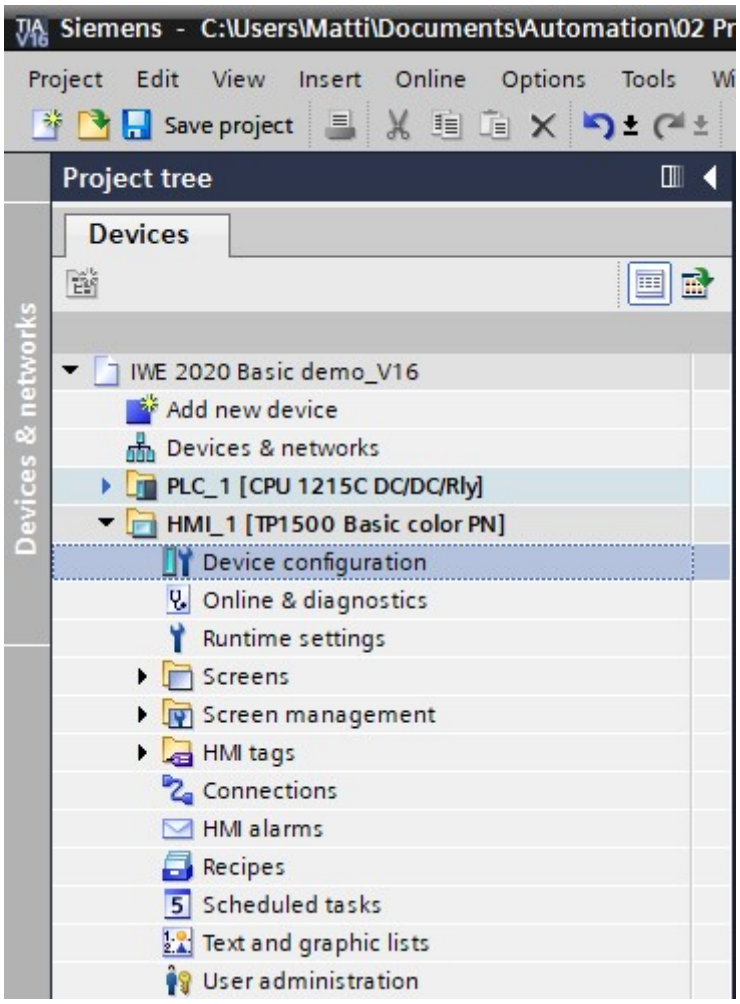


Device configuration of HMI Panel

The TIA Portal now automatically changes to the Project view and displays the root screen of the visualization.

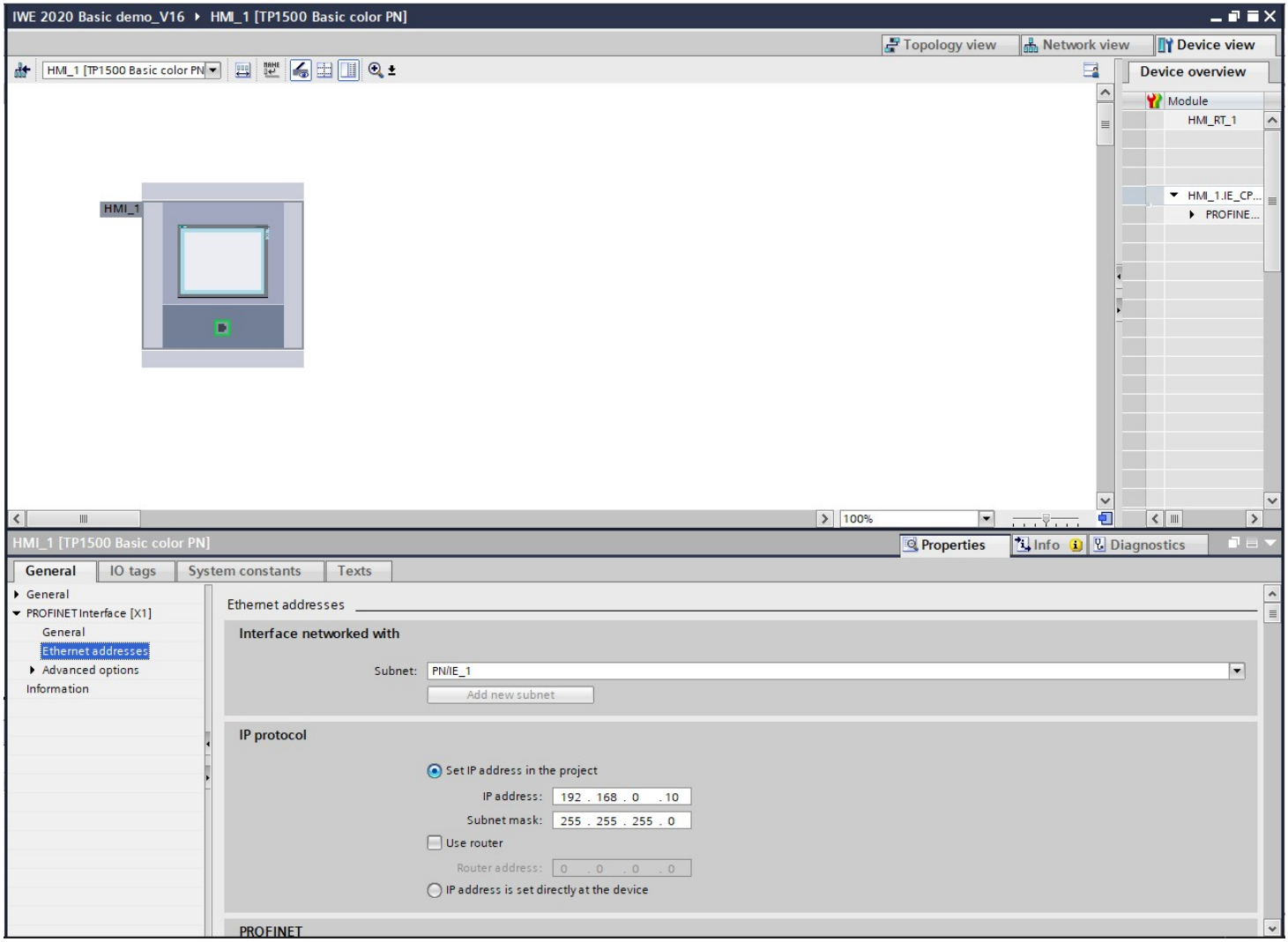


To configure the panel, select "Panel KTP700 Basic" in the project tree and open its "Device configuration" with a double-click.



Setting the IP adress

Select the Ethernet interface of the panel in the Device view with a double-click.
Under "General" in "Properties", open menu item "PROFINET interface [X1]" and select in the "Ethernet addresses" entry.
Set the IP address "192.168.0.10" under IP protocol.



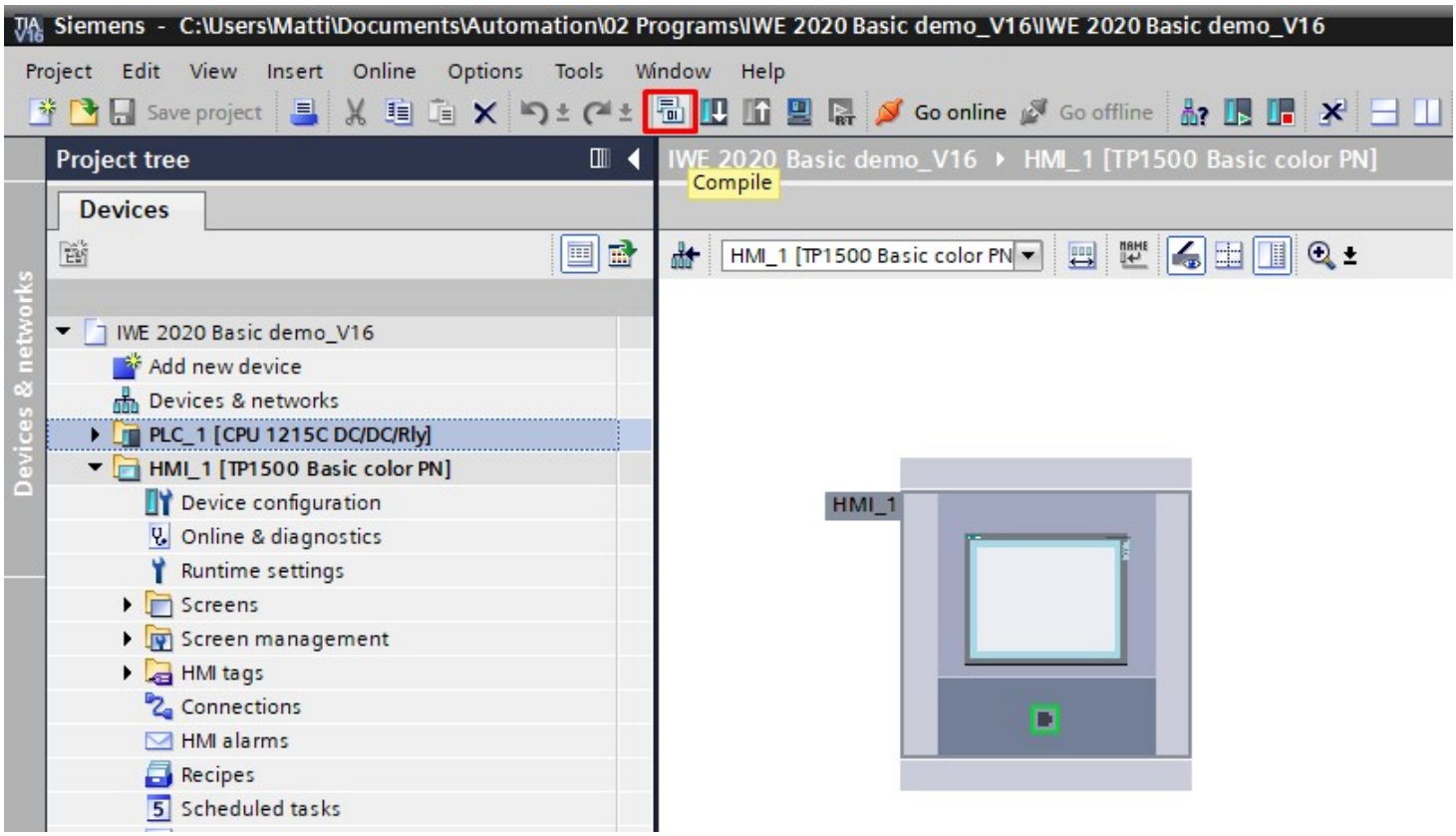
Remarks

– The subnet mask was already set in the settings of the CPU 1215C and is automatically applied by the panel.

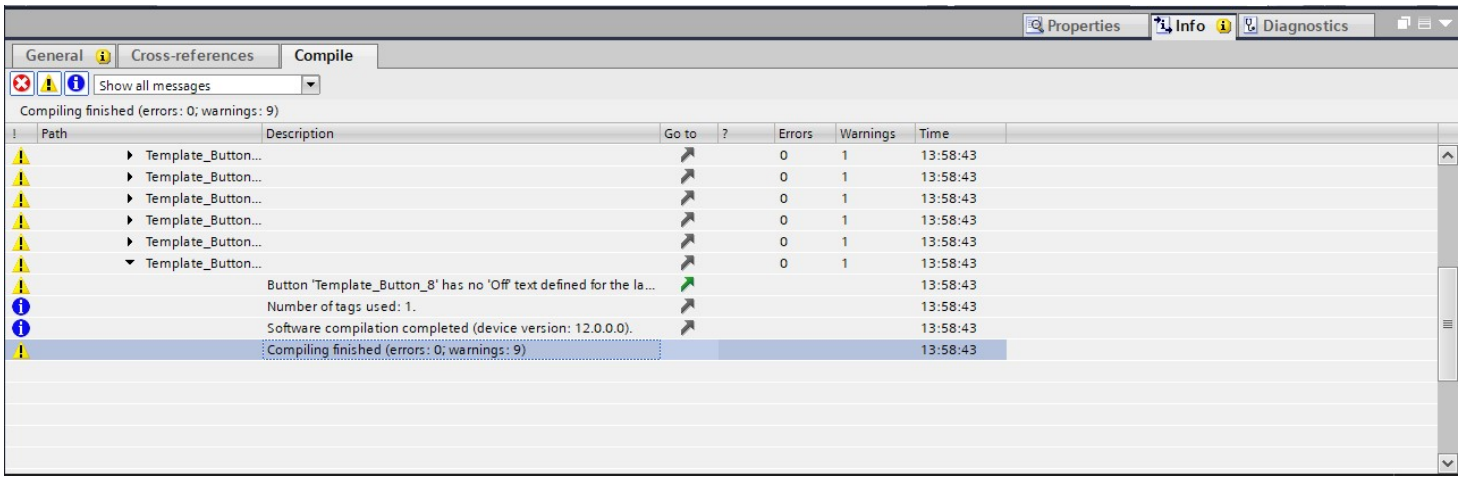
Compiling the CPU and panel and saving the project

To compile the CPU, click on the "CPU_1215C" folder, and select the "Compile" button for compiling in the menu. To compile the panel, click on the "Panel KTP1500 Basic" folder, and select the "Compile" button for compiling in the menu. You can save your project by clicking on the "Save Project" button in the menu.

(CPU_1215C > "Compile" > Panel KTP700 Basic > "Compile" > Save project).



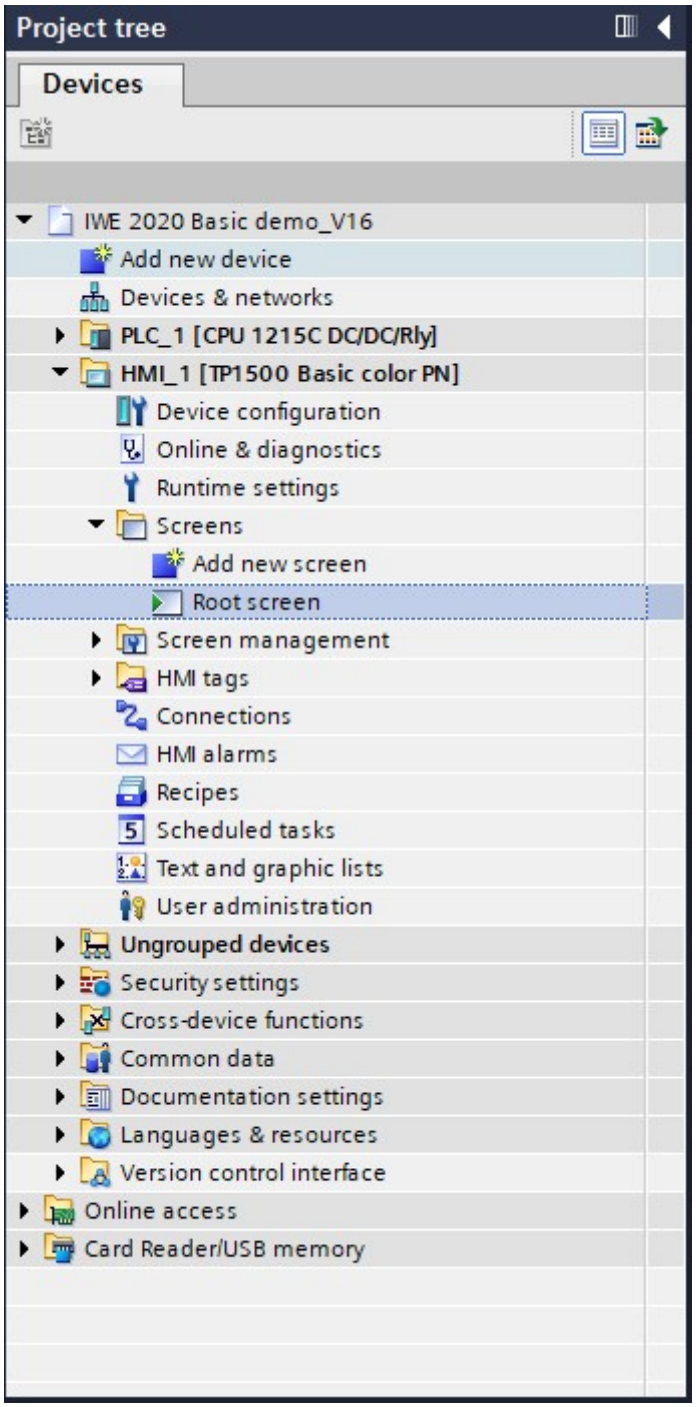
In the "Info" area under "Compile", it is then shown whether the compilation was successful or whether warnings or errors have occurred.



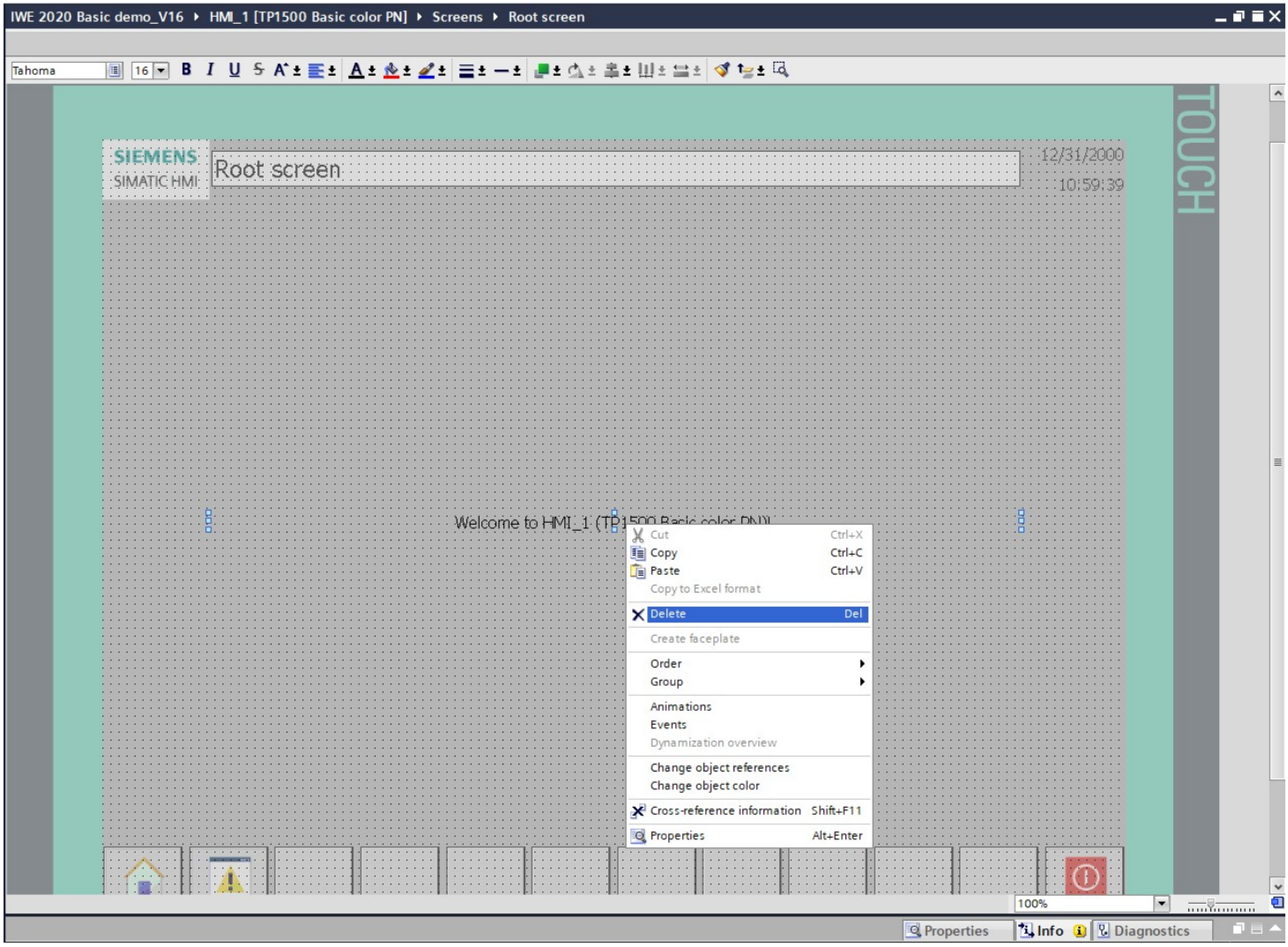
Changin screens and objects

Screens

After successful compilation, you want to design the first screen for the visualization. To do this, open the > "Root" screen with a double-click:

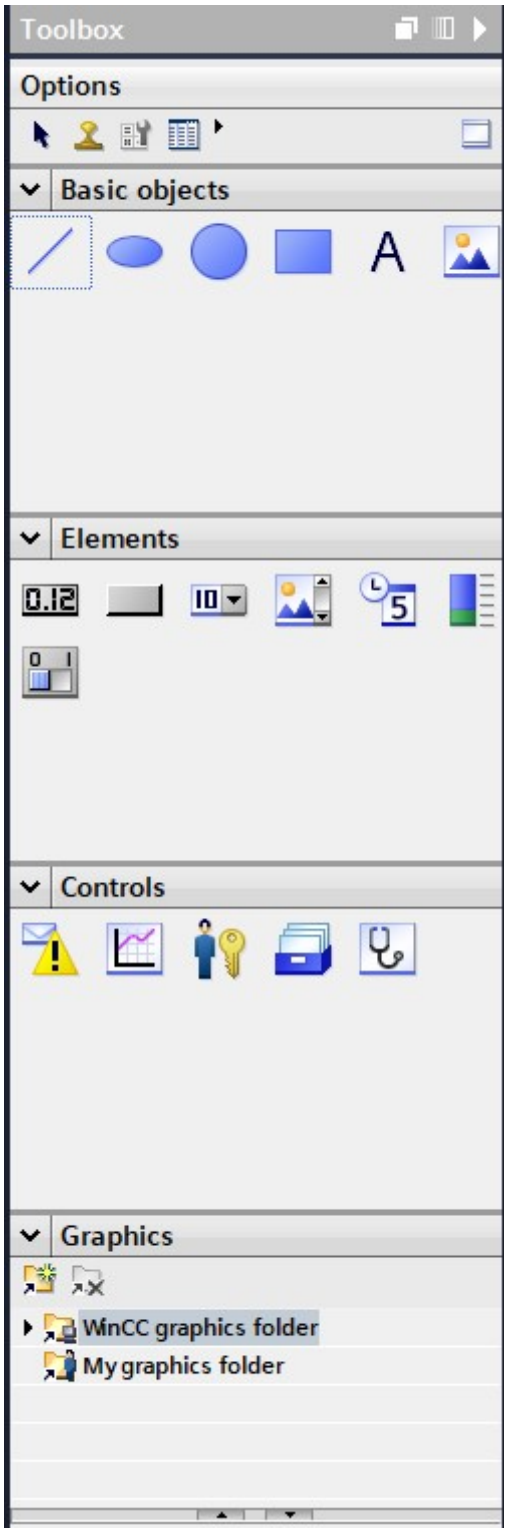


You will see a text box in the center of the screen, we will remove this by right clicking the text box and selecting "Delete". This also can be done by pressing you keyboard button "Delete".



Toolbox

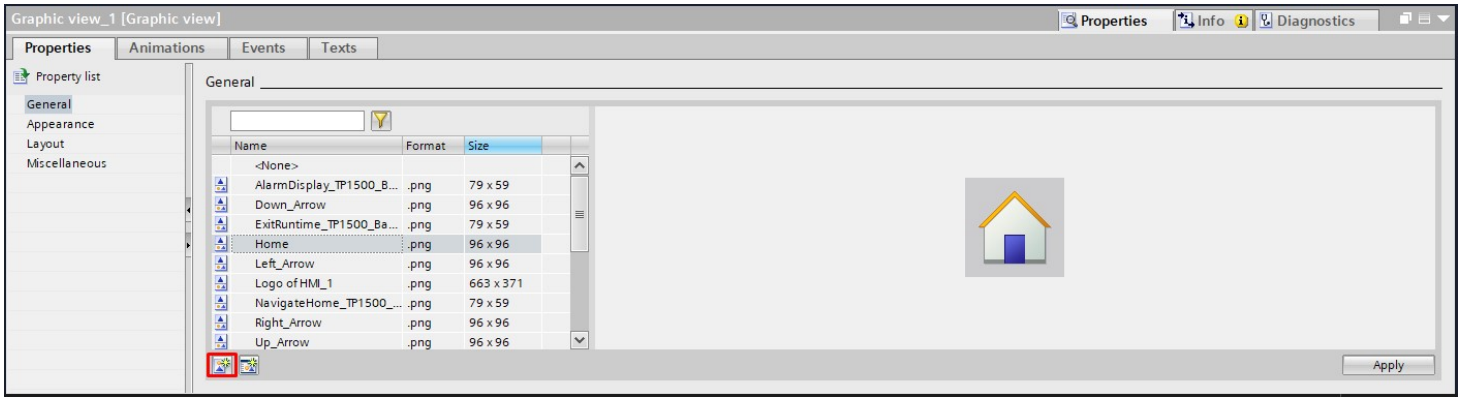
These contain the most commonly used objects, elements and controls used in a HMI display.



Basic objects

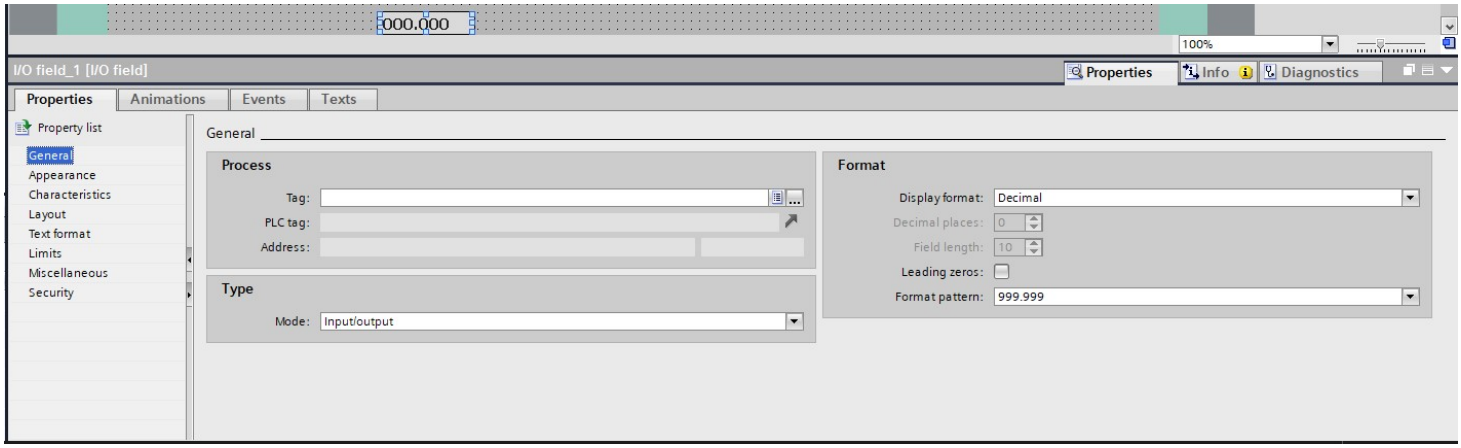
The basic objects contain a text box, rectangle, circle, line, ellipse and a graphic view.
These are added by simply dragging them onto on the screen or selecting one in the toolbox section and clicking on the desired screen. To customise them further you'll have to click on the properties of the object. For example a rectangle, in the properties you can change the appearance, layout and miscelaneous.

These properties are the same for all basic objects except for the text box and graphic view. Graphic view has the ability to show custom images. This is done by selecting the grpahic view and placing it on a screen. Then in options you'll have to go to General > bottom button to add custom files. There is already a pre existing list of images you can choose from. But to add a custom image:

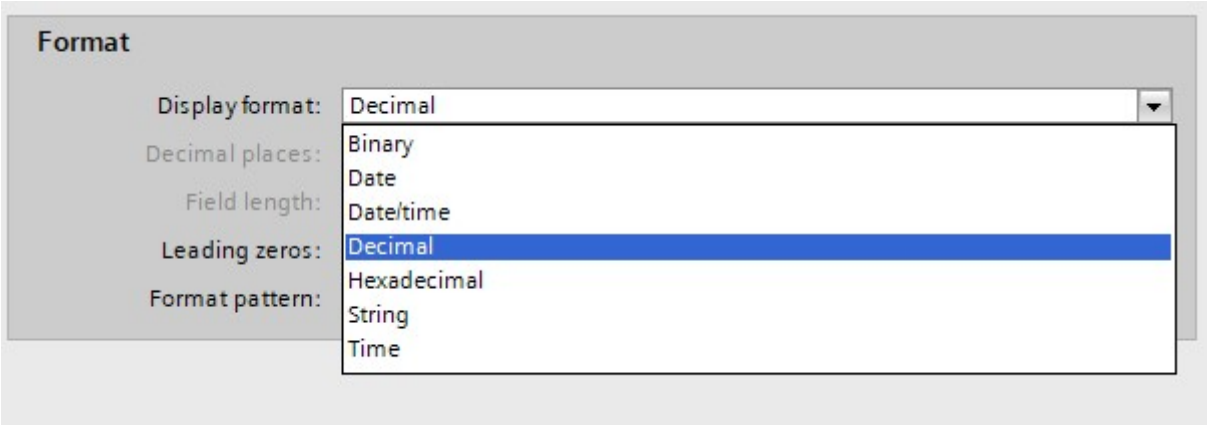


Elements

The elements are objects that can be linked to actual PLC data / are ment to be used as a way of interacting with PLC data. These stock ones contain an I/O-Field, button, symbolic I/O-Field, graphical I/O Field, date/time field, bar and a switch. Once dragged into the screen you can change the appearance however you want and link them with the correct PLC data type. For example an I/O-Field.



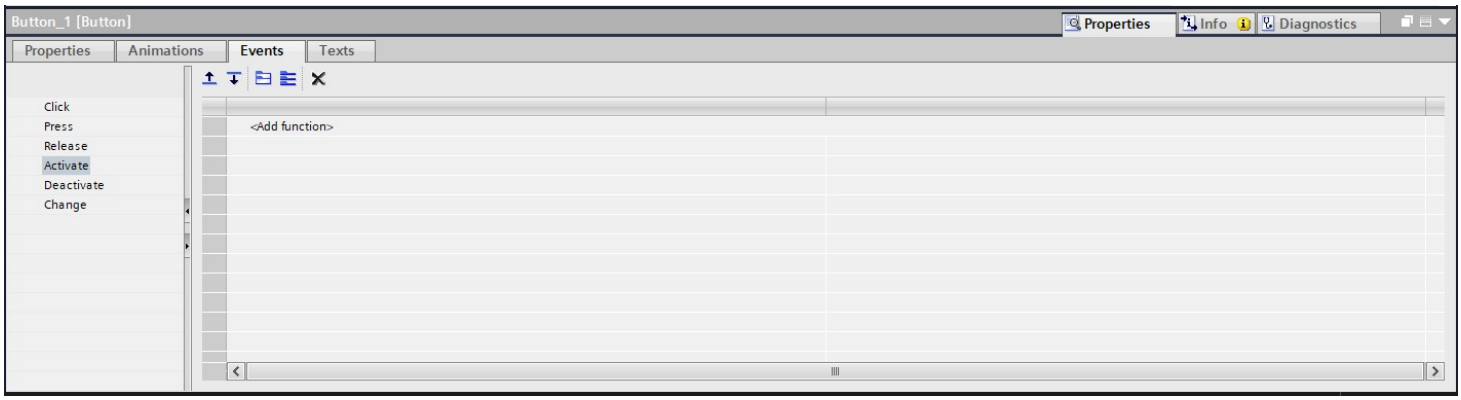
In the properties of this I/O field you can assign a Tag from the HMI or PLC to it. This will read out the value that tag has. An I/O field is mostly used for reading or giving in a desired value. In "format" you can customise how the value gets displayed. For example:



You can also change the type of I/O field by changing it to input or output only. Input only will only show input values. Output only will only allow a measured value to be displayed and NOT changed.

Events

Each object or element can have events. These can change values, screens on the HMI, calculations scripts etc.. For an example we'll use a button to make it behave like a Start button.



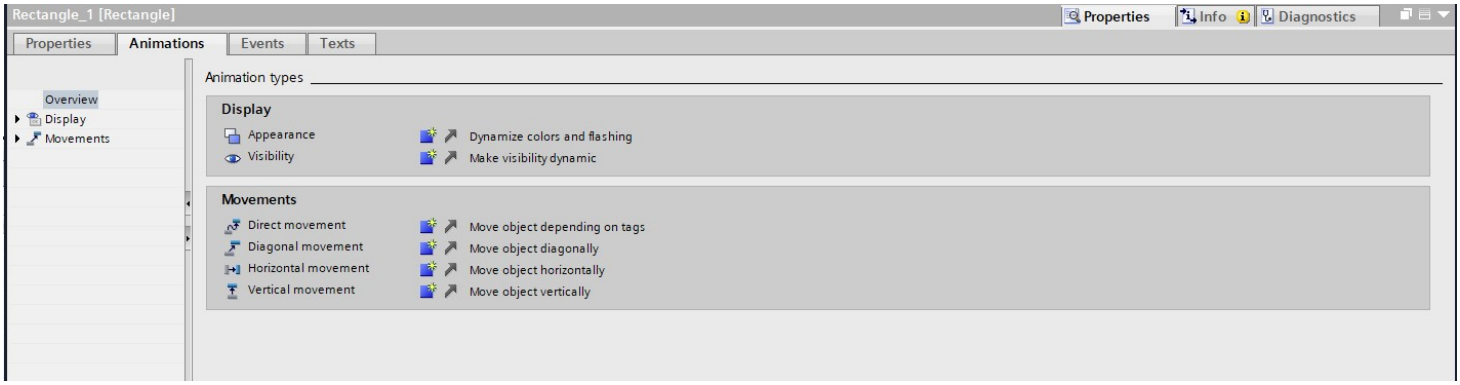
To assign a function to the button you click on "Properties" > "Events" > "Click" > "< Add function >" you will get the following selection.

Select "Edit bits", in here there are several options of changing a bit. For a start button the most common function is "SetBitWhileKeyPressed", this will set the asigned bit to 1 while you press the button. If you release the button the bit value will be set to 0 again.

Animations

Display

Within the properties screen you can find the tab "Animations". After which you get the option to add either a **Display** or **Movements**. In this chapter i'll explain the **Display**.

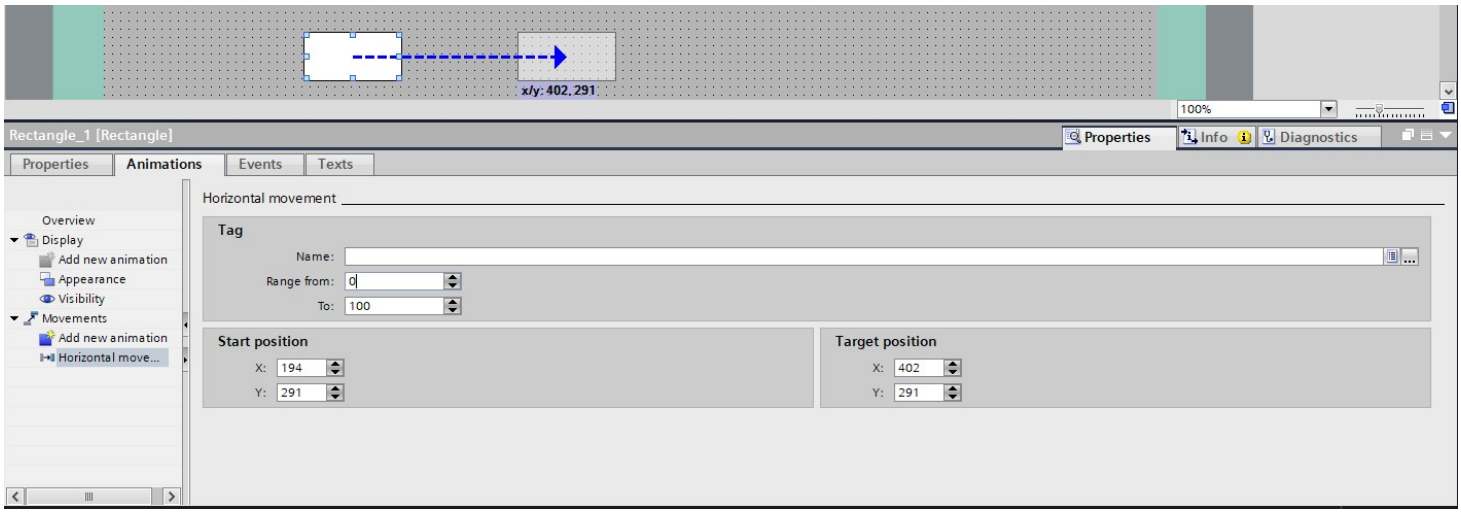


Within a display you can have a "Appearance" or "Visibility" animation. The appearance will give you the ability to change the colours of a object depending on a tag value. Visibility will give you the option to hide the object depending on a tag value.

Movements

Within **movements** there are 4 different movements, direct movement, diagonal movement, horizontal movement and vertical movement. Direct movement will allow you to move a object from point A to B in a direct way. Diagonal movement will move from point A to B diagonally. Horizontal movement will move from point A to B horizontaly. Vertical movement will move from point A to B vertically.

Horizontal and vertical movement can be assigned to a tag value so that depending on that value the object will move towards one point. For example:



The range will determine how much of your tag value will be used (0-50 of the tag value will move your object between the two points in that range 0 being point A and 50 being point B).

GRAFCET

General

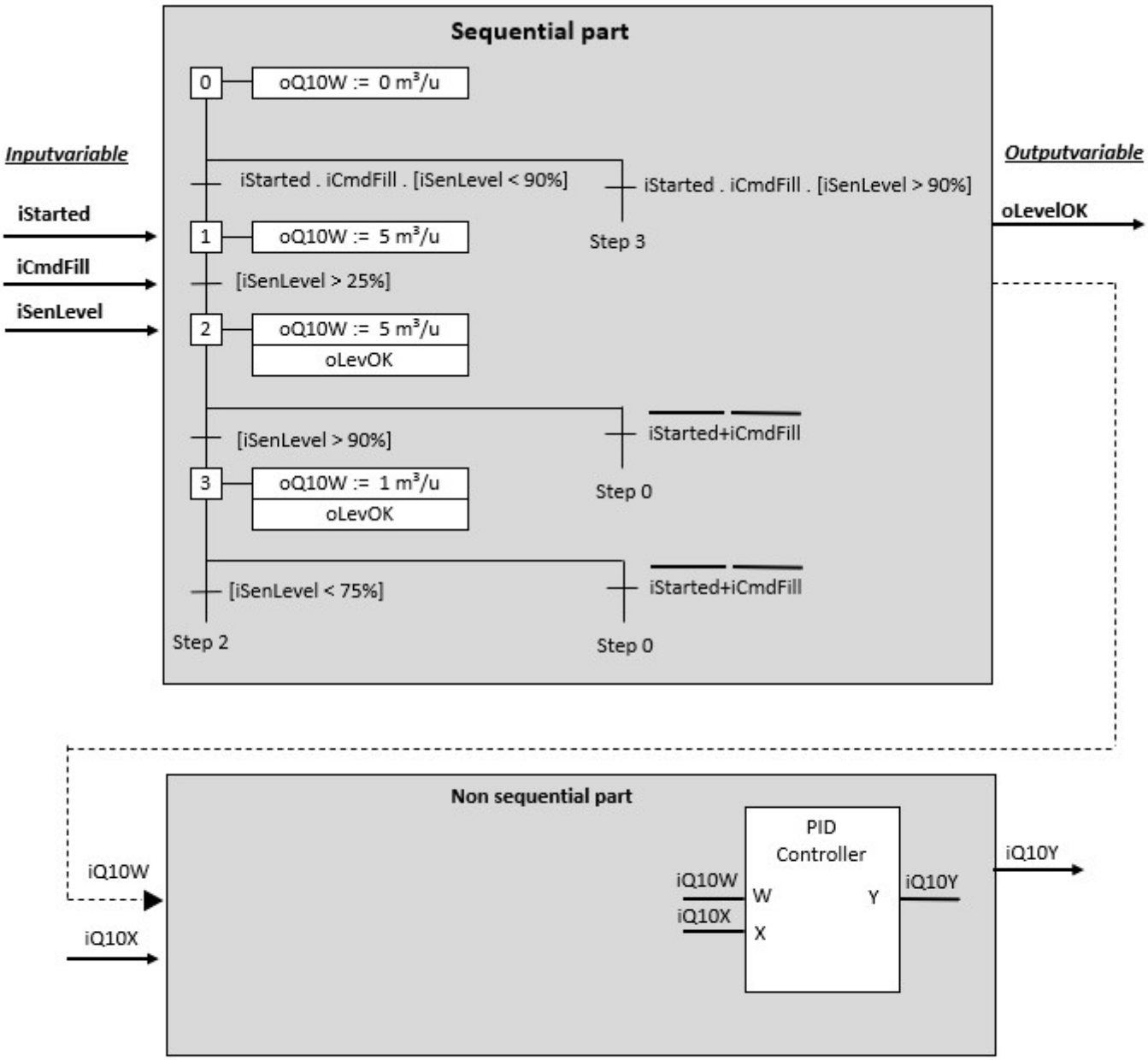
8.2 Addendum 4 GRAFCET

The implementation of an automated system requires, in particular, a description relating cause and effect. To do this, the logical aspect of the desired behaviour of the system will be described.

The **sequential part** of the system is the logical aspect of this physical system. The behavior indicates the way which the output variables depend on the input variables. The object of the GRAFCET chart is to specify the behavior of the sequential part of the system.

The **GRAFCET design language** is characterized by different graphical elements and by text that gives information about the variables. By connecting these various elements and text, the behavior of the automatic machine/installation is described.

This behavior is known as steps and a GRAFCET contains multiple steps. The evolution of one step to another is translated by one or several transitions.



iStarted - Automatic process is started
iCmdFill - Command to fill the tank
iSenLevel - Tank level sensor in %

oLevelOK - Level OK for the next tank
oQ10W - Desired flow rate
oQ10X - Measured flow rate
oQ10Y - Controloutput

A GRAFCET will be executed as follows:

- A GRAFCET will run from top to bottom
- A GRAFCET starts with an initial step
- A transition is displayed as a mathematic boolean expression
- The result of a transition is TRUE or FALSE
- While the GRAFCET is executed there is at least one active step
- Only steps connected to the active step can be executed
- Other steps can be activated on the condition that they are connected with the active step if the result of the connected transition is TRUE

There are 5 programming languages included in the standard IEC 61131 including SFC[4] which is inspired on the GRAFCET design language. However, there are some differences:

- SFC is a programming language
- GRAFCET is a design language
- The SFC program language uses other program languages, such as FBD and LAD, and different abbreviations to program transitions and actions
- The execution of an OR-convergence, if all conditions are TRUE, is different

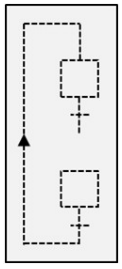
Conclusions

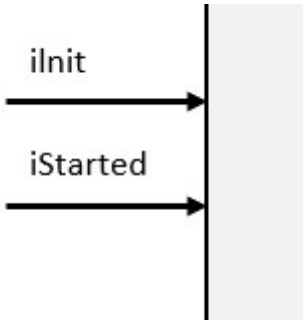
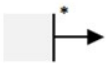
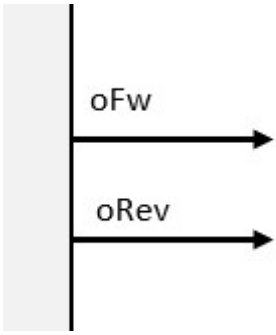
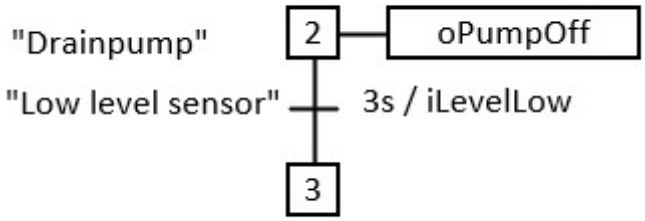
- It is possible to program a GRAFCET in each programming language described in the standard IEC 61131
- The SFC program language looks like GRAFCET design language but is not 100% the same

Designing of a GRAFCET in IEC 60848

8.2 Addendum 4 GRAFCET

GRAFCET diagram

Symbol	Description
	A GRAFCET diagram is a collection of steps, actions, transitions, connections, etc. which form a complete diagram. The collection of all elements is surrounded by a rectangle.

Symbol	Description
	**Input variables** are on the left with an incoming arrow **Example**: "Initial step activation" and "installation started" inputs 
	**Output variables** are located on the right with an outgoing arrow. **Example**: "Forward" and "Backward" output signals. 
"*"	A **comment** clarifies the working of certain parts and is written between double quotation marks, whereby the asterisk symbol gets replaced by the description. **Example**: Stop a drain pump if the level is too low. 

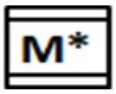
Step

A **step** displays a defined condition of the sequential process. A step is either **Active** or **Not Active**.

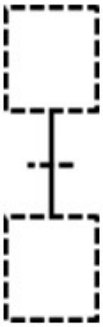
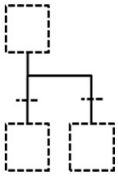
On a certain moment during the sequential proces:

- Is a step active or not active
- The set of active steps determines the state of the process
- The GRAFCET determines which step or steps can become active

Symbol	Descpription
	A **step** is shown as a square with an unique label. For practical reasons the most commonly used label are numbers which replaces the asterisk symbol. **Example**: Step 2 
	The **initial step** characterizes the initial situation and is displayed as a double square. In case of the initial step being active, all other steps in the GRAFCET won't be active. **Example**: Step 0 
	An **enclosed step** means that this step contains other steps. If the conditions after the enclosed step are TRUE, we will proceed to the next step and all internal steps will be inactive. It is allowed that an enclosed step contains multiple GRAFCET diagrams, but the enclosed internal steps can only be assigned to one enclosed step.
	An **enclosed initial step** means that this step has multiple internal steps that participate in the initial condition. The enclosed initial step contains minimum one internal initial step and can contain multiple GRAFCET diagrams.

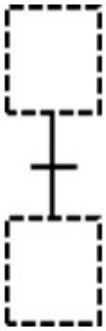
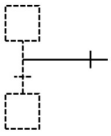
Symbol	Descpription
	A **macro step** means that this step has multiple internal steps. We can describe it as an independent piece of software. A macro is not designed as standalone software, it’s meant to support a different piece of software. The internal steps always start with a source step and always end with an end step. Only in the case of the end step being active can the macro exit. Unlike an enclosed step, a macro contains a maximum of one GRAFCET diagram and the asterisk symbol gets replaced by one unique label that can deviate from step labels, in numbered order.
	In case that an **active step** needs to be displayed, this will be done by placing a point under the label.

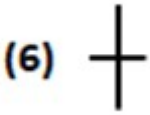
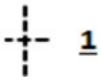
Connections

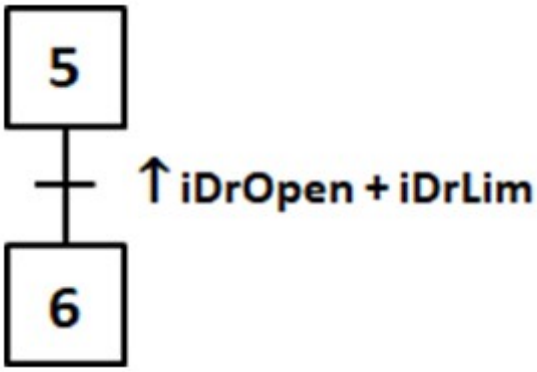
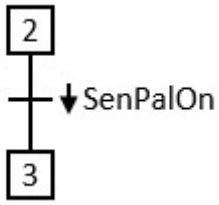
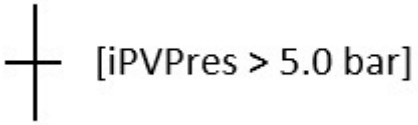
Symbol	Description
	Connections are lines in the network that connect steps.
	Both horizontal and vertical lines are allowed. Diagonal lines are to be avoided. They are allowed, but only to clarify.
	The flow of a connection is always from top to bottom. The use of arrows is allowed in case of clarification.

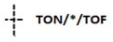
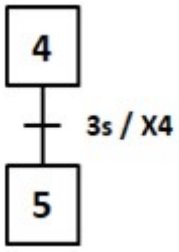
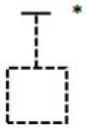
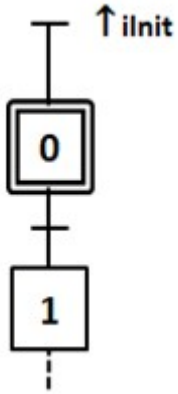
Symbol	Description
	If a directed link has to be broken (for example for complex charts or when a chart covers several pages) the number of the destination steps and the number of the page on which it appears, shall be indicated. **Example**: Reference to step 12 on page 2 

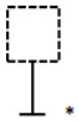
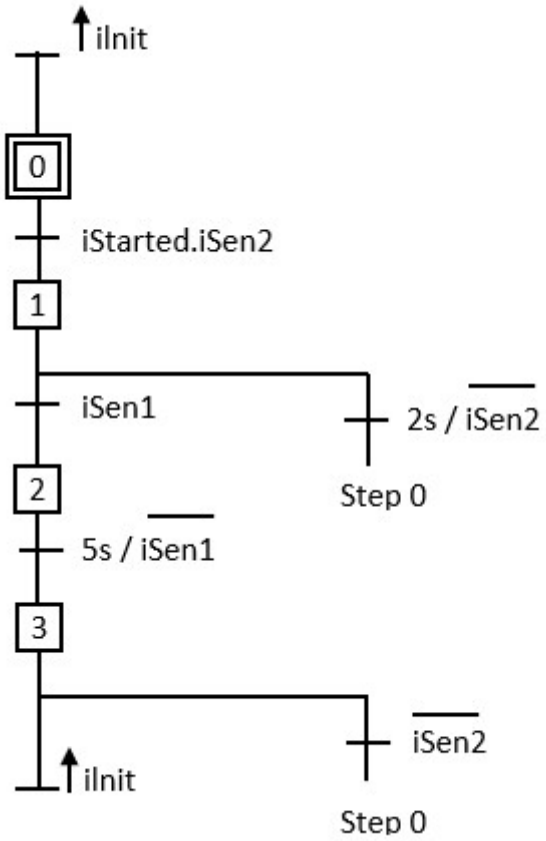
Transition

Symbol	Description
	A transition between two steps is indicated by a horizontal line right through the connection line. The transition-condition is active if the previous step is active. Between 2 steps one condition is allowed.
	It’s allowed to use vertical transitions for graphical reasons.

Symbol	Description
	Each transition contains a condition. This is a mathematical boolean expression composed by variables, they replace the asterisk symbol. The result of a transition-condition is TRUE or FALSE. The transition-condition is always at the right of the transition. **Example**: Start button AND stop button 
	The transition may have an unique designation ( ) at the left of the transition. **Example**: Label 6 
	A transition condition that is always TRUE is displayed with the underscored expression 1.
	The status of a step (active or not active) can be added in a transition-condition with the capital letter "X". The asterisk symbol will be replaced by a label of the step. **Example**: Step variable of step 7

Symbol	Description
↑*	An upward arrow in the transition-condition means that it is only TRUE the moment the variable changes from FALSE to TRUE. **Example**: The transition-condition is TRUE on a rising edge of the "Door is Open" sensor OR if the "Door Limit switch" is activated. 
↓*	A downward arrow in the transition-condition means that it is only TRUE the moment the variable changes from TRUE to FALSE. **Example**: The transition condition is TRUE on a decreasing flank of the pallet fotocel. 
[*]	A **comparison** is noted between [ ]. The asterisk symbol gets replaced with a comparison. The result of a comparison instruction is TRUE or FALSE. **Example**: The transition-condition is TRUE in case the actual pressure is higher than 5,0 bar. 

Symbol	Description
	A variable that is time dependent is displayed with the **/** symbols (TON / variable / TOF). Hereby, the transition-condition is TRUE after an on-delay and stays TRUE with an off-delay. It is allowed to simplify the notation by removing the off-delay in case this isn't used. **Example**: The transition condition is TRUE 2 s after the iSen is TRUE and stays 5s TRUE after iSen becomes FALSE.  **Example**: 3 s after step 4 is activated the transition-condition becomes TRUE and step 5 will be activated. 
	A **source transition-condition** is a transition-condition without previous steps. Each time the transition condition is TRUE, the next step will be activated. It is recommended to provide a transition condition with a rising or dropping flank to avoid the activation of the next step. **Example**:The initialization step 0 will be activated on a rising flank from the initialization input signal. 

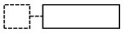
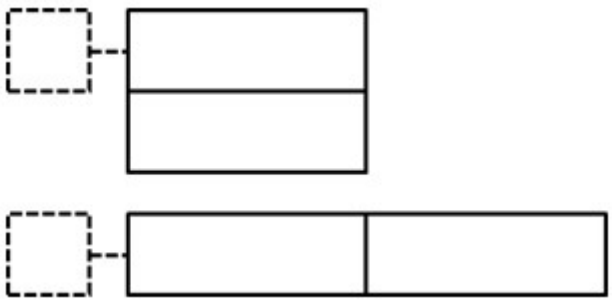
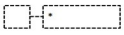
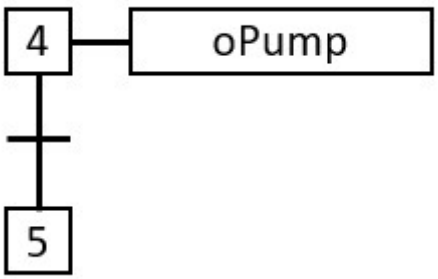
Symbol	Description
	An **end transition-condition** is a transition-condition where no steps follows. Each time the transition condition is TRUE, the upwards steps will be disabled. **Example**: Sequence with initialization of a sourcestep where all steps get activated 

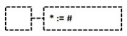
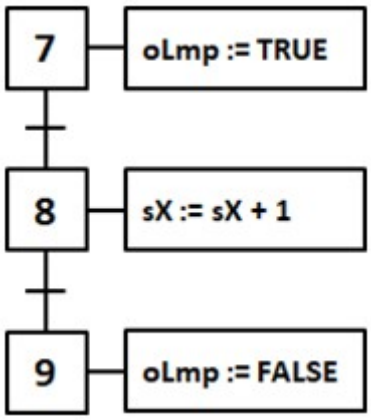
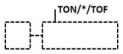
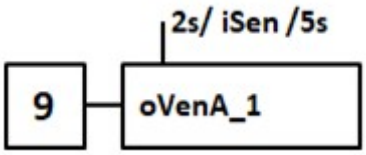
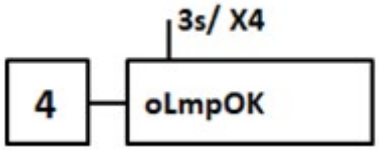
Explanation symbolic image

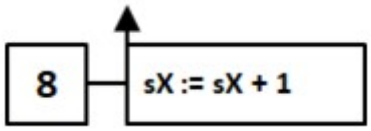
- iInit = digital input – GRAFCET initialise
- iStarted = digital input – Result of a start-stop circuit
- iSen1 = digital input – Sensor 1
- iSen2 = digital input – Sensor 2

Action

Symbol	Description

Symbol	Description
	An **action** is assigned to a step and gets illustrated by a rectangle which is connected to that step with a horizontal line. It is allowed to use multiple actions in the same step, if each of them have their own rectangle. **Allowed multiple actions:** 
	Each action has an action label which clarifies the executed task. The label is written in the rectangle where the asterisk symbol is replaced by a variable. A **continue action** will have the status of the variable TRUE the moment the corresponding step is active. All other moments the action is FALSE. **Example**: The pump action is TRUE on step 4 and FALSE on step 5 

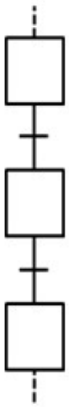
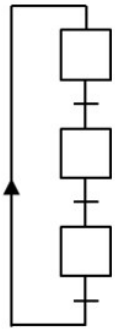
Symbol	Description
	A **memory action** has a specific value assigned to a variable which gets stored. The asterisk symbol gets replaced by a variable and the # symbol gets replaced by a (mathematical) value, formula, ... **Example**: The lamp gets activated in step 7, is still activated in step 8 and turns off in step 9. The internal variable "sX" is increased by 1 in step 8. 
	A time dependent **conditional action** is displayed with the / symbols. The action is TRUE after an on-delay and stays TRUE with an off-delay. It is allowed to simplify the condition by removing the off-delay in case this isn't used. **Example**: 2s after "iSen" becomes TRUE valve A+ will be activated. 5s after "iSen" become FALSE valve A+ will be deactivated if step 9 is activated.  **Example**: 3s after step 4 is activated the OK lamp lights up. 

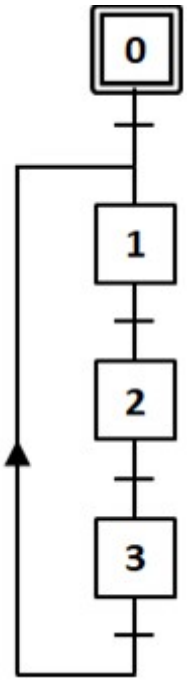
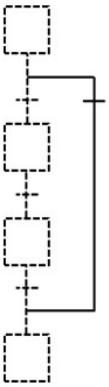
Symbol	Description
	It is possible to run a memory action with the activation of a step. This is indicated with an upwards arrow. **Example**: With the activation of step 8 the formula will be ran. 

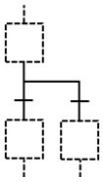
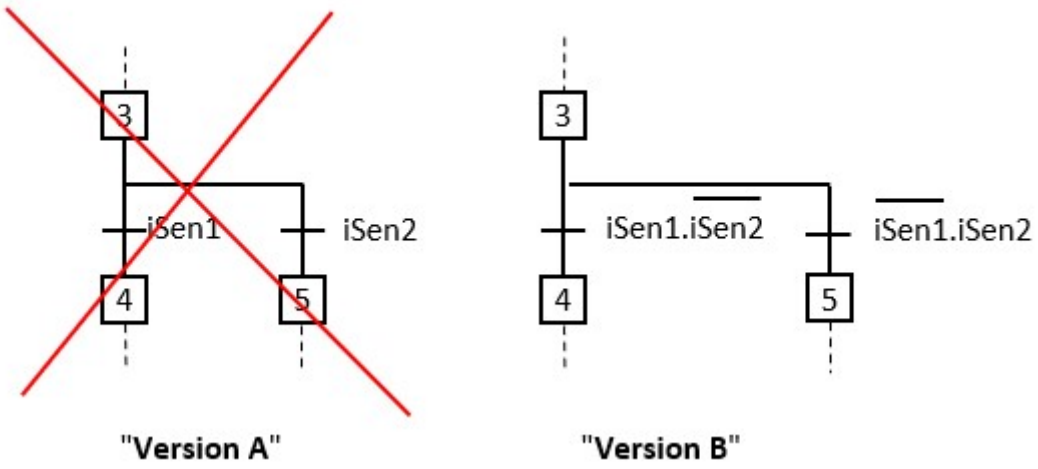
Explanation of the used symbols:

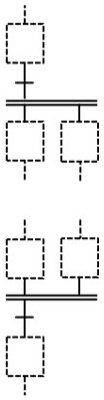
- oPump = digital output – Activation of a pump
- oLmp = digital output – Activation of a lamp
- oLmpOK = digital output – Activation of an OK lamp
- oVlvA_1 = digital output – Activation of Valve A+
- sX = static variable X
- sNumNOK = static variable – Amount of NOK parts

Structures

Symbol	Description
	A **sequence** is a series of steps where each step contains max. one transition-condition. The sequence is active if at least one step of the sequence is active. The sequence is inactive when all steps are inactive.
	A simple **loop sequence** is a sequence of steps whereby each step contains max. one transition-condition and where the last step is connected to the first step.

Symbol	Description
	A **sequence with source step** has a step without previous transition- condition. **Example**: Sequence with a initializing sourcestep. 
	A **sequence with end step** has a step where there are no transition- conditions after it. An end step (and a source step) are necessary with macros.
	It is possible to jump to a step with a **forward sequence skip**. Notice that between 2 steps only one transition is allowed.

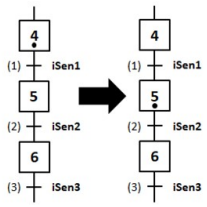
Symbol	Description
	It is possible to loop back with a **backwards sequence skip**. This makes it possible to repeat a sequence. Notice that between 2 steps only one transition is possible.
	Using a **OR-convergence** makes it possible to choose between different sequences where between 2 steps only one transition is allowed. The designer needs to make sure that both sequences can't be activated at the same time. **Example**: In the GRAFCET version A it is possible to activate both step 4 and 5. This can happen when "iSen1" and "iSen2" have the status TRUE and in the moment step 3 is active. In the GRAFCET version B it isn't possible due to the extended transition-condition. 

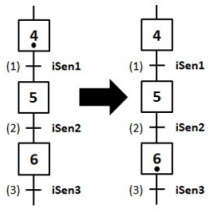
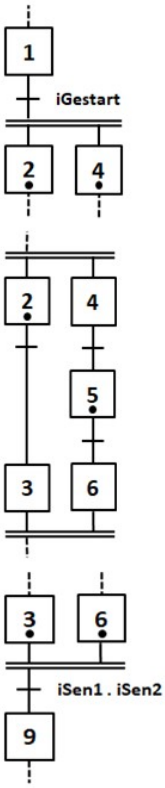
Symbol	Description
	A **AND-convergence** allows to activate parallel sequences at the same time. They will be started after a starting transition. An startind AND-convergence is showed by means of a double line after the starting transition. Once the parallel sequence is activated both sequences will run seperatly from each other. An AND-convergence gets back ends if all the parallel end steps are active and the ending transition-condition is TRUE. An ending AND-convergence is showed by a double line before the ending transition.

Function rules

The **function of a GRAFCET** is in general step by step.
If a step is active and the transition condition(s) are met than the next step will be activated. If the next step gets activated the previous step will be deactivated immediately.

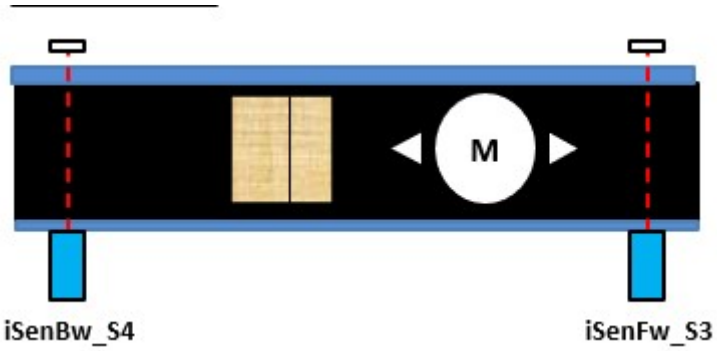
It is possible that the status of the different transtion-conditions the fucntion of a GRAFCET seems not to run step by step. It is the task of the designer to avoid that functions which can cause an unstable function of actions.

Function	Description
	A **non transient action** will run step by step. Situation: Step 4 active, iSen1 = iSen2 = Isen3 = FALSE Function: iSen1 (1) is TRUE which activates step 5 and deactivates step 4.

Function	Description
	With a **transient action** the steps won't run step by step. Situation Step 4 active, iSen1 = iSen3 = FALSE iSen2 = TRUE Function: iSen (1) is TRUE which causes step 5 to be activated and step 4 gets deactivated. Because iSen3 (2) is true, step 6 will inmediatly be activated and step 5 will be deactivated. Disadvantage: In case we use an action instead of a memory action, it is possible that the assigned actions of a transient step are not or transient executed (= unstable function).
	An **AND-convergence** parallel sequences will be started in case the previous transition condition is TRUE. Situation 1: If step 1 is active and transition conditoin iGestart is TRUE then step 2 and 4 will be activated. Situation 2: Once the parallel sequences are activated they will run separatly. Situation 3: Step 9 gets activated in case step 3 and step 6 are active and in case the transition-condition "iSen1.iSen2" is TRUE.

Example

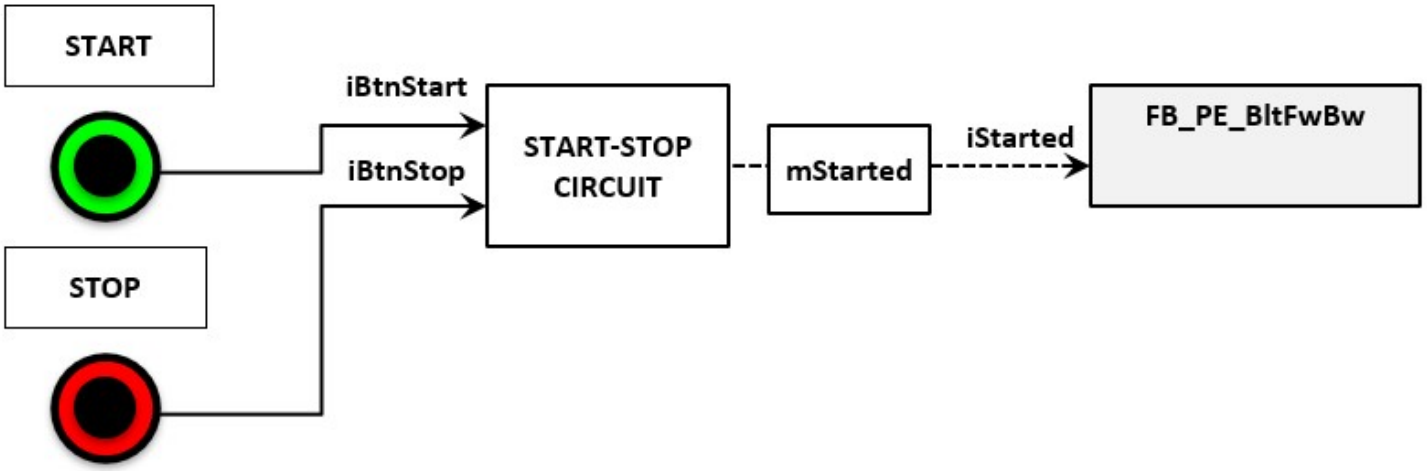
The next example shows a GRAFCET for the functionality of a conveyor belt. A box is displaced 5x times from start to end before it stops. After this operation it is necessary to restart the installation.



The GRAFCET has the name FB_PE_BeltFwBw:

- FB = GRAFCET will be programmed in a function block (FB)
- PE = This part is a procedure element according ANSI/ISA S88 standard
- BeltFwBw = Conveyor belt forwards & backwards

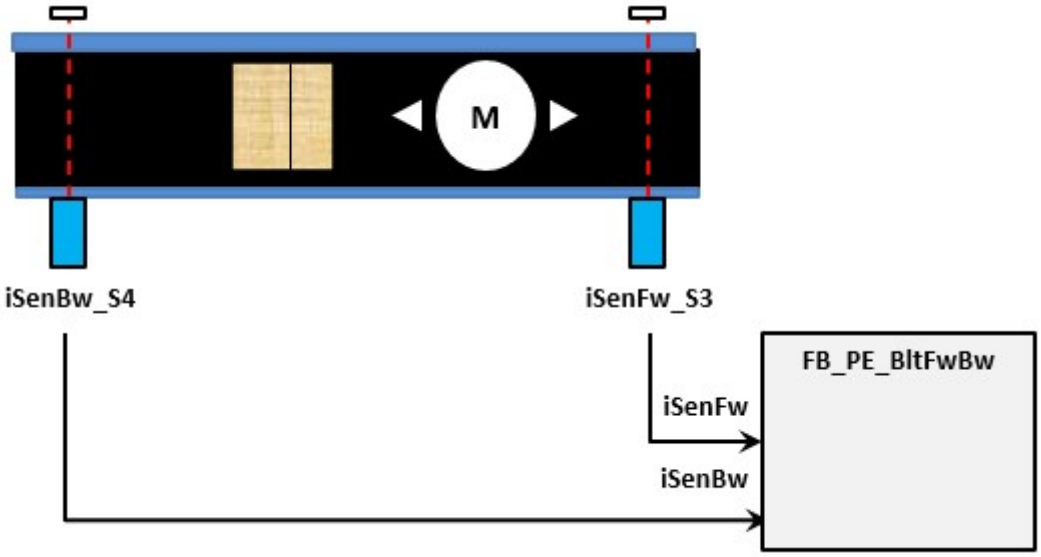
The conveyor belt is **started and stopped** by means of a start button and a stop button. The functionality of these buttons is not included in the GRAFCET but gets executed by an external start-stop basic circuit. The result of this start-stop basic circuit will be linked with the GRAFCET input variable "iStarted".



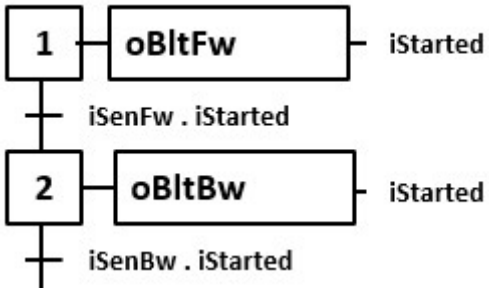
Each time the stop button is pressed the conveyor belt will immediatly stop. When the start button is pressed again, the conveyor and GRAFCET continues where they ended.

Conveyorbelt GRAFCET

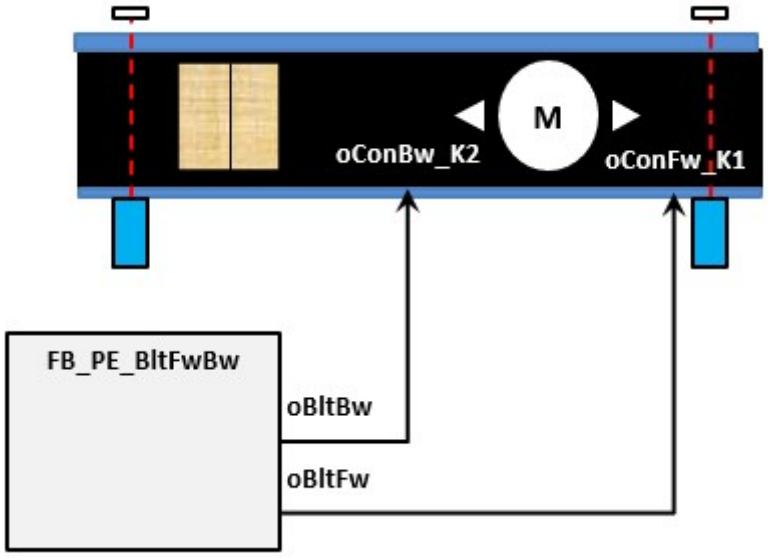
The **photocell** sensors on the conveyor belt detects the presence of the box when the infrared beam between photocell and reflector is interrupted. The status of the photocells (%I) is linked with the GRAFCET input variables "iSenFw" and "iSenBw".



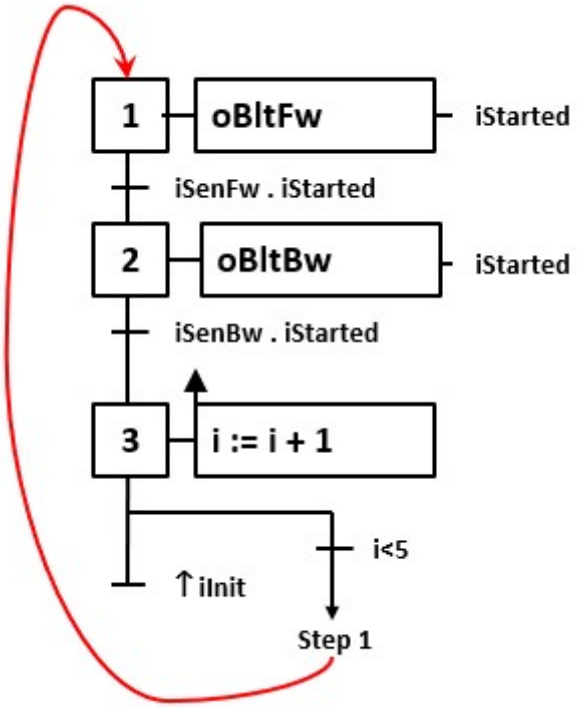
Controlling the conveyor belt forwards and backwards will be determined by step 1 and step 2 on condition that the installation is started.



The effective **control of the conveyor belt** happens by the GRAFCET output variables "oBeltFw" and "oBeltBw" which are linked to the contactors (%Q) and the conveyor belt motor (asynchronous motor).

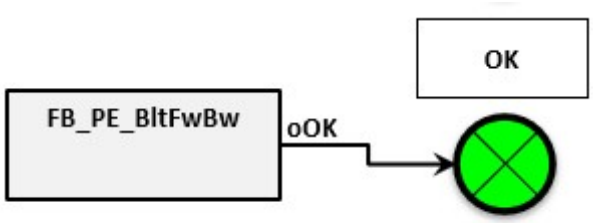


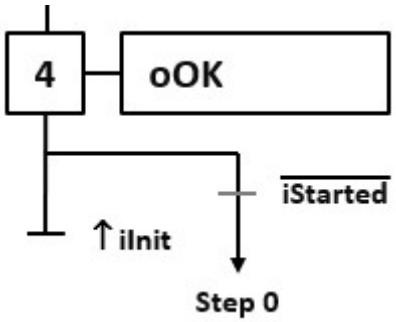
Counting of the **number of backward and forward movements** is controlled by the internal INT variable "i". This variable is an internal function block parameter of the type STATIC. This makes it possible to remember the condition of variable "i" also without voltage (=retentive).



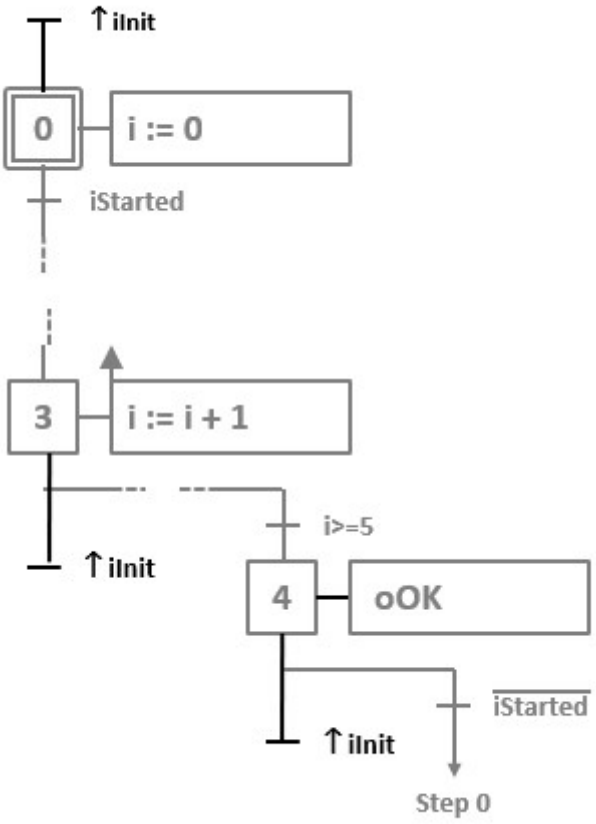
Increasing the variable "i" is executed in step 3, after which step 1 gets activated because there is a loop sequence between step 3 and step 1 but only if the value of the variable "i" is less than the decimal value 5. Noticed that the increasing of the variable "i" is only executed on the moment that step 3 is activated (rising edge). This is to prevent wrongly increasing the value of the variable in case step 3 is active longer the one PLC cycle.

In case the box went 5x backwards and forward this will be displayed with a green OK lamp. This lamp (%Q) is connected with the GRAFCET output variable "oOk". Now the installation needs to be stopped with the stop button before the installation can restart.

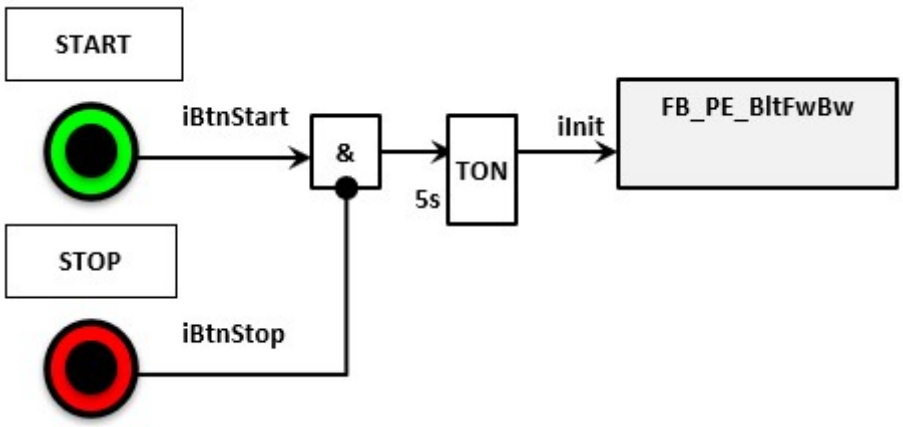




It is possible to **initialize** the GRAFCET. This is the activation of the initial step (step 0) by using GRAFCET input variable "iInit". All the other active steps get deactivated. The initialising is only activated on the rising edge of "iInit".



You could choose to initialize the installation in case you press the start and stop button simultaneously for 5 seconds or more.



GRAFCET programming in LAD-FBD using BOOL

8.2 Addendum 4 GRAFCET

Converting a **GRAFCET design to software code** is demonstrated with the GRAFCET described in subchapter 2.

The GRAFCET is programmed in the LAD or FBD programming language in the function block (%FB) with the use of STATIC parameters. STATIC parameters can remember their status without the PLC being powered on if they are configured to retain.

FB_PE_BltFwBw

	Name	Data type	Default value	Retain	Setpoint	Comment
2	iInit	Bool	false	Non-retain		Initialisation
3	iStarted	Bool	false	Non-retain		Installation started
4	iSenFw	Bool	false	Non-retain		Front sensor
5	iSenBw	Bool	false	Non-retain		Back sensor
6	Output					
7	oBltFw	Bool	false	Non-retain		Belt forward
8	oBltBw	Bool	false	Non-retain		Belt backwards
9	oOK	Bool	false	Non-retain		Movement finished
10	InOut					
11	Static					
12	pfiInit	Bool	false	Retain		Help variable rising edge iInit
13	pfx3	Bool	false	Retain		Help variable rising edge step 3
14	Step	Array[0..4] of Bool		Retain		Active GRAFCET step
15	i	Int	0	Retain		Counter

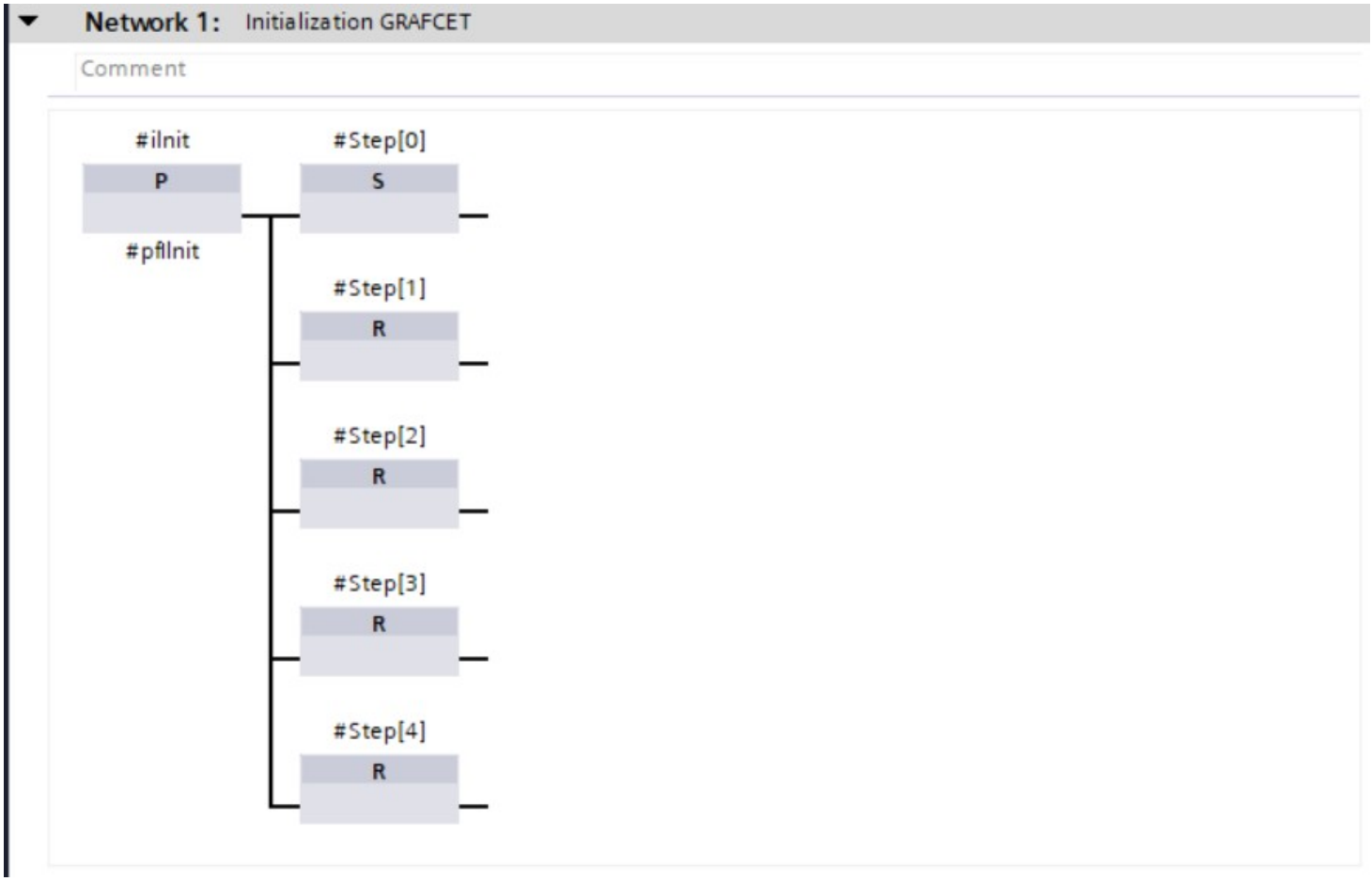
The programming is split into **3 parts** which are chronologically programmed in different networks:

- Initialization (network 1)
- Transition-conditions (network 3 ... x)

- Actions (network x+1 ... last network)

The **GRAFCET programming in LAD/FBD with BOOL** follows the next rules

- Each step is repesented by an unique BOOL variable
- This variable is an ARRAY of BOOL starting with 0 and ending with max. step number
- In case the corresponding variable is TRUE, the step will be active
- Input "iInit" is always present which causes the activation of the initial step on a rising edge of this input
- Input "iStarted" is always present which processes the result of an external start-stop basic circuit

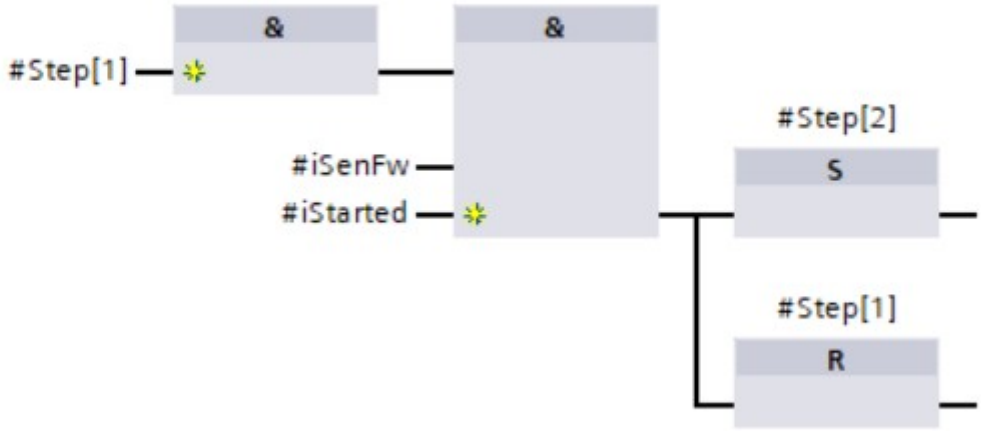


Network 2: Transition-condition step 0 to step 1

Comment

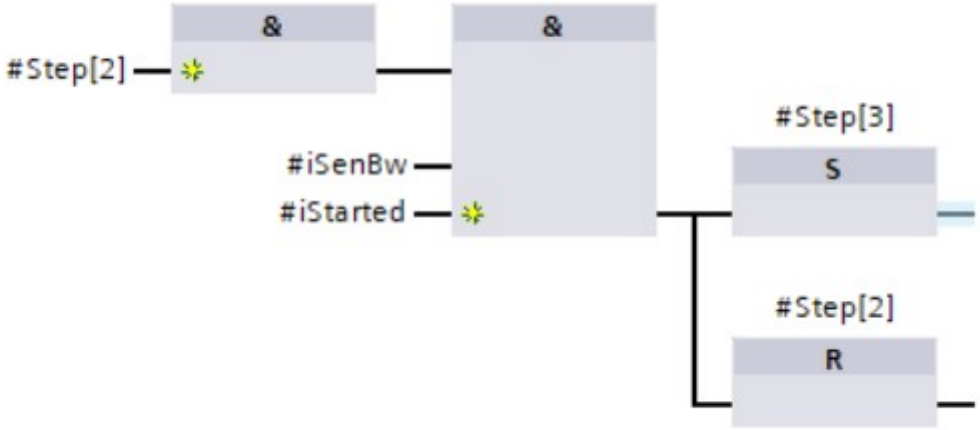
Network 3: Transition-condition step 1 to step 2

Comment



Network 4: Transition condition step 2 to step 3

Comment



Network 5: Transition-condition step 3 to step 1 or step 3

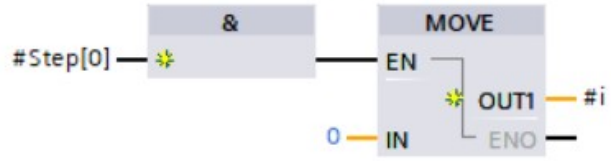
Comment

Network 6: Transition-condition step 4 to step 0

Comment

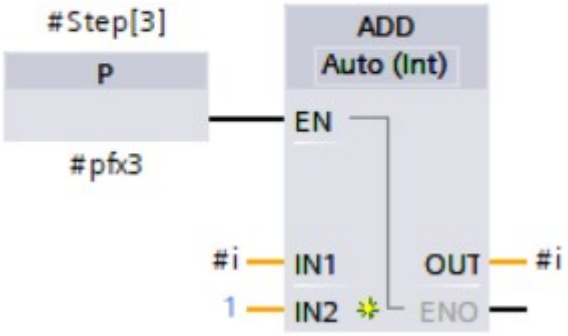
Network 7: Action - set i to 0

Comment



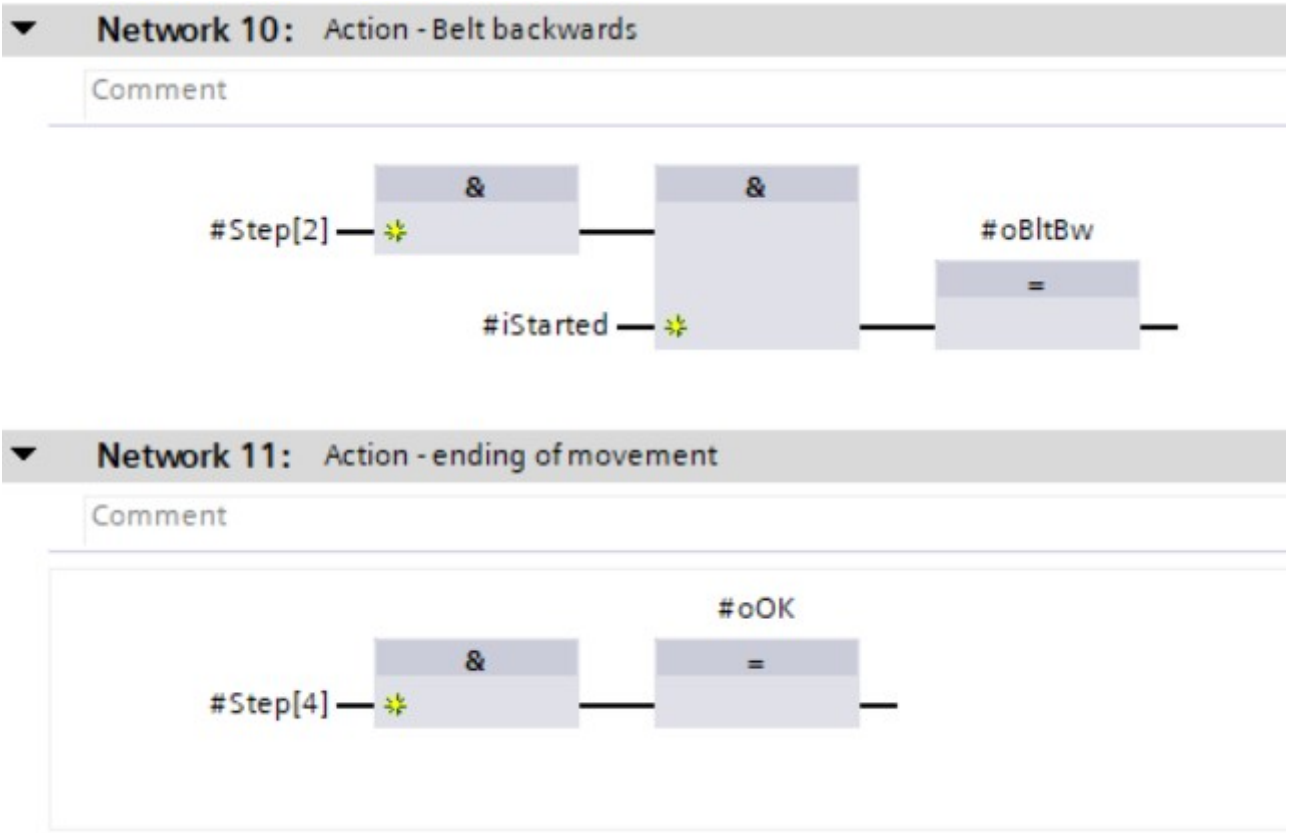
Network 8: Action i= i +1

Comment



Network 9: Action - Belt forward

Comment



Advantages	Disadvantages
Simplicity (1 step = 1 variable)	Initial step is not activated during the first download of the program
	Monitoring of active steps is complicated

GRAFCET programming in LAD-FBD using INT

8.2 Addendum 4 GRAFCET

Converting a **GRAFCET design to software code** is demonstrated with the GRAFCET described in subchapter 2.

The GRAFCET is programmed in the LAD or FBD programming language in the function block (%FB) with the use of STATIC parameters. STATIC parameters can remember their status without the PLC being powered on if they are configured to retain.

FB_PE_BltFwBw

		Name	Data type	Default value	Retain	Setpoint	Comment
1		Input					
2		iInit	Bool	false	Non-retain		Initialisation
3		iStarted	Bool	false	Non-retain		Installation started
4		iSenFw	Bool	false	Non-retain		Front sensor
5		iSenBw	Bool	false	Non-retain		Back sensor
6		Output					
7		oBltFw	Bool	false	Non-retain		Belt forward
8		oBltBw	Bool	false	Non-retain		Belt backwards
9		oOK	Bool	false	Non-retain		Movement finished
10		InOut					
11		Static					
12		pfiInit	Bool	false	Retain		Help variable rising edge iInit
13		pfx3	Bool	false	Retain		Help variable rising edge step 3
14		Step	Int	0	Retain		Active GRAFCET step
15		i	Int	0	Retain		Counter

The programming is split into **3 parts** which are chronologically programmed in different networks:

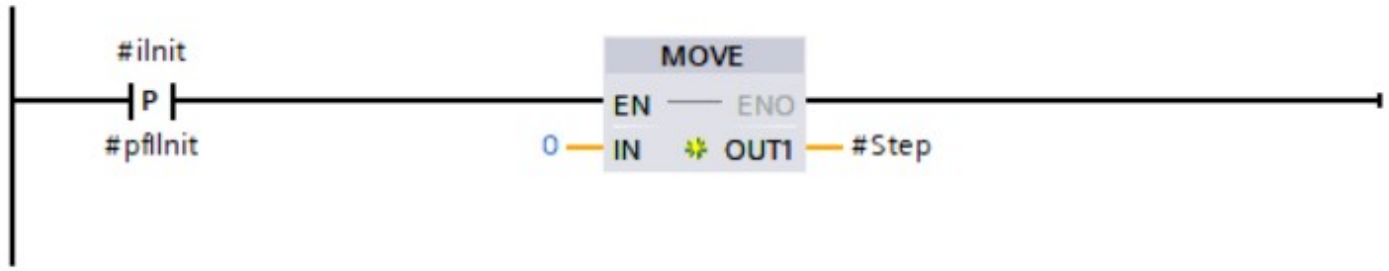
- Initialization (network 1)
- Transition-conditions (network 3 ... x)
- Actions (network x+1 ... last network)

The **GRAFCET programming in LAD/FBD with INT** follows the next rules

- Only the actual step needs to be known
- The actual step is represented by an STATIC INT variable (step)
- The initial value of this variable is the decimal value 0
- The actual value of this variable corresponds to the active GRAFCET step
- The initial step is automatically activated the first time the software is downloaded to the PLC; this is because the INT number initial value is equal to the decimal value 0
- Input "iInit" is always present which causes the activation of the initial step on a rising edge of this input
- Input "iStarted" is always present which processes the result of an external start-stop basic circuit

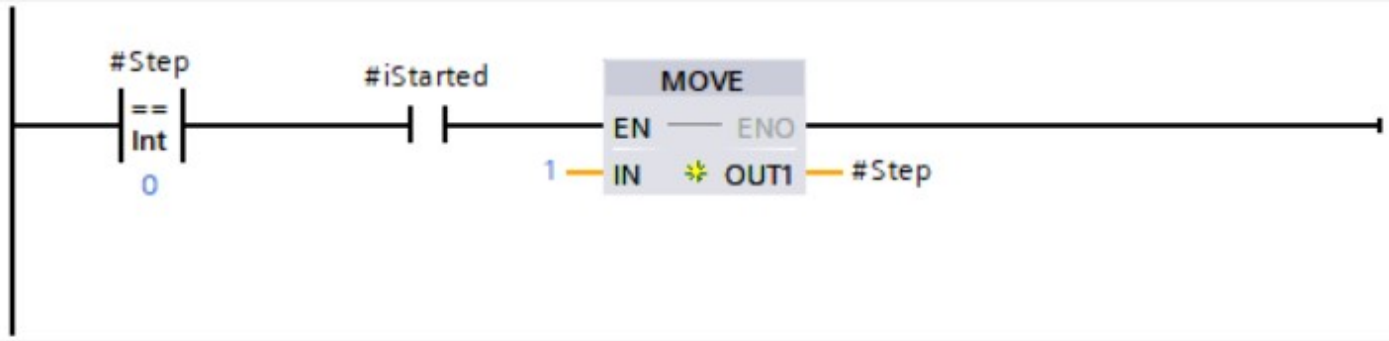
Network 1: Initialization GRAFCET

Comment



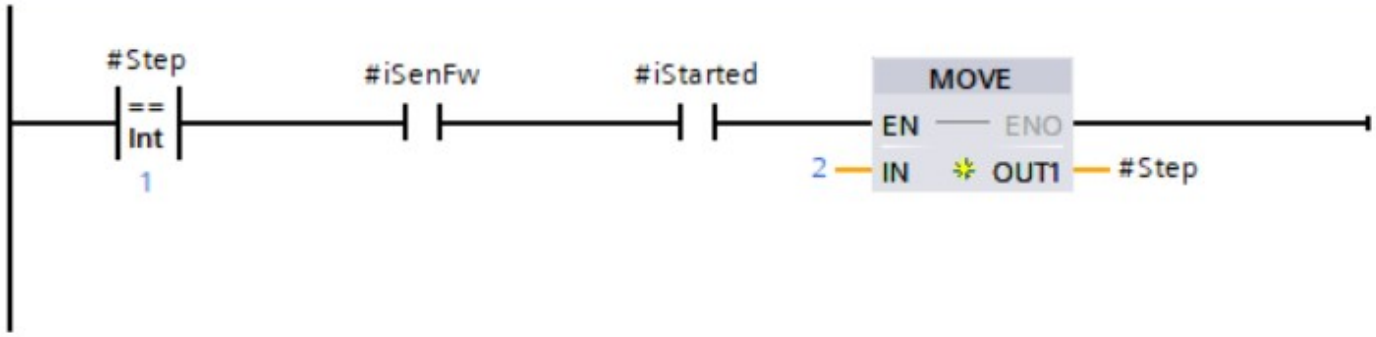
Network 2: Transition-condition step 0 to step 1

Comment



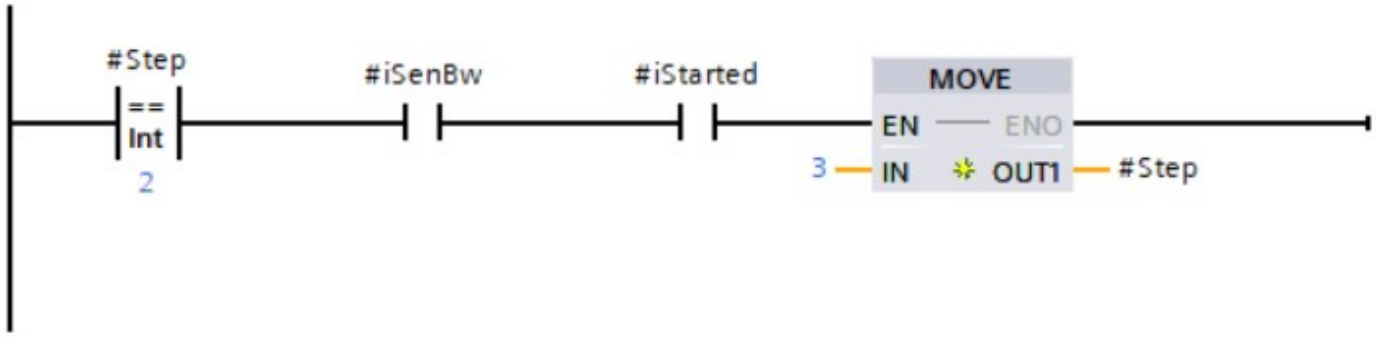
Network 3: Transition-condition step 1 to step 2

Comment



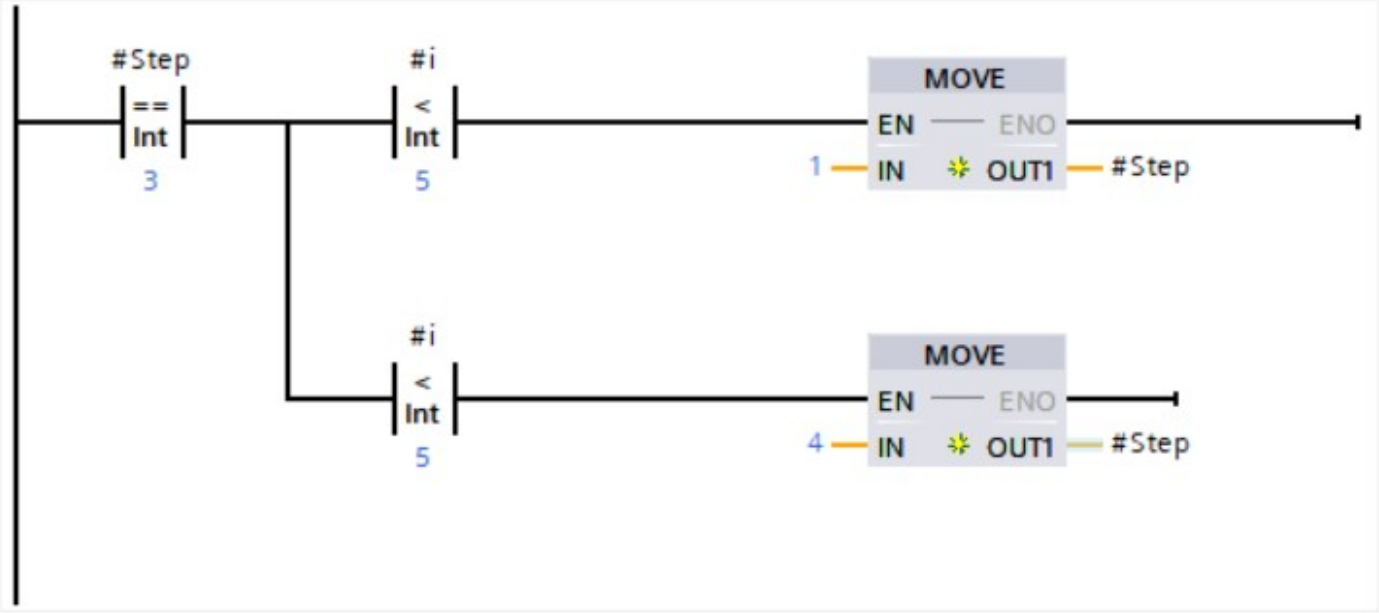
Network 4: Transition condition step 2 to step 3

Comment



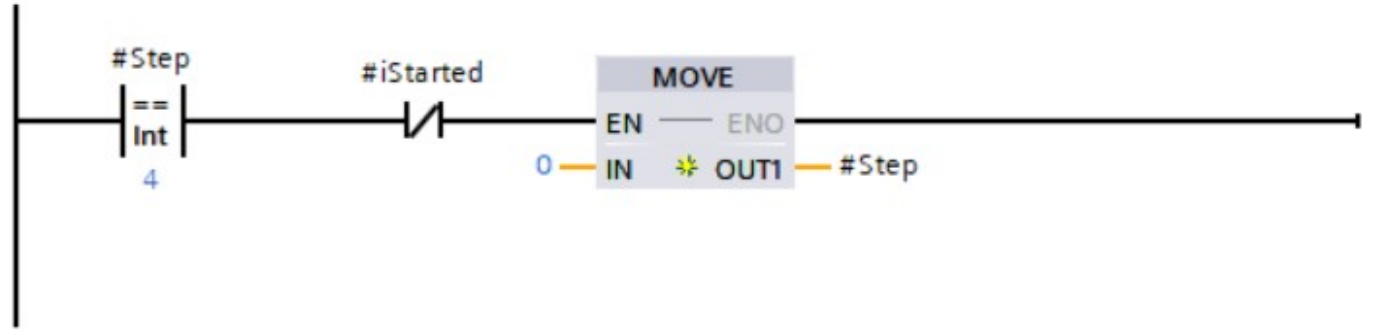
Network 5: Transition-condition step 3 to step 1 or step 3

Comment



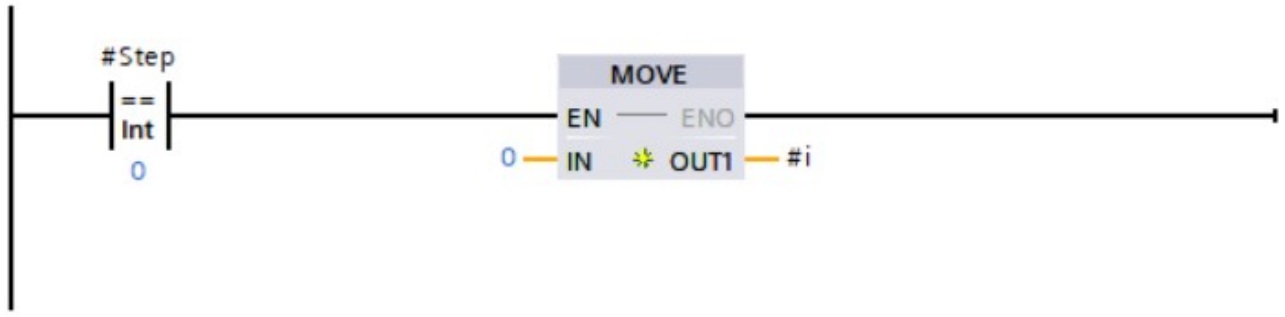
Network 6: Transition-condition step 4 to step 0

Comment



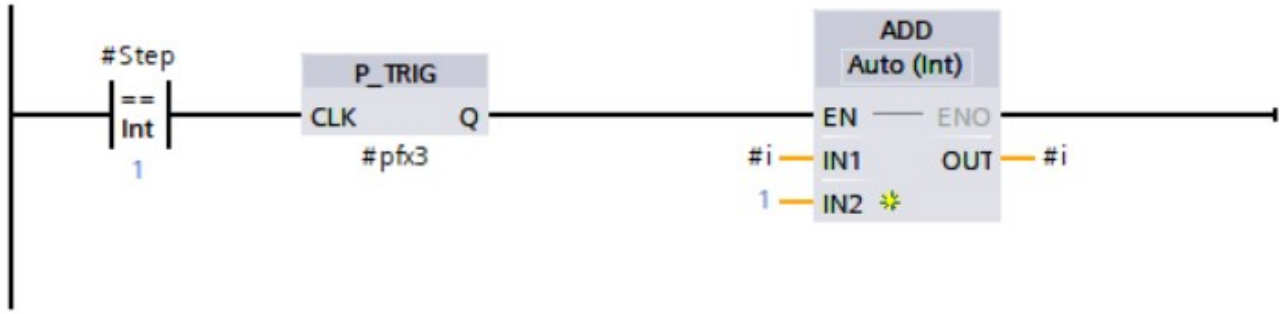
Network 7: Action - set i to 0

Comment



Network 8: Action i= i +1

Comment

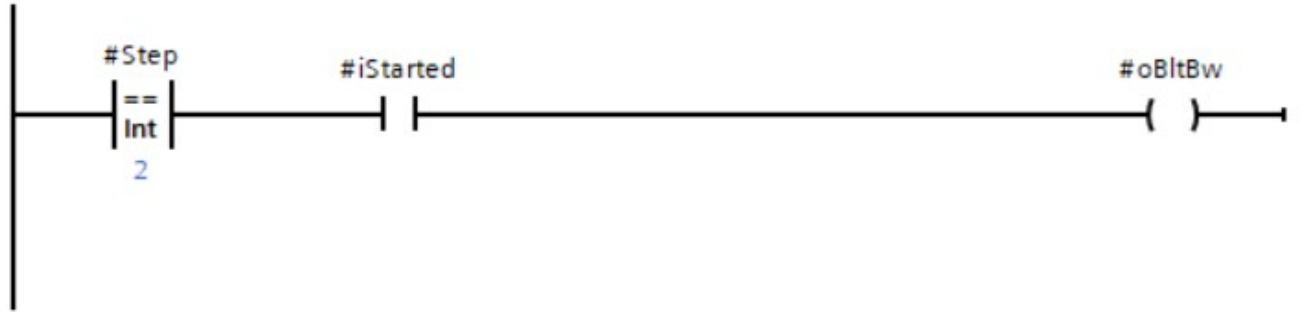


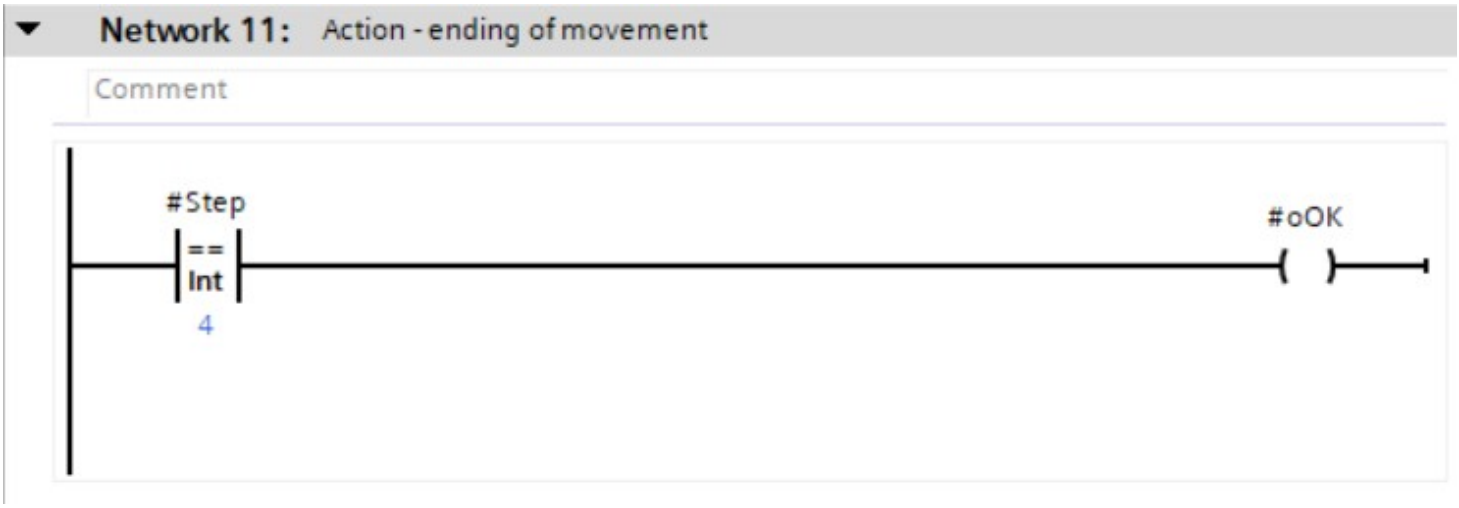
Network 9: Action - Belt forward

Comment

Network 10: Action - Belt backwards

Comment





Advantages	Disadvantages
Initial step is activated during the first download of the program	More complex, advanced programming then with LAD/FBD BOOL method
Monitoring of active steps is easier	Programming of AND-convergence is more complex then with LAD/FBD BOOL variant

GRAFCET programming in ST

8.2 Addendum 4 GRAFCET

Converting a **GRAFCET design to softwarecode** is demonstrated with the GRAFCET described in subchapter 2.

The GRAFCET is programmed in the LAD or FBD programming language in the function block (%FB) with the use of STATIC parameters. STATIC parameters can remeber their status also without voltage if they are configured as retain.

FB_PE_BltFwBw

	Name	Data type	Default value	Retain	Setpoint	Comment
1	Input					
2	iInit	Bool	false	Non-retain		Initialization
3	iStarted	Bool	false	Non-retain		Installation started
4	iSenFw	Bool	false	Non-retain		Front sensor
5	iSenBw	Bool	false	Non-retain		Back sensor
6	Output					
7	oBltFw	Bool	false	Non-retain		Belt forward
8	oBltBw	Bool	false	Non-retain		Belt backwards
9	oOK	Bool	false	Non-retain		Movement finished
10	InOut					
11	Static					
12	pfiInit	Bool	false	Non-retain		Help variable rising edge iInit
13	pfx3	Bool	false	Non-retain		Help variable rising edge step 3
14	Step	Int	0	Non-retain		Active GRAFCET step
15	i	Int	0	Non-retain		Counter
16	ID_pfiInit	R_TRIG				Rising edge iInit
17	ID_pfx3	R_TRIG				Rising edge pfx3

The programming is split into **3 parts** which are chronologically programmed in different networks:

- Initialisation (network 1)
- Transition-conditions (network 3 ... x)
- Actions (network x+1 ... last network)

The **GRAFCET prgramming in ST** is submitted to the next rules

- The use of CASE .. OF .. ELSE control structure which handles the processing of transition-conditions
- Only the actual step needs to be known
- The actual step is represented by a STATIC ANY_INT variable (step)
- The initial value of this variable is the decimal value 0
- The actual value of this variable corresponds to the active GRAFCET step
- The initial step is automatically activated the first time the software is downloaded to the PLC; this because the INT number initial value is equal to the decimal value 0
- Input "iInit" is always present which causes the activation of the initial step on a rising edge of this input
- Input "iStarted" is always present which processes the result of an external start-stop basic circuit

```
//=====================================================
// PART 1 : INITIALIZATION
// =====================================================
// Rising edge
#ID_pfilnit(CLK := #pfilnit,
            Q => #pfilnit);

// Deleting current step and setting the value to 0
// End transition-condition & source transition-condition
IF #pfilnit = TRUE THEN
    #Step := 0;
END_IF;

//=====================================================
// PART 2 : TRANSITION-CONDITIONS
// =====================================================

CASE #Step OF
    0://Transition-condition from step 0 to step 1
        IF #iStarted = TRUE THEN
            #Step := 1;
        END_IF;
    1://Transition-condition from step 1 to 2
        IF #iSenFw = TRUE AND #iStarted = TRUE THEN
            #Step := 2;
        END_IF;
    2://Transition-condition from step 2 to 3
        IF #iSenBw = TRUE AND #iStarted = TRUE THEN
            #Step := 3;
        END_IF;
    3://Transition-condition from step 3 to 1 or step 4
        IF #i < 5 THEN
            #Step := 1;
        ELSE
            #Step := 4;
        END_IF;
    4://Transition-condition from step 4 to step 0
        IF #iStarted = FALSE THEN
            #Step := 0;
        END_IF;
END_CASE;
```

```
43  //=====================================================
44  // PART 3 : ACTIONS
45  // =====================================================
46  // Counter i
47  // STEP 0 => i:0
48 IF #Step = 0 THEN
49      #i := 0;
50  END_IF;
51
52  // STEP 3 => i:=i+1
53  #ID_pfx3(CLK:= #Step=3,Q=>#pfx3);
54 IF #pfx3 = TRUE THEN
55      #i := #i + 1;
56  END_IF;
57
58  // Output conveyor belt forward
59 IF #Step = 1 AND #iStarted = TRUE THEN
60      #oBltFw := TRUE;
61      #oBltBw := FALSE;
62  END_IF;
63
64  // Output conveyor belt backwards
65 IF #Step = 2 AND #iStarted = TRUE THEN
66      #oBltBw := TRUE;
67      #oBltFw := FALSE;
68  END_IF;


70  // Output conveyor belt OK
71 IF #Step = 3 THEN
72      #oOK := TRUE;
73  ELSE
74      #oOK := FALSE;
75  END_IF;
```

Advantages	Disadvantages
Initial step is not activated while the the first download of the program	More complex programming than LAD/FBD variant
Smaller programming then LAD/FBD variant	Programming of AND-convergence is more complex than the LAD/FBD BOOL method
Monitoring of active steps are easier	Debugging [5] in ST is harder than in FBD/LAD

Characteristics and defenitions

8.2 Addendum 5 Controllers

Controllers are used mainly to control continuing processes. Also non continuing can be controlled. This way a GRAFCET can run t he controller as action in a determined step. We use analog sensors to control analog or digital actuators.

Controllers are defined by several characteristics which are explained in the table below.

Definition	Abbreviation	Description
Process value	X *PV*	The value measured by the analog sensor *German name = Istwert*
Setpoint	W *SP*	The value that we want to achieve. *German name = Sollwert*
Loop manipulated value	Y *LMN*	The result that the actuator that affects the process adjusts *German name = Regelabweichung*
Error	E *ER*	Difference between measured values and the setpoint *German naming = Stellgrösse*
Hysteresis	H	The area wherein an actuator gets turned on and off.
Dead band	XDo *Db*	The area in which multiple digital acutators get turned off. With analog actuators the status of the output that isn't in the dead band changes.H *German name = Bandbreite*
Dead time	T0/Tt Td	The time delay between the change of the loop manipulated value and the change of the measured value. *German name = Totzeit*
Gain	Kr *GAIN*	The proportional action or P-action amplifies the output in proportion to input. The magnitude is determined by the gain factor, which can be positive or negative.
Reset time	TI	The integrating action ensures a constant sum of the error and keeps outputting more signals depending on how long an error exists between the measured and desired value. The integrator or I action is characterized by the time response of the integrator

Definition	Abbreviation	Description
Derivative time	TD	The D action responds to the rate of change of the error. So only when creating a step will the D action give its contribution to the controller. The differentiating action or D action is characterized by the time response of the differentiator

The measure difference is the difference between the loop manipulated value and the measured value.

E=W-X

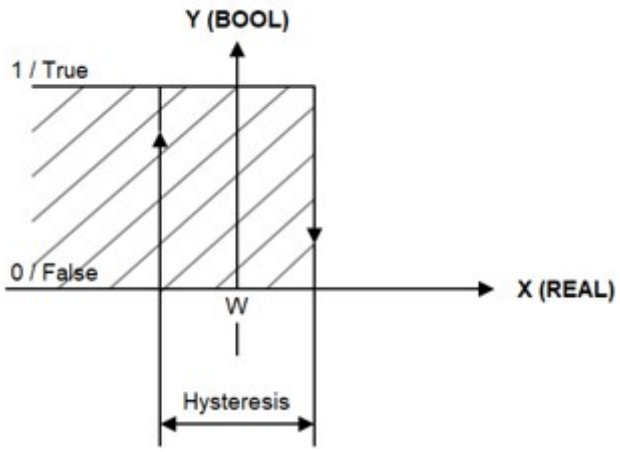
Notice that the control difference can have a positive or a negative value.

On-off circuit

8.2 Addendum 5 Controllers

The **on-off circuit** gets used to switch a control output Y [BOOL] on or off in function of a measured value X [REAL] and a set value W [REAL]. The on-off switch ensures that the actuator does not switch on and off too often by using 2 threshold values, namely:

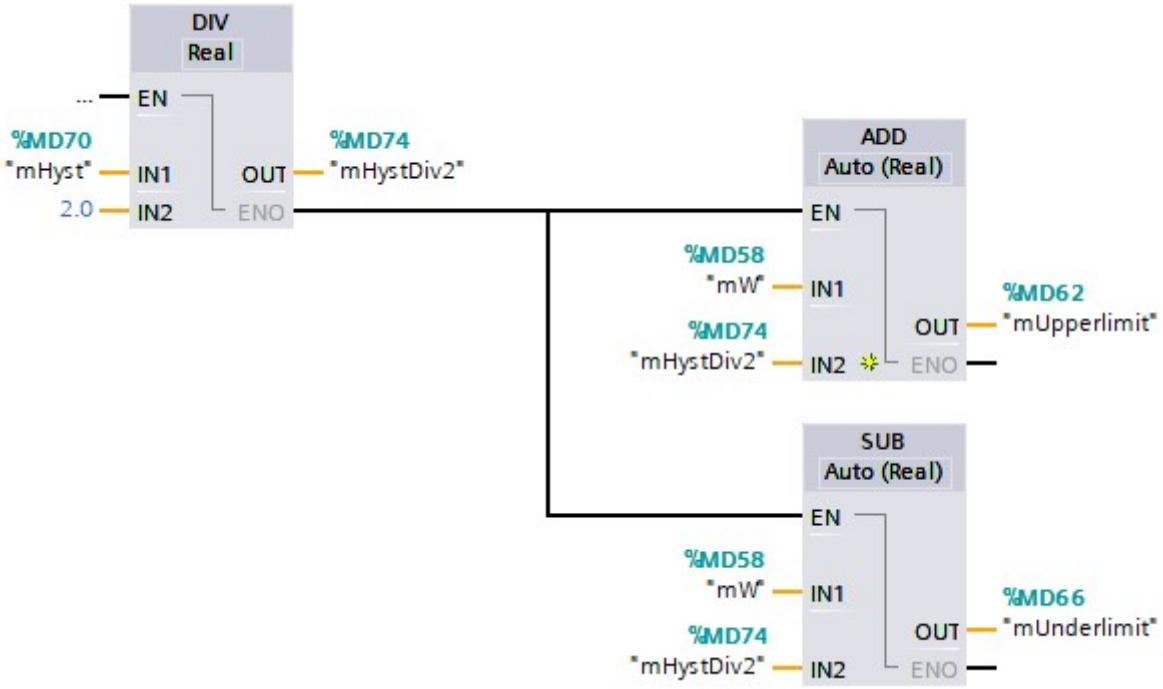
- The switch-on threshold value (lower limit)
- The switch-off threshold value (upper limit)



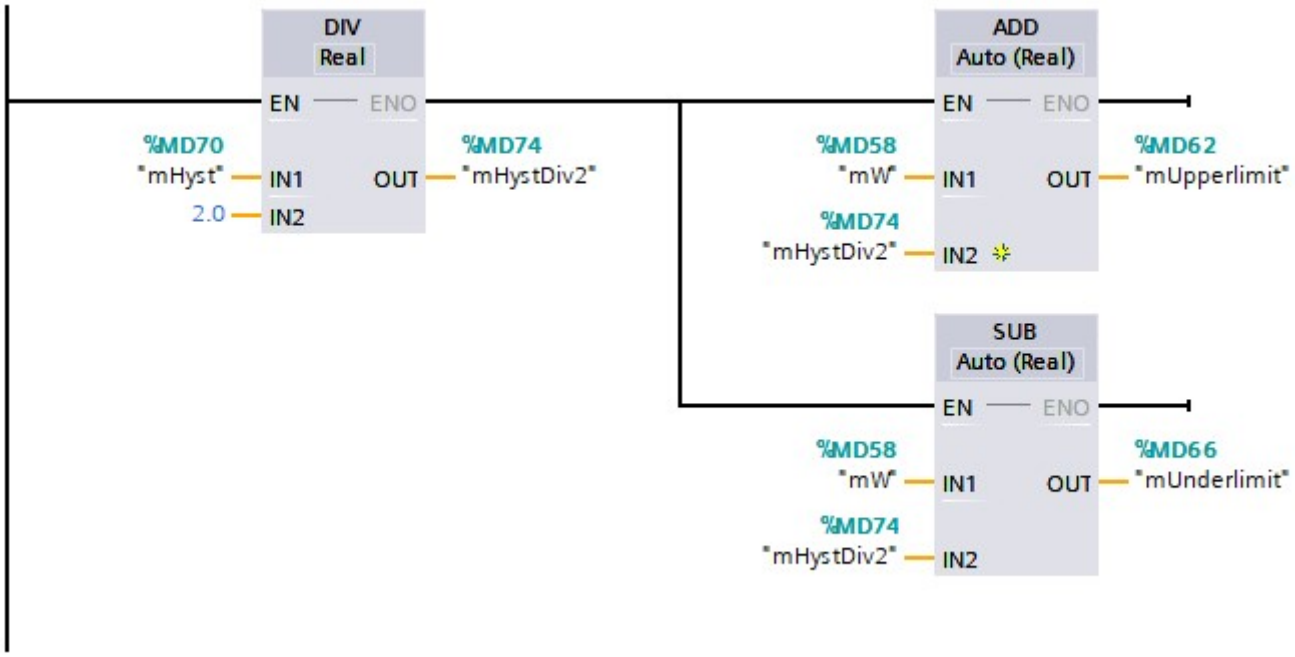
The difference between the switch-on and switch-off threshold values becomes the so called hysteresis. The following mathematical formulas apply:

Switch-on threshold or lower limit = X - Hysteresis/2.0
Switch-off threshold or upper limit = X + Hysteresis/2.0

FBD



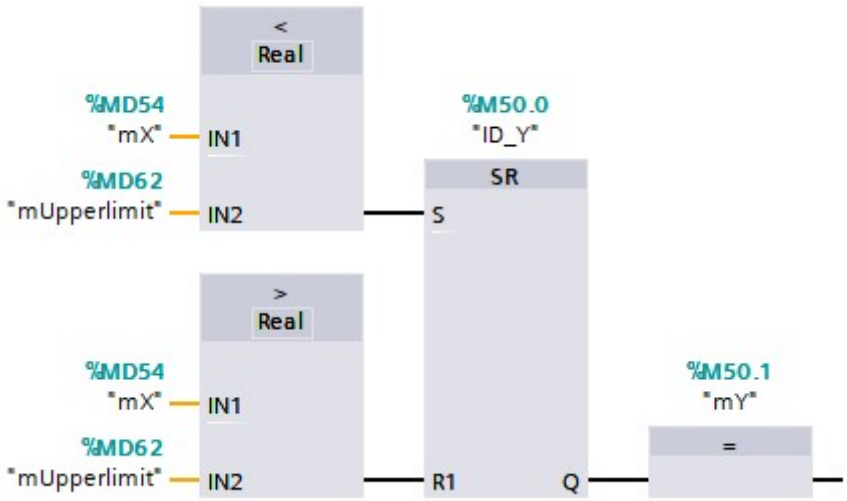
LD



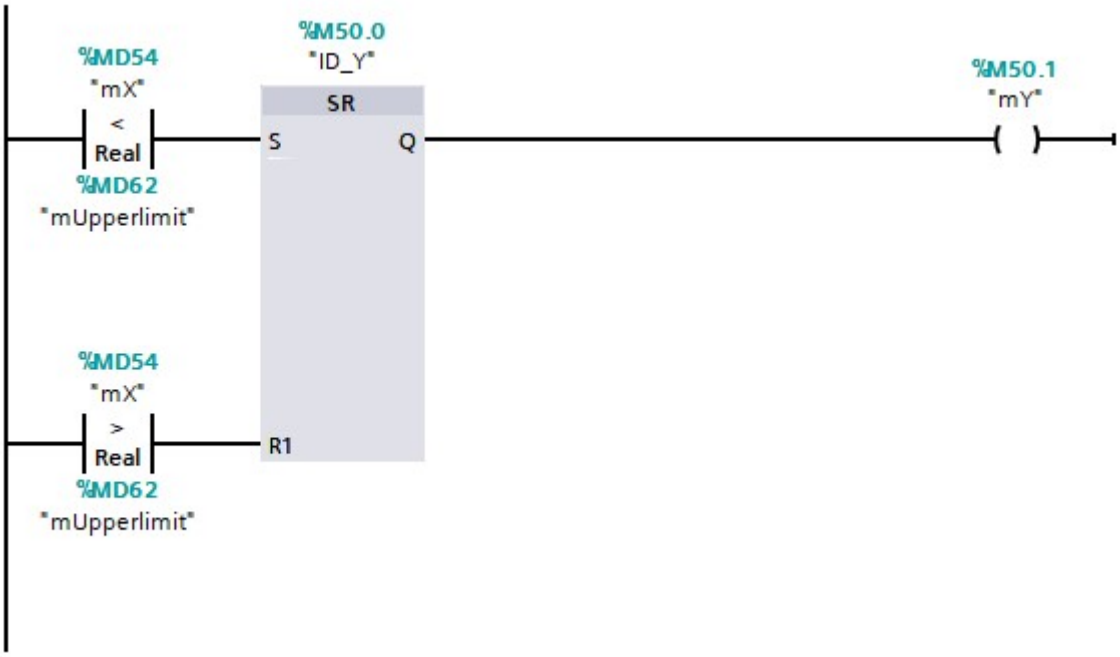
In case the process value is lower then the switch-on threshold, the loop manipulated value will be turn off.

As soon as the process value reaches the switch-off threshold, the loop manipulated value will be turn off.

FBD



LD



Example on-off switch - Heating in a home

Homes are often equipped with a thermostat to measure and control the temperature in a room.

- The thermostat measures the room temperature = measured value X
- The ideal temperature is entered on the thermostat = desired value W
- If it is too cold, the thermostat ensures that the boiler is switched on = closed contact = control output Y on
- If it is too hot, the thermostat ensures that the boiler is switched off = open contact = control output Y off
- Depending on the type of thermostat, the hysteresis is a fixed value or adjustable (order of magnitude 0.5 to 1.0 ° C)

PID controller

8.2 Addendum 5 Controllers

Functioning

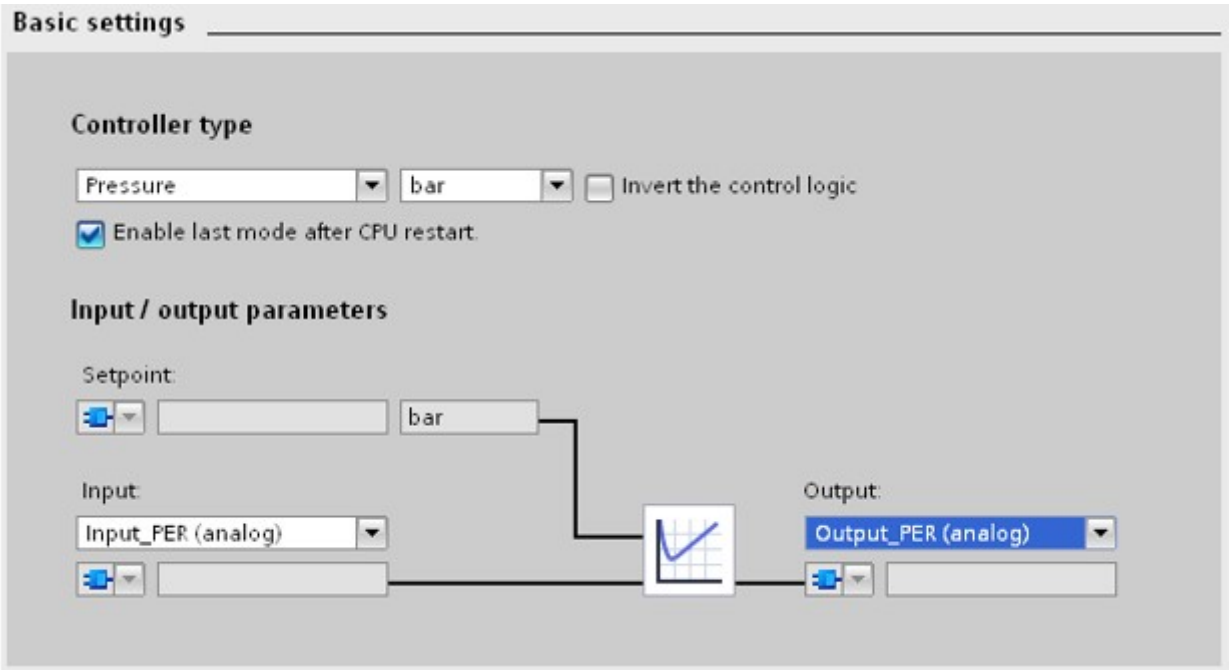
A PID controller is used to control processes via an analog actuator
[Y = INT or WORD]. A PID controller consists of several sub-functions. So, one distinguishes:

- P or Proportional action
- I or Integrative action
- D or Differentiating action

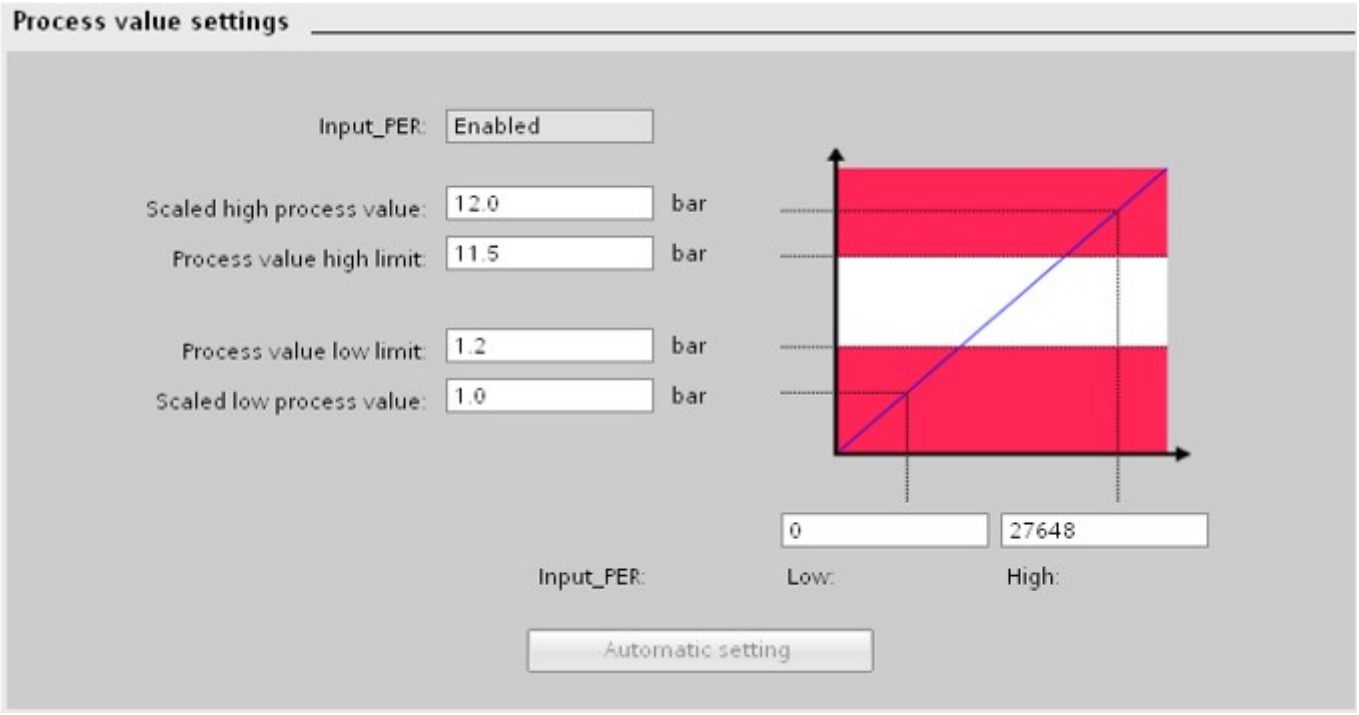
Compact PID controller

The compact Siemens PID controller is limited compared to the continuous PID controller in its possibilities. Most of the parameters can be set via associated pop-up menus and can therefore only be set using a programming device (PC with TIA Portal).

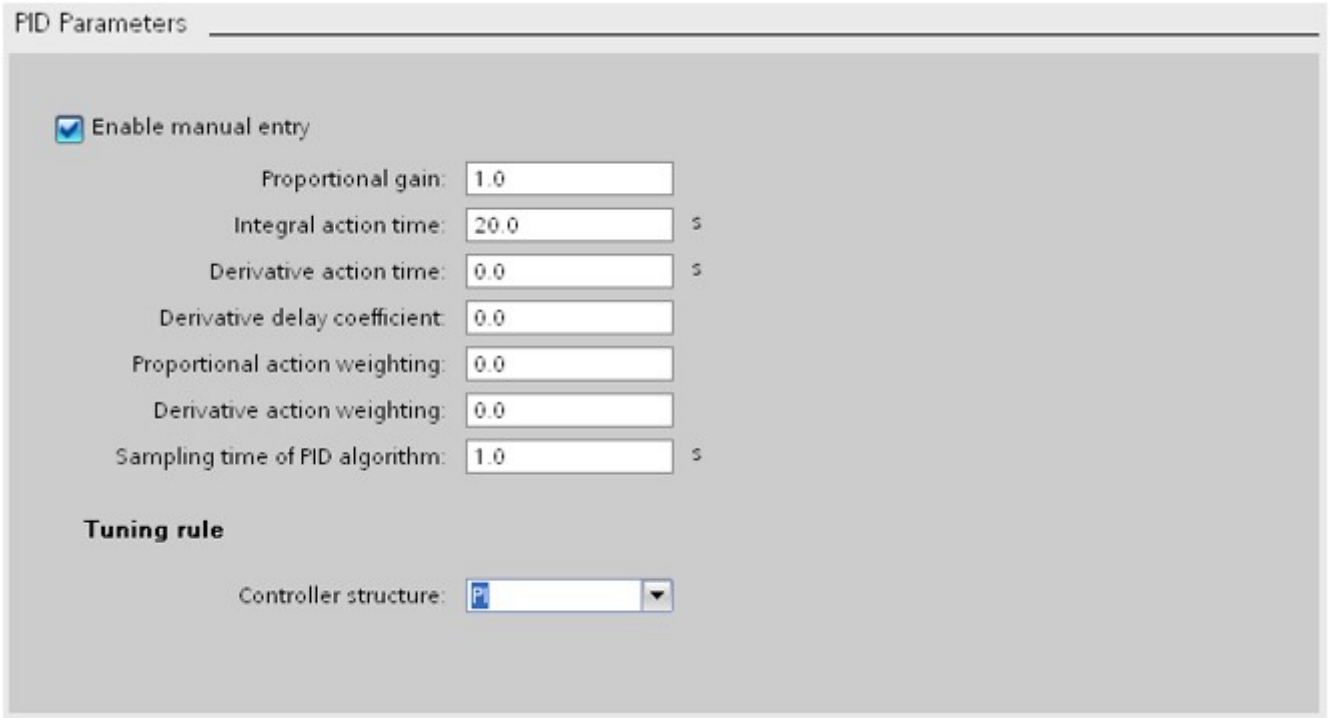
As an advantage it can be quoted that configuring this controller is done by using these pop-up screens which is much easier. This way one can make a choice between the different quantities and different SI units and one can opt to operate via a normalized input (output) or a periphery (entrance exit).



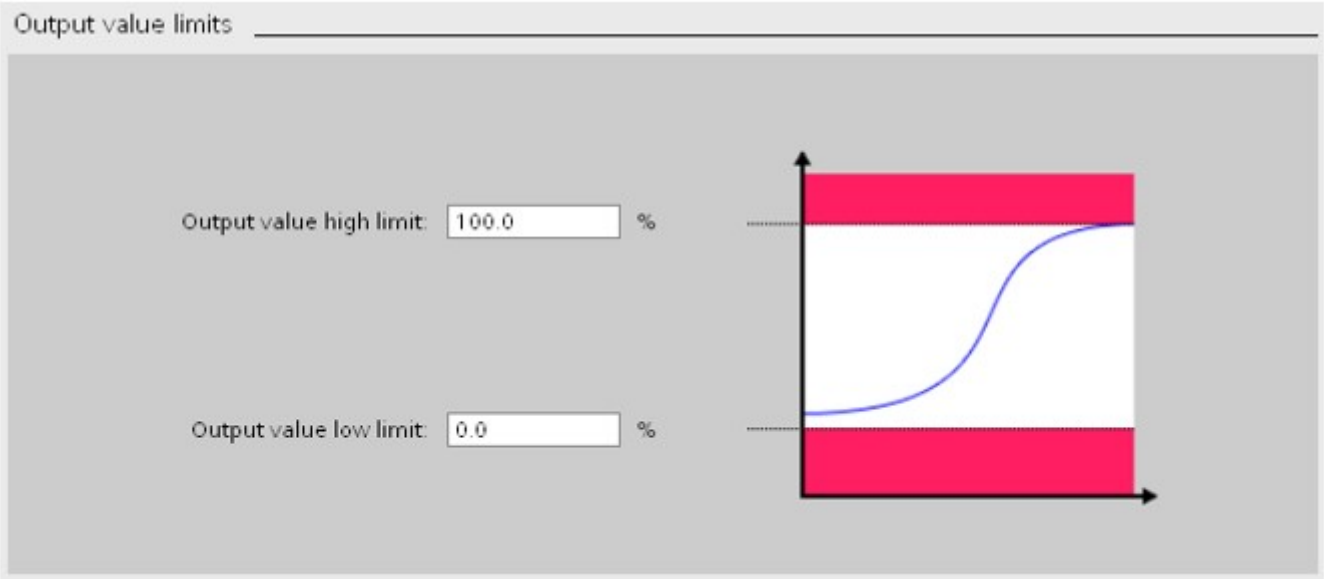
If you opt for a peripheral input, you can convert it to the correct measuring range using the screen *“Process value settings”*.



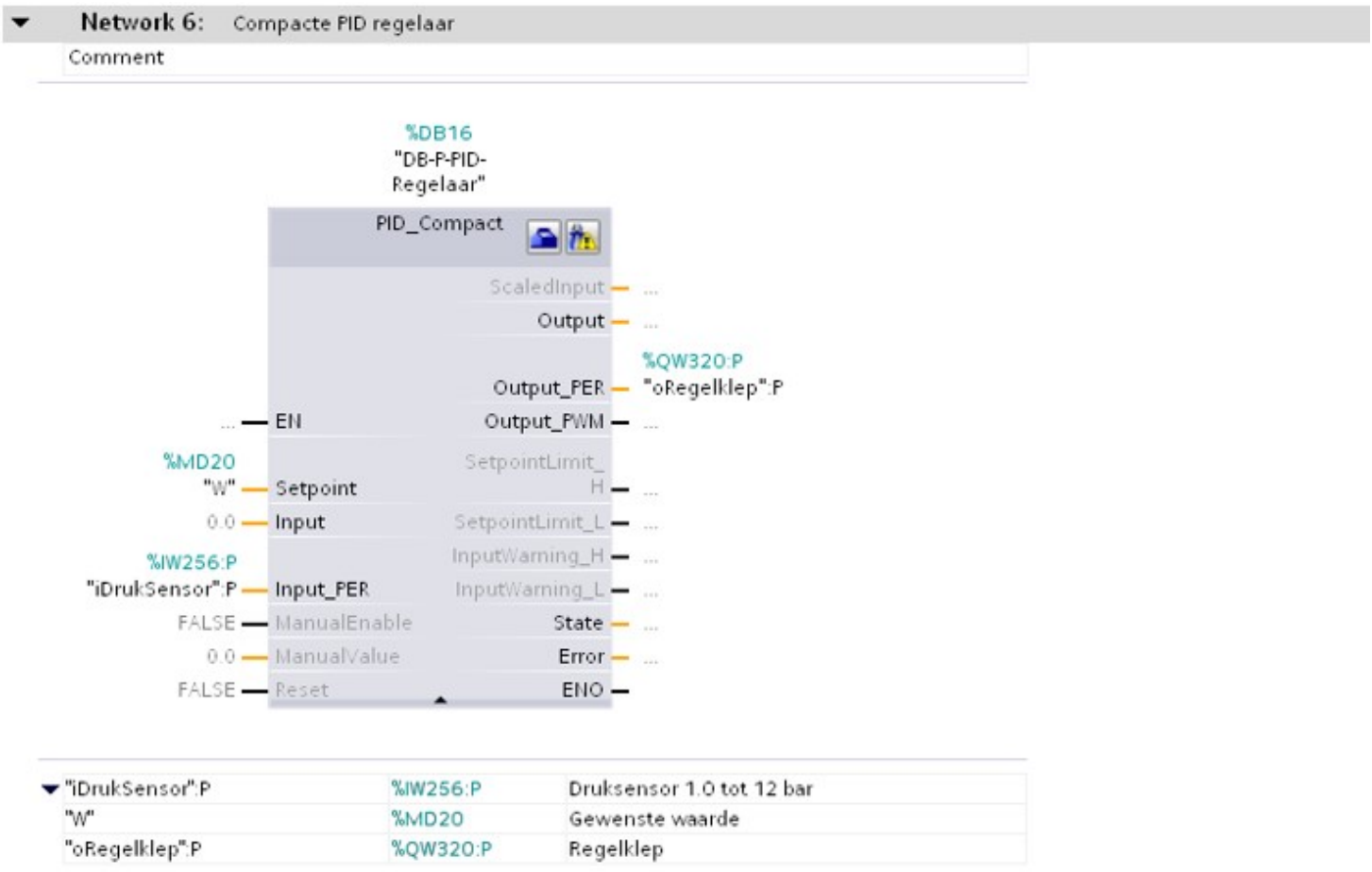
The P, I and D action can be set via the screen *“PID Parameters”*. Notice that the different actions cannot be selected individually. One can only make a choice between a PID and a PI controller. Note that every action is separately correctable. For example, one can calculate the weight of the P action and the D-action can be individually adjusted to even turn off and one can assign a wait coefficient for the D action.



The output can be limited just like a continue controller. This can be done in the *"Output value limits"* screen.



Because of the different parameters being adjustable by using pop-up screens, the PID building block will be compacter than the continuing Siemens PID controller.



Programming example – Continue PID controller

In the programming example below will you find the programming of a continue PID controller.

The analog pressure sensor %IW256 gets formed internally so that the following results are obtained:

- PV_NORM = (output CRP_IN) . PV_FAC + PV_OFF
- PV_NORM = (output CRP_IN) . 0,11 + 1.0
- 1.0 bar = (0%) . 0,11 + 1.0
- 12.0 bar = (100%) . 0,11 + 1.0

The loop manipulated value is variable adjustable suing %MD20. This way we can adjust the loop manipulated value with changing the user program.

The dead band is adjustable at 1.2 bar. In case (W - XDo/2) < X < (W + XDo /2)
The output of the controller doesn't change.

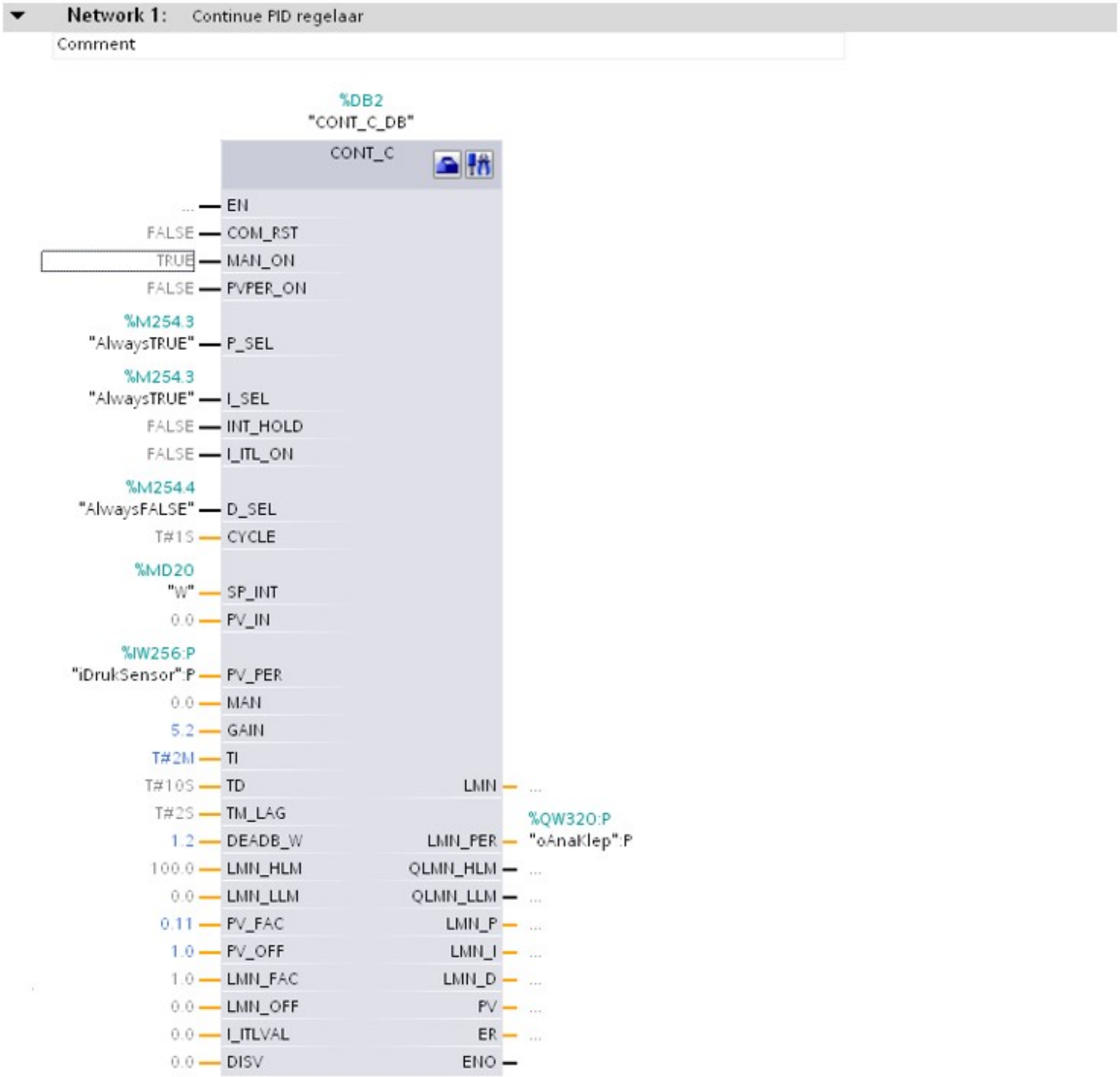
The controller is adjustable so that:

- The P-action is activated and the gain is set to 5.2
- The I-action is activated and the reset time is set to 2 min.
- The D-action is deactivated

The output is limited between 0 and 100+ (standard settings) and transformed to the peripheral output %PQW320.

Notice that the values are shown in light grey colour which are the standard values.

The PID buildblock gets saved by TIA PORTAL in the folder“Program Blocks\System Blocks\Program Resources”

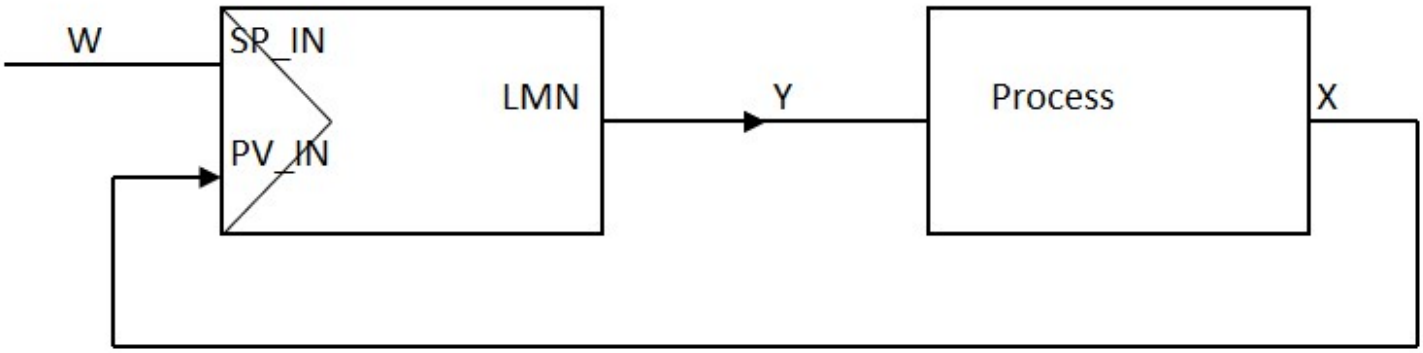


Controller cicruit structuring

8.2 Addendum 5 Controllers

Singular control circuit

This is the simplest control circuit. The controller keeps the controlled unit [X] stable on the set value [W]

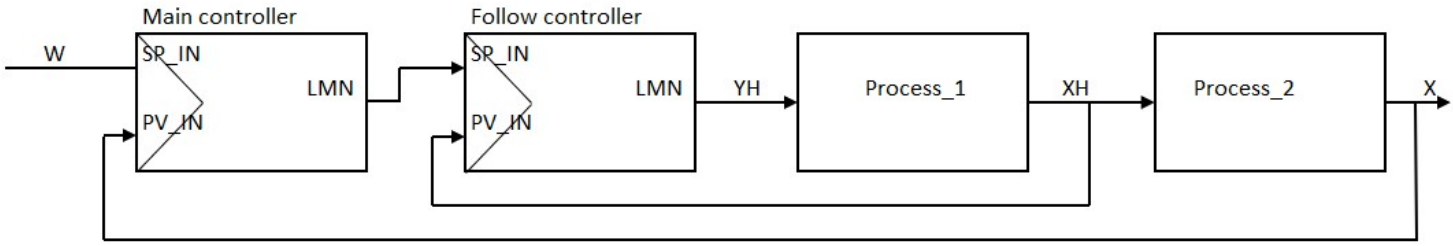


Singular feedback control circuits are commonly used where the influence of the controldynamic and the control result are minor.

Cascade controller or master/slave controller

The imperfections of a single control loop are mainly improved by a cascade control. In cascade control, the control loop becomes divided into a main control loop and an auxiliary control loop. For this there is at least one main control controller (master) and one auxiliary or follower control (slave) required.

- The main or control controller regulates the main control variable to the desired one value [W]
- The main or control controller returns an analog SI unit [Yf] which is processed by the auxiliary or follow-up controller as the desired value [Yf = Wh]
- The result of the auxiliary or tracking controller [Yh] influences the process of the analog measurement of the main or control controller



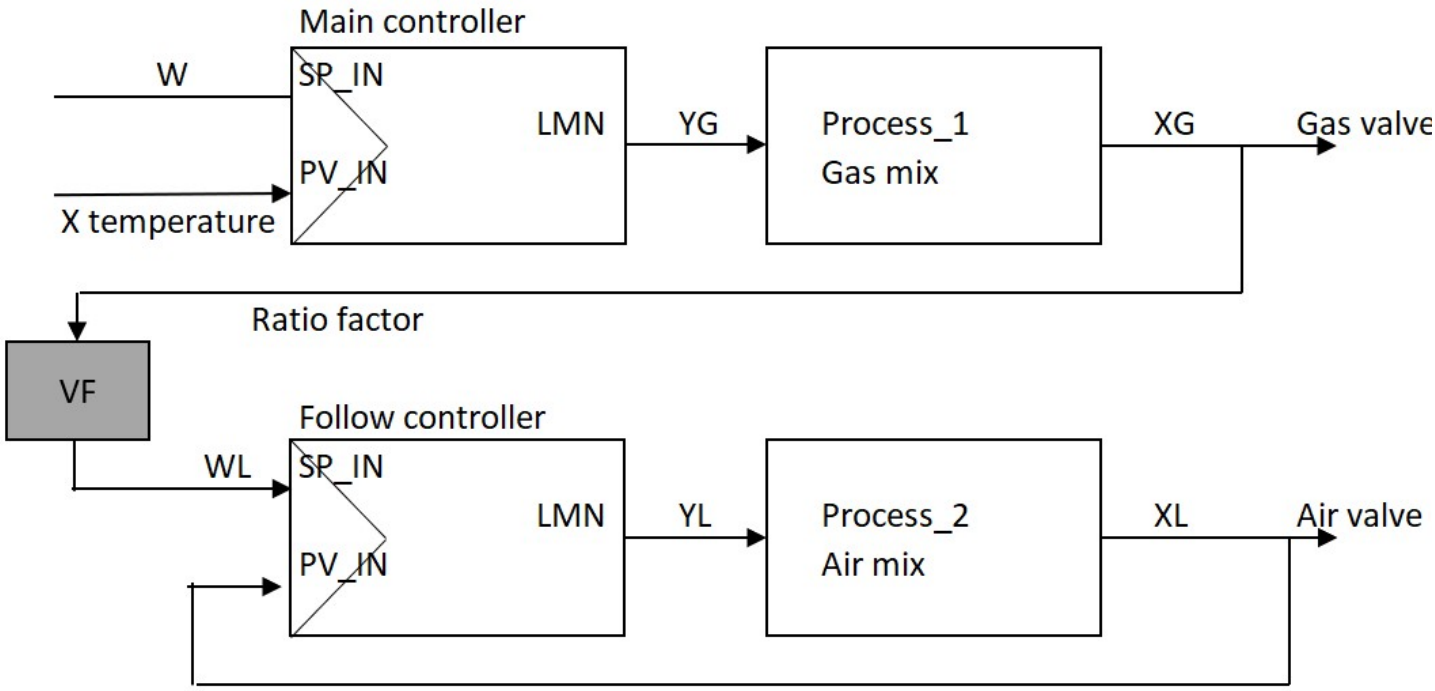
Depending on the needs a cascade controller can be equipped with multiple help controllers. Consequently you could place multiple help/follow controllers behind a head controller.

Ratio controller

The ratio controller has just like a cascade controller a head controller and a help- or follow controller. The intention is to have multiple processunits in a constant ratio. The ratio controller gets used mostly

for controlling 2 flow streams, between these 2 flow streams a determined ratio needs to be present.

The simplest example of a ratio controller is for example the gas and air supply in a gas incinerator. The head controller controls the amount of gas, depending on the desired oven temperature. The help or follow controller gets controlled by the actual value of the head controller which then controls the amount of air.



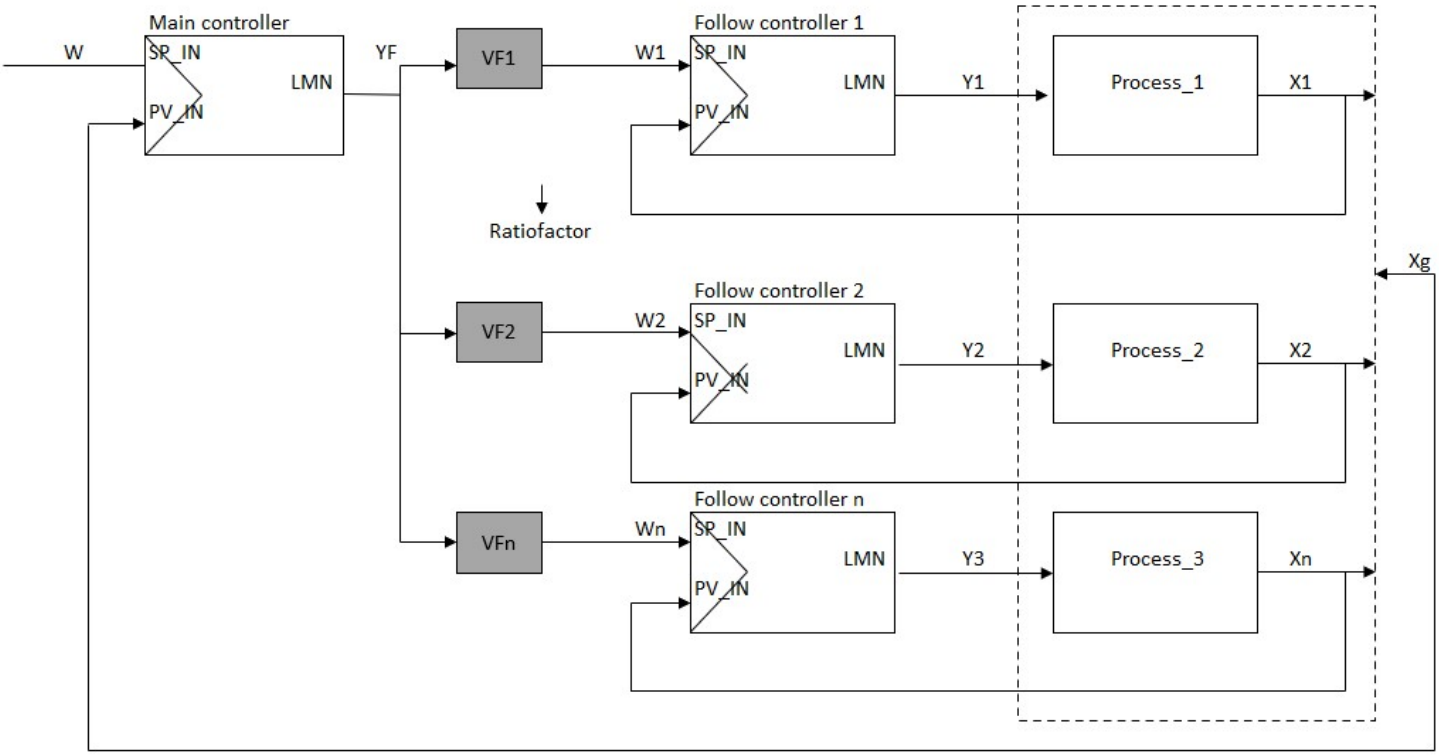
The ratio between both SI units, gas and air gets used with a ratio factor on the setpoint for the control or follow controller.

Mix Ratio Controller

A mix ratio controller is a ratio controller with a main controller and several subordinate auxiliary or follow-up controllers.

With the mixing ratio control it is possible to make a product from several basic components consists of mixing [X1, X2,… .Xn] into a final product with a constant mixing ratio.

The main- or control-controller controls the joint composition [Xg] it controls all subordinate component controllers with its control output [Yf].The percentage share of each component [X1, X2 ..Xn] with respect to the joint mixing ratio [Xg] is entered with the ratio factor "for".



Split range controller

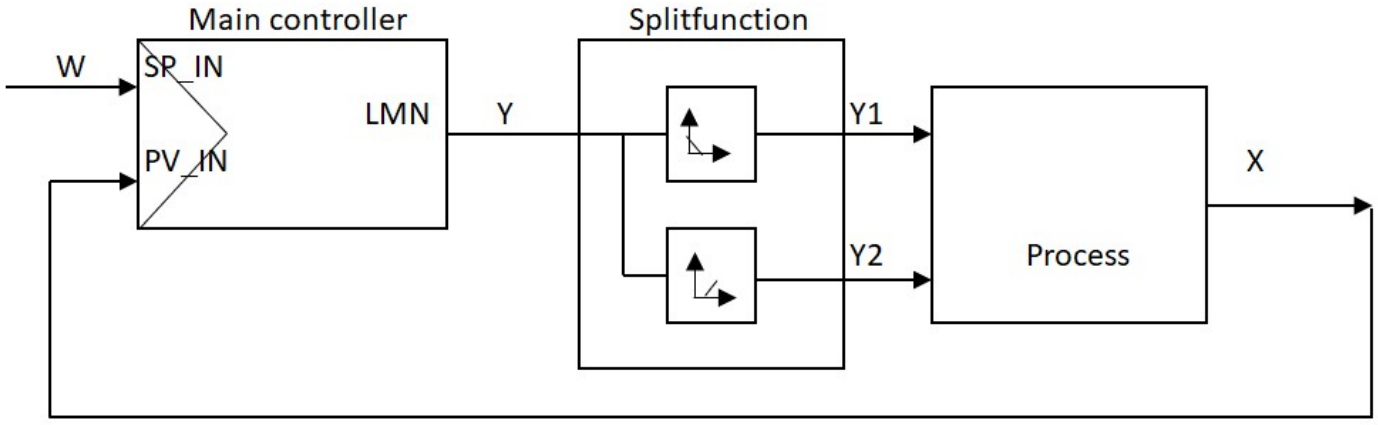
Some applications need multiple ajustment ratios, that can be achieved with only one adjusting device, for example a controlvalve.

A split range controller is a controller with one controlling SI unit and multiple controlled SI units.

The controlling unit divides its actions over for example two adjustment devices.

Split range controllers get used a lot in systems for heating and cooling.

In case the controlled variable varies over a big range, will it be useful for applications.



The controller output gets split in parallel paths, each with an adjusting device.

Software model following ANSI-ISA-88

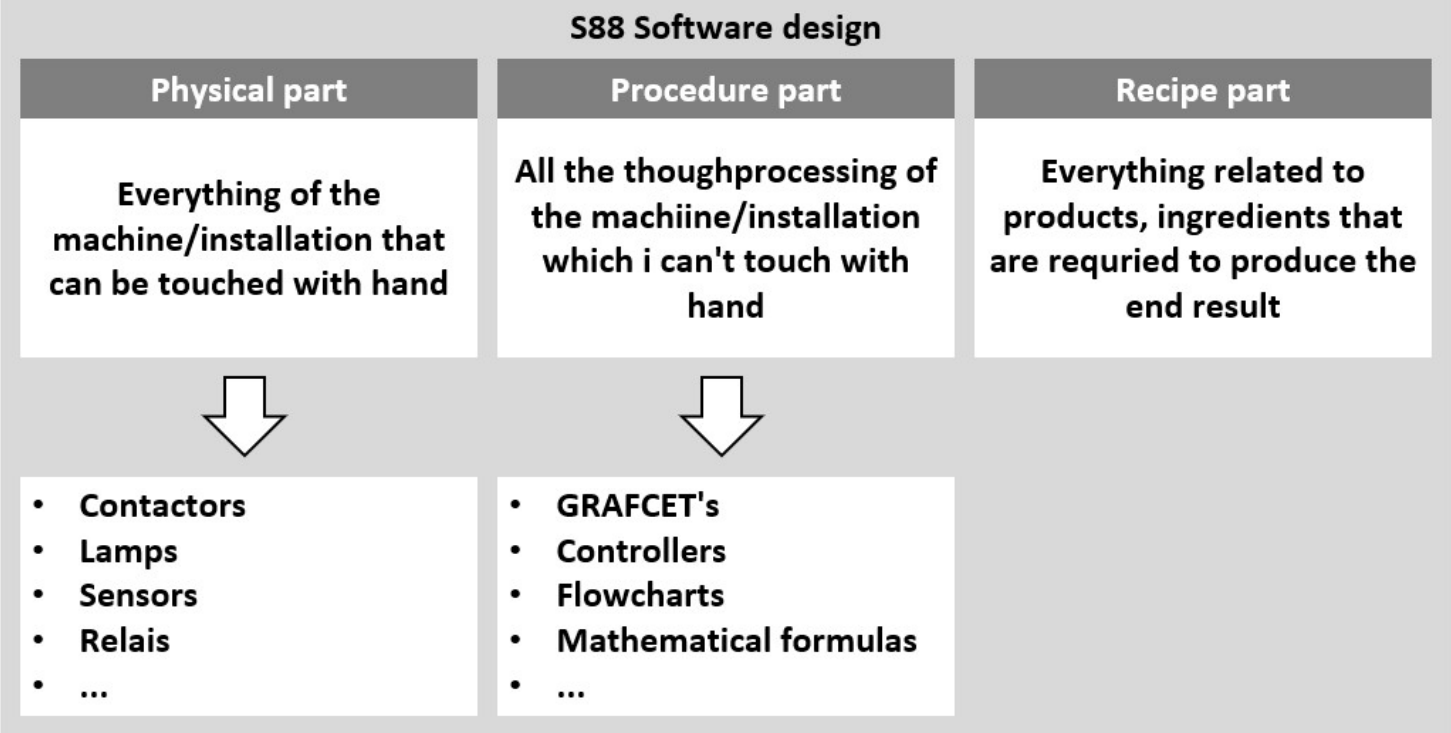
8.4 Addendum 6 S88

The different parts

The ANSI/ISA-88 norm or the **S88 software model** is a norm that describes how a machine/installation (batch)process can be subdivided in different parts.

The advantage of this is that one big problem[6] will be divided in different smaller partial problems; smaller problems are often easier to solve than bigger problems. A strategy will be developed for each small partial problem that will cause the bigger problems to be solved one by one.

- The physical part
- The procedure part
- The recipe part

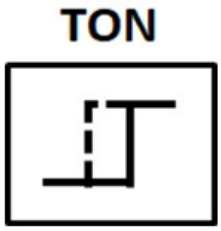
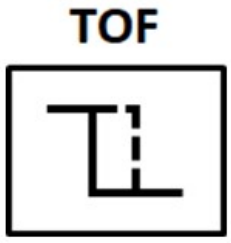
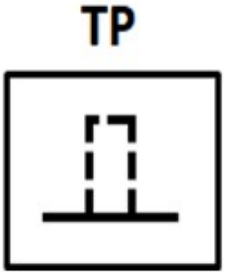


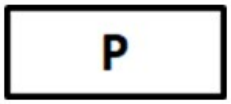
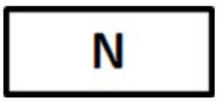
Because the S88 software model is very abstract and expanded we will be using a very simple form in this course:

- The back spine is the physical part
- The procedure part gets integrated in the physical part.
- The recipe part won't be applied

This means that the software building blocks only get designed for the processing of the physic part or only the procedure part.
The building blocks will exhange information between each other.

The following chapters describe different building blocks that are included in the software library. The operation of each individual building block is explained with the use of a operation scheme with the following symbols:

Symbol	Description
	AND port
	OR Port
	NOT connection
	Connection
	Risedelay
	Drop-off delay
	Time Puls

Symbol	Description
	A collection of instructions that together a combination basiccircuit form (in this case the start-stop circuit)
	Positive flank signal
	Negative flank signal

The operation scheme gets drawn up so that every incoming signal is as far to the left as possible and all output signals are to the right. Connections are when needed drawn with dotted lines (with crossing lines) to avoid confusion.

Physical part - Control modules

Control modules are software blocks that
- Process sensor input singals (%I)
- Activate / control output signals (%Q)

This way a control module gets represented by a certain type of actuator or sensor and by preference gets included in the software library.
Control modules are preferably progammed in "Function buildblocks" whereby, the TAG-naming gets expanded with the letters CM.

Sensors

8.4 Addendum 6 S88

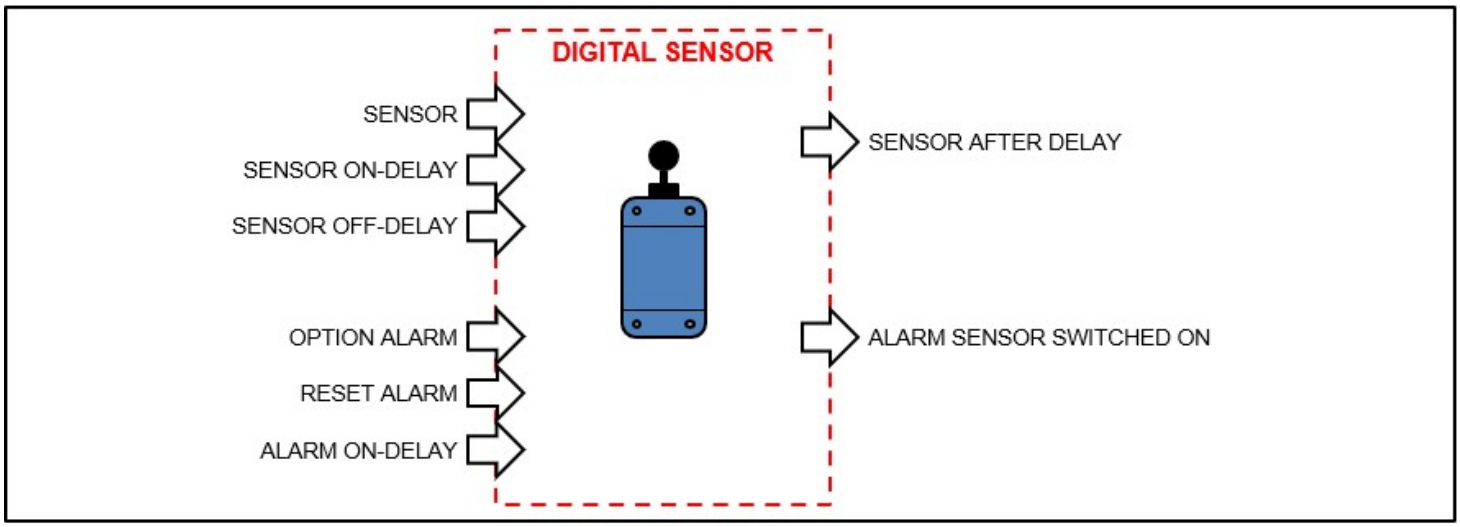
Digital sensor

A **digital sensor** (Ex.:limit switch, inductive sensor, capacitive sensor, tuning fork,...) processes mainly the presence of a product, object, person, etc. It has 2 conditions which indicate whether these products, objects or persons are preset or not.

Functionally seen these sensors monitor:

- The correct automatic process whether or not with the needed delay (example, opening of a door with the help of a photocell after which the door stays open for a bit)
- The protection against defects (example, overflow protection)

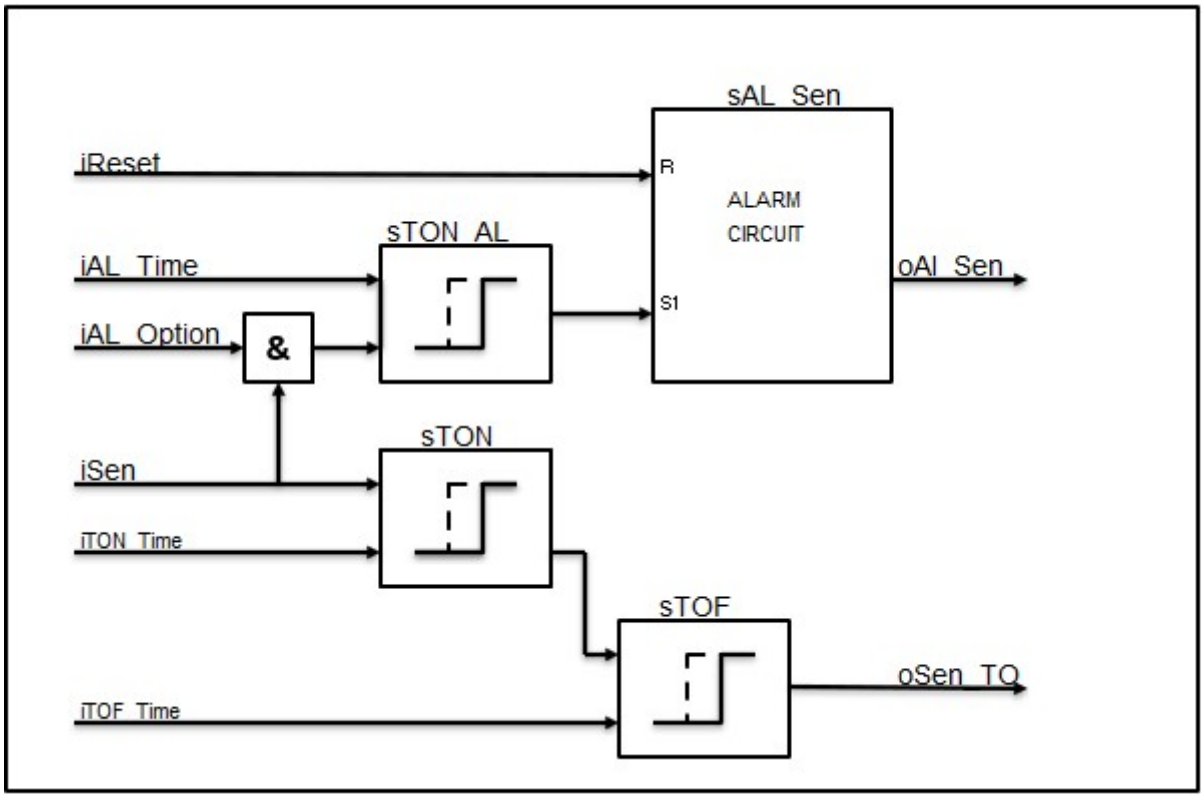
One can design a building block wherein all the above functionalities are processed. As a Consequently, this building block is the software representative of a digital sensor.



This building block belongs to the group of **control modules** are provided with following functionalities:

- The module will ensure that the sensor signal (iSen) which optionally can be delayed with a on-delay(iTON_Time) and/or a off-delay (iTOF_Time) for a correct operation, which then provides the output signal (oSen_TO)
- In case the option alarm (iAL_Option) is enabled, the module will activate an alarm(ioAL_Sen) as soon as the sensor (iSen) is disabled, taking into account the off-delay(iAL_Time).
- If the sensor(iSen) isn't switched on anymore, the module will turn off the alarm(ioAL_Sen) as soon as it gets reset(iReset)

It is possible with the description to draft an operation scheme for the control module with the name FB_CM_DI_Sensor.



This results into a **"Function buildblock"** which looks like the following images.

Text	Image
FDB example	%DB5 "FB_CM_DI_ Sensor_DB" %FB10 "FB_CM_DI_Sensor" ... — EN false — iSen false — iReset false — iAL_Option T#0ms — iAL_Time — oSen_TO — false T#0ms — iTON_Time — oAL_Sen — false T#0ms — iTOF_Time — ENO

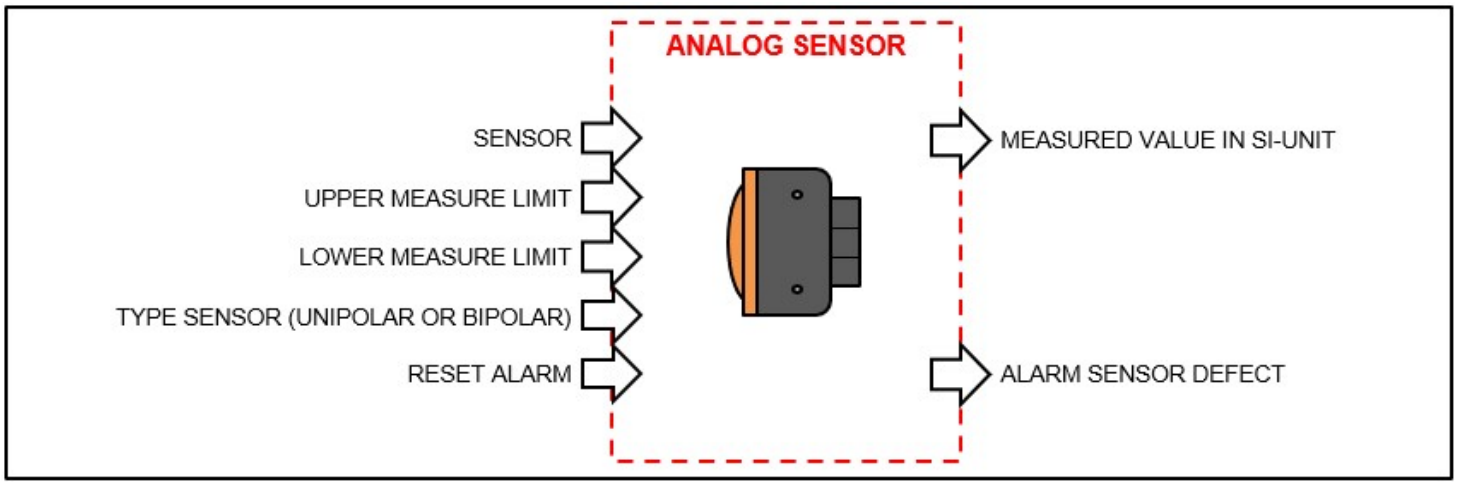
Text	Image
More simple example	

Analog sensors

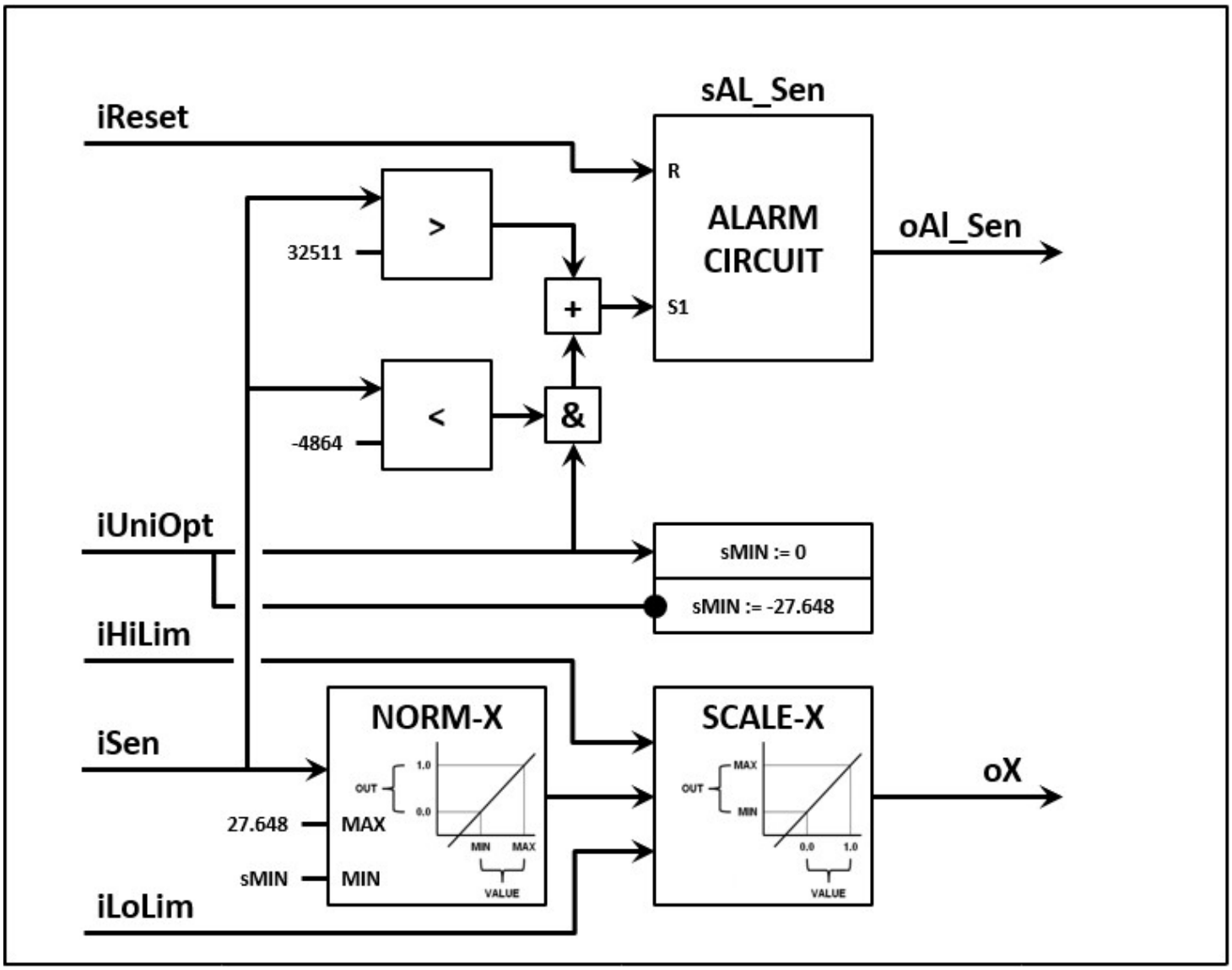
It is possible to process for example: the current level of a liquid with an **analog sensor** in a programmable manager circuit ("sturing"). It's needed to convert the number given to the correct SI-unit, this is because the current value isn't given in the correct SI-unit (ex. : mm). A unipolar sensor is only capable of converting a positive signal (ex. 0 .. 20mA, 4 .. 20mA, 0 .. 10 V, ...). A bipolar sensor processes both positive and negative signals (ex. -10V .. + 10 V).

A **control module** for this type of sensors has the following tasks:

- Converting the provided number (iSen) which is a mirror of the measured value, to a SI-unit (oX) whereby taking into account the unipolar and bipolar signals (iUniOption) and the max. (iHiLim) and min. (iLoLim) measure range of the analog sensor.
- Making an alarm (ioAL_Sen) in case of an abnormal situation (ex. Cable break or overcurrent)
- If the abnormal situation is fixed will the module will turn off the alarm as soon as it gets resetted (iReset)



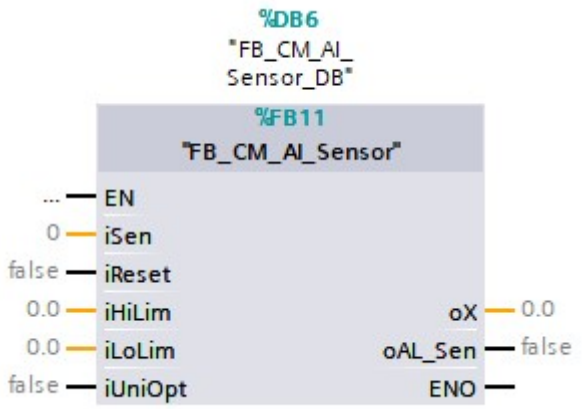
It is possible with the description to draft an operation scheme for the control module with the name FB_CM_AI_Sensor.



Notice that the operation scheme is drafted for analog sensors that work following the Siemens principle, they have a normal range of 0 .. 27.648 / -27648 .. + 27648.

The end result is a **"Function building block"** which looks like the following images.

Text	Image

Text	Image
FDB example	
More simple example	

Examples

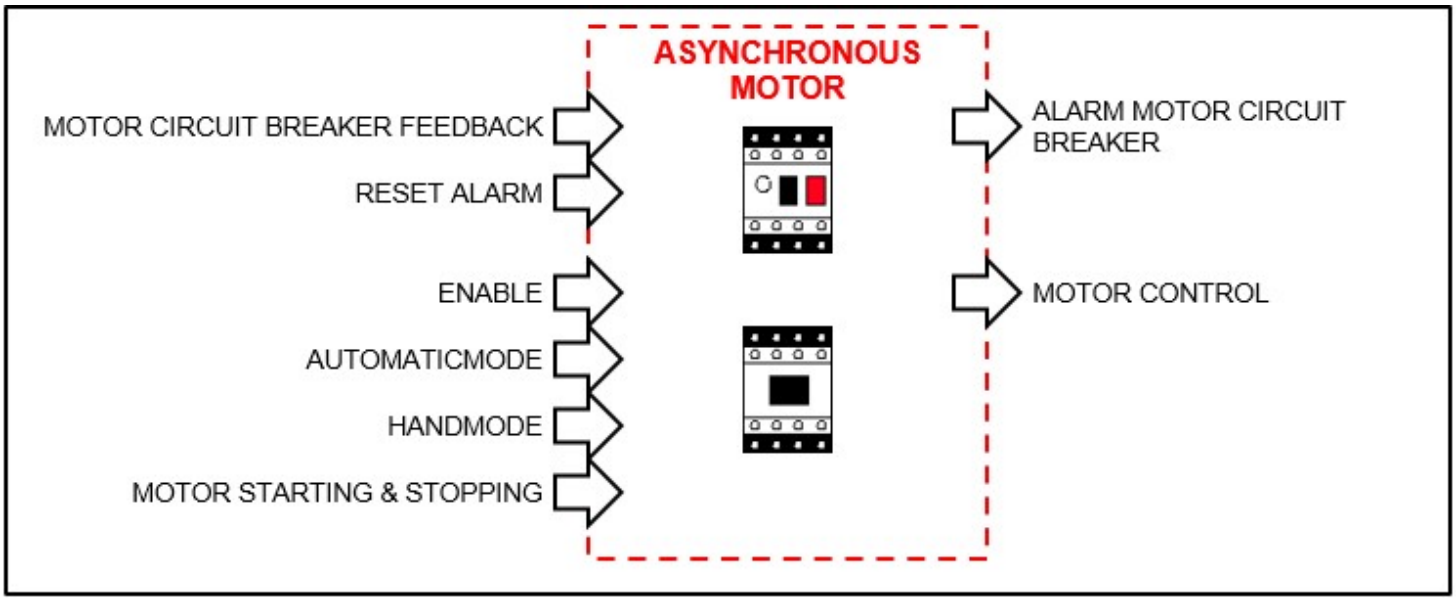
Tag	Processing of a digital sensor
FB_CM_DI_Sensor	Processing of a digital sensor
FB_CM_AI_Sensor	Processing of an analog sensor
FB_CM_DOL	Controlling an asynchronous motor with 1 speed and 1 rotating direction
FB_CM_DOLRev	Controlling an asynchronous motor with 1 speed and 2 rotating directions
FB_CM_Valve	Controlling of a (pressurised air) valve
FB_CM_Relay	Controlling of a relay
FB_CM_Lamp	Controlling of a (LED) lamp

Asynchronous motors

Asynchronous motor with set speed and one turn direction

With the current technology an asynchronous motor that only runs forward with a set speed can't operate without:

- 1x motor circuit breaker
- 1x relay



A **control module** for this type actuator is inseperable connected with a motor circuit breaker and a relay. The control module shortly does the following:

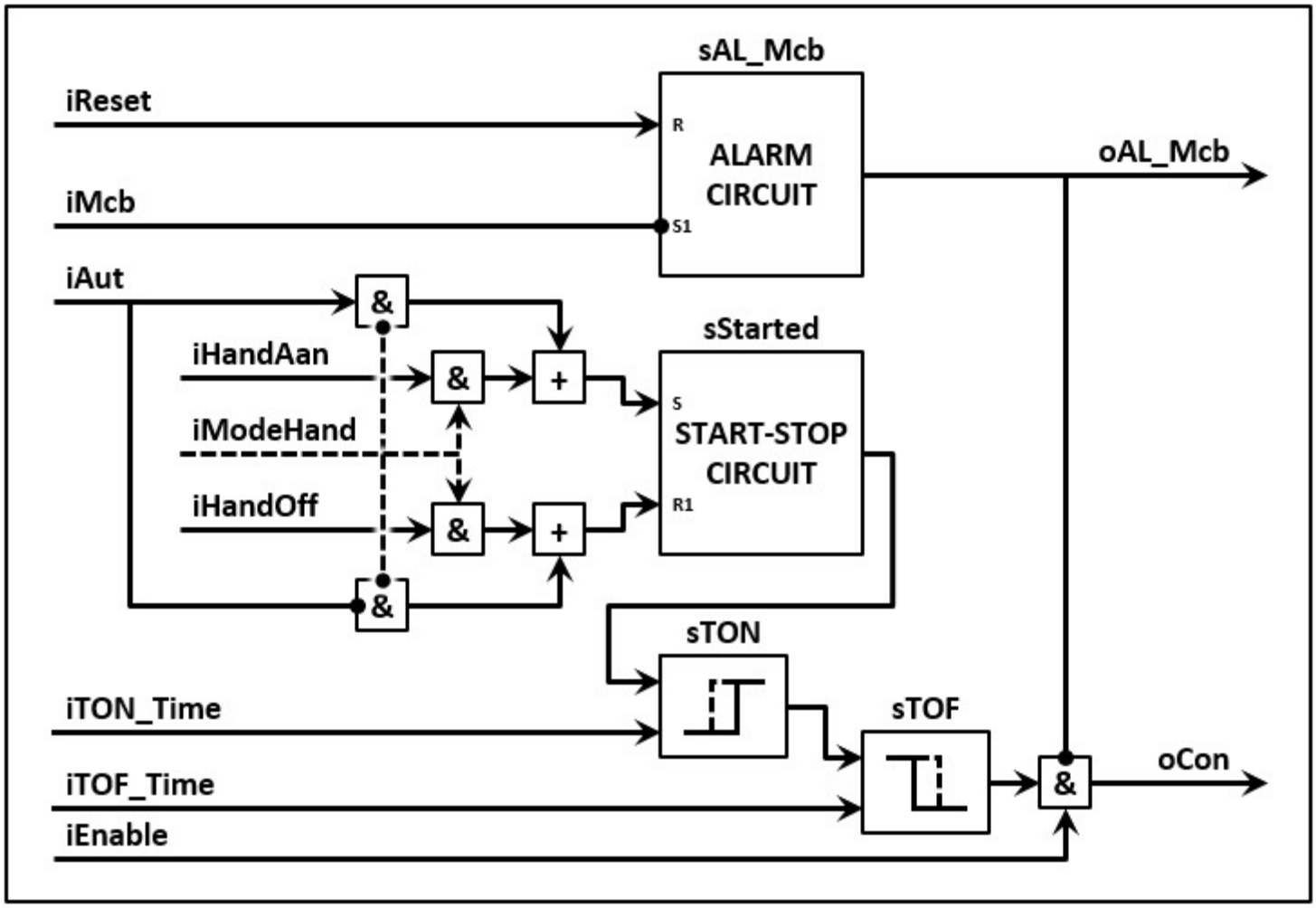
- If the think process(iAut) asks that if the motor needs to run, the control module will let the motor run (oCon)
- But if the motor circuit breaker (iMcb) is turned off the module won't let the motor run en it'll activate the alarm (ioAL_Mcb)
- The motor will only start running again if the motor circuit breaker has been activated and the alarm reset has been reset(iReset)

One can expand the functionalities of the control module:

- The motor will only run (oCon) if the module is enable (iEnable)
- If manual mode is activated (iModeHand), the module will ignore the request from the think process (iAut) and runs the motor whenever the manual signals are given (iHandOn & iHandOut)

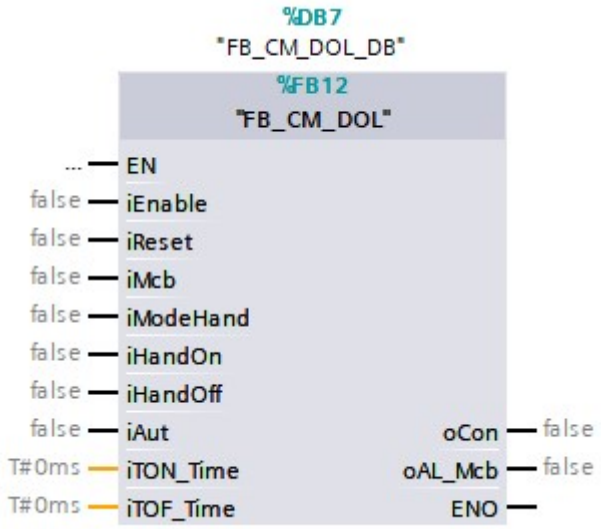
- If the motor needs to run (oCon) the module can start the motor with an on delay (iTON_Time) and/or an off delay(iTOF_Time)

It is possible with the description to draft an operation scheme for the control module with the name FB_CM_DOL.



The end result is a **"Function building block"** which looks like the following images.

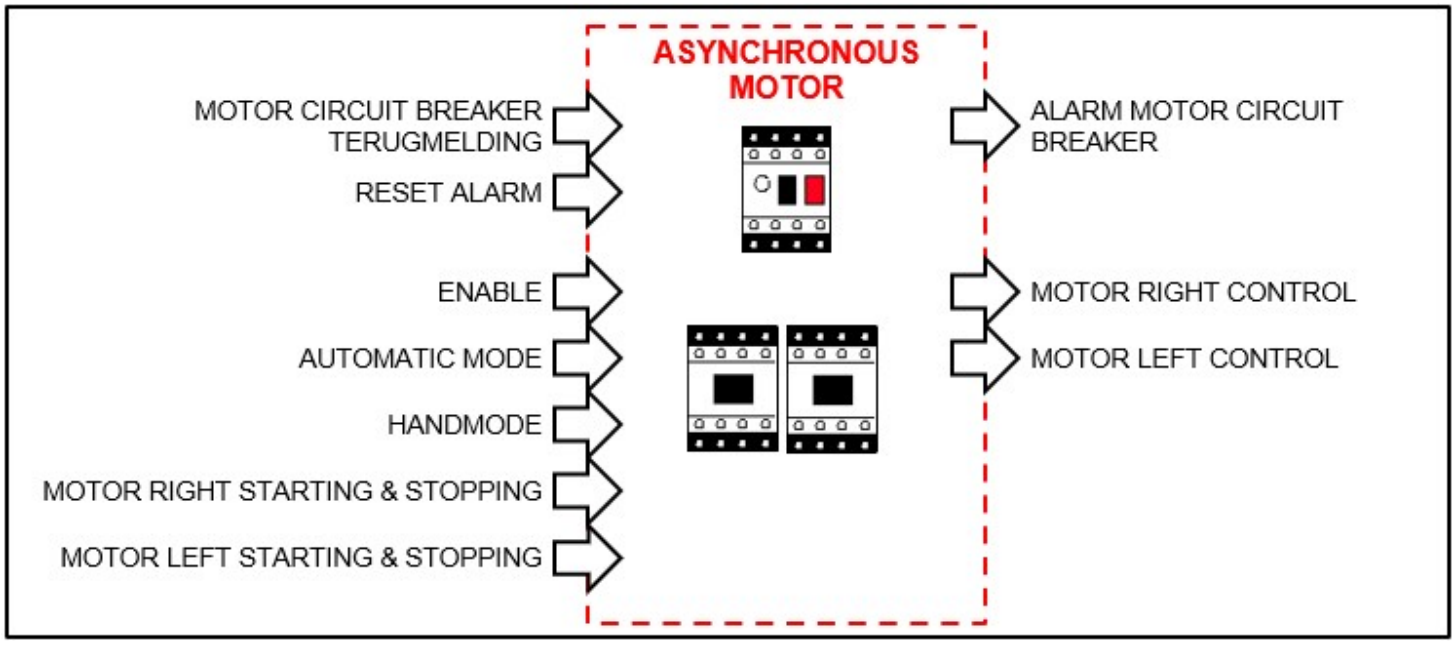
Text	Image

Text	Image
FDB example	
More simple example	

Asynchronous motor with set speed and two turn directions

With the current technology an asynchronous motor that runs forward and backwards with a set speed can't operate without:

- 1x motor circuit breaker
- 2x relays



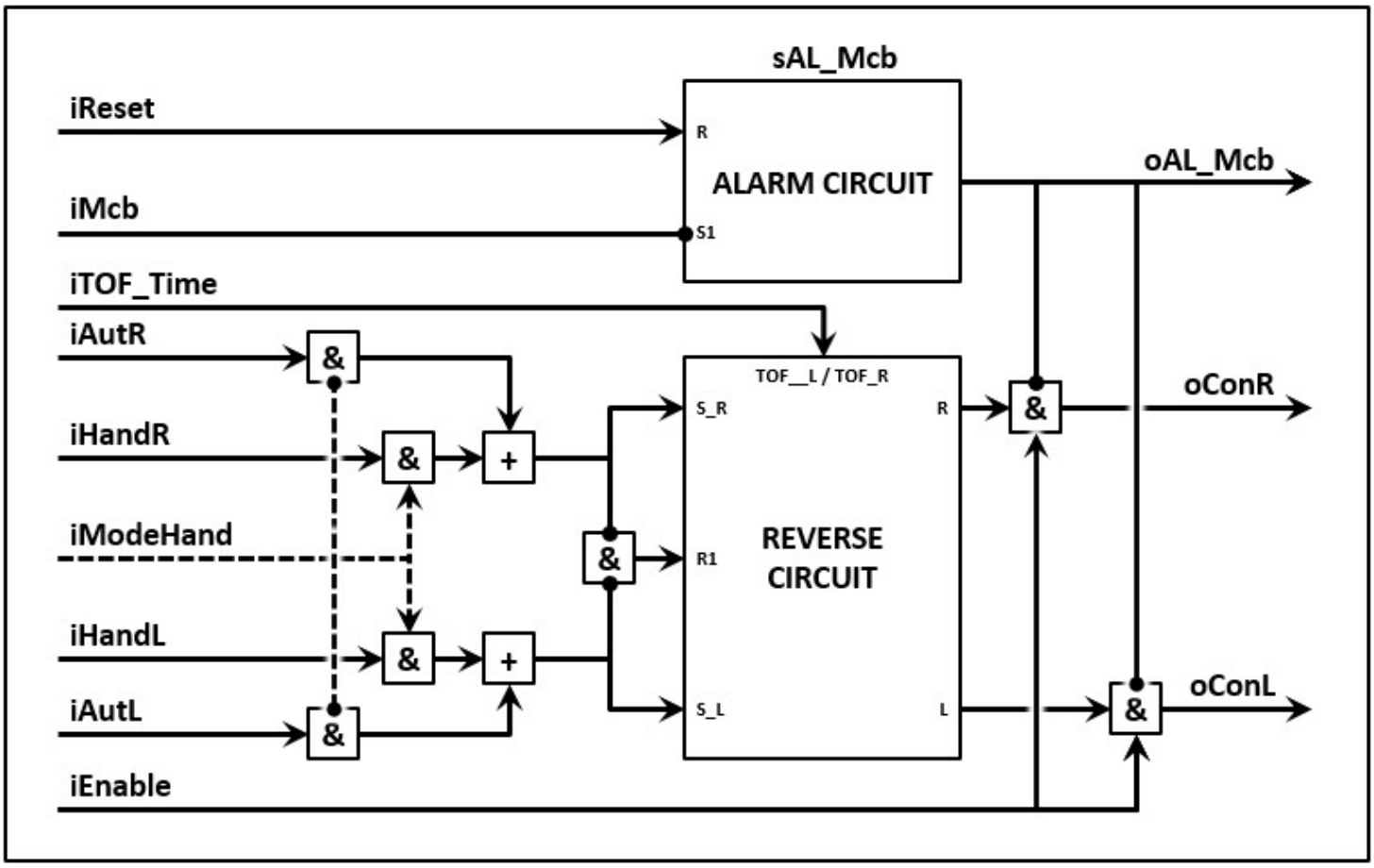
A **control module** for this type of actuator is inseperably connected with a motor circuit breaker and a relay. The control module, in short does the following:

- If the think process(iAutL) asks if the motor needs to run left, the control module will let the motor run left (oConL)
- If the think process(iAutR) asks if the motor needs to run right, the control module will let the motor run right (oConR)
- It is possible to run through a waiting time(iTOF_Time) if it is requested to change direction
- But if both directions are requested (left and right) the direction doesn't change and the motor will keep spinning the way it was before the request.
- But if the motor circuit breaker (iMcb) is turned off the module won't let the motor run en it'll activate the alarm (ioAL_Mcb)
- The motor will only start running again if the motor circuit breaker has been activated and the alarm reset has been reset(iReset)

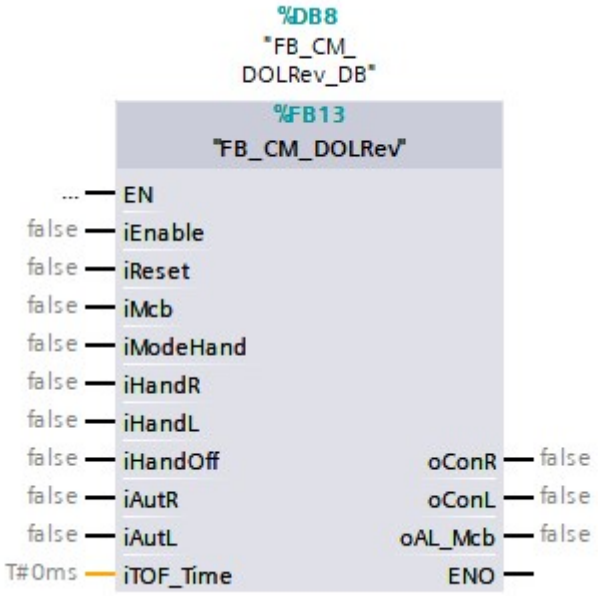
One can expand the functionalities of the control module:

- The motor will only run (oConR & oConL) if the module is enable (iEnable)
- If manual mode is activated (iModeHand), the module will ignore the request from the think process (iAutR & iAutL) and runs the motor to the right(oConR) whenever the manual signal is given (iHandR)
- If manual mode is activated (iModeHand), the module will ignore the request from the think process (iAutR & iAutL) and runs the motor to the left(oConL) whenever the manual signal is given (iHandL)
- The control module won't change running condition if the mode changes from automatic mode (NOT iModeHand) to hand mode (iModeHand)

It is possible with the description to draft an operation scheme for the control module with the name FB_CM_DOLRev



The end result is a **"Function building block"** which looks like the following images.

Text	Image
FDB example	

Text	Image
More simple example	

Valve

8.4 Addendum 6 S88

A valve is used to power compressed air or hydraulic actuators (ex. compressed air cylinder). The combination of a valve and actuator has a specific functionality:

- Monostable power circuit: In case there is a loss of power the actuator will automatically take its residual state (ex. single-acting compressed air cylinder)
- Bistable power circuit: In case there is a loss of power the actuator will keep the last position (ex. double-acting compressed air cylinder)
- Monostable control circuit: In case there is a loss of power in the control circuit the valve will automatically take its residual state (ex. 3/2 valve with spring return)
- Bistable control circuit: In case there is a loss of power in the control circuit the valve will automatically keep its last state (ex. 5/2 valve with electromagnetic control on both sides)

A **control module** for a valve will be built without taking into account the already existing functions of the combination valve - actuator. The control module will work following the bistable process.

Why would you use a monostable valve and cylinder?

During the design of a machine/installation one needs to ask themselves: What can go wrong during an unexpected event? How do i take care of potential risk to a human? Following the machine guidelines, no moving part of the machine or no single object that is held by the machine can be dropped or ejected. (2006/42/EG,2006)

Unexpected events like for example a fire, an accident, an earthquake, a flood, etc. can cause interruptions in the control- and/or power circuits. The interruption of these circuits can cause dangerous situations.

Example

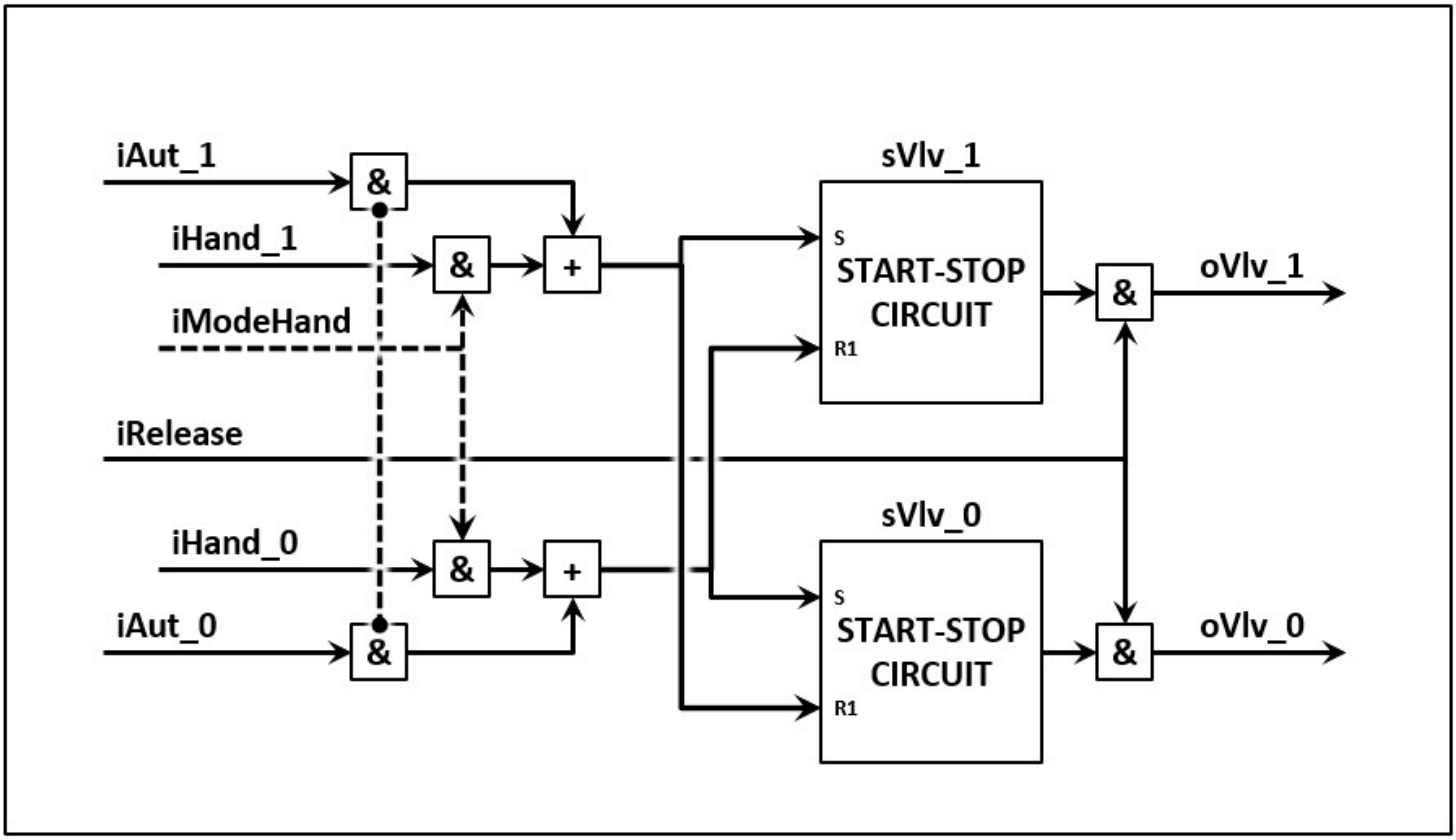
Because of a fire in a technical room, the air compressor stopped working which has the side effect that there is no more compressed air. A robot that moves part of +/- 2 kg on highspeed is equipped with a pneumatic grabber. There is the danger that in case the compressed air falls away on the moment the robot moves at high speed, that the robot lets go of the object and basically throws away the object. This has the potential to hurt humans that work near the robot.

In this situation one chooses a monostable compressed air cylinder with a spring return, this will keep the grabber "grijper" to remain closed in case the compressed air falls away.

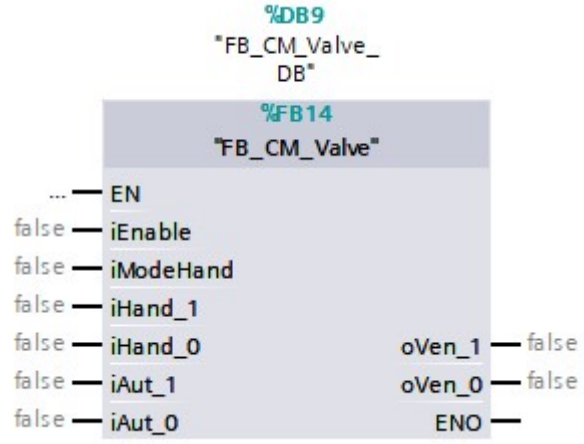
The functionality of this type control module:

- The control module will work on the following a bistable principle;
- - In case the think process asks to activate the "+" side of the valve (iAut_1) the control module will do this (oVlv_1) and it will keep the condition in case the think process doesn't ask for it anymore, until the "-" side gets activated
- - In case the thinkprocess asks to activate the "-" side of the valve (iAut_0) the control module will do this (oVlv_0) and it will keep the condition in case the think process doesn't ask for it anymore, until the "+" side gets activated
- The control module will only change the condition of the electromagnetic control in case this is allowed (iEnable)
- If the hand mode is active (iModeHand) the control module ignores the think process signals (iAut_1 & iAut_0) and sends the valve (oVlv_1 & oVlv_0) commands based off the hand signals (iHand_1 & iHand_0)

It is possible with the description to draft a operation scheme for the control module with the name FB_CM_Valve



The endresult is a **"Function buildblock"** which looks like the following images.

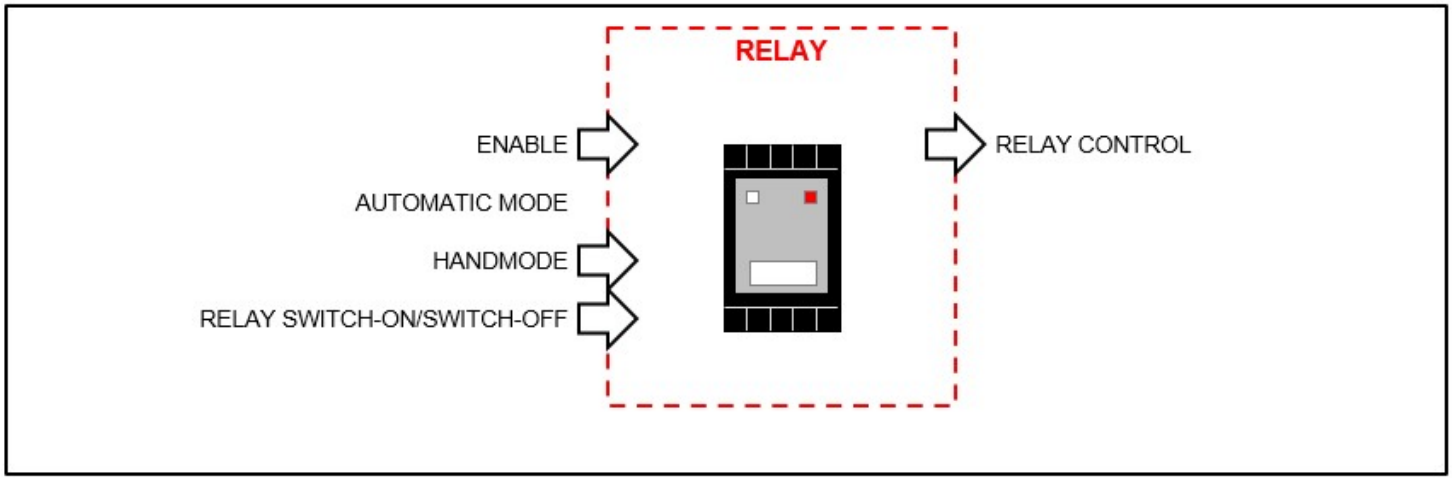
Text	Image
FDB example	

Text	Image
More simple example	

Relay

A **relay** is often used to build up communication with:

- Other PLC's via a potential-free contacts
- Other devices like frequency controllers

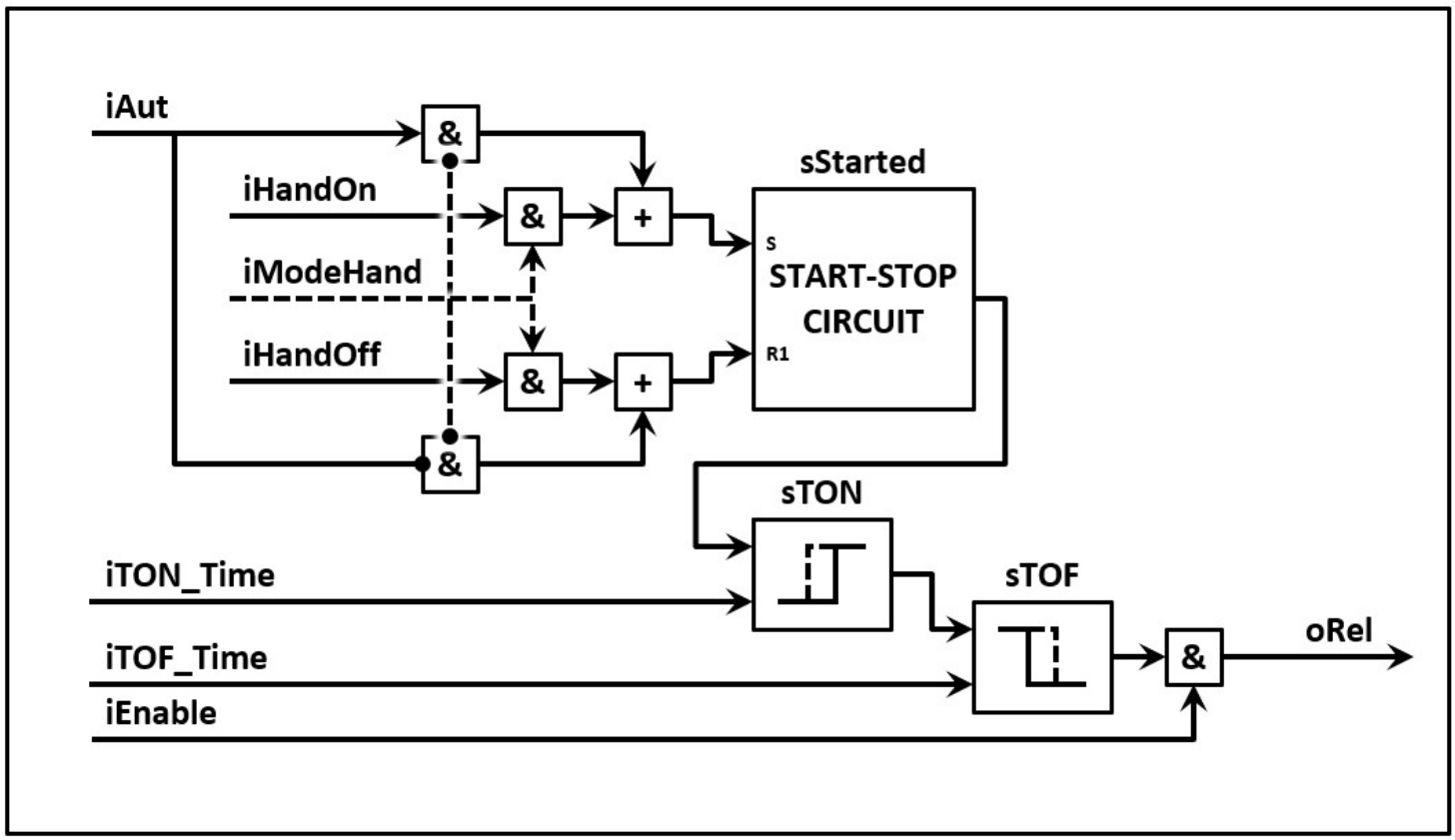


Just like an asynchronous motor one can assign multiple functionalities to the corresponding control module such as:

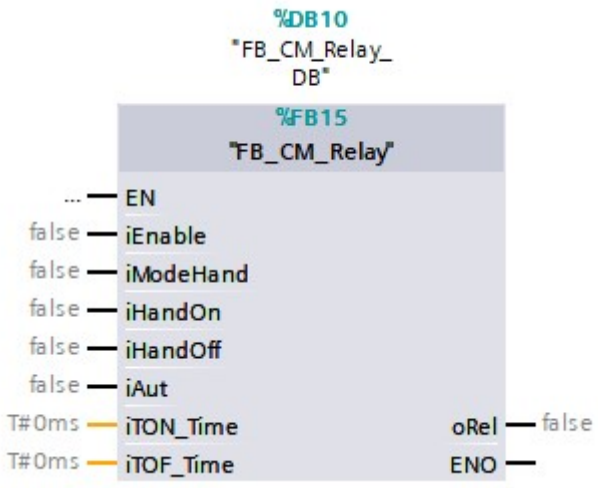
- If the think process asks to activate the relay (iAut), the relay will be activated (oRel)
- The relay will only be activated if this is enabled (iEnable)
- If hand mode (iModeHand) is activated then the module will ignore the think process's signal (iAut) and activates the relay based on the hand signals

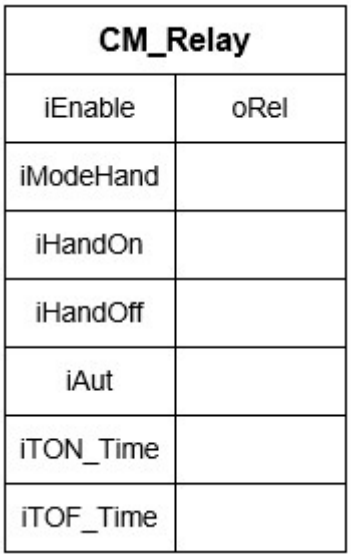
- If it's asked to activate the relay, the module has the possibility to activate a rise delay (iTON_Time) and/or drop-out delay (iTOF_Time)

It is possible with the description to draft an operation scheme for the control module with the name FB_CM_Relay



The end result is a **"Function building block"** which looks like the following images.

Text	Image
FDB example	

Text	Image
More simple example	

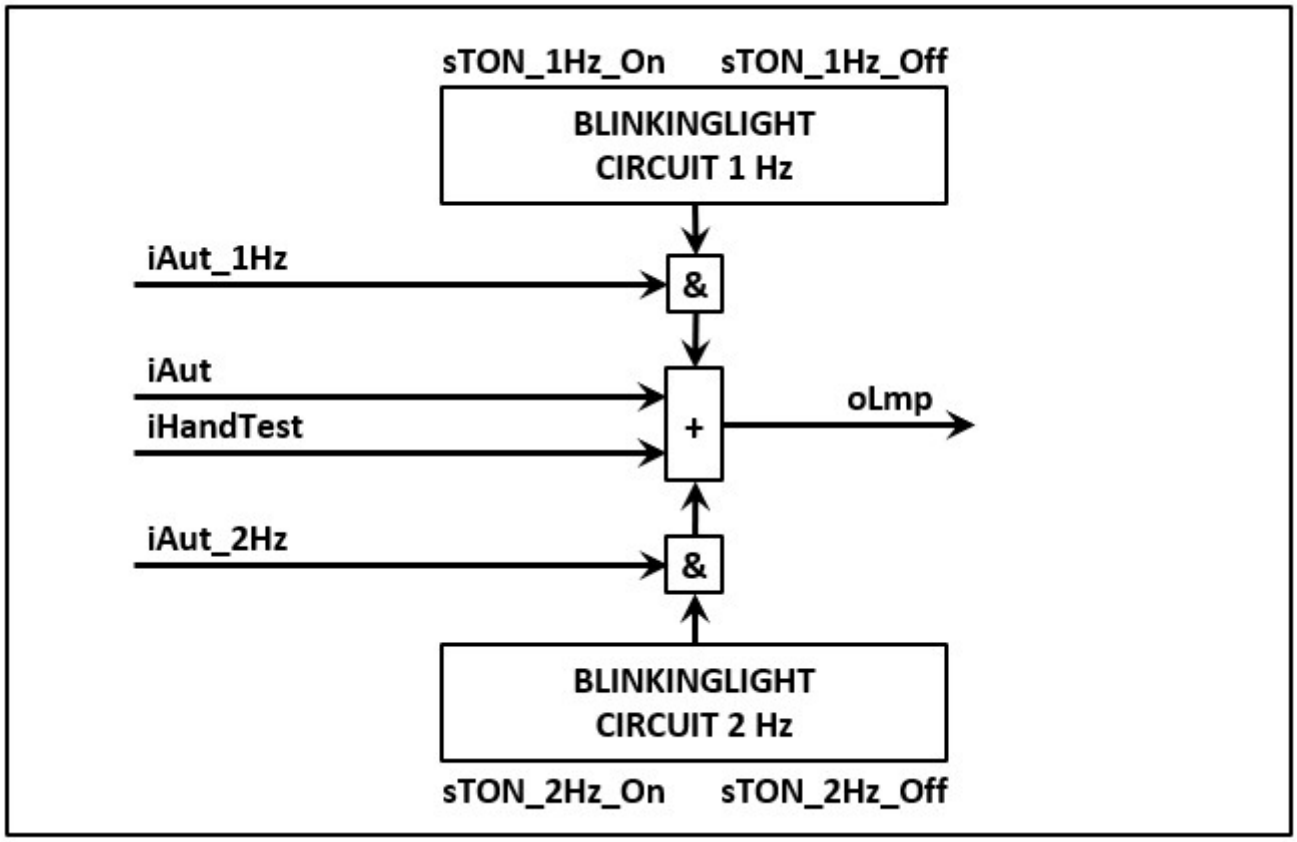
Lamp

A **lamp** is used to inform an operator about the status of a machine/installation or part of it.

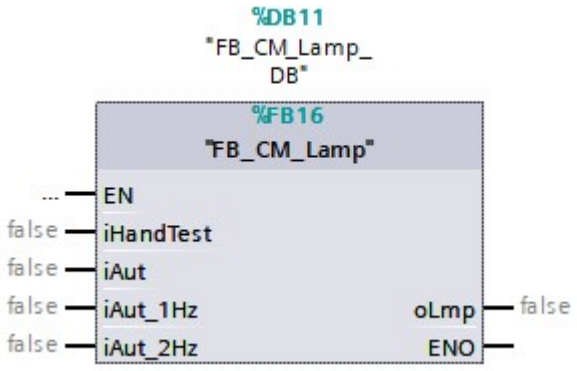
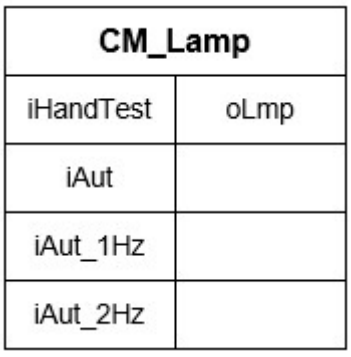
A lamp control module handles following functionalities:

- Continued lighting of the lamp (iAut)
- Blinking of the lamp (iAaut_1Hz)
- Fast blinking of the lamp (iAut_2Hz)
- Activating the lamp if a lamp test(= controlling the lamps on defective lamps by maintenance technicians) is being executed (iHandTest)

It is possible with the description to draft an operation scheme for the control module with the name FB_CM_Lamp



The end result is a **"Function building block"** which looks like the following images.

Text	Image
FDB example	
More simple example	

CM_Lamp	
iHandTest	oLmp
iAut	
iAut_1Hz	
iAut_2Hz	

Physical part

8.4 Addendum 6 S88

Equipment modules

An **equipment module** is a collection of multiple control modules and/or other equipment modules. The collection is built upon the physical relationship they have with each other.
In other words, an equipment module is a software building block that has a minimum of 2 building blocks of the type control modules and/or equipment modules/.
Equipment modules are preferably programmed in "Functions", the TAG-naming gets expanded with the letters EM.

Examples	Description
FC_EM_CC	Includes programming of the control cabinet
FC_EM_Airco	Includes programming of the airco installation
FC_T10_EM_Level	Includes programming of the level controlling of tank T10
FC_EM_X_Axis	Includes programming of the X axis

Procedure part

Procedure

A **procedure** is a strategy, think process to solve a problem. First, a strategy gets designed on paper using a certain method. Next the strategy will be translated to a software building block which we call the procedure element.

The designing of a strategy can be done with the following methods:
- By designing a GRAFCET drawing
- By designing a flowchart drawing
- By determining the needed mathematical formulas
- By drawing of an operation scheme
- By selecting a controller and determining the corresponding parameters in the shape of a table

Procedure element

A **procedure element** is the software translation(programming) of a procedure. A procedure drawing, scheme or table needs to be present for each procedure element. Some of these procedure elements are commonly used in machines/installations. This causes them to preferably be included into a software library. Other procedure elements get delivered by the producer of the processing unit:

- Start-stop procedure (software library) = To start and stop actuators, machines/installations in the correct way
- Reset procedure (software library) = To create a reset signal in the correct way
- Two-point controller (software library) = Controlling a digital sensor using an on-off controller with the help of an analog sensor
- PID-controller (software catalog Siemens) = To control an analog output

Procedure elements get preferably programmed in "Function building blocks", the TAG-naming gets expanded with the letters PE.

Examples	Description
FB_PE_StarStop	Start-stop procedure
FB_PE_Reset	Reset procedure

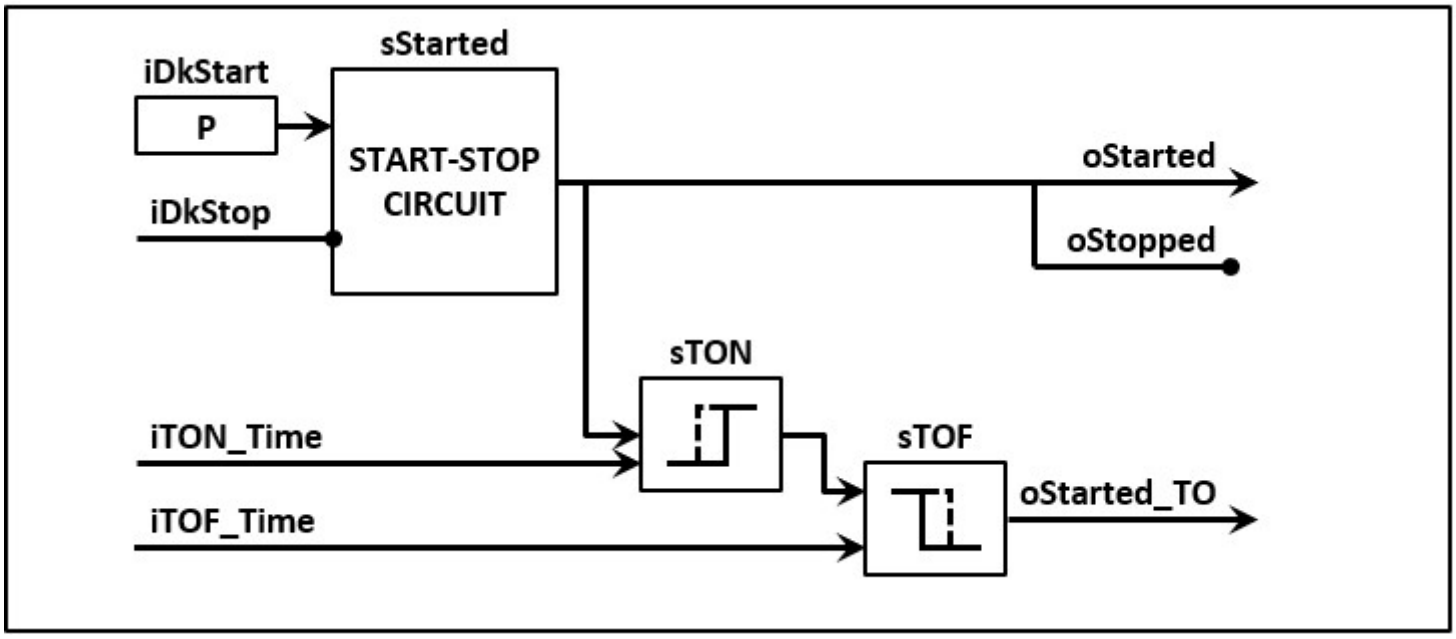
Start-stop procedure elements

A **start-stop procedure** is used to start or stop an actuator and/or the automatic process of a machine/installation (or parts of it). We use a classic start-stop circuit that is expanded with extra functionality.

Characteristics of the start-stop procedure:

- The stop action (iBtnStop) has priority on the start action (iBtnStart) which is mandatory following the machine guidelines
- The start signal is of the type NO-contact[7], the stop signal is of the type NC-contact[8]
- The operator is obligated to press the start button (iBtnStart) (Electrically bridging the start button isn't allowed)
- There is the possibility to start slower (iTON_Time) and/or stopping slower (iTOF_Time)

It is possible with the description to draft an operation scheme for the control module with the name FB_PE_StartStop



The end result is a **"Function building block"** which looks like the following images.

Text	Image
FDB example	%DB12 "FB_PE_ StartStop_DB" %FB30 "FB_PE_StartStop" ... EN false iBtnStart — oStarted false false iBtnStop — oStopped false T#0ms iTON_Time — oStarted_TO false T#0ms iTOF_Time — ENO
More simple example	PE_StartStop iBtnStart | oStarted iBtnStop | oStopped iTON_Time | oStarted_TO iTOF_Time |

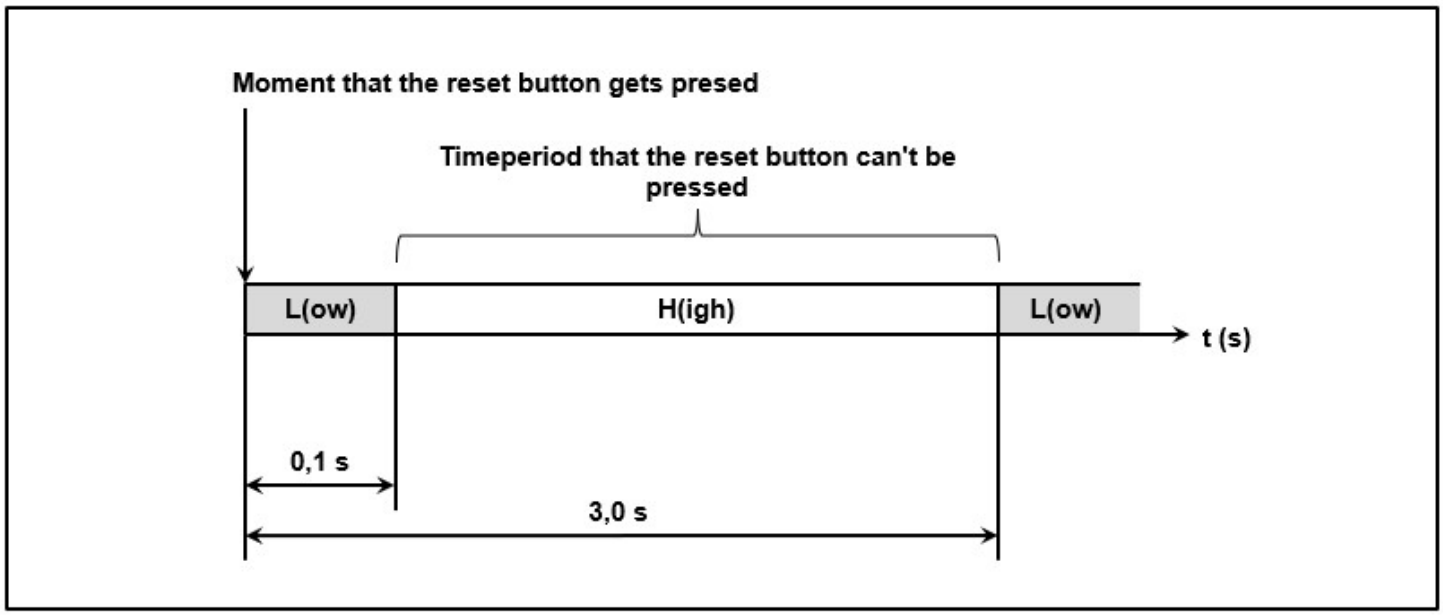
Reset procedure elements

The **reset procedure** gets used to create a checked reset signal. Checked because the signal coming from ex. an electrical reset button(NO-contact) can include issues like:

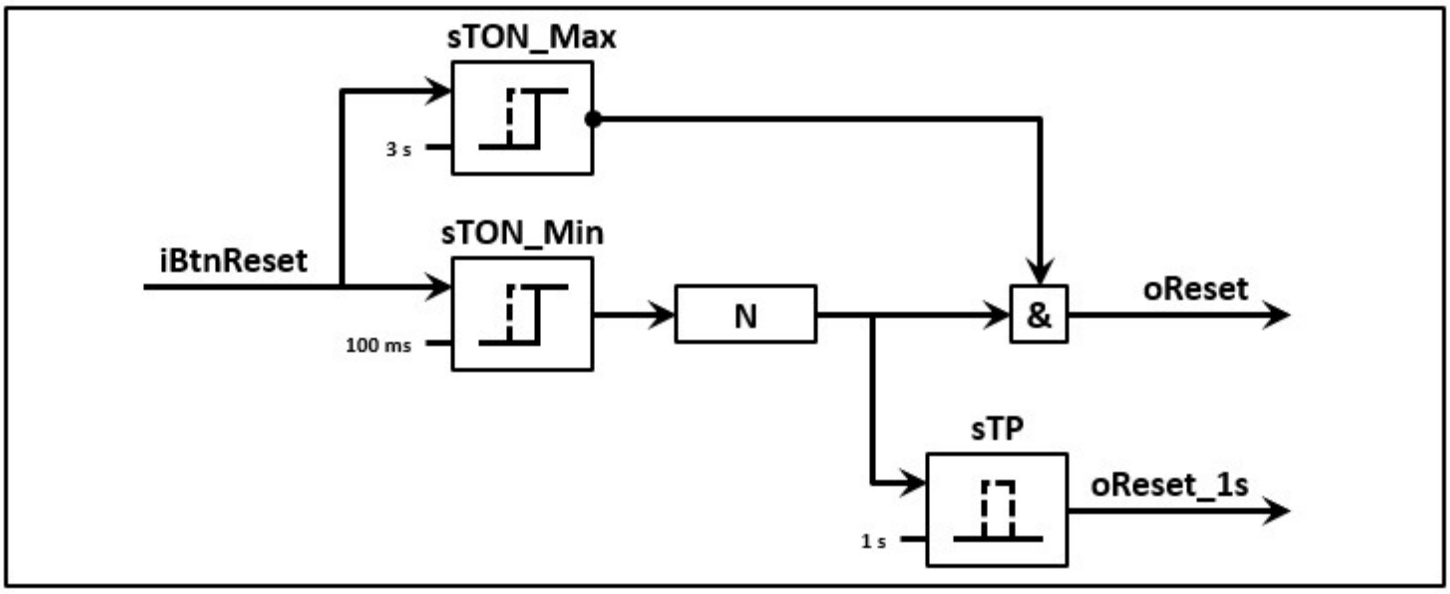
- An electrical circuit of the reset button can have a short circuit (it is like the button is being pressed the entire time)
- The reset button is electrically bridged (it is like the button is being pressed the entire time)
- Bad/fake contact in the electrical circuit of the reset button (it is possible by vibrations in the installation the contact on/off/on/off/on/off/.. switches)

Because these situations can lead to uncontrolled situations, the reset procedure gets designed with the following functionalities:

- LHL[3:1] functionality after pressing the reset button (iBtnReset) this between a set time (the high range) has to be let go to produce an outputsignal
- A checked output signal that is max. 1s is TRUE (oReset_1s)
- A checked output signal that is max. 1 PLC-cycle TRUE is (=edge signal)(oReset)



It is possible with the description to draft an operation scheme for the control module with the name FB_PE_Reset



The end result is a **"Function building block"** which looks like the following images.

Text	Image
FDB example	%DB13 "FB_PE_Reset_DB" %FB31 "FB_PE_Reset" oReset — false ... — EN oReset_1s — false false — iBtnReset ENO
More simple example	PE_Reset iBtnReset | oReset oReset_1s

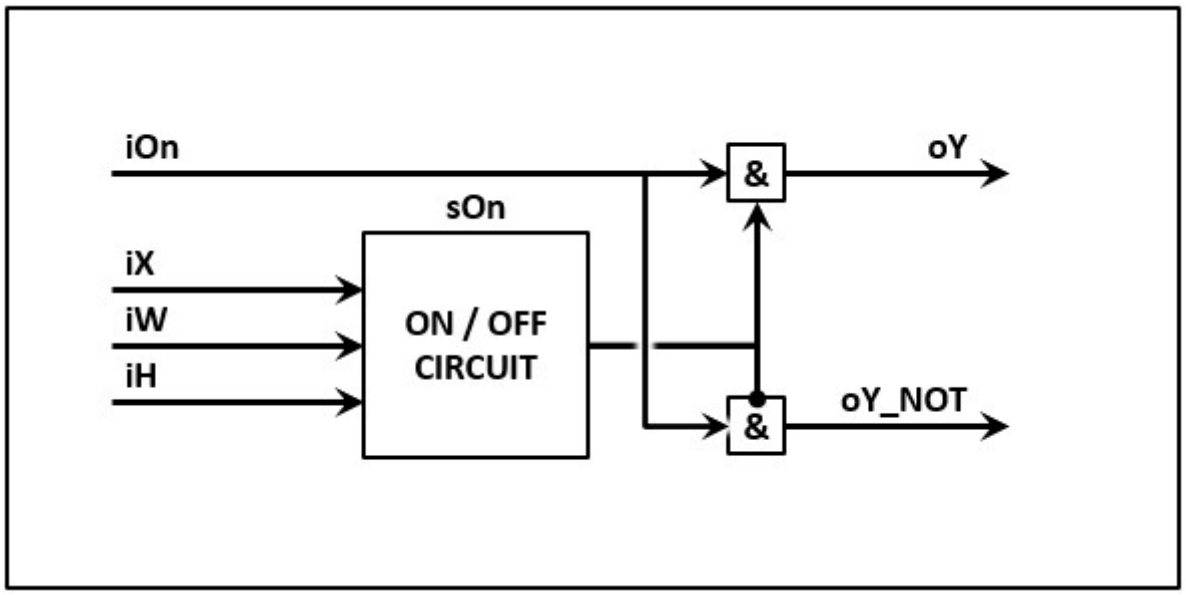
Two-point controller with hysteresis

A **two-point controller with hysteresis** uses an on-off switch to switch an actuator either on or off in function of a measure physical unit (= measured value x) and the desired physical unit (= setpoint W).

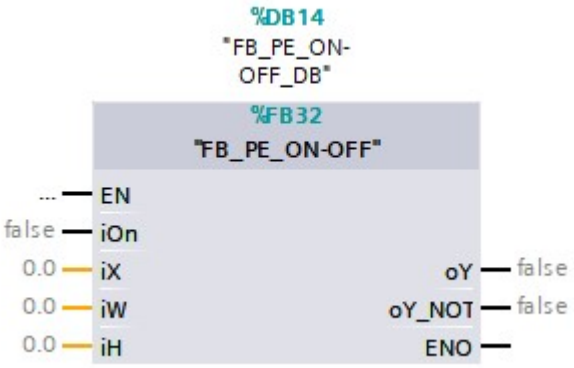
A **two-point controller with hysteresis** is consequently an on-off circuit with extra functionality like:

- The result of the controller (oY) is also offered inverted (oY_NOT)
- The possibility to switch the controller on and off. With turned-off controllers all the control outputs have the status FALSE(oY & oY_NOT)
- Setpoint (iW), the measured value (iX) and the hysteresis (iH) are adjustable

It is possible with the description to draft an operation scheme for the control module with the name FB_PE_TWPH



The end result is a **"Function building block"** which looks like the following images.

Text	Image
FDB example	
More simple example	

PE_ON-OFF	
iOn	oY
iX	oY_NOT
iW	
iH	

Specific designed procedure elements

Not all the think process can be collected with standard procedures. It's often necessary to design specific procedures and procedure elements. One of these following analysis methods gets applied to determine the strategy:

- GRAFCET
- Flowchart
- Mathematical formulas
- Operation schemes
- Selection controllers and explanation of control parameters

Exercise 1

Back

Study material

Literature

Equipment

> **1** Engineering station
> **2** SIMATIC S7-1200 controller, e.g. CPU 1215C DC/DC/DC – firmware V4.2 or higher
> **3** SIMATIC STEP 7 software in TIA Portal – V15 SP1 or higher
> **4** Ethernet connection between engineering station and controller

Additional literature

The Crane Project

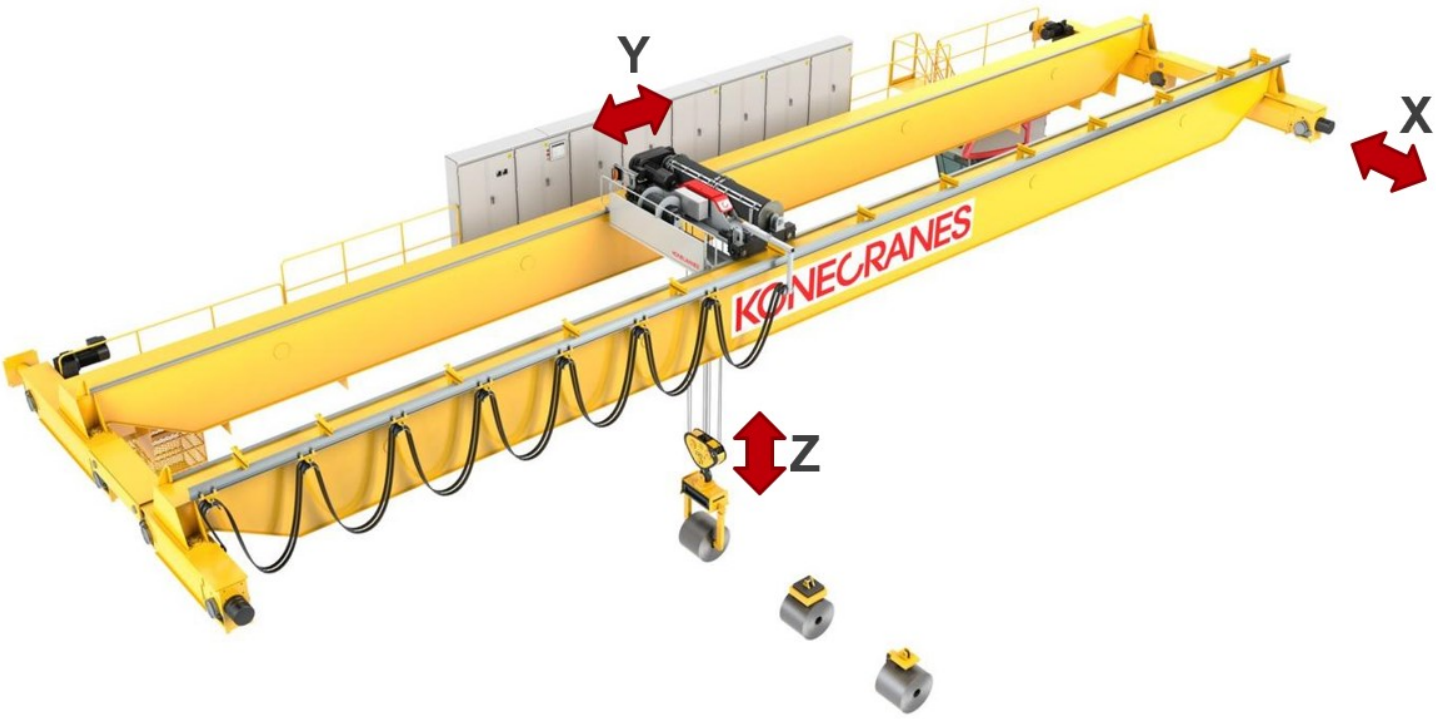
- The first goal is to add ProfiNET based devices
- The second goal is to add Profibus based devices
- The third goal is to add Drives

Back to the project scope

Scope1

Make a networkconfiguration of a crane that has the follwing:

- 5 Digital sensors
- 3 Motorstarters
- 2 Analog sensors
- A digital levelsensor
- 2 Profibus Devices
- 1 Drive



Goal 1 To add ProfiNET based devices

ProfiNET

Step 1 : Create a new TIA Portal project

```
Project name  : Ex1-TheCraneProject
Author        : Your name
Comment       : The Crane Project
```

Step 2 : Add a PLC-device with next CPU settings

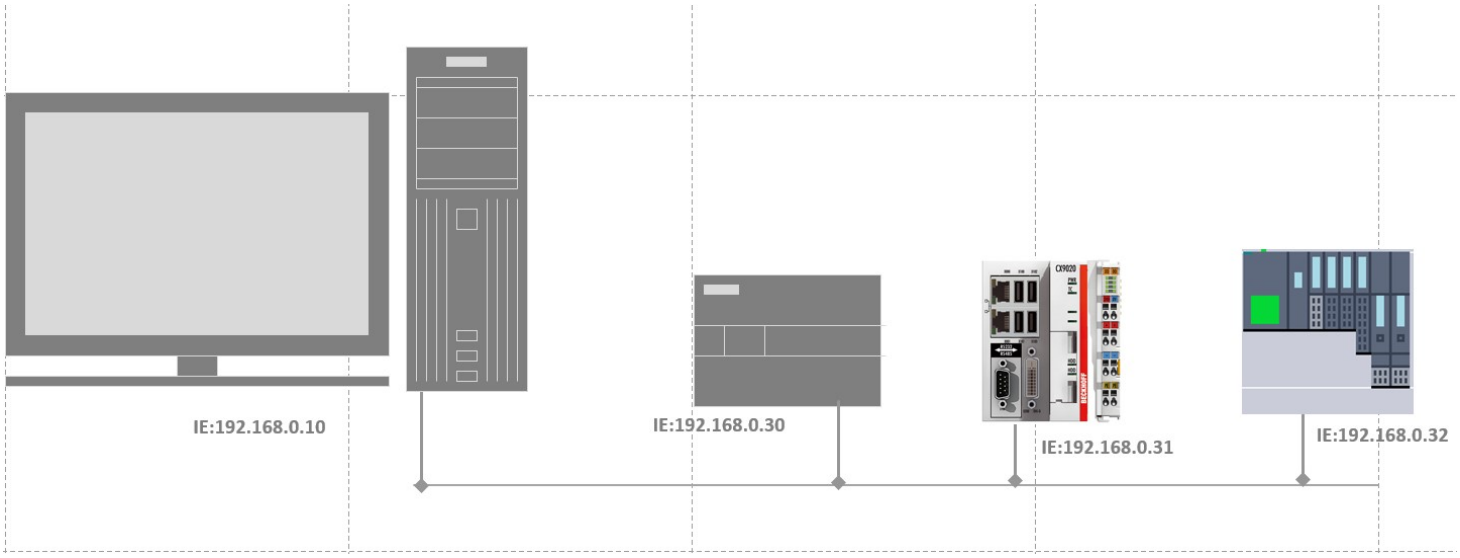
```
Type                          : See available CPU
System byte                   : %MB254
Clock memory byte             : %MB255
Digital input start address   : %IB0
Output start address          : %QB0
Analog input start address    : %IB64
IP-address                    : 192.168.0.30
IP-address subnet mask        : 255.255.255.0
```

Step 3: Search for the correct GSD files for the following devices:

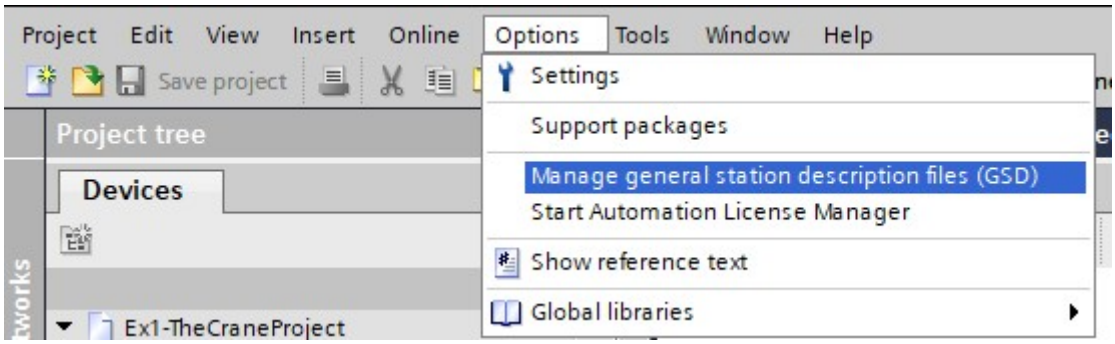
```
Beckhoff CX8093 island (IO on bridge)
-       3x digital sensor (grabber open, rabber closed, grabber on top)
-       2x digital sensor (eindeloop left, eindeloop right)

Siemens ET200S island 1  (pumps)
-       3x motorstarter (supply- & drainpump & heating)
-       2x analog measurement (level and temperature)
-       1x digital levelmeasurement (overflow)
```

If there is no internet available the required GSD files are included in the Documents.

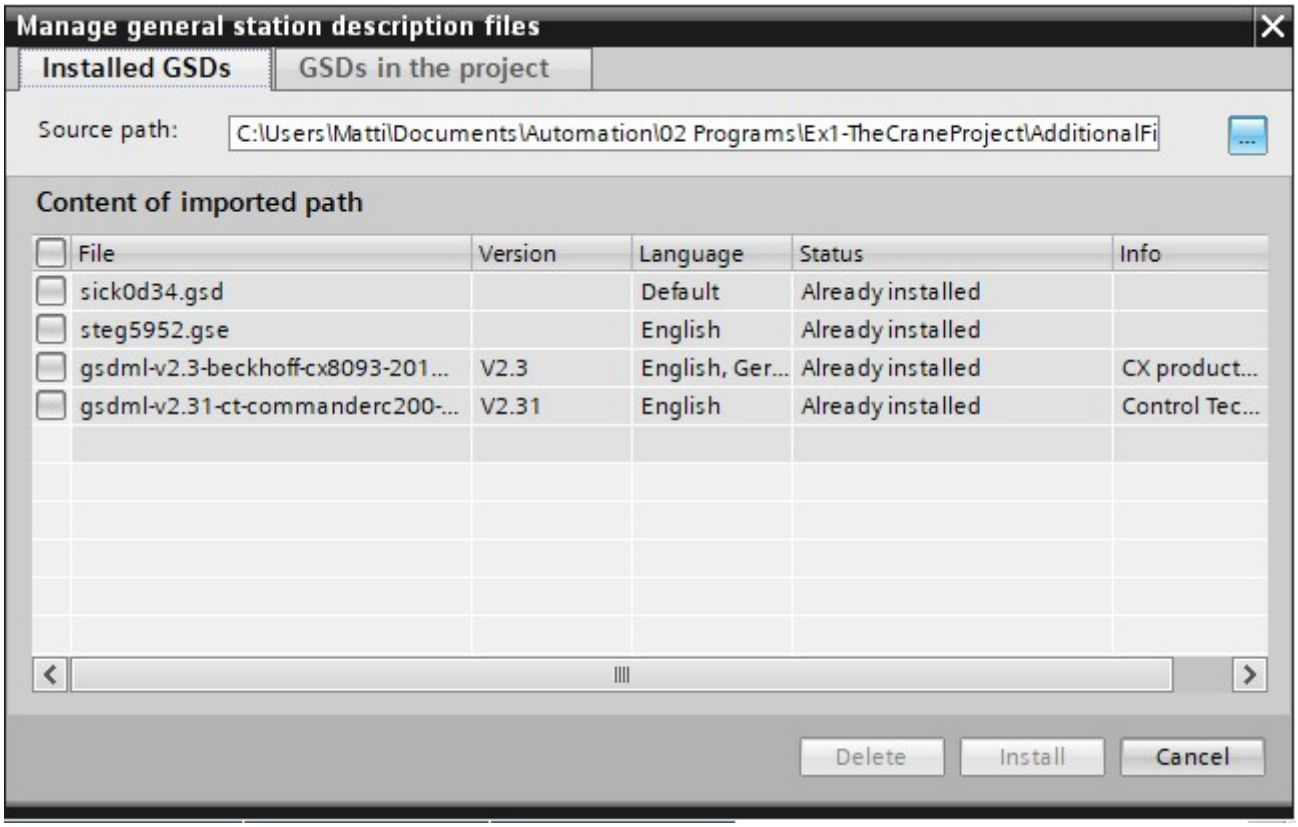
Overview of IP adresses and devices



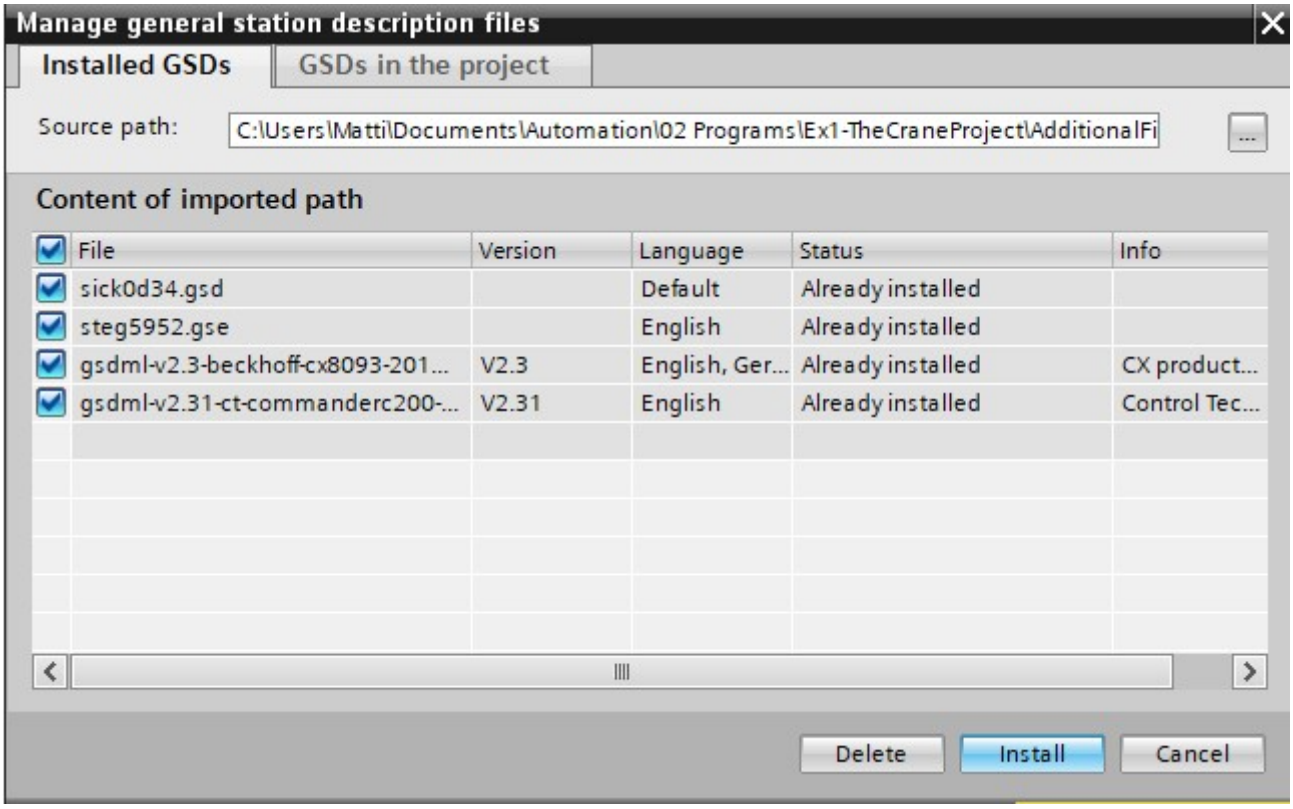
Step 4: Importing these GSD files:



Step 5: Select the right GSD files wherever you stored them:



Step 6: Install the selected GSD files:



Step 7: Import the correct devices from the "Hardware catalog" into "Network view"

Step 8: Connect the devices and give them the right IP adress

Step 9: Configure them for the right configuration given in **Step 3**

The Crane Project

- The first goal is to add ProfiNET based devices
- The second goal is to add Profibus based devices
- The third goal is to add Drives

Back to the project scope

Goal 2 to add Profibus based devices

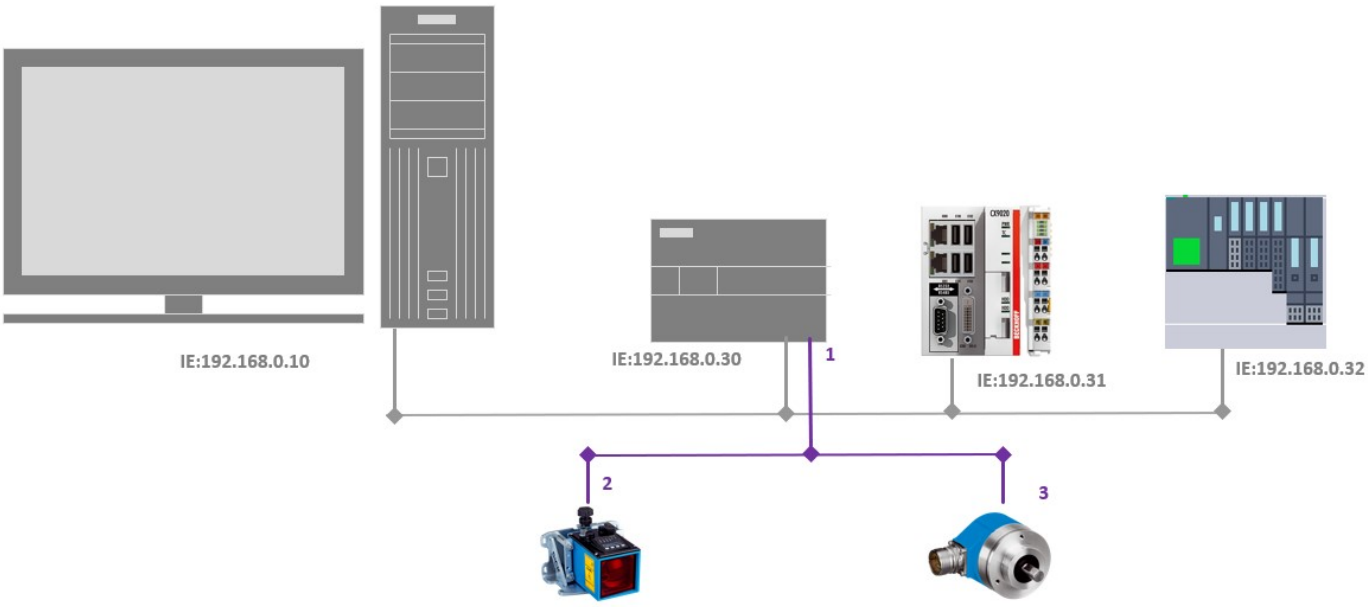
Profibus

Step 1: Search for the correct GSD files for the following devices:

- Sick Long-range-sensor DX100
- Sick wire-encoder ATM60

Step 2: Link them to the PLC

Overview of the network



Step 3: Configure the imported devices to the right measurement type

The Crane Project

- The first goal is to add ProfiNET based devices
- The second goal is to add Profibus based devices
- The third goal is to add Drives

Back to the project scope

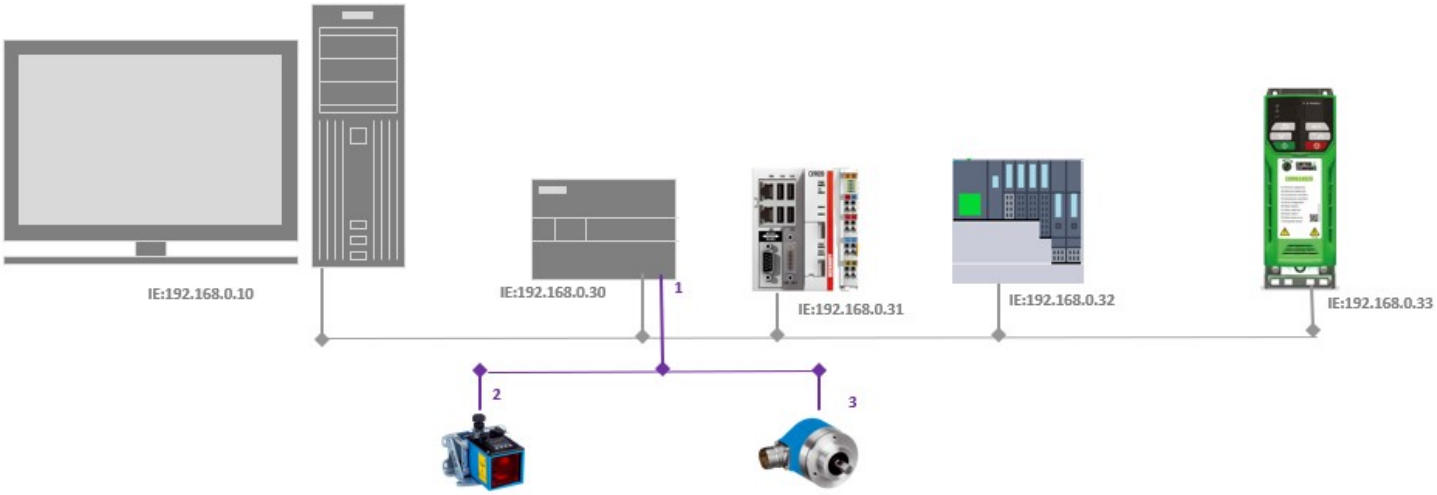
Goal 3 to add Drives

Drives

Step 1: Search for the correct GSD file for the following device:

```
Control Techniques Commander C300
```

Step 2: Link the drive to the PLC



Step 3: Compile the entire project and check for errors

Normal functionallity

- TIA compiles the project without issues

Exercise 2

Back

Study material

Literature

- Addendum 06 : Software model following ANSI/ISA-88

Equipment

1 Engineering station 2 SIMATIC S7-1200 controller, e.g. CPU 1215C DC/DC/DC – firmware V4.2 or higher 3 SIMATIC STEP 7 software in TIA Portal – V15 SP1 or higher 4 Ethernet connection between engineering station and controller 5 Factory IO scene Pick & Place.factoryio

The Pick and Place Project

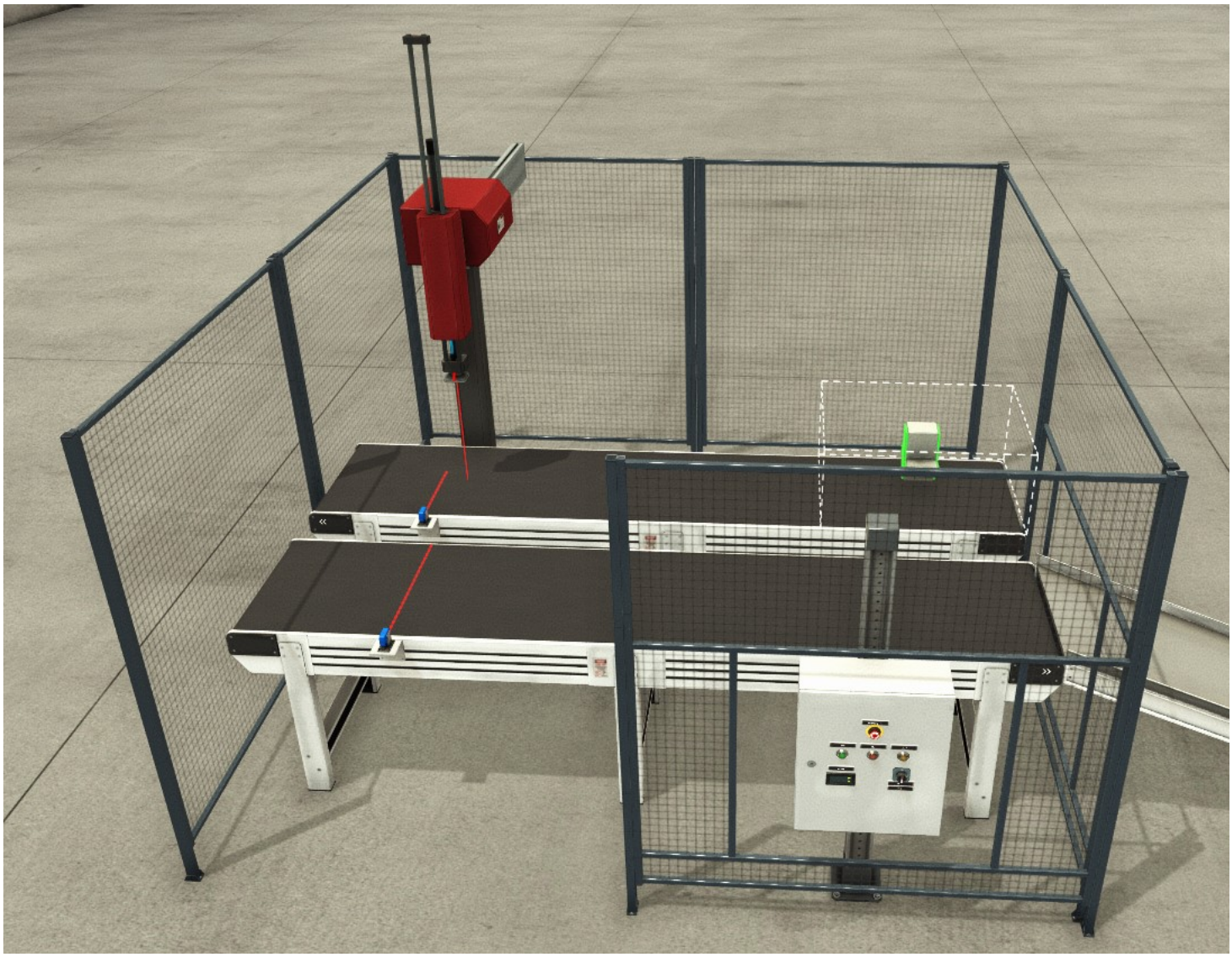
- The first goal is to retrieve an archived program.
- The second goal is to retrieve an archived library
- The third goal is to program the S88 following the S88 design
- The fourth goal is to import a exernal source file
- The last goal is to deliver a working project

Back to the project scope

Scope2

Automate the process of picking up packages and placing them on a different conveyor. This will be equipped with the following:

- 2 Digital photocells
- 2 Digital motor circuit breakers
- 2 Digital preasurised air valves
- 2 Digital contactors to control the conveyorbelt motors
- A digital vacuum grabber



Use the buttons on the PLC to control the motor circuit breakers.
Use the control board in FactoryIO to start and stop the machine.

The Pick and Place Project

- The first goal is to retrieve an archived program
- The second goal is to retrieve an archived library
- The third goal is to program the S88 following the S88 design
- The fourth goal is to import a exernal source file
- The last goal is to deliver a working project

Back to the project scope

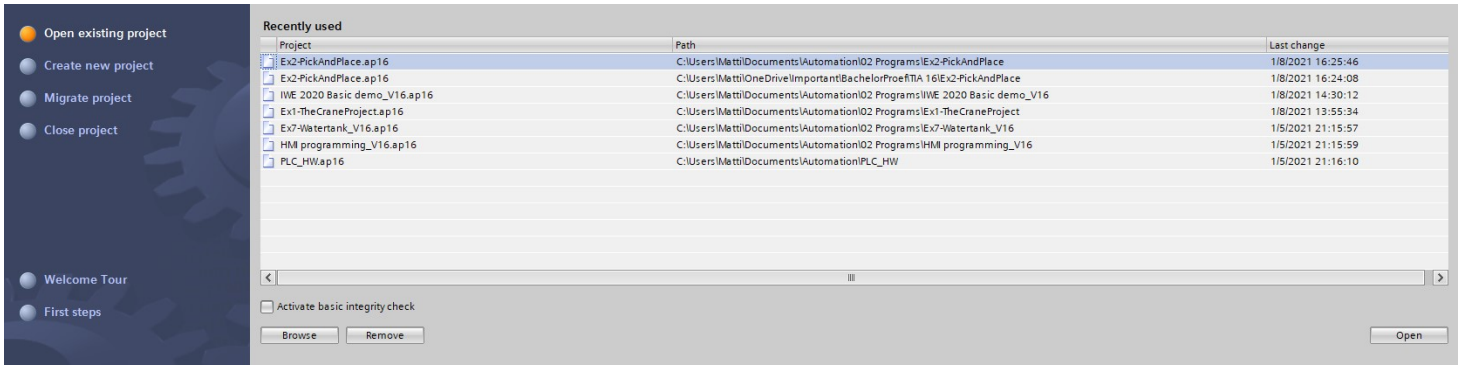
Goal 1 To retrieve an archived program

Step 1:

Copy/download the included Ex2-PickAndPlace.zap16 file. Copy the file into:

```
Filename : Ex2-PickAndPlace.zap16
Destination : \Documents\Automation
```

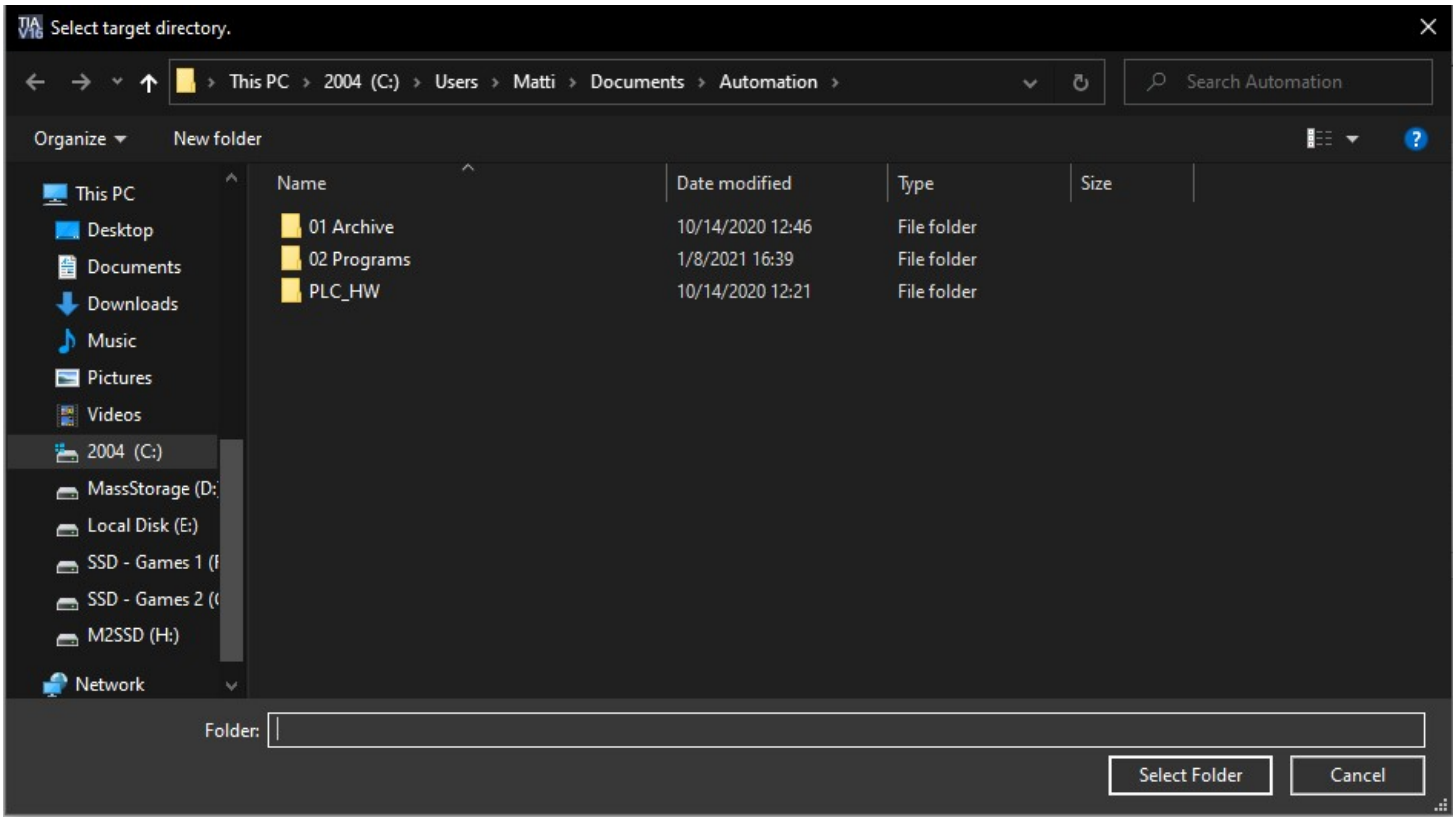
Step 2: Start TIA Portal and click on "Open existing project"



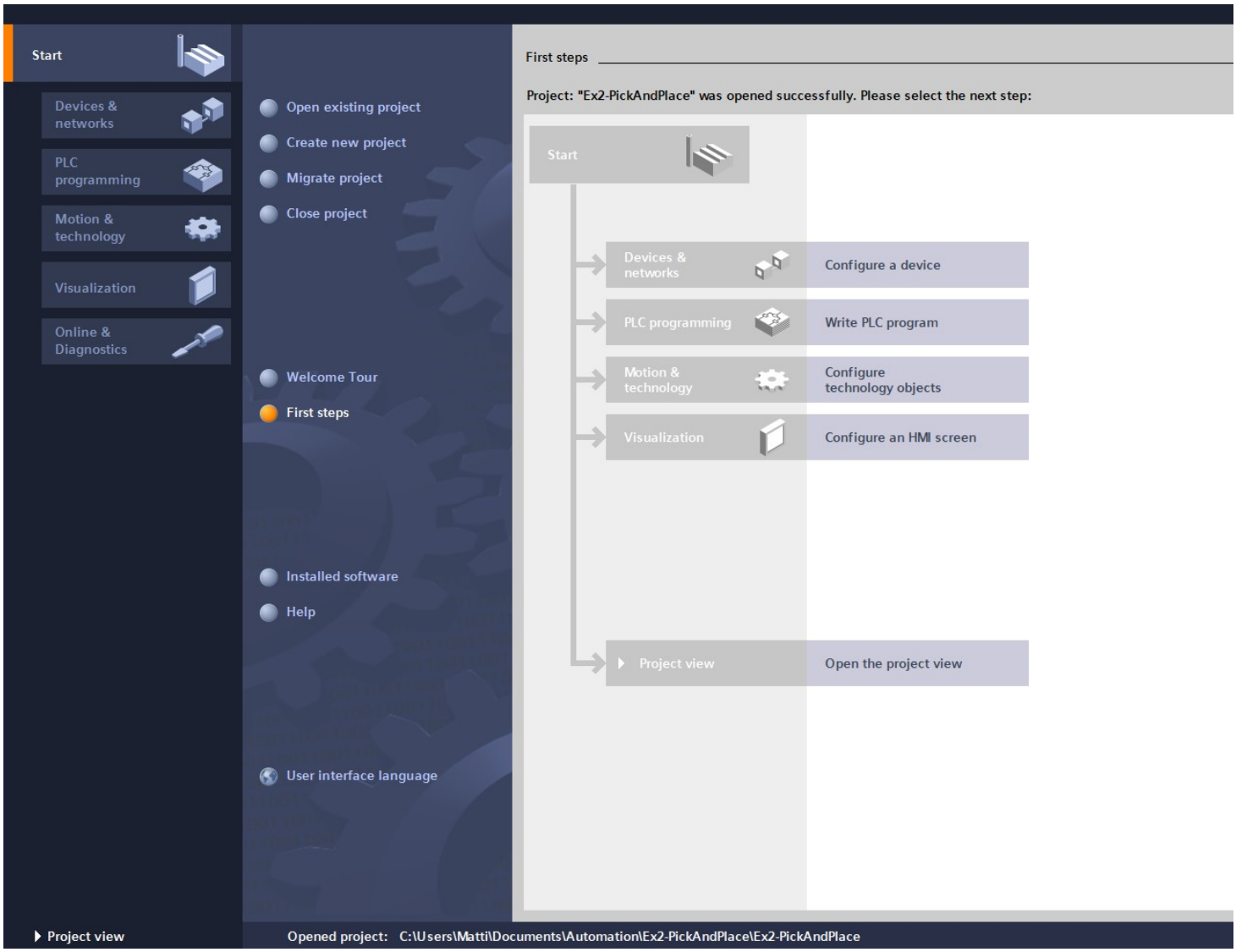
Step 3: Click on browse and search for the right archived file

```
Documents\Automation\Ex2-PickAndPlace.zap16
```

Step 4: Once selected you'll have to select the target destination. Select Documents\Automation in our case.



Step 5: Once this screen pops up you have succesfully opened the archive. Click on "Project view" to continue the exercise



The Pick and Place Project

- The first goal is to retrieve an archived program
- The second goal is to retrieve an archived library
- The third goal is to program the S88 following the S88 design
- The fourth goal is to import a exernal source file
- The last goal is to deliver a working project

Back to the project scope

Goal 2 To retrieve an archived library

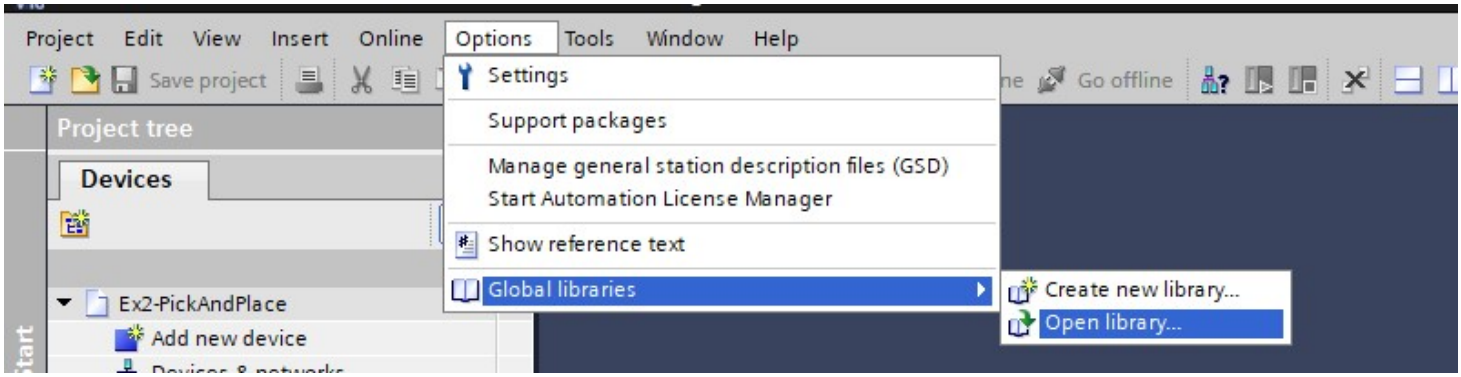
The point of retrieving this archived library is that this has all the control modules and procedure elemts programmed for you. So that later when you build your S88 in TIA you can drag them from the library into your project.

Step 1:

Copy/download the included .zal file named. Make a new subfolder into automation called "Library"(If it doesn't exist already). Copy the file into:

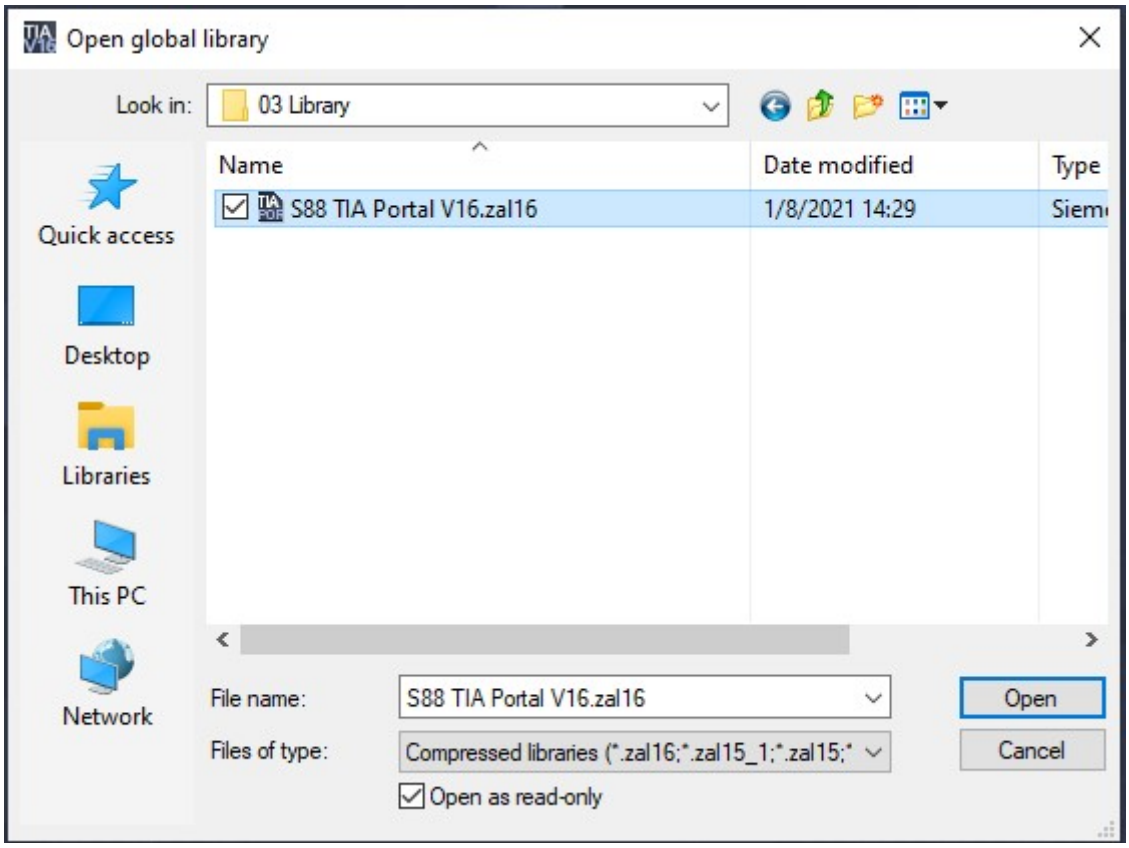
```
Filename : S88 TIA Portal V16.zap16
Destination : \Documents\Automation\Library
```

Step 2: To select the library go to "Options > Global libraries > Open library..."

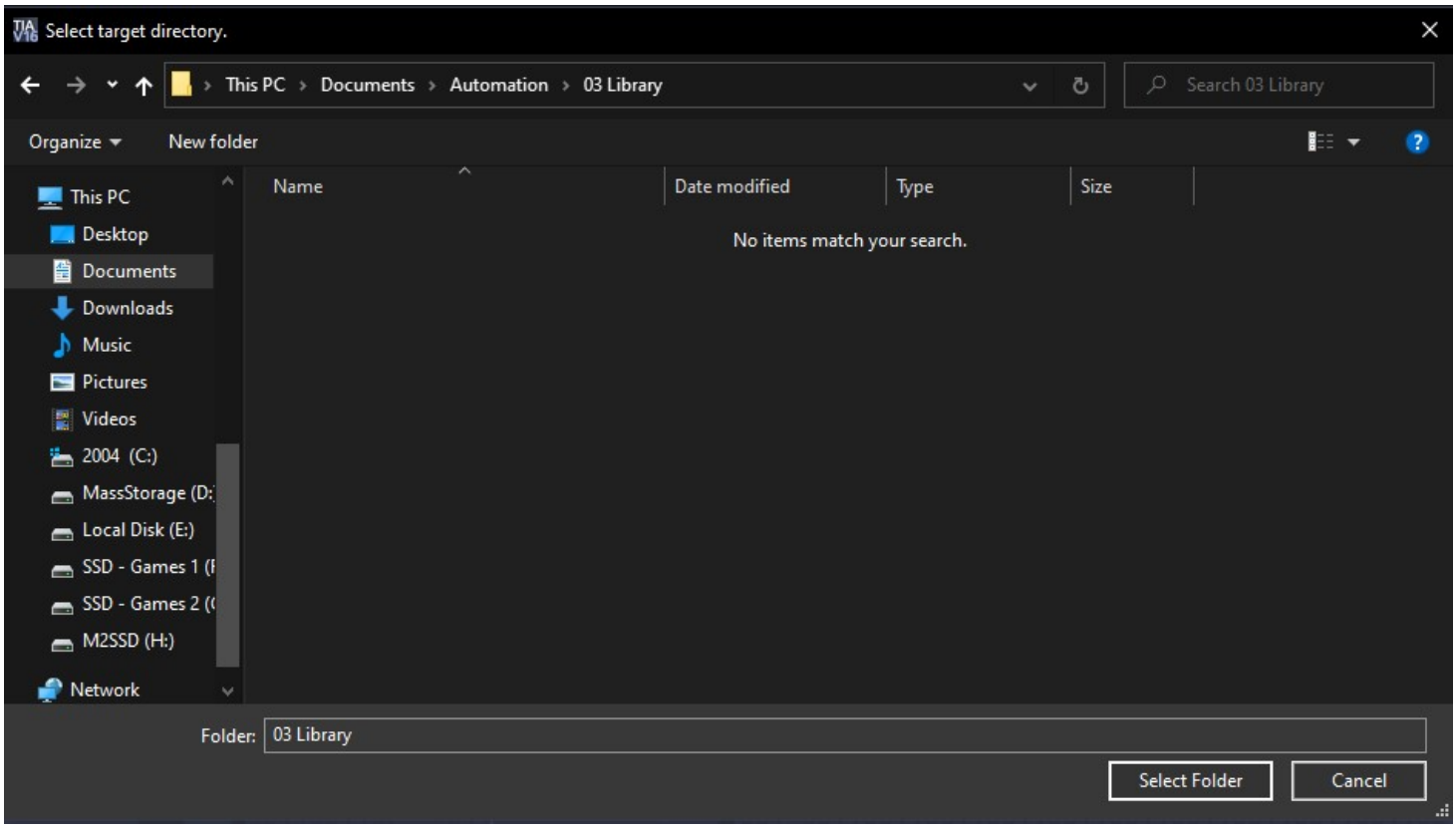


Step 3: Open in the follwing screen the saved library

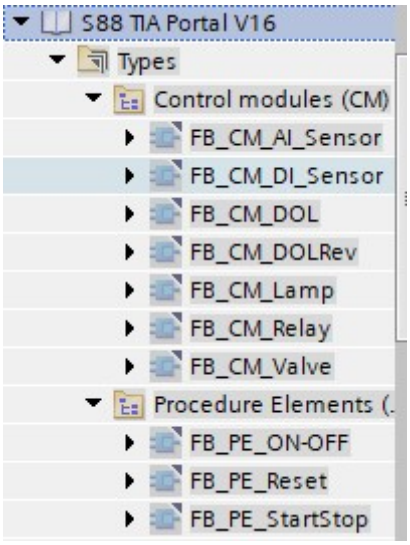
```
Files of type : Compressed Libraries
Destination : \Documents\Automation\Library
```



Step 4: Once selected you'll have to select the target destination. Select "Documents\Automation\Library" in our case.



Step 5: To make sure you have got the library opened check the right bottom of TIA Portal in "Global Libraries". This is done by clicking on libraries on the right side of tia portal.



The Pick and Place Project

- The first goal is to retrieve an archived program.
- The second goal is to retrieve an archived library
- The third goal is to program the S88 following the S88 design
- The fourth goal is to import a exernal source file
- The last goal is to deliver a working project

Back to the project scope

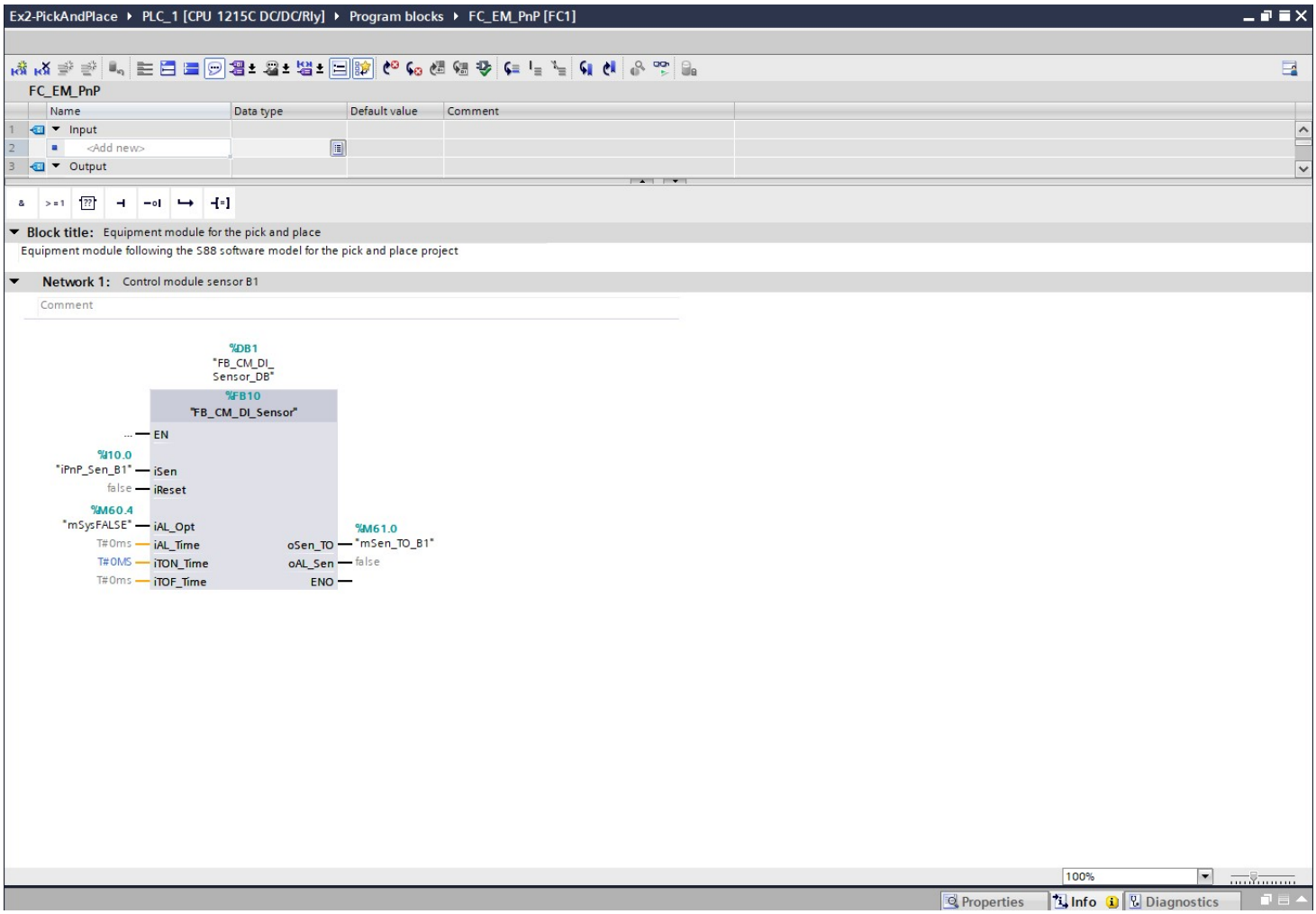
Goal 3 To program the S88

Step 1: Create the necessary PLC Tags:

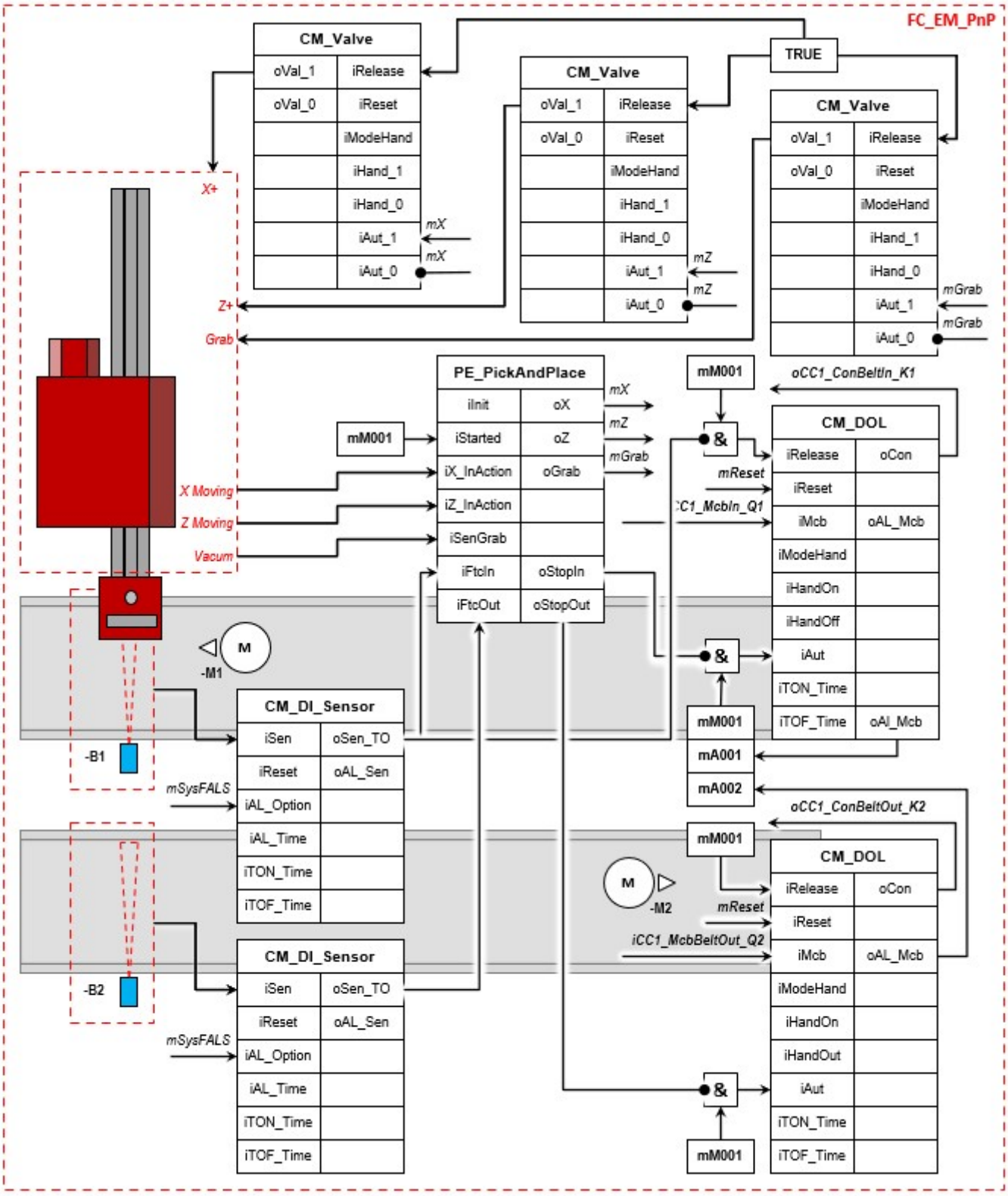
```
//Inputs
iCC1_McbConveyorIn_Q1 - BOOL - %I 0.0 - Motor circuit breaker for conveyor belt entry
iCC1_McbConveyorOut_Q2 - BOOL - %I0.1   - Motor circuit breaker for conveyor belt exit
iPnP_Sen_B1 -   BOOL - %I10.0 - Sensor item at entry
iPnP_Sen_B2 - BOOL - %I10.1 - Sensor item at exit
Moving X - BOOL - %I10.2 - Robot is moving in the X axis
Moving Z - BOOL - %I10.3 - is moving in the Z axis
Vacuum - BOOL - %I10.4 - The vacuum of the robot is active
iCC1_BtnStart_S1 - BOOL - %I10.5 - Start button
iCC1_BtnReset_S3 - BOOL - %I10.6 - Reset button
iCC1_BtnStop_S2 - BOOL - %I10.7 - Stop button
iCC1_BtnEms_S4  - BOOL - %I11.0 - Emergency stop button


//Outputs
iCC1_McbConveryorIn_K1 - BOOL - %Q10.0 - Contactor conveyor belt entry
iCC1_McbConveyorOut_K2 - BOOL - %Q10.1 - Contactor conveyor belt exit
Move X - BOOL - %Q10.2 - Moves the robot in the X axis
Move Z -  BOOL - %Q10.3 - Moves the robot in the Z axis
Grab - BOOL - %Q10.4 - Grabs an item
oCB1_LmpError_H1 - BOOL - %Q10.7 - Error lamp


//Flags
mM001 - BOOL - %M50.0 - System started
mA001 - BOOL - %M50.1 - Motor circuit breaker conveyot belt entry alarm
mA002 - BOOL - %M50.2 - Motor circuit breaker coneyor belt exit alarm

mZ - BOOL - %M60.1 - Flag move Z-axis of the robot
mGrab - BOOL - %M60.2 - Flag grab item
mReset - BOOL - %M60.3 - Flag reset
mSysFALSE - BOOL - %M60.4 - Flag FALSE
mStopIn - BOOL - %M60.6 - Flag stop conveyor belt entry
mStopOut - BOOL - %M60.7 - Flag stop conveyor belt exit
mSen_TO_B1 - BOOL - %M61.0 - Flag sensor B1
mSen_TO_B2 - BOOL - %M61.1 - Flag sensor B2
mSysIlnit       - BOOL - %M60.5 - Flag initilization
```

Step 2 : Open the Function FC_EM_PnP[FC1]

Step 3 : There is one control module already present and linked to the right tags.



Step 4: Program the remaining control modules like the following S88 design. *For each control module or procedure element you need to have a seperate network*



The Pick and Place Project

- The first goal is to retrieve an archived program.

- The second goal is to retrieve an archived library
- The third goal is to program the S88 following the S88 design
- The fourth goal is to import a exernal source file
- The last goal is to deliver a working project

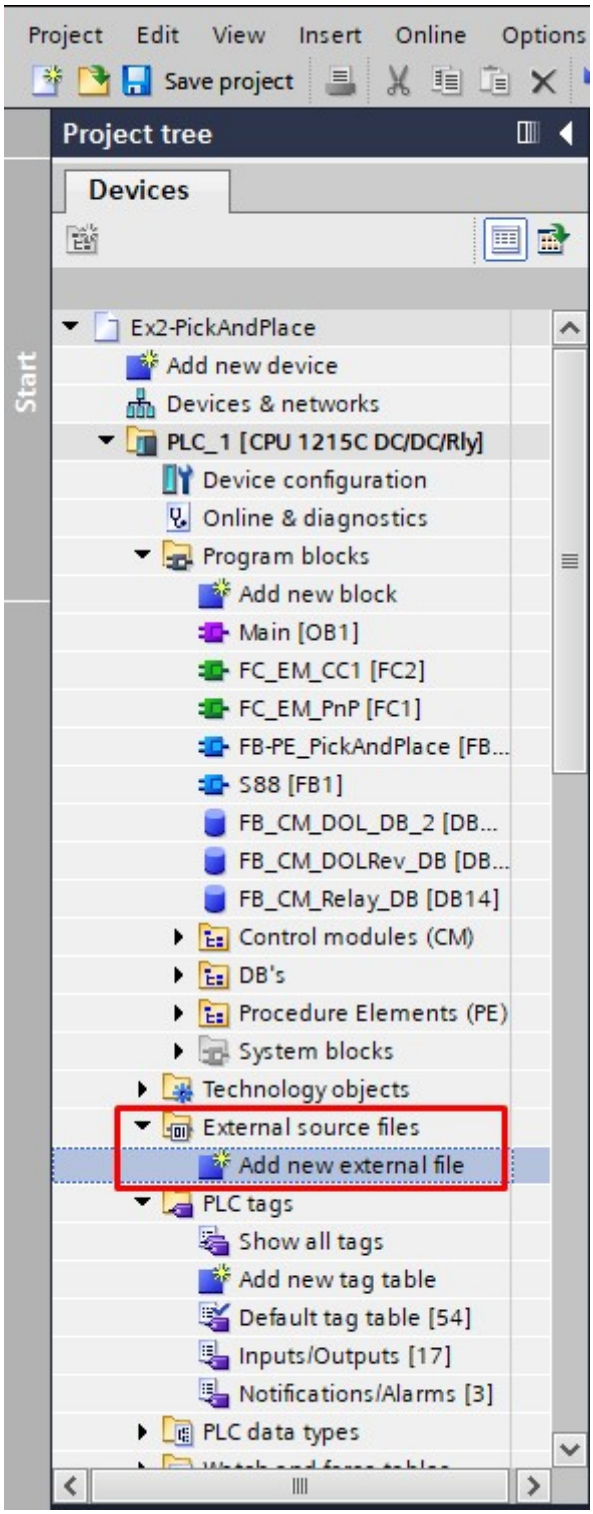
Back to the project scope

Goal 4 To import an external source file

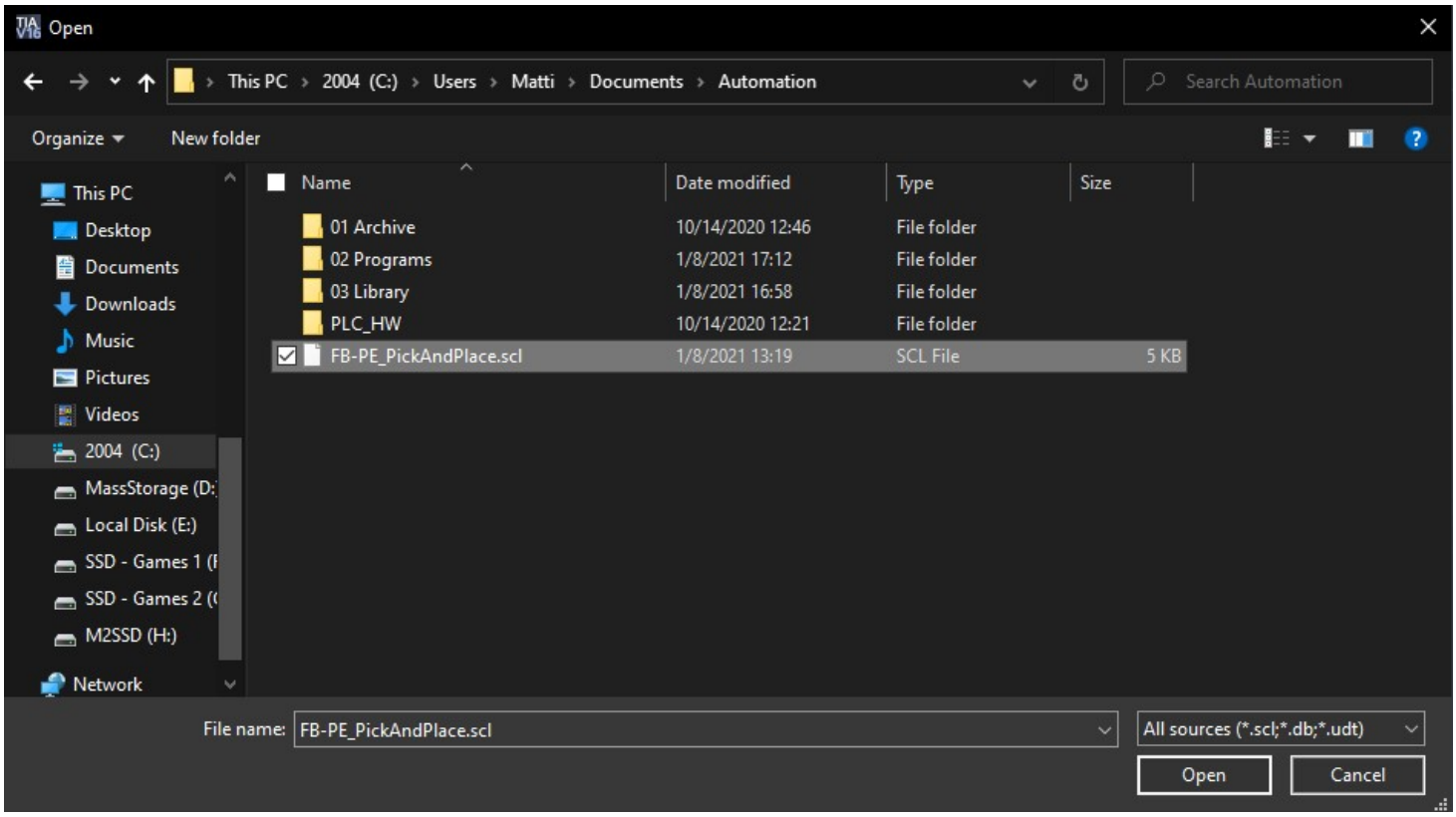
Step 1: Download/copy FB-P_PickAndPlace.scl and place it under

```
Filename : FB-P_PickAndPlace.scl
Destination : \Documents\Automation
```

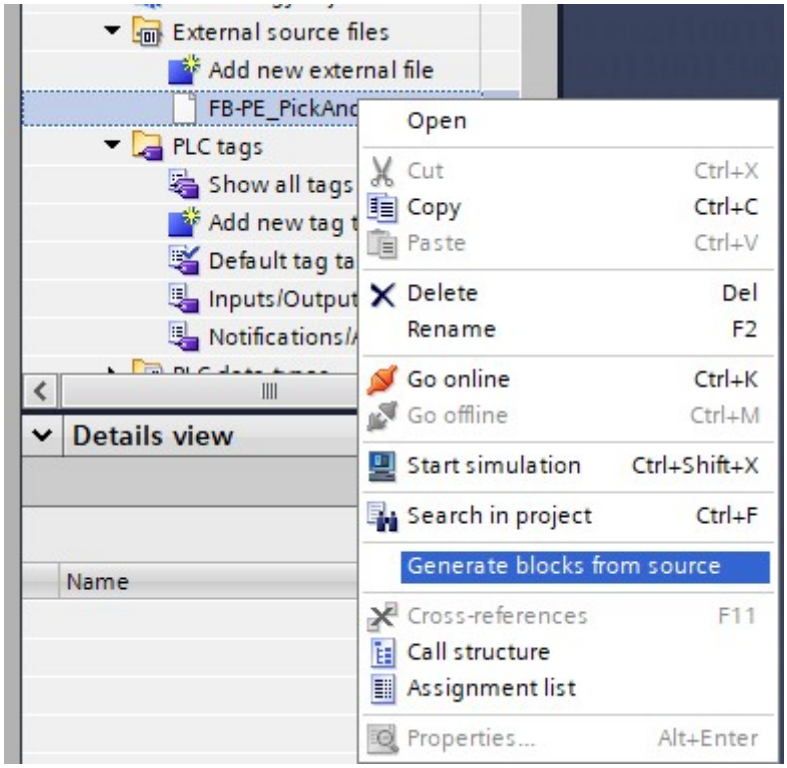
Step 2: Search for "External source files" in the project tree and click on "Add new external file"



Step 3: In the file browser select FB-P_PickAndPlace.scl and open it



Step 4: Under the "External source files" the selected file will pop up. Right click on it and run "Generate source blocks from source"



Step 5: Add both the Functions into *Function block* FC_EM_PnP [FC1]:

```
FB-P_PickAndPlace into a new network
```

Step 5: Link the right tags with the block that has been generated

The Pick and Place Project

- The first goal is to retrieve an archived program.
- The second goal is to retrieve an archived library
- The third goal is to program the S88 following the S88 design
- The fourth goal is to import a exernal source file
- The last goal is to deliver a working project

Back to the project scope

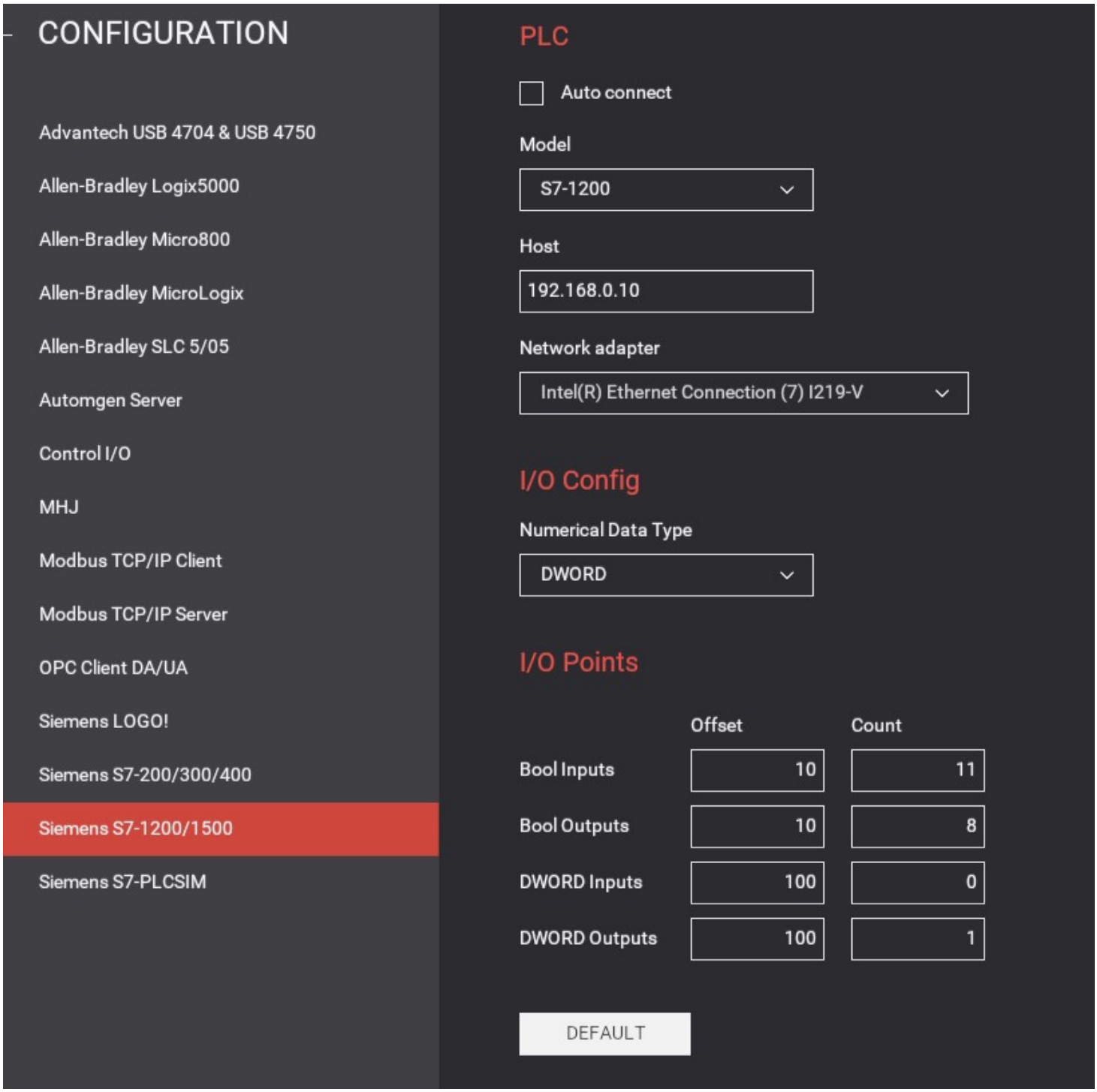
Goal 5 To deliver a working project2

Step 1: Open the FactoryIO scene called "Pick and Place" (it's one of the default scene's)

Step 2: Configure the driver to the right PLC

Step 3: Open up the configuration

```
IP adress: 192.168.0.10
Bool inputs: 10
Bool outputs: 10
```



Step 4: Compile the hardware with a rebuild all command

Step 5: Compile the software with a rebuild all command

Step 6: Download hardware and software to the PLC_1

Step 7: Test the Project

Normal functionallity

- Start the conveyorbelt by pressing the start button in FactoryIO

- The sensor will detect an item on the entry conveyor belt
- Entry conveyor belt will stop and the robot will pick up the item
- Exit conveyor belt will stop and the robot will put down the item

Exercise 3

Back

Study materials

Literature

- Addendum 04 : Grafcet

Equipment

1 Engineering station 2 SIMATIC S7-1200 controller, e.g. CPU 1215C DC/DC/DC – firmware V4.2 or higher 3 SIMATIC STEP 7 software in TIA Portal – V15 SP1 or higher 4 Ethernet connection between engineering station and controller 5 Factory IO scene Pick & Place.factoryio

The Pick and Place Project

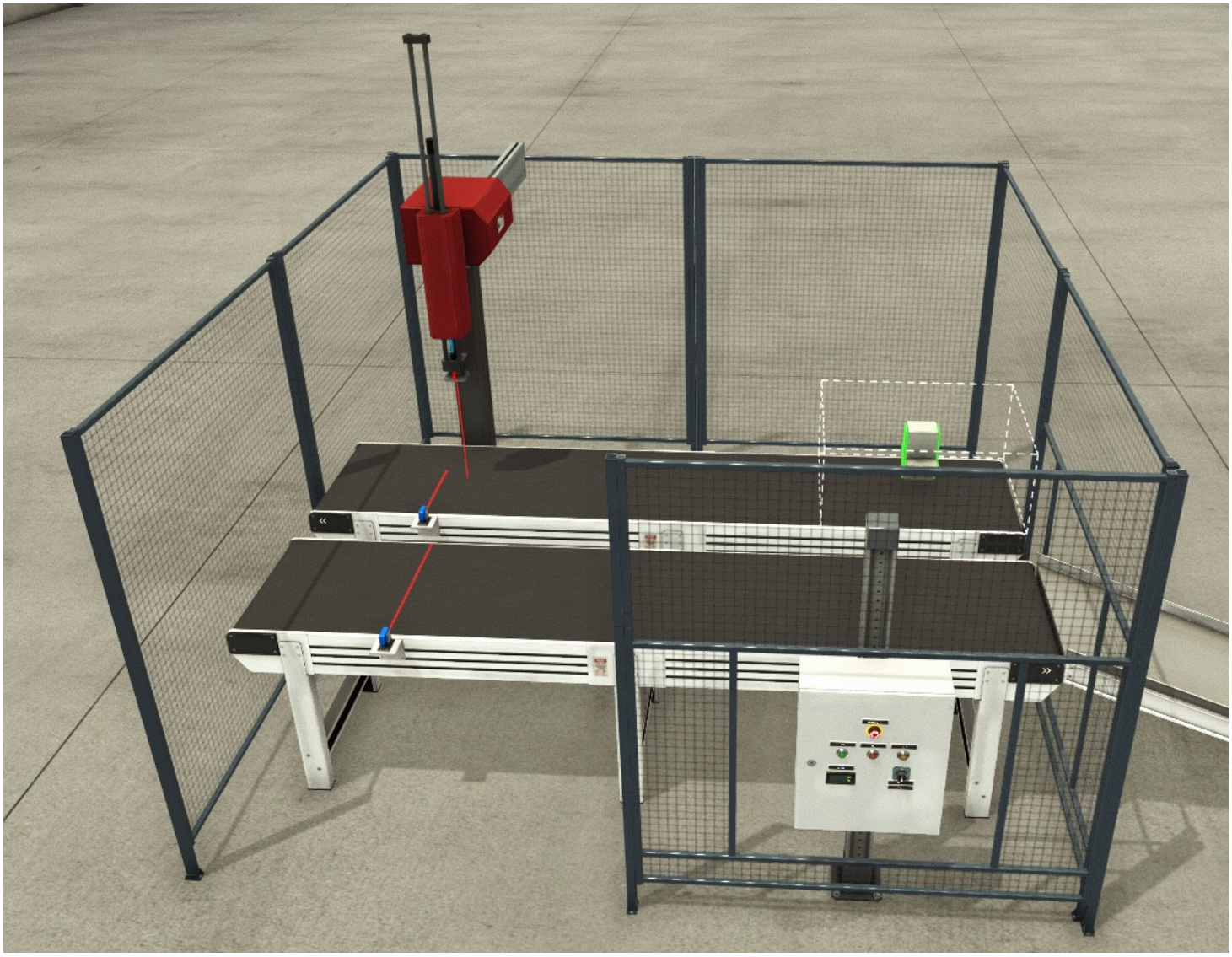
- The first goal is to program a GRAFCET
- The second goal is to program a Flowchart
- The third goal is to deliver a working

Back to the project scope

Scope3

Automate the process of picking up packages and placing them on a different conveyor. This will be equipped with the following:

- 2 Digital photocells
- 2 Digital motor circuit breakers
- 2 Digital preasurised air valves
- 2 Digital contactors to control the conveyorbelt motors
- A digital vacuum grabber



Use the buttons on the PLC to control the motor circuit breakers.
Use the control board in FactoryIO to start and stop the machine.

Goal 1 To program a GRAFCET

Step 1: Open the previous exercise Ex2-PickAndPlace.

```
Filename : Ex2-PickAndPlace.ap16
```

Step 2: Remove the function block that we previously ported into TIA.

```
Functionblock : FB-P_PickAndPlace
```

Step 3: Copy/download the included .zal file named. Make a new subfolder into automation called "Library"(If it doesn't exist already). Copy the file into:

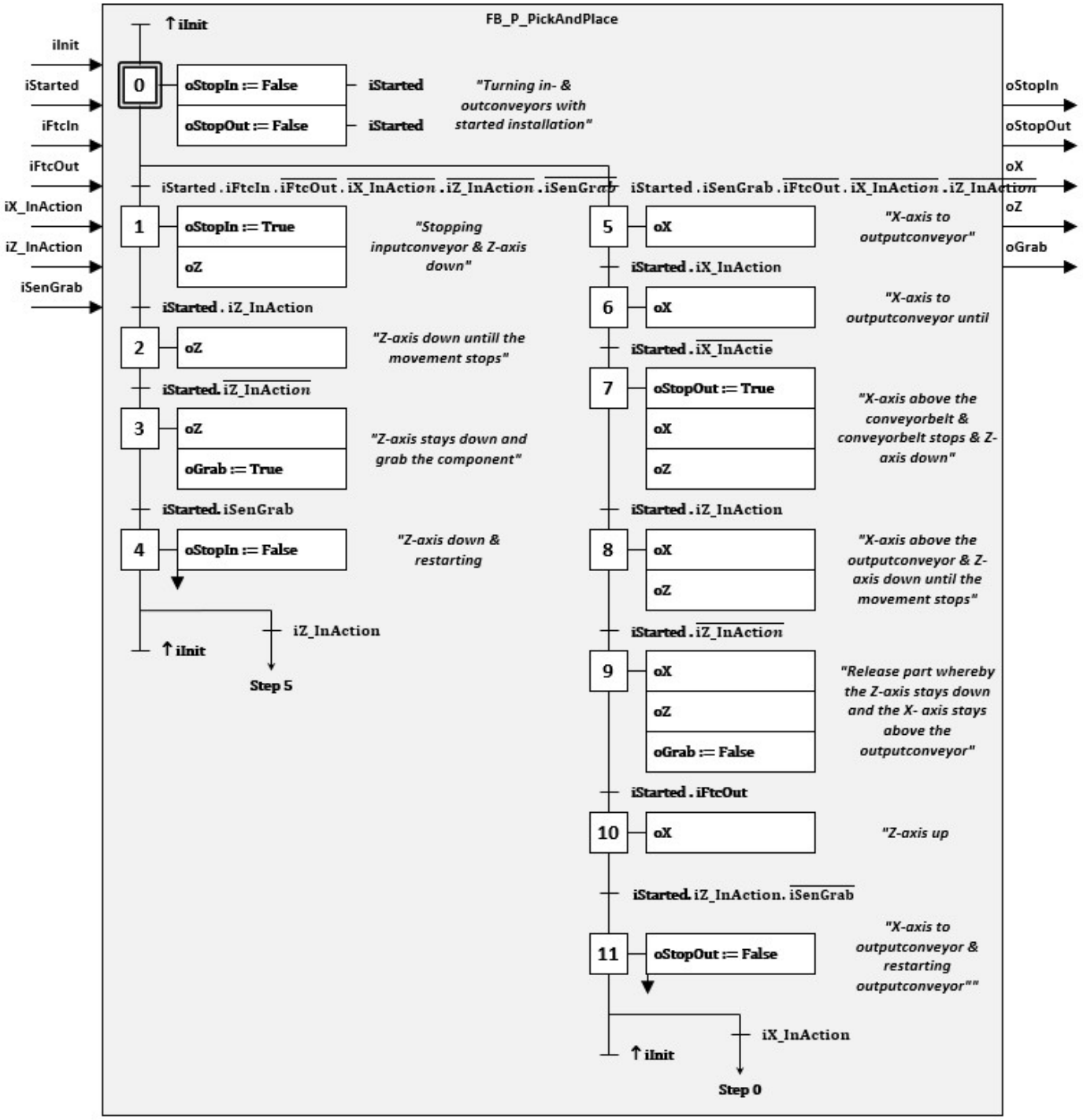
```
Filename : S88 GRAFCET.zap16
Destination : \Documents\Automation\Library
```

Step 4: Open the archive as we did in Ex02. Here you'll find a template of a GRAFCET under "Master Copies" called "FB-P_GRAFCET". Drag this into your TIA portal project.

Step 5: Rename the block to FB-P_PickAndPlace.

Remark: The previous block "FB-P_PickAndPlace" in "FC_EM_PnP" will be red, to fix this right click on the block and press "Update block call".

Step 6: Program the following GRAFCET into FB-P_PickAndPlace.



The Pick and Place Project

- The first goal is to program a GRAFCET
- The second goal is to program a Flowchart
- The third goal is to deliver a working

Back to the project scope

Goal 2 To program a Flowchart

Step 1: Create the necessary PLC Tags:

```
//Outputs
Counter - DWORD - %QD100 - Amount of processed packages

//Flags
mA003 - BOOL - %M50.3 - Motor circuit breaker coneyor belt exit alarm
mCounter - DWORD - %QD100 - Flag amount of processed packages
```

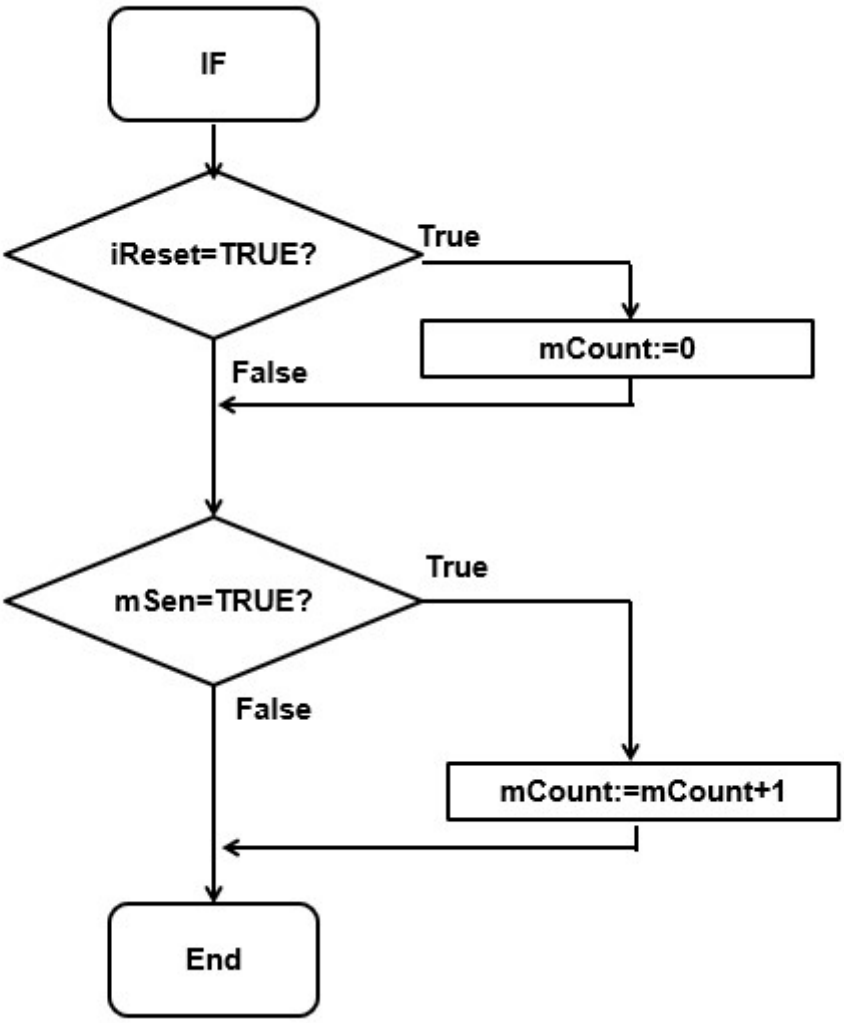
Step 2: Create the Function Block FB_Counter[FB1] in the language SCL

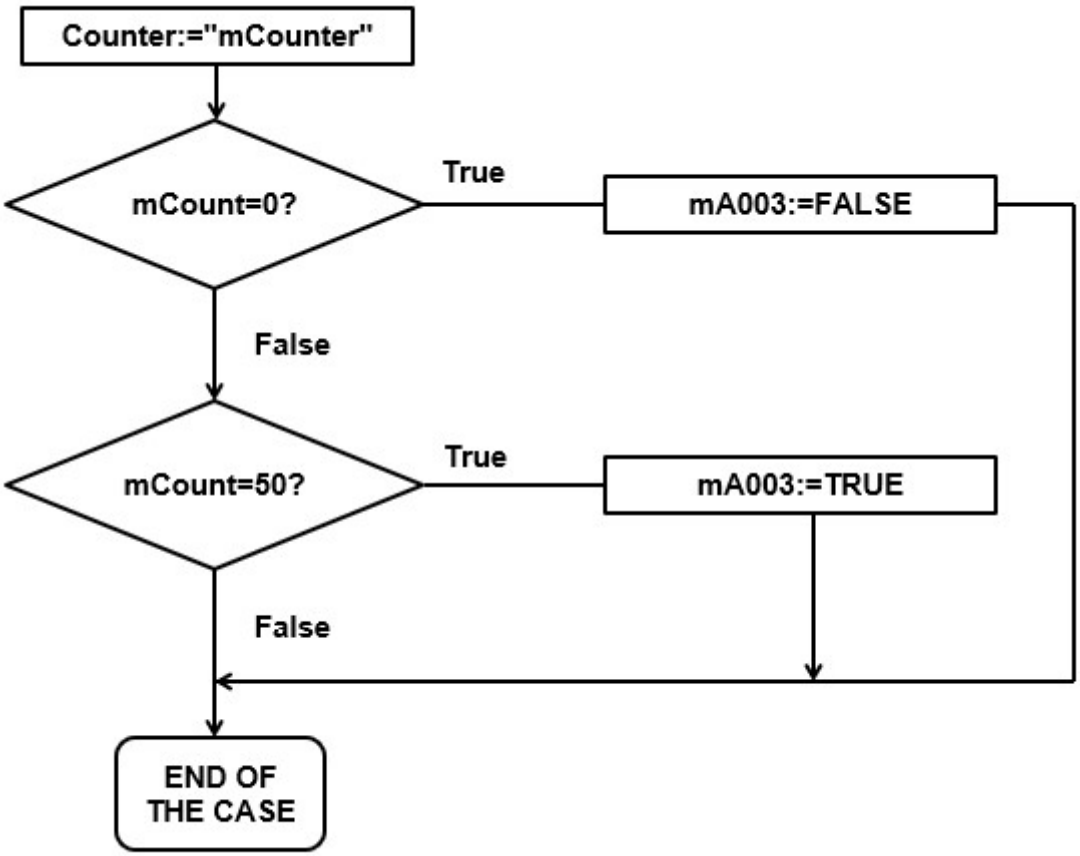
Step 3: Create the necessary block tags:

```
//Static
mSen - BOOL - Rising edge detection for sensor on the output conveyor
```

Step 4: Add a rise edge direction for "mSen_TO_B2"
Remark "mSen_TO_B2" will be the input and "mSen" will be the output

Step 5: Create the following Flowcharts


IF
iReset=TRUE?
True
mCount:=0
False
mSen=TRUE?
True
False
mCount:=mCount+1
End



The Pick and Place Project

- The first goal is to program a GRAFCET
- The second goal is to program a Flowchart
- The third goal is to deliver a working project

Back to the project scope

Goal 3 To deliver a working project3

Step 1: Compile the hardware with a rebuild all command

Step 2: Compile the software with a rebuild all command

Step 3: Download hardware and software to the PLC_1

Step 4: Test the Project

Normal functionallity

- Start the conveyorbelt by pressing the start button in FactoryIO
- The sensor will detect an item on the entry conveyor belt
- Entry conveyor belt will stop and the robot will pick up the item
- Exit conveyor belt will stop and the robot will put down the item
- The counter counts up each time a object gets detected by the fotocell on the outputconveyor
- Stop light lights up when you reach 50 moved packages

Exercise 4

Back

Study material

Literature

- Addendum 05 Controllers

Equipment

1 Engineering station 2 SIMATIC S7-1200 controller, e.g. CPU 1215C DC/DC/DC – firmware V4.2 or higher 3 SIMATIC STEP 7 software in TIA Portal – V15 SP1 or higher 4 Ethernet connection between engineering station and controller 5 Factory IO scene Level Control.factoryio

The Watertank Project

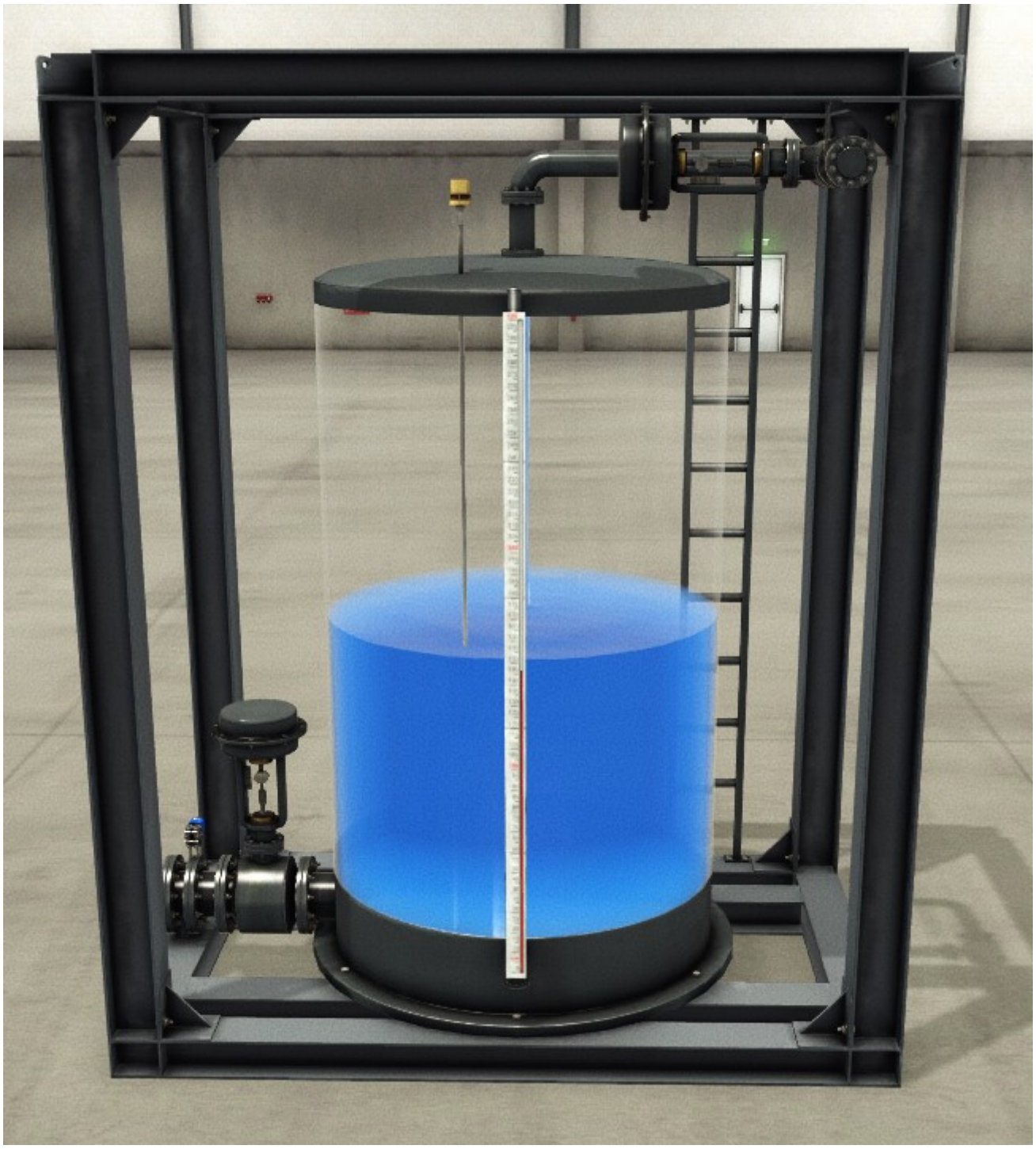
- The first goal is to program an ON/OFF controller
- The second goal is to program a PID controller
- The third goal is to deliver a working program

Back to the project scope

Scope4

Automate controlling the level in **watertank T1**. that is equipped with

- An analog level sensor
- An analog flow sensor on the outlet
- An analog inlet valve
- An analog outlet valve



Use the buttons, lamps, potentiometer and analog indicator on the ASTI PLC board to control the watertank.

Characteristics

- Height: 3 m
- Diameter: 2 m
- Discharge pipe radius: 0.125 m
- Input flow: 0.25 m^3/s

- Output flow: 0.3543 m³/s

The Watertank Project

- The first goal is to program an ON/OFF controller
- The second goal is to program a PID controller
- The third goal is to deliver a working program

Back to the project scope

Goal 1 To program an ON OFF controller

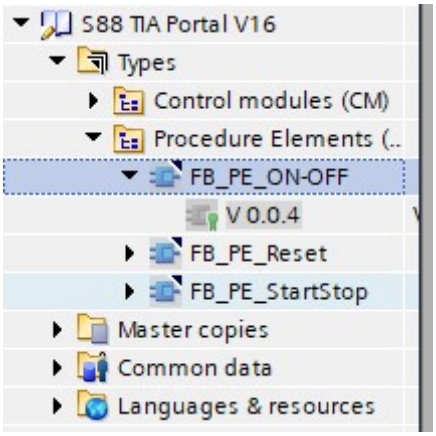
Step 1: Open project Ex7-Watertank

Step 2: Open the *Function* FC_T1[FC2]

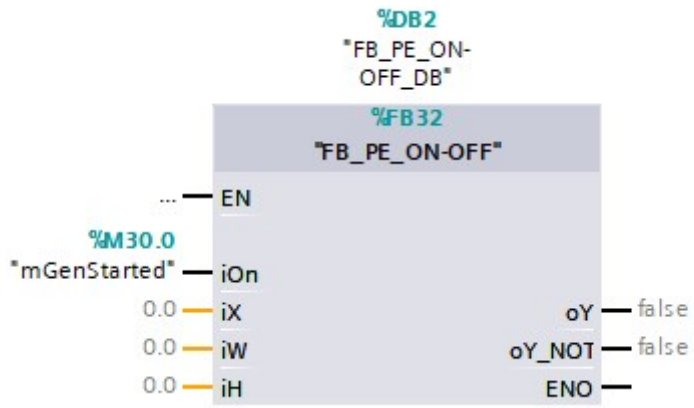
Step 3: Delete the content within network 4 : Level control

Step 4: Open the library "S88 TIA Portal V16"

Step 5: Copy "FB_PE_ON-OFF" into the *Function* FC_T1[FC2] network 4 :



Step 6: Link the right in- & outputs of the ON-OFF controller.



Step 8 : Open the FactoryIO scene called:

```
Filename : Level_Control.factoryio
Filelocation : \Documents\Factory IO\My Scenes
```

Step 9: Compile the hardware with a rebuild all command

Step 10: Compile the software with a rebuild all command

Step 11: Download hardware and software to the PLC_1

Step 12: Test the Project

Normal functionallity

- If you change the iH value the hysteresis of the controller will change
- If you change the iW value the setpoint will change
- The on/off controller will control the level set by you in iW
- Play around with these values and see what they do

The Watertank Project

- The first goal is to program an ON/OFF controller
- The second goal is to program a PID controller
- The third goal is to deliver a working program

Back to the project scope

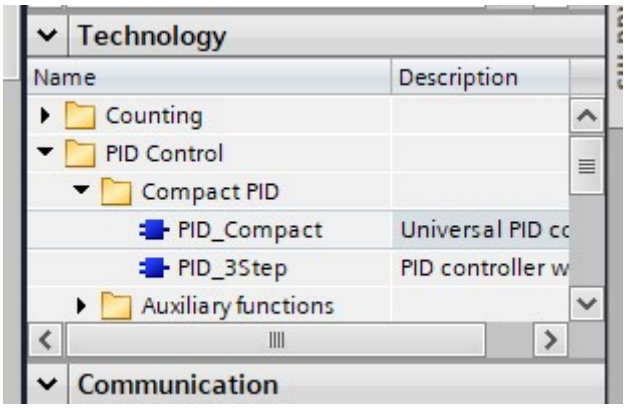
Goal 2 To program a PID controller

Step 1: Open project Ex7-Watertank

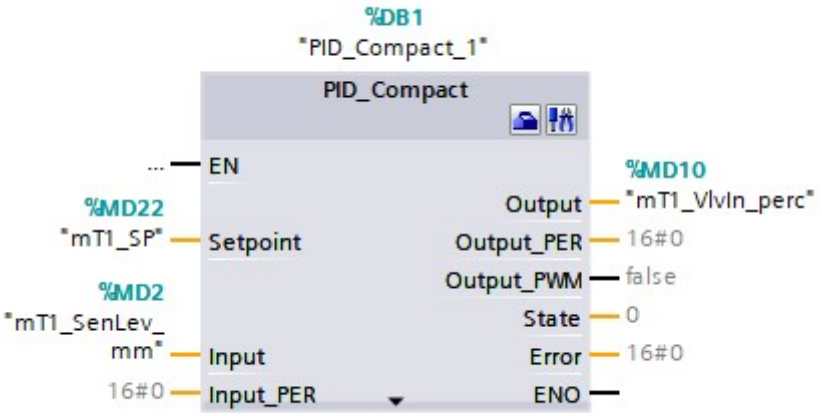
Step 2: Delete network 4 : Level control

Step 3: Create a cyclic interrupt

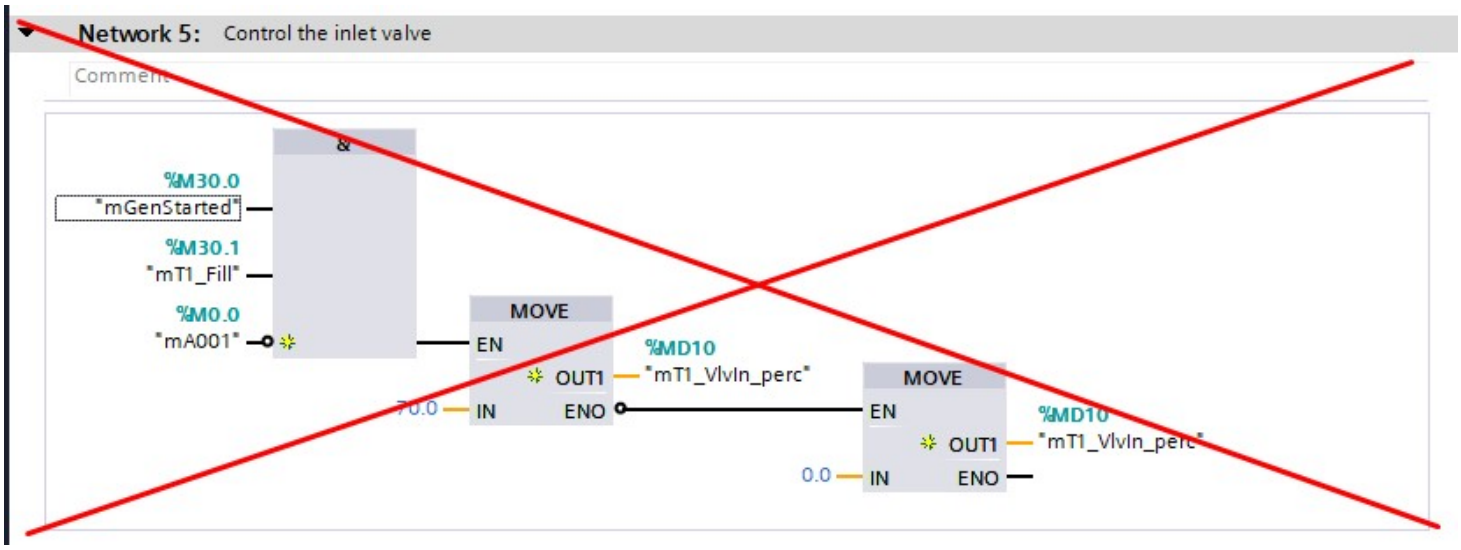
Step 4: Add PID_Compact into *cyclic interrupt*



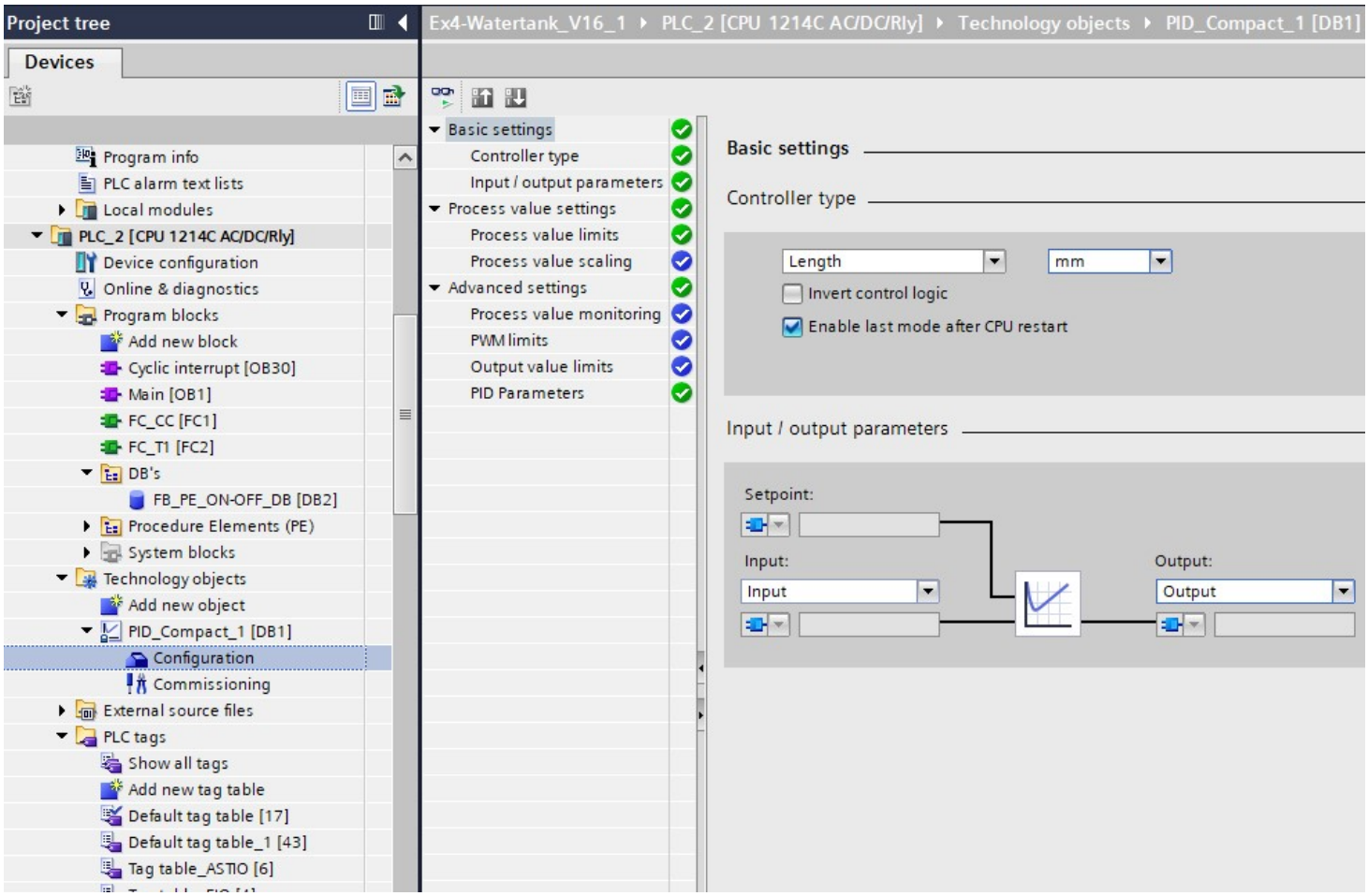
Step 5: Connect the right in- & outputs



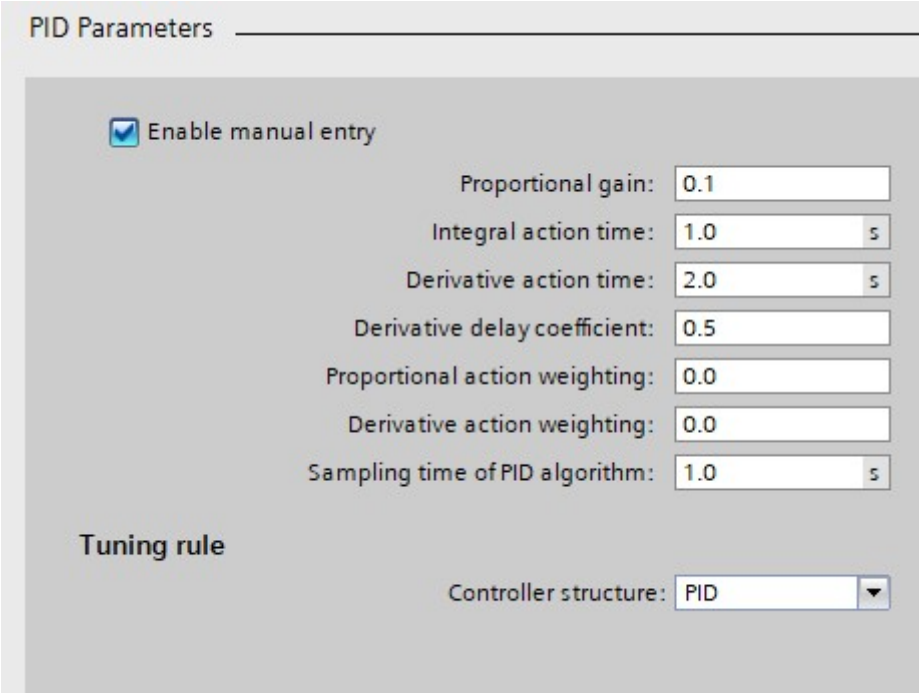
Step 6: Delete network 5 : Control the inlet valve



Step 7: Configure the PID_Compact



Step 8: Play with the following paramaters



Step 9 : Open the FactoryIO scene called:

```
Filename : Level_Control.factoryio
Filelocation : \Documents\Factory IO\My Scenes
```

The Watertank Project

- The first goal is to program an ON/OFF controller
- The second goal is to program a PID controller
- The third goal is to deliver a working program

Back to the project scope

Goal 3 To deliver a working program4

Step 1: Compile the hardware with a rebuild all command

Step 2: Compile the software with a rebuild all command

Step 3: Download hardware and software to the PLC_1

Step 4: Go to Exercise 5 to test the program on a HMI screen

Exercise 5

Back

Study material

Literature

- Addendum 03 HMI
- Addendum 05 Controllers

Equipment

> **1** Engineering station
> **2** SIMATIC S7-1200 controller, e.g. CPU 1215C DC/DC/DC – firmware V4.2 or higher
> **3** SIMATIC STEP 7 software in TIA Portal – V15 SP1 or higher
> **4** Ethernet connection between engineering station and controller
> **5** Factory IO scene Pick & Place.factoryio

Additional literature

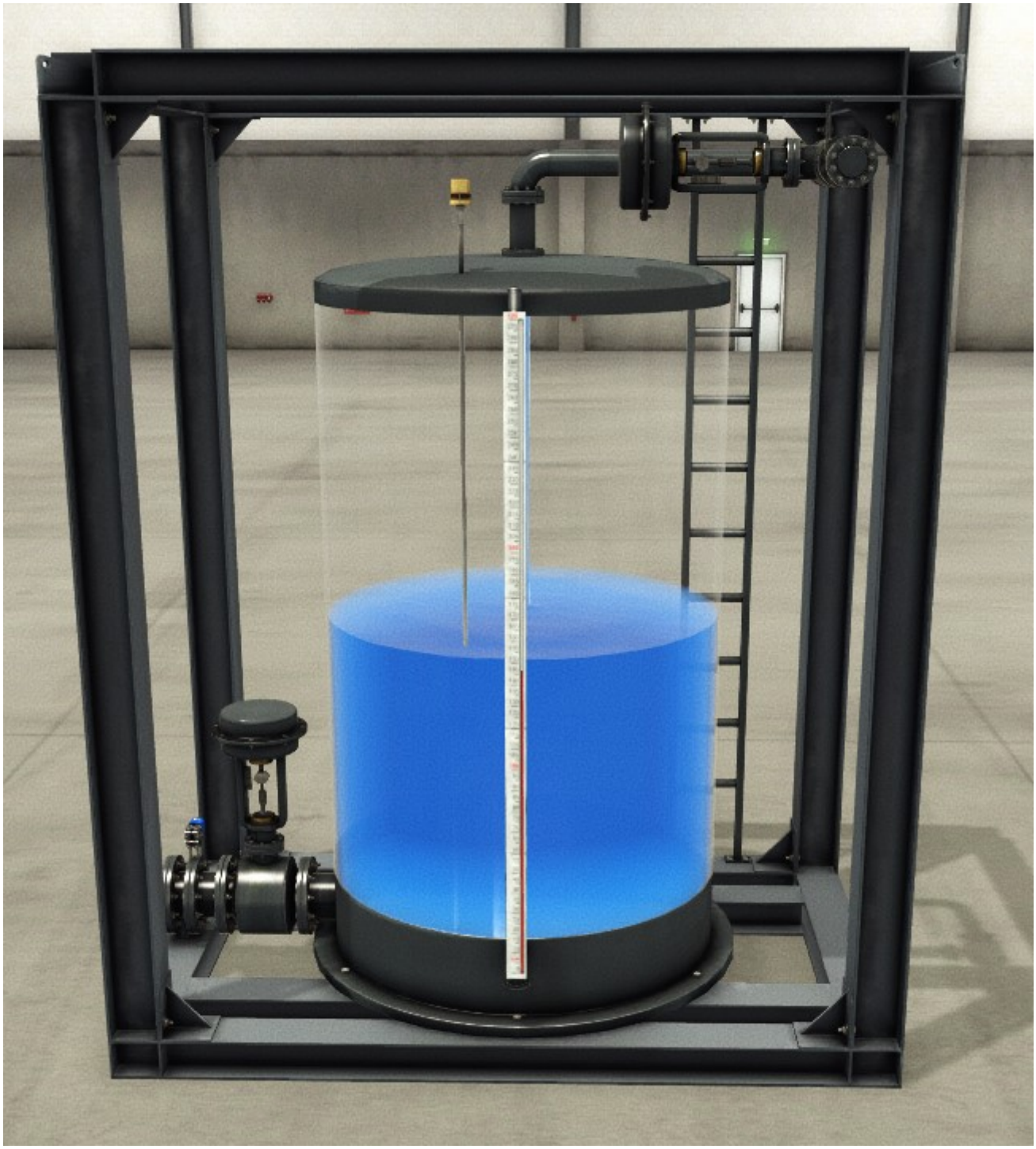
- Real Games Factory IO manual - https://docs.factoryio.com/

The Watertank Project

Scope

Automate controlling the level in **watertank T1**. that is equipped with

- An analog level sensor
- An analog flow sensor on the outlet
- An analog inlet valve
- An analog outlet valve



Use the HMI simulation to control the tank leven and control the PID parameters

Step 1: Open project Ex4-Watertank

Step 2 : Open the FactoryIO scene called:

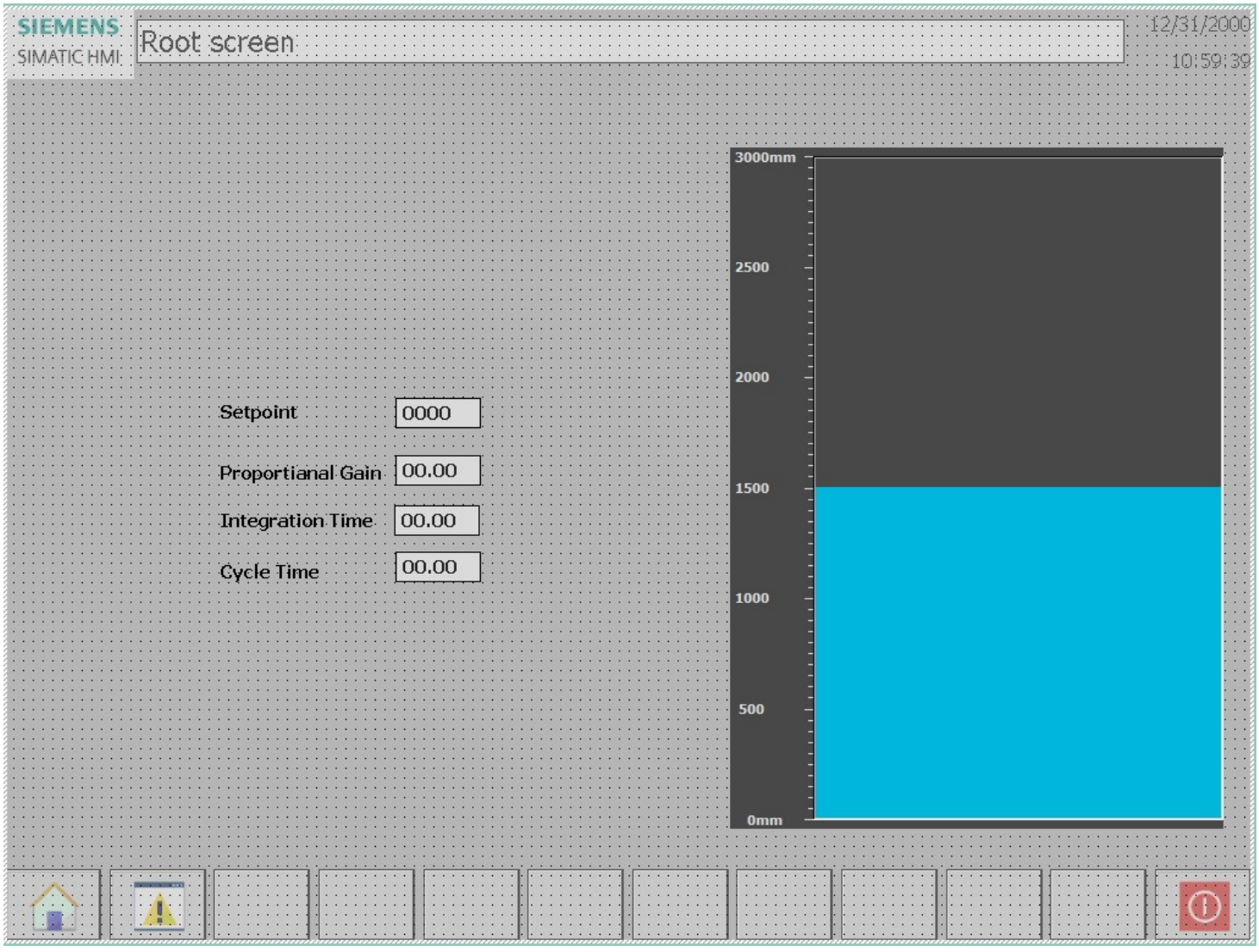
```
Filename : Level_Control.factoryio
Filelocation : \Documents\Factory IO\My Scenes
```

Step 3: Add a TP1500 Basic color PN HMI panel to the project

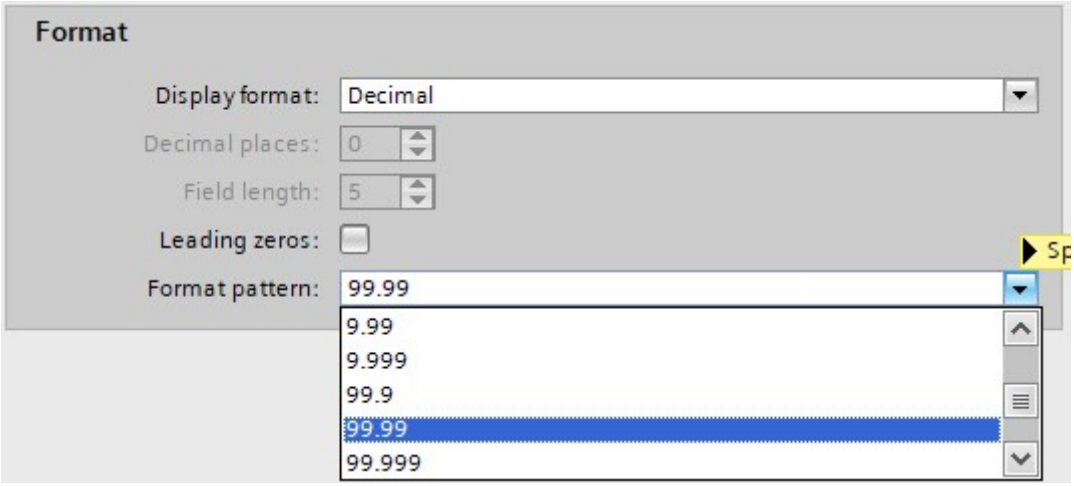
Step 4: Link the HMI to the PLC configured in the project.

```
IP-address                    : 192.168.0.31
IP-address subnet mask        : 255.255.255.0
```

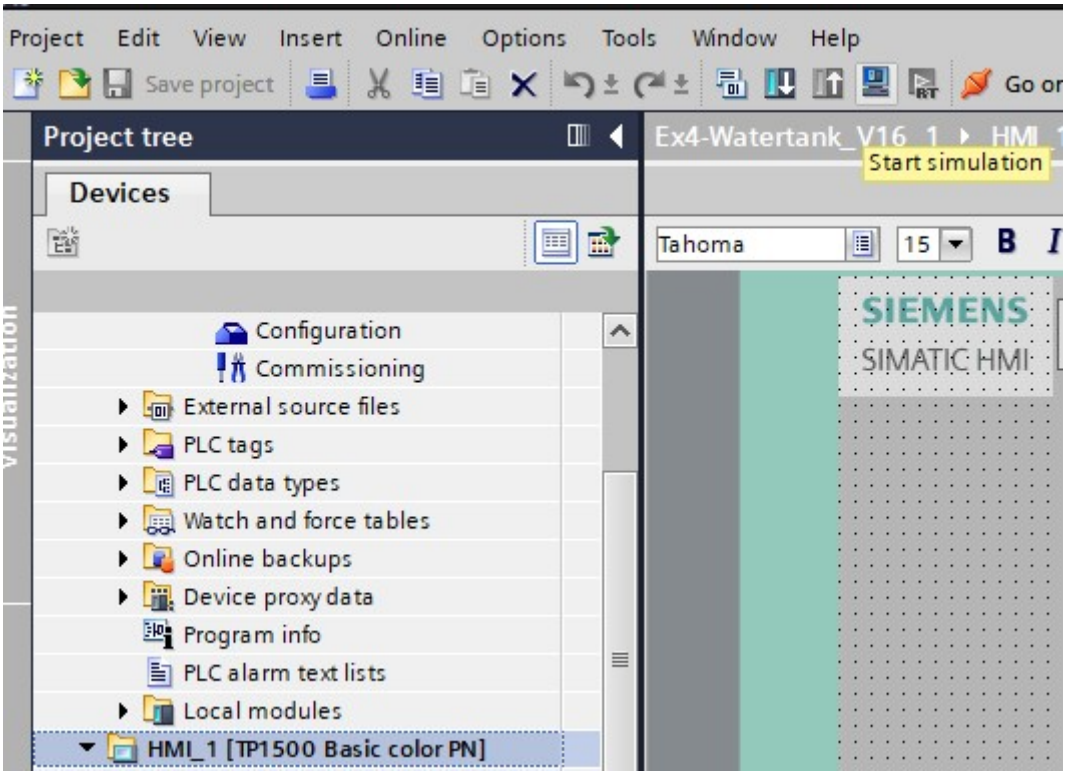
Step 5: Create the following HMI screen, (adjust the PID parameters through HMI)



Remark: to show and use the parameters in 00.00 values in a IO field;



Step 6: Start the HMI simulation



Remark: if the HMI simulation can't find your PLC connection go to the following

```
"C:\Program Files\Common Files\Siemens\CommunicationSettings"
```

Acces point > S7ONLINE > "Your networkcard"

Normal functionallity

- The PID will slowly increase(or decrease) when setpoint changes and ultimately stop at the setpoint
- Play with the PID parameters until it works

1. Markdown is een opmaaktaal op basis van platte tekst die ontworpen is voor HTML gebaseerde webpagina's. (Bestandsextensie .md) ↩
2. ADD = Addendum, een onderwerp wordt hierin volledig uitgelegd. ↩
3. LHL = Low / High / Low ↩ ↩
4. SFC = Sequential Function Chart, Siemens uses the name GRAPH ↩
5. Debugging = Searching for (programming) faults ↩
6. Within (process)automation this is commonly the automation of an entire machine/installation. The S88 software model divides a machine/installation proces in 3 big parts: ↩
7. NO = Normal open ↩
8. NC = Normal closed ↩