Use Case 1: Connecting Simulink Models to SIMATIC PLCSIM Advanced via API

SIMATIC S7-PLCSIM Advanced
Simulink

https://support.industry.siemens.com/cs/ww/en/view/109749187

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1 Introduction

1.1 Overview

In automation and control engineering, the Simulink software from MathWorks is frequently used to simulate processes and create algorithms. The requirement is to simulate the model, algorithm or function in a virtual environment via PLCSIM Advanced or, based on hardware, using a software controller in just a few steps.

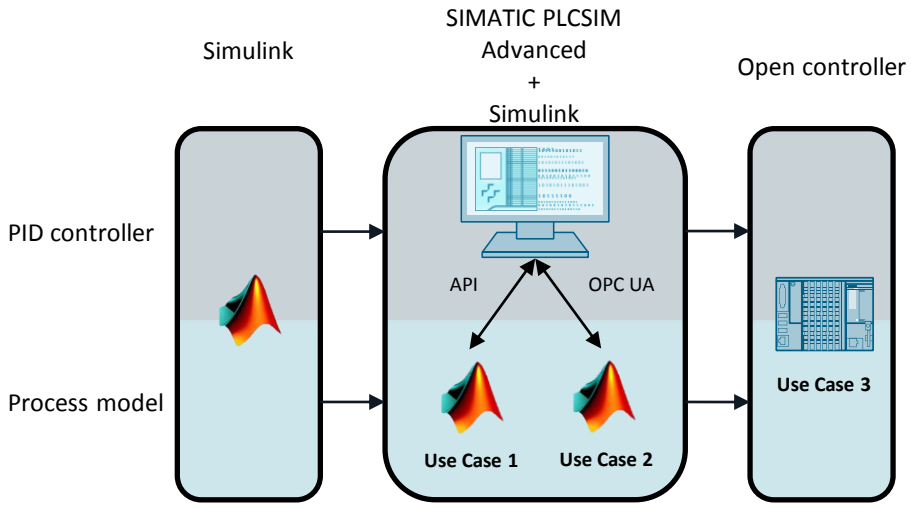
This application example provides you with the “PLCSIM Advanced” S-function for Simulink for communication and data exchange with a virtual controller via the API of PLCSIM Advanced. This enables validation and virtual commissioning of a PID controller that runs on a virtual controller in the context of a simulated process in Simulink.

This document describes the steps necessary to configure, start up and use the application example.

The following documents make up the entire application example:

- Main document: Overview of the three use cases and the Simulink model
- Use Case 1: Connecting Simulink models to SIMATIC PLCSIM Advanced via API (this document)
- Use Case 2: Connecting Simulink models to SIMATIC PLCSIM Advanced via OPC UA
- Use Case 3: Using SIMATIC Target 1500S for a Hardware-Based Simulation of the Simulink Model

Figure 1-1: Use cases overview



1.2 How the application example works

This application example provides you with a fully programmed S-function called “PLCSIM Advanced”. This function allows you to read/write tags of a virtual controller of PLCSIM Advanced.

In Simulink, the function is placed in a control loop instead of a controller.

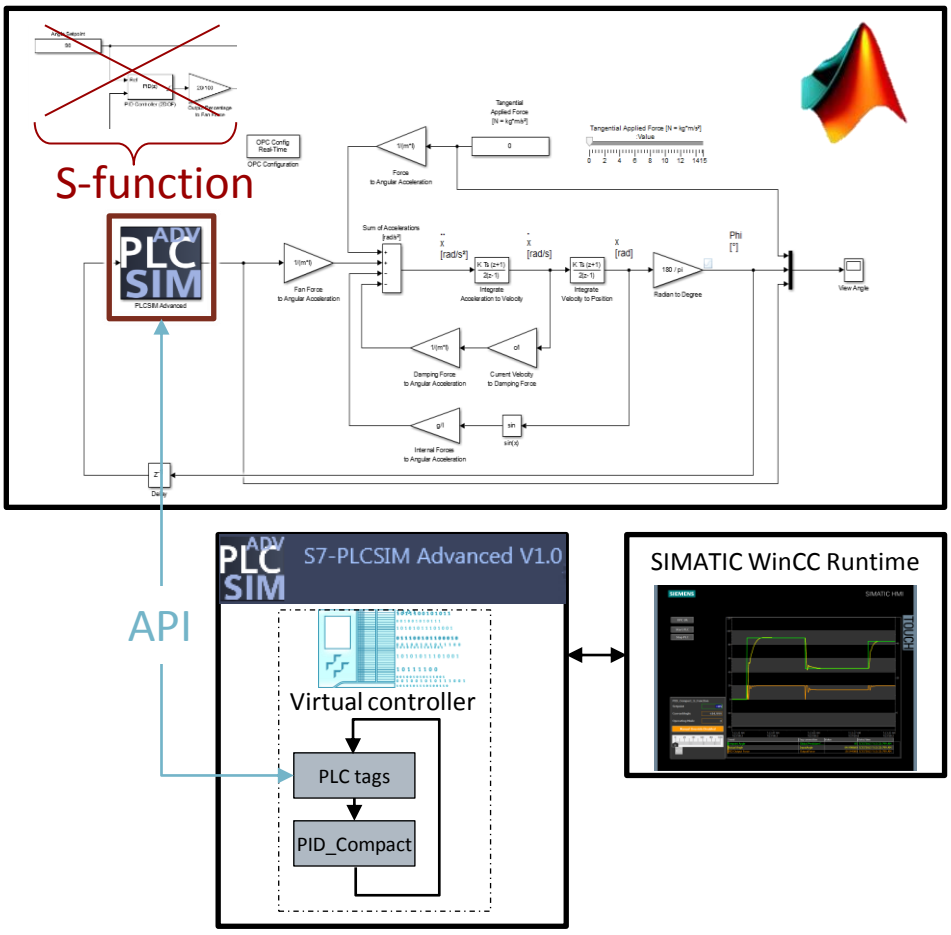
In a TIA Portal project, the “PID_Compact” PID controller is configured and downloaded to the virtual controller in order to test it in the context of the simulation model.

Tags are exchanged via the PLC tags of the virtual controller. This exchange always takes place at the controller’s cycle check point.

The control result and the controller’s control are visualized by a simulated HMI screen of WinCC Runtime.

Note The configuration of the HMI is not part of this application example.

Figure 1-2



1.3 Components used

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

Table 1-1: Software components

Component	Article number / note / link
(R2016a) MATLAB V9.0 Simulink V8.7	MathWorks Online Documentation: http://en.mathworks.com/help/
STEP 7 V14 Professional	6ES7822-1..04-.. Manual: https://support.industry.siemens.com/cs/ww/en/view/109742272
S7-PLCSIM Advanced V1.0	6ES7823-1FE00-0YA5 Manual: https://support.industry.siemens.com/cs/ww/en/view/109739153

This application example consists of the following components:

Table 1-2: Components of the application example

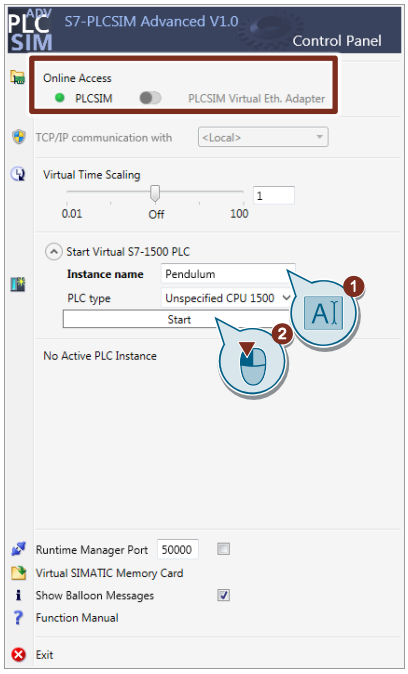
Component	Contents
109749187_DIGI_Usecases_API_DOC_V10_en.pdf	This document.
109749187_DIGI_Usecases_TIA_PROJ_V10_en.zip	TIA Portal project for Use Cases 1-3.
109749187_DIGI_Usecases_Simulink_PROJ_V10_en.zip	Simulink models for Use Cases 1-3.

2 Engineering

2.1 Setting up and starting the virtual controller

1. Start S7-PLCSIM Advanced V1.0. The info part of the Windows taskbar displays the PLCSIM Advanced icon. Left-click the icon to open the graphical user interface of PLCSIM Advanced, the Control Panel.

2. Use the Control Panel to start an instance of the virtual controller.
   1. Enter an instance name, for example, “Pendulum”.
   2. Click “Start”.

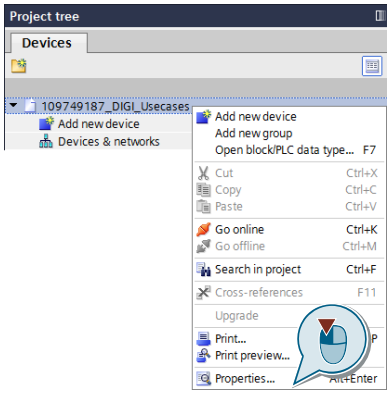


2.2 STEP 7 program in TIA Portal

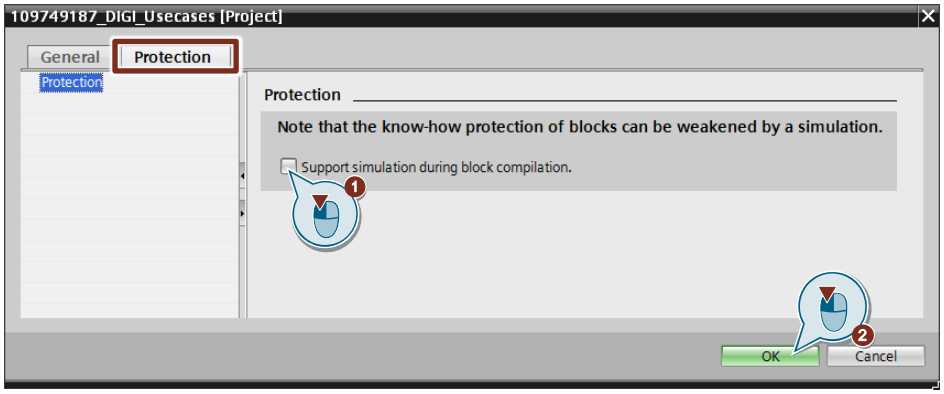
2.2.1 Simulation

Perform the following steps to activate the simulation with PLCSIM Advanced.

1. Create a new TIA Portal project.
2. Open the “Properties…” of your project.



3. In the “Protection” tab, activate the simulation with PLCSIM Advanced.
   1. Check “Support simulation during block compilation.”.
   2. Click “OK” to confirm the change.



2.2.2 Creating the program

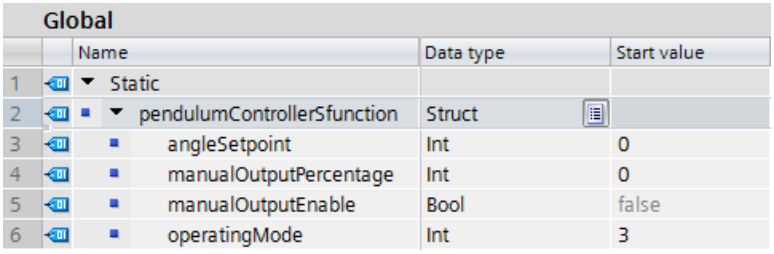
OBs and global DBs

Perform the following steps to create the global project tags and tags for communication with the Simulink model.

4. Insert an S7-1500 CPU with firmware V2.0 into the project. For example, a CPU 1511-1 PN V2.0.
5. Rename the CPU to “PLC_PLCSIM_Adv”.
6. Add the following blocks to your S7 program:
   - Cyclic interrupt OB: “Cyclic20ms” (with an interrupt time of 20 ms)
   - Global DB: “Global”

Note
The cycle of the “Cyclic20ms” OB must match the cycle Ts of the Simulink model (here: Ts=0.02 or 20 ms).

7. Open the “Global” DB and add the following tags. The tags are combined by a structure.
   - pendulumControllerSfunction [Struct]
     - angleSetpoint [Int]
     - manualOutputPercentage [Int]
     - manualOutputEnable [Bool]
     - operatingMode [Int]
8. For the “operatingMode” tag, enter the value 3 as the “start value”. This defines that the PID controller is operated in automatic mode.

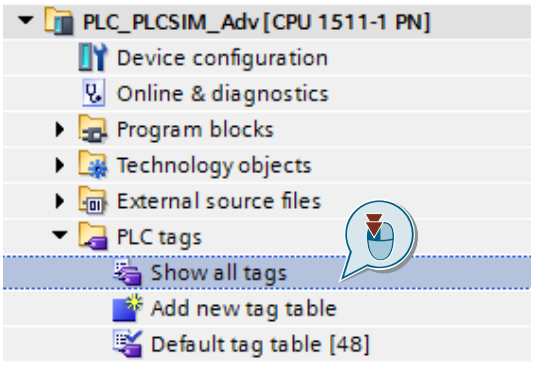


Global

	Name	Data type	Start value
1	Static		
2	pendulumControllerSfunction	Struct	
3	angleSetpoint	Int	0
4	manualOutputPercentage	Int	0
5	manualOutputEnable	Bool	false
6	operatingMode	Int	3

PLC tags

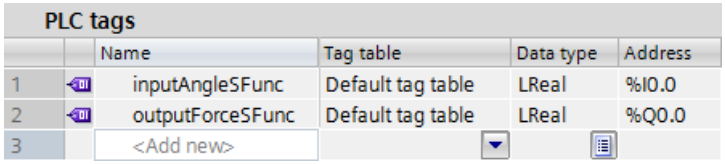
1. Open the “PLC tags”.



2. Add the tags for data exchange with the controlled system from MATLAB Simulink.

   Process value of Simulink model: inputAngleSFunc [LReal]

   Output for Simulink model: outputForceSFunc [LReal]



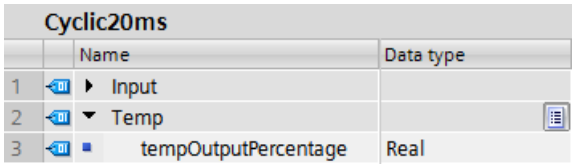
PLC tags

	Name	Tag table	Data type	Address
1	inputAngleSFunc	Default tag table	LReal	%I0.0
2	outputForceSFunc	Default tag table	LReal	%Q0.0
3	<Add new>			

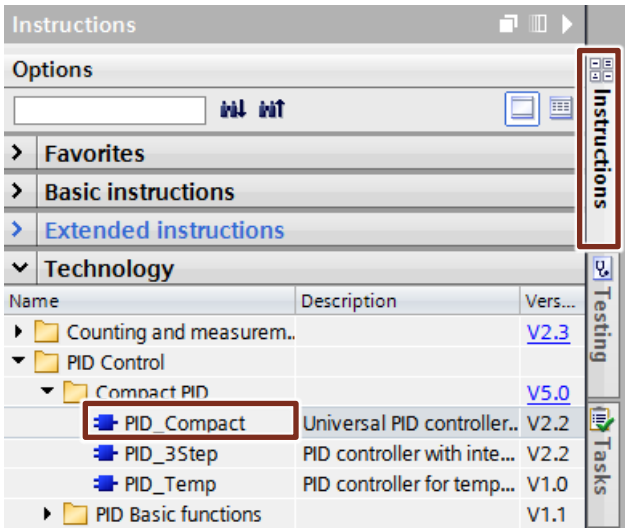
“Cyclic20ms” OB

Perform the following steps to program the “Cyclic20ms” OB.

1. Open the “Cyclic20ms” cyclic interrupt OB.
2. Add a temporary tag, “tempOutputPercentage”.



3. In “Technology > PID Control > Compact PID”, drag the “PID_Compact” controller from “Instructions” to the cyclic interrupt OB.



4. Name the instance DB “InstPIDCompactSFunction” and interconnect the instruction as shown in the following figure.

```
// PID controller for controlling simulink model via API
"InstPIDCompactSFunction"(Setpoint := "Global".pendulumControllerSfunction.angleSetpoint,
                          Input := LREAL_TO_REAL("inputAngleSFunc"),
                          ManualEnable := "Global".pendulumControllerSfunction.manualOutputEnable,
                          ManualValue := "Global".pendulumControllerSfunction.manualOutputPercentage,
                          ModeActivate := TRUE,
                          Output => #tempOutputPercentage,
                          Mode := "Global".pendulumControllerSfunction.operatingMode);
```

5. Scale the PID controller’s output percentage to the maximum force of 20 Newton.

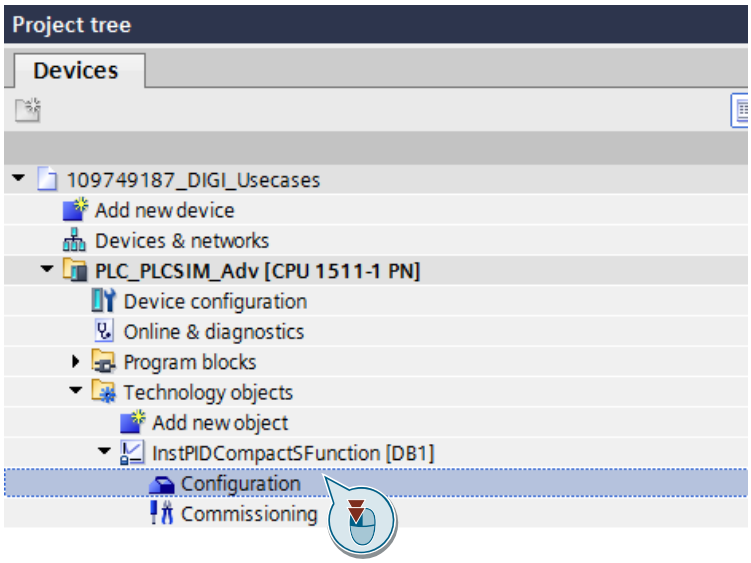
```
//  Scaling the output of PID controller (0..100 %) to maximum power (0..20 N)
   "outputForceSFunc" := #tempOutputPercentage * 20 / 100;
```

Configuring the PID controller

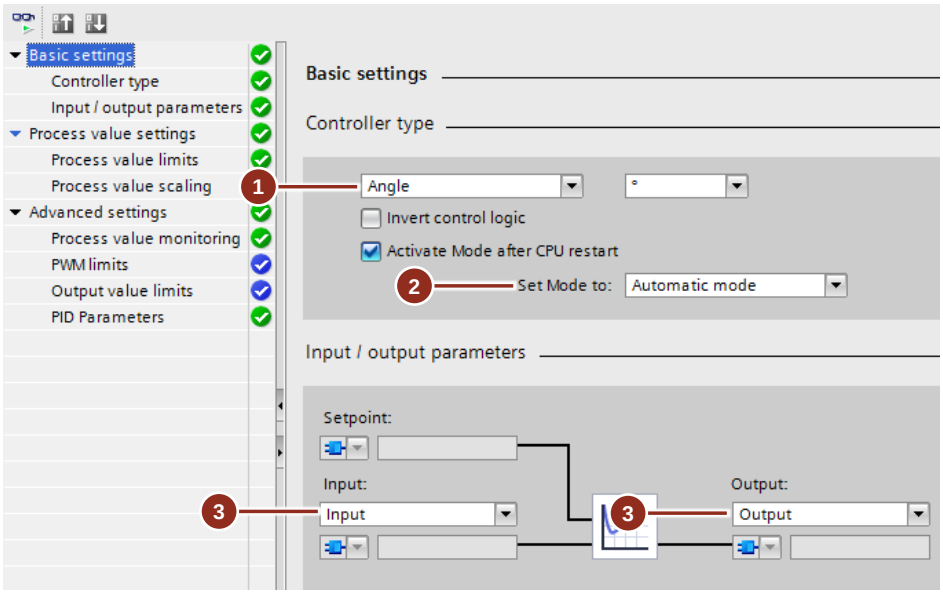
Note For the calculation of the PID parameters from step 5, refer to the main document:
“109749187_DIGI_Usecases_MAIN_DOC_V10_en.pdf”

Perform the following steps to configure the PID controller.

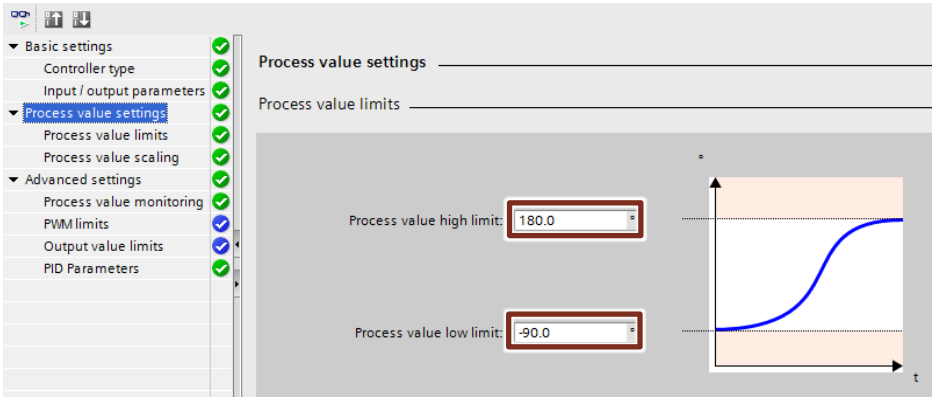
1. In the project tree, open the “Configuration” of the “InstPIDCompactSFunction” instance of the PID controller.



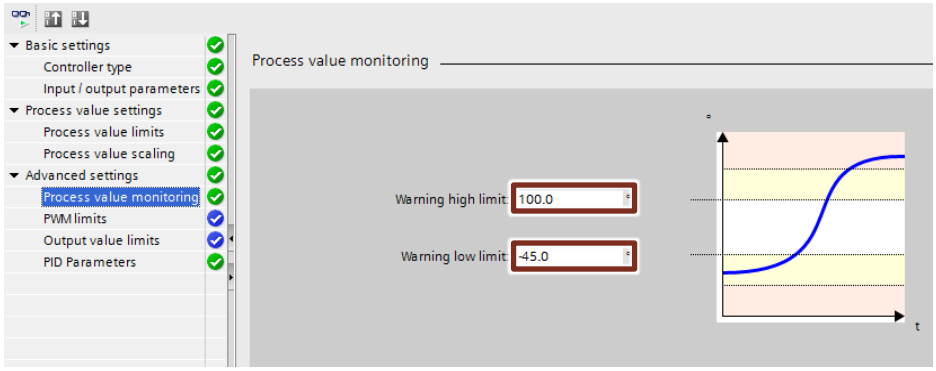
2. Make the basic settings.
   1. In “Controller type”, select “Angle” as the physical quantity.
   2. Set the mode to “Automatic mode”.
   3. Select “Input” for the input parameter and “Output” for the output parameter.



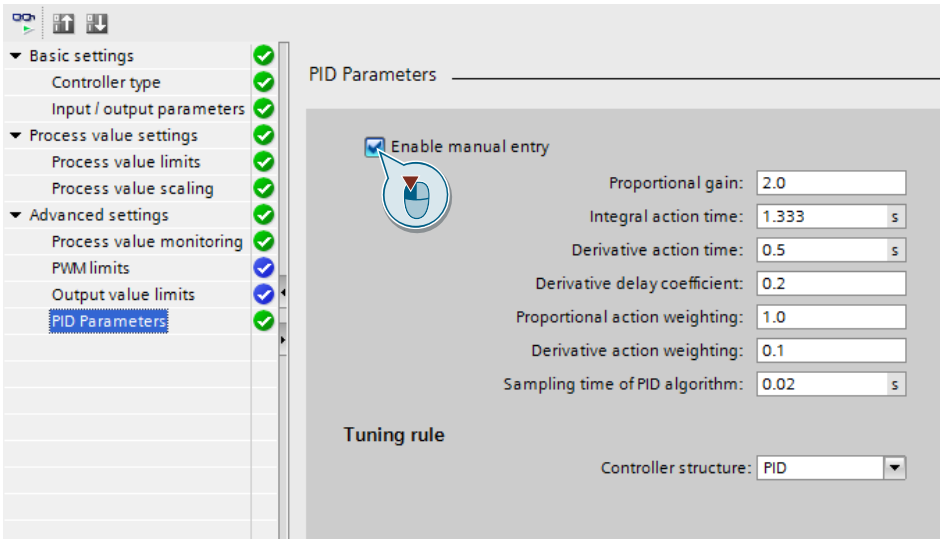
3. Make the process value settings.
   For the process value high limit, set 180.0. For the process value low limit, select -90.0.



4. In the advanced settings for process value monitoring, set 100.0 as the warning high limit and -45.0 as the warning low limit.

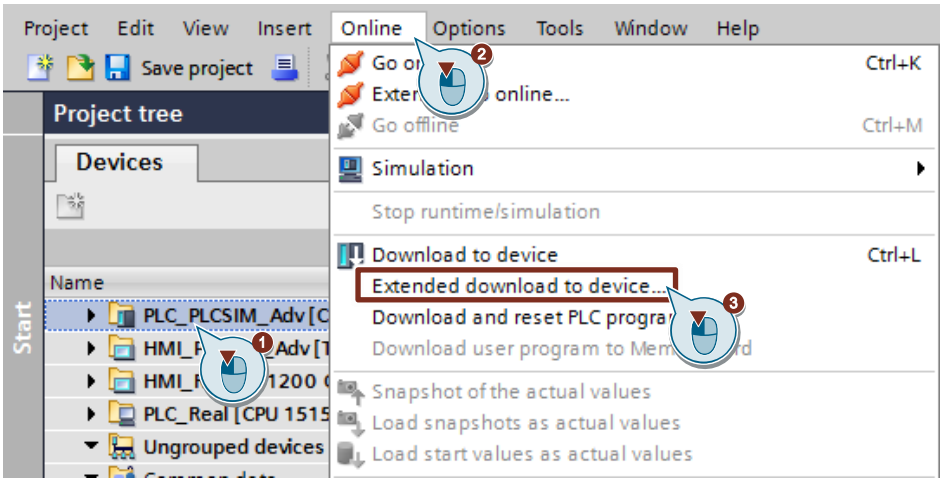


5. In the “Advanced settings”, set the PID parameters.
   To do this, check “Enable manual entry” and set the following PID parameters.
   - Proportional gain = 2
   - Integral action time = 1.333
   - Derivative action time = 0.5
   - Derivative delay coefficient = 0.2
   - Proportional action weighting = 1.0
   - Derivative action weighting = 0.1
   - Sampling time of PID algorithm = 0.02

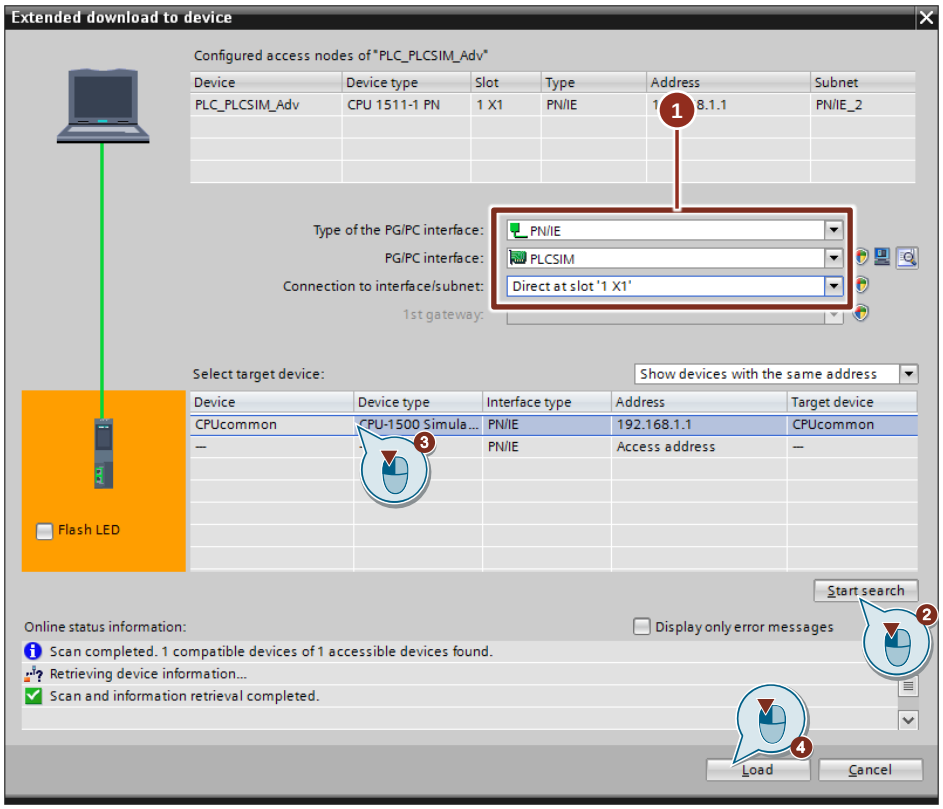


2.2.3 Downloading the program

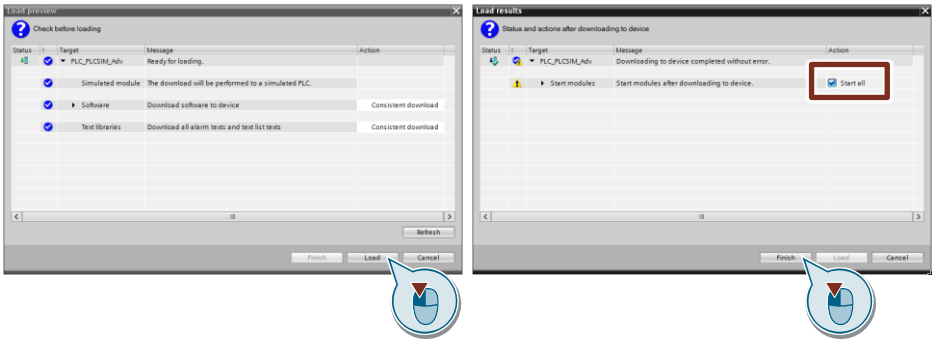
1. In the project tree, select the “PLC_PLCSIM_Adv” controller and from the TIA Portal menu bar, select “Online > Extended download to device…”.



2. 1. Set the interface to the controller.
   2. Start the search.
   3. From the list, select the virtual controller that has been found.
   4. Download the project.



3. Follow other TIA Portal messages and start the controller



The virtual controller is set to “RUN”.

Control Panel:

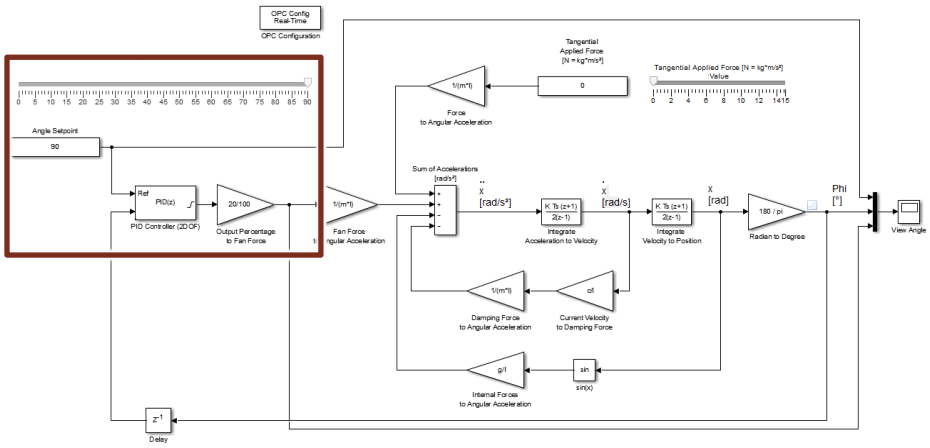
2.3 Using the S-function in the Simulink model

Requirement

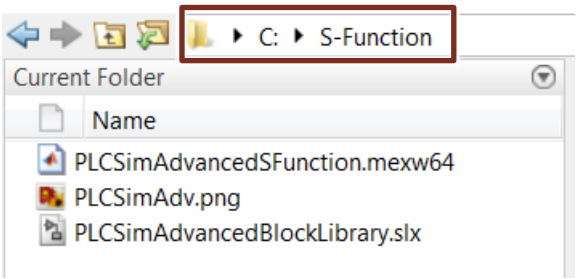
- You have started an instance of the virtual controller with PLCSIM Advanced.
- You have finished programming the S7 program and downloaded it to the virtual controller.
- You have stored the supplied “S-Function” folder from the “Simulink_Usecase1” zip folder in a known directory on your computer and added the folder, including all subordinate files, to the MATLAB search path.

Perform the following steps to use the S-function in the Simulink model.

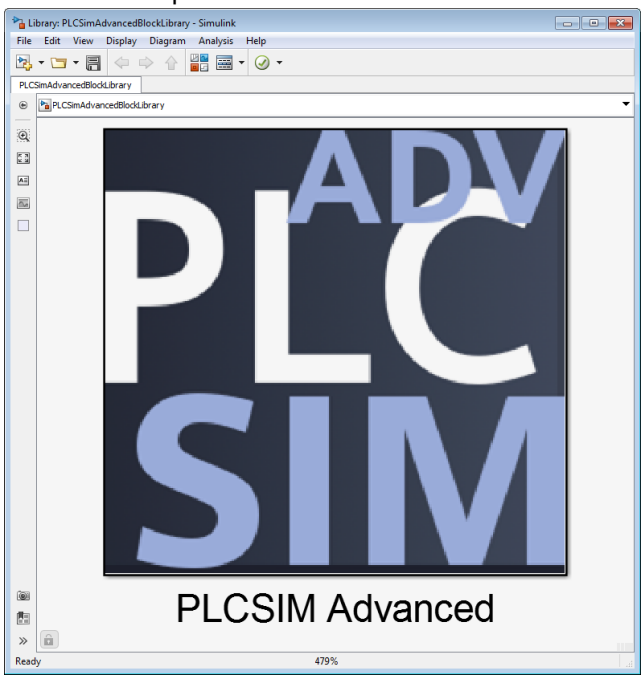
1. Open the “Pendulum_Controlled” Simulink model from the “Simulink_Main” zip folder.
   Remove the PID controller and the functions that are executed by the S7 program.



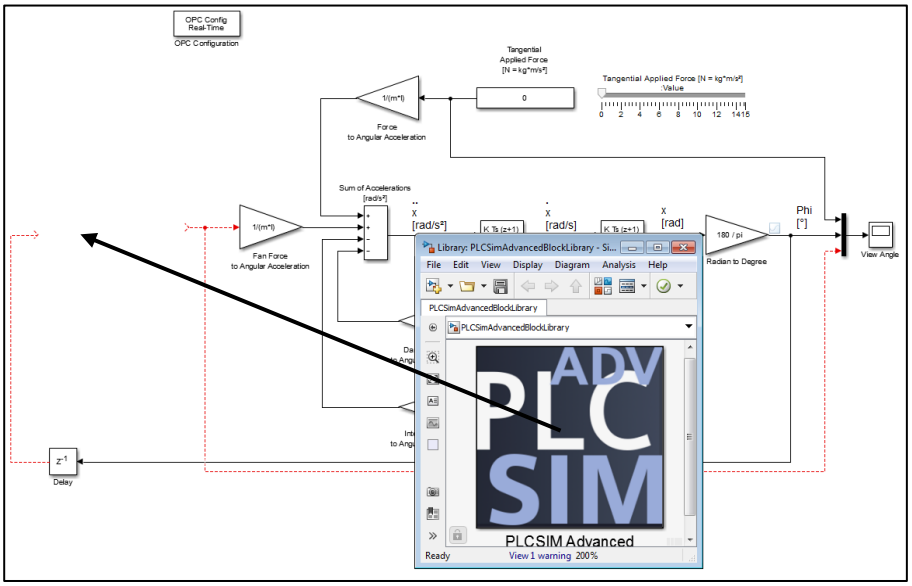
2. Go to the MATLAB user interface and in the directory, navigate to the location of the unzipped “S-Function” folder.



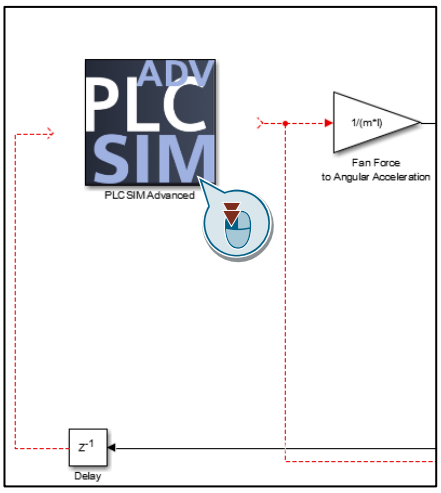
3. Double-click to open the “PLCSimAdvancedBlockLibrary.slx” library object. A new window opens.



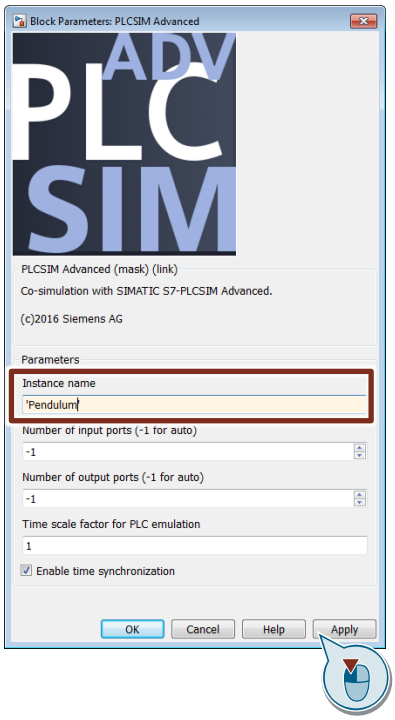
4. Use drag and drop to move the “PLCSIM Advanced” S-function block to the Simulink model with the controlled system.



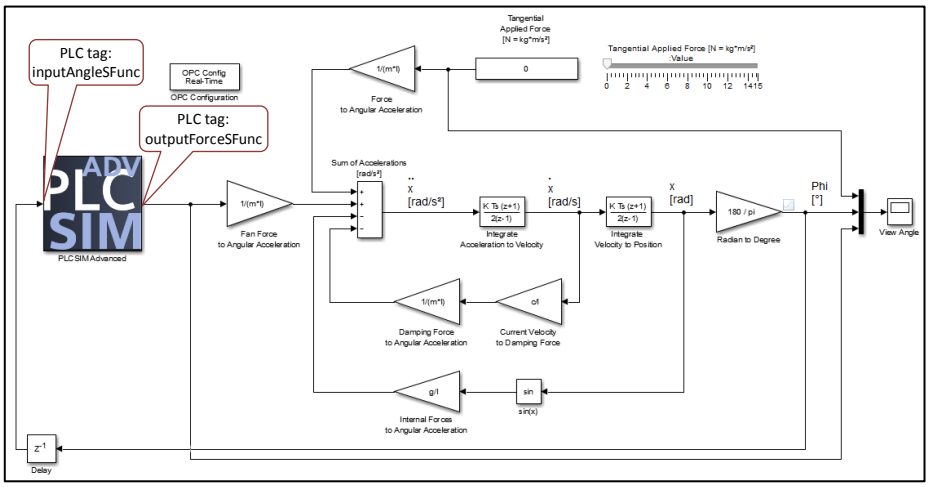
5. Double-click to open the block parameters of the “PLCSIM Advanced” S-function.



6. Enter the instance name of the started virtual controller of PLCSIM Advanced between the single quotation marks (‘Pendulum’) and select “Apply” to apply the change.



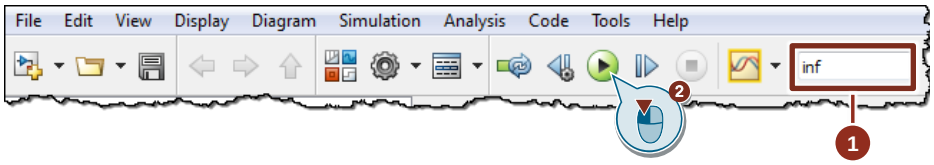
7. The S-function’s inputs and outputs are derived from the PLC tags and generated automatically. Connect the “PLCSIM Advanced” block to the controlled system.



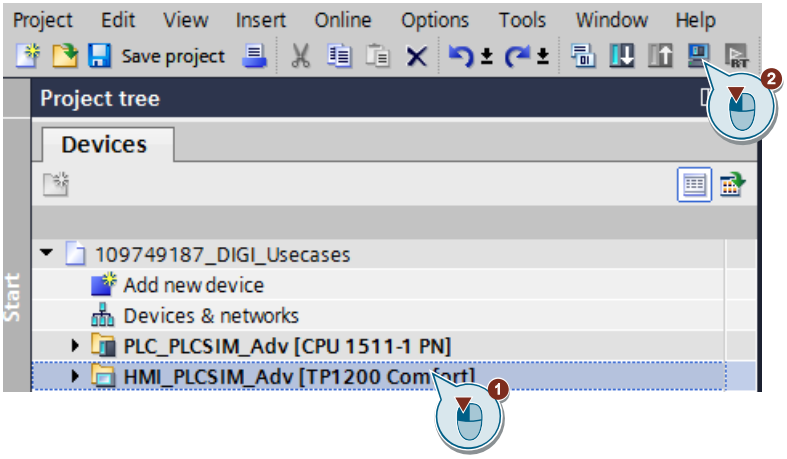
2.4 Starting up the sample application

Perform the following steps to start up the simulation with the supplied TIA Portal project and the supplied Simulink model. The S-function has already been inserted into the Simulink model with the configured instance name “Pendulum”.

1. Start a virtual controller with the instance name “Pendulum”.
2. Use TIA Portal to open the “109749187_DIGI_Usecases” sample project and download the “PLC_PLCSIM_Adv” CPU to the virtual controller.
3. Open the supplied “Pendulum_PLCSIMAdv_API.slx” Simulink model.
   Note
   The “S-Function” folder must have been added to the MATLAB search path.
4. Start the simulation of the Simulink model:
   1. Set the simulation duration to “inf” (infinite).
   2. Click the “Run” icon.



5. In TIA Portal, start the HMI’s WinCC Runtime simulation for monitoring the control result and operating the PID controller:
   1. In the project tree, select the “HMI_PLCSIM_Adv” HMI.
   2. Click “Start simulation”.

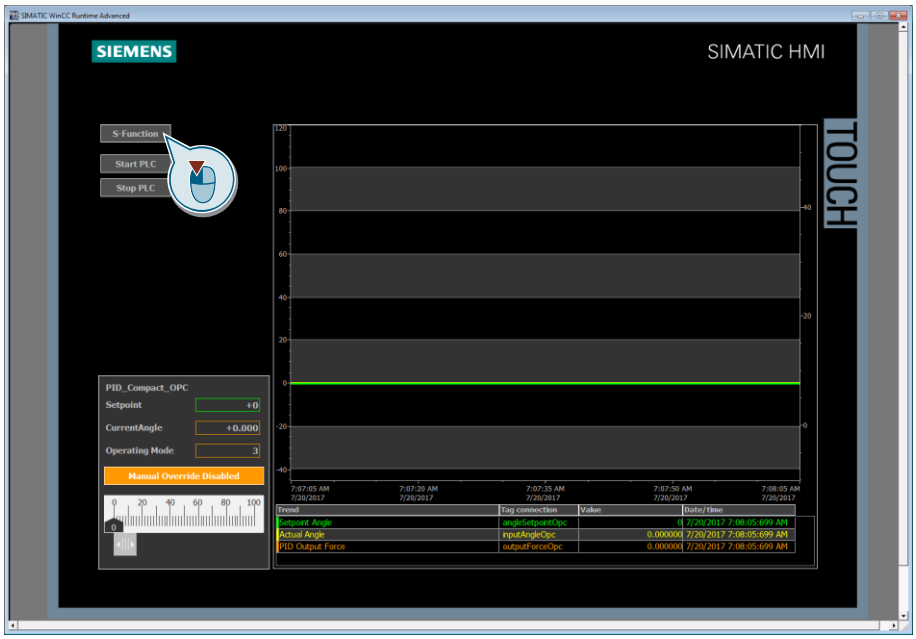


2.5 Operation

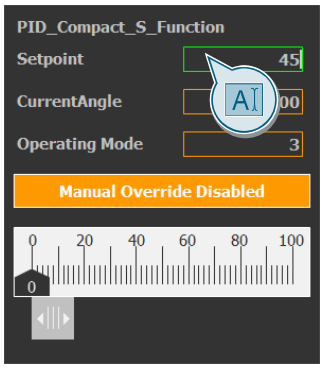
2.5.1 Operating the PID controller

Setting the setpoint

1. Open the window where WinCC Runtime has started and click “S-Function” to select the S-function screen.

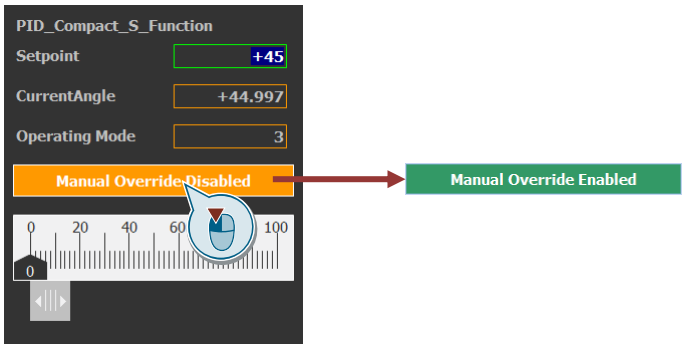


2. Click the “Setpoint” input field and enter a setpoint for the angle of deflection of the pendulum. Press Enter to confirm your entries.

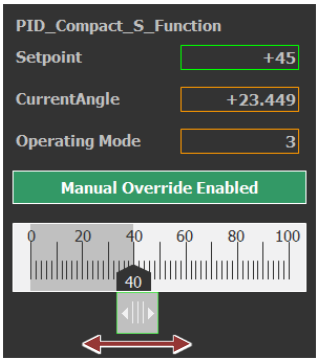


Manually overriding the output

1. In the window where WinCC Runtime has started, click “Manual Override Disabled” to enable manual override.



2. Move the slider to manually override the PID controller’s output.

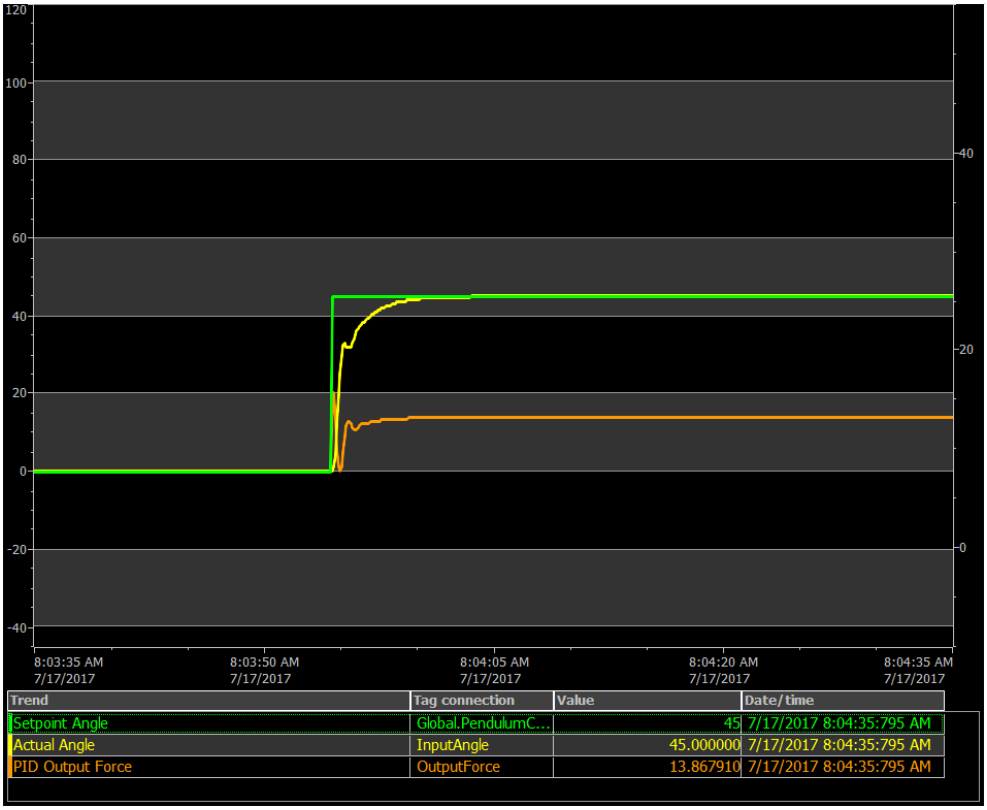


2.5.2 Monitoring the control result

Two options are available for monitoring the control result.

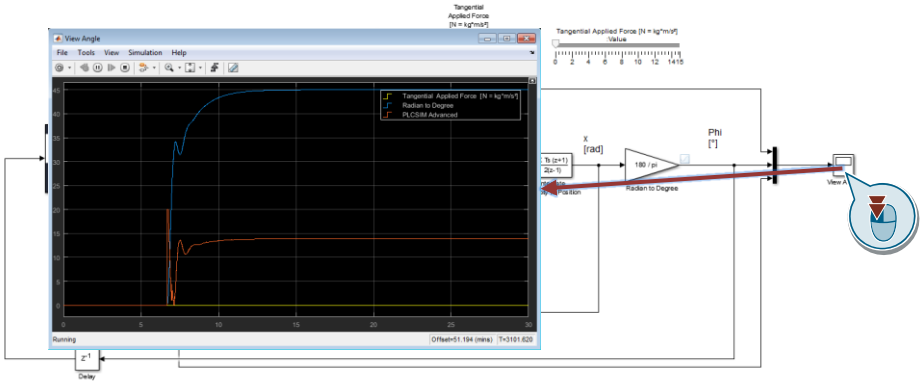
On the one hand, the trace in the HMI’s simulation graphically represents the trend of the setpoint, actual value (angle of deflection) and output (force) of the PID controller. The figure shows a trend for a set setpoint angle of 45°.

Figure 2-1



On the other hand, you can monitor the control result in a display window in Simulink. Double-clicking the “Scope” function in the Simulink model opens the display window.

Figure 2-2



2.5.3 Speeding up/slowing down the virtual time of the controller

For test purposes, you can speed up or slow down the virtual time of the controller using a scale factor.

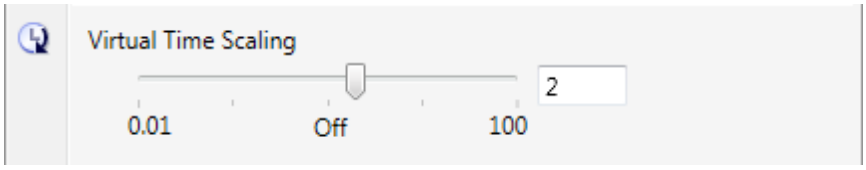
- **Fast mode**: A scale factor greater than 1 speeds up the virtual clock.
  Example: Scale factor 2.0 → The virtual time speed doubles.
- **Slow mode**: A scale factor less than 1 slows down the virtual clock.
  Example: Scale factor 0.5 → The virtual time progress slows down to 50%.

Note Fast and slow mode do not change the execution speed of the CPU machine code. For example, the modes do not change the speed at which all operations of an OB1 cycle are performed. The execution speed depends on the processor of the PC on which the virtual controller is running. When you change the scale factor, more or less cycle check points are reached in a fixed time span of the virtual time.

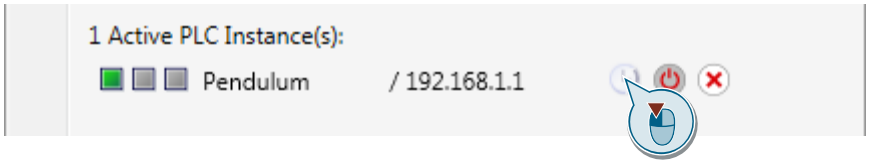
Make sure that the “Enable time synchronization” check box is checked in the block parameters of the “PLCSIM Advanced” S-function to ensure that the Simulink model synchronizes with the changed simulation speed.

Perform the following steps to speed up or slow down the virtual time of the controller.

1. Open the graphical user interface of PLCSIM Advanced.
2. Use the slider to set the desired scale factor.



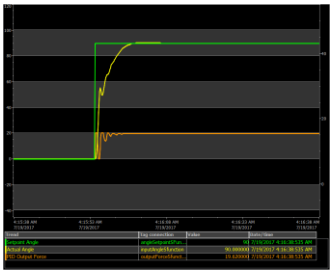
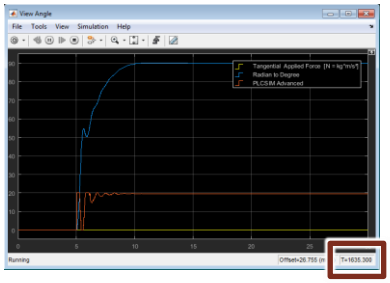
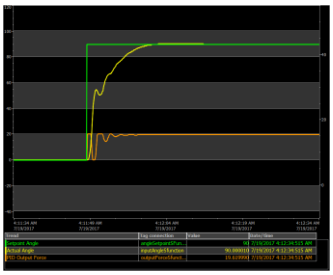
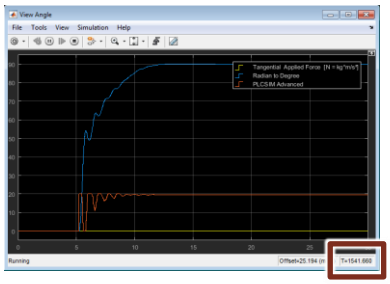
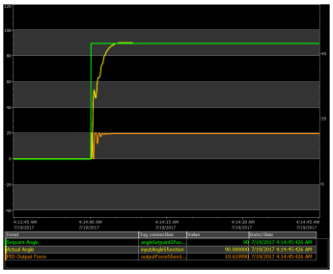
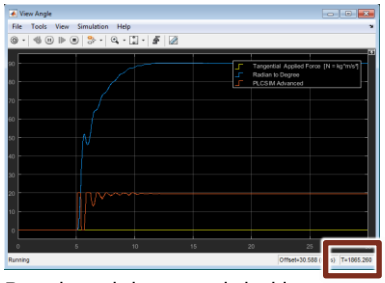
3. Enable the scale factor for the instance of the virtual controller.



4. Enter a setpoint for the PID controller and monitor the effects of the changed virtual time.

The following figure shows possible effects of the speeded up or slowed down virtual time.

Figure 2-3

Scale factor	WinCC Runtime	Simulink
1.0	 Virtual time almost identical to real time.	 Pseudo real time almost identical to real time.
0.5	 Virtual time 50% slower. Slower control based on real time base.	 Pseudo real time 50% slower, synchronized with controller's virtual time.
2.0	 Virtual time speed doubles. Faster control based on real time base.	 Pseudo real time speed doubles, synchronized with controller's virtual time.

3 Valuable Information

3.1 Basics

3.1.1 Block parameters of the “PLCSIM Advanced” S-function

Figure 3-1: Block parameters of the “PLCSIM Advanced” S-function

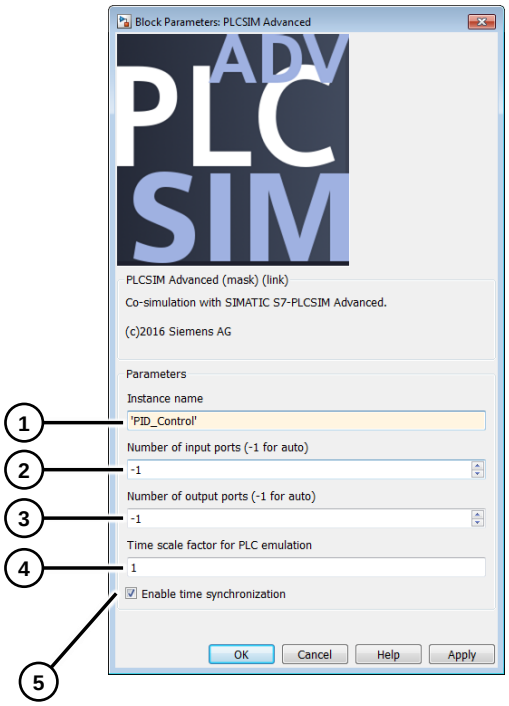


Table 3-1: Block parameter description

No.	Description	Note
1.	Instance name of the virtual controller	The instance name must be written between two single quotation marks.
2.	Number of inputs	When entering “-1”, the number of inputs is automatically derived from the number of PLC input tags.
3.	Number of outputs	When entering “-1”, the number of outputs is automatically derived from the number of PLC input tags.
4.	Scale factor for the virtual time of the virtual controller	Default setting of the scale factor. Relevant to generating the instance of a virtual controller from Simulink.
5.	Synchronization with the virtual time of the virtual controller.	Speeds up or slows down the pseudo real time of Simulink.

3.2 Details about the method of functioning

3.2.1 “PLCSIM Advanced” S-function

The source code for the “PLCSIM Advanced” S-function is programmed in the C++ high-level language and contains statements for data exchange with an instance of the virtual controller via the API of PLCSIM Advanced. For the code to be executed in MATLAB, a MEX file is generated from this data. The MEX file can be integrated into Simulink using an S-function.

Automatic generation of an instance of the virtual controller

Mechanisms for generating a new instance of the virtual controller are programmed in the code of the “PLCSIM Advanced” S-function if it does not yet exist.

Applying the changed block parameters of the S-function automatically generates a new instance of the virtual controller if the entered instance name does not yet exist in the directory of the Virtual SIMATIC Memory Card[1] of PLCSIM Advanced.

If PLCSIM Advanced has already been started, the instance is started immediately. Otherwise, only the SIMATIC Memory Card with the instance name is created in the directory of the Virtual SIMATIC Memory Card and the instance must be started manually using the PLCSIM Advanced Control Panel.

Note

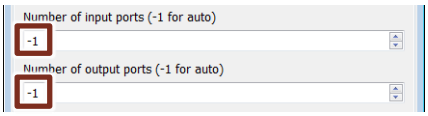
The “PLCSIM Advanced” S-function automatically derives the number of inputs and outputs for the block from the PLC tags of the virtual controller.

It is therefore recommended to start the virtual controller and download a project to it first before inserting the S-function into Simulink.

Inputs/outputs

The “PLCSIM Advanced” S-function automatically derives the number of contacts for the inputs and outputs of the block from the PLC tags of the virtual controller if “-1” is set for the number of inputs/outputs in the block parameters of the S-function.

Figure 3-2:



With regard to when the contacts are generated, there are two cases:

- The S-function is inserted into the Simulink model before a virtual controller has been started and a TIA Portal project has been downloaded to it. When the instance name of the virtual controller has been entered in the block parameters of the S-function and the changes have been applied, an instance of the virtual controller is automatically generated when PLCSIM Advanced has been started. The contacts are not generated until the TIA Portal project has been downloaded to the virtual controller and the Simulink simulation has been started once. After stopping the simulation, the S-function can be connected to the Simulink model.

[1] The Virtual SIMATIC Memory Card stores the user program, the hardware configuration and the retentive data for the virtual controller.

- The instance of the virtual controller was generated manually and the TIA Portal has already been downloaded. The S-function is then inserted into the Simulink model. When the instance name of the virtual controller has been entered in the block parameters of the S-function and the changes have been applied, the contacts are automatically generated and the block can be connected.

Tag exchange

Tags are exchanged at the cycle check point of the virtual controller. If the cycle check point has not yet been reached, the S-function waits for the virtual controller's 'end of cycle'. The S-function reads the output tags and writes the input tags from the list of PLC tags.

3.2.2 Synchronization

With the S-function, the Simulink model can be synchronized with the virtual time of the virtual controller. This requires that the "Enable time synchronization" check box be checked in the block parameters of the S-function.

In this case, the tags are not only exchanged at the cycle check point, but also when the pseudo real time of the Simulink model and the virtual time of the virtual controller are almost identical. To follow the changed virtual time of the virtual controller, Simulink slows down or speeds up the pseudo real time.

4 Appendix

4.1 Service and Support

Industry Online Support

Do you have any questions or do you need support?

With Industry Online Support, our complete service and support know-how and services are available to you 24/7.

Industry Online Support is the place to go to for information about our products, solutions and services.

Product Information, Manuals, Downloads, FAQs and Application Examples – all the information can be accessed with just a few clicks:
https://support.industry.siemens.com

SITRAIN – Training for Industry

Well-trained employees are a crucial factor in any company's success. Skills development and expert knowledge make companies competitive and innovative. With our globally available training courses for industry, we help you achieve these goals – with practical experience, innovative learning methods, and a concept that's tailored to the customer's specific needs.

www.siemens.com/sitrain

Technical Support

Siemens Industry's Technical Support offers you fast and competent support for any technical queries you may have, including numerous tailor-made offerings ranging from basic support to custom support contracts.

You can use the web form below to send queries to Technical Support:
www.siemens.com/industry/supportrequest.

Service offer

Our service offer includes the following services:

- Product Training
- Plant Data Services
- Spare Part Services
- Repair Services
- Field & Maintenance Services
- Retrofit & Modernization Services
- Service Programs & Agreements

For detailed information about our service offer, please refer to the Service Catalog:
https://support.industry.siemens.com/cs/sc

Industry Online Support app

The "Siemens Industry Online Support" app provides you with optimum support while on the go. The app is available for Apple iOS, Android and Windows Phone:
https://support.industry.siemens.com/cs/ww/en/sc/2067

4.2 Links and literature

Table 4-1

No.	Topic
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Link to the entry page of the application example https://support.industry.siemens.com/cs/ww/en/view/109749187
\3\	Manual: SIMATIC S7-PLCSIM Advanced https://support.industry.siemens.com/cs/ww/en/view/109739153
\4\	MathWorks Online Documentation: http://en.mathworks.com/help/
\5\	Manual: STEP 7 V14 Professional https://support.industry.siemens.com/cs/ww/en/view/109742272

4.3 Change documentation

Table 4-2

Version	Date	Modifications
V1.0	12/2017	First version