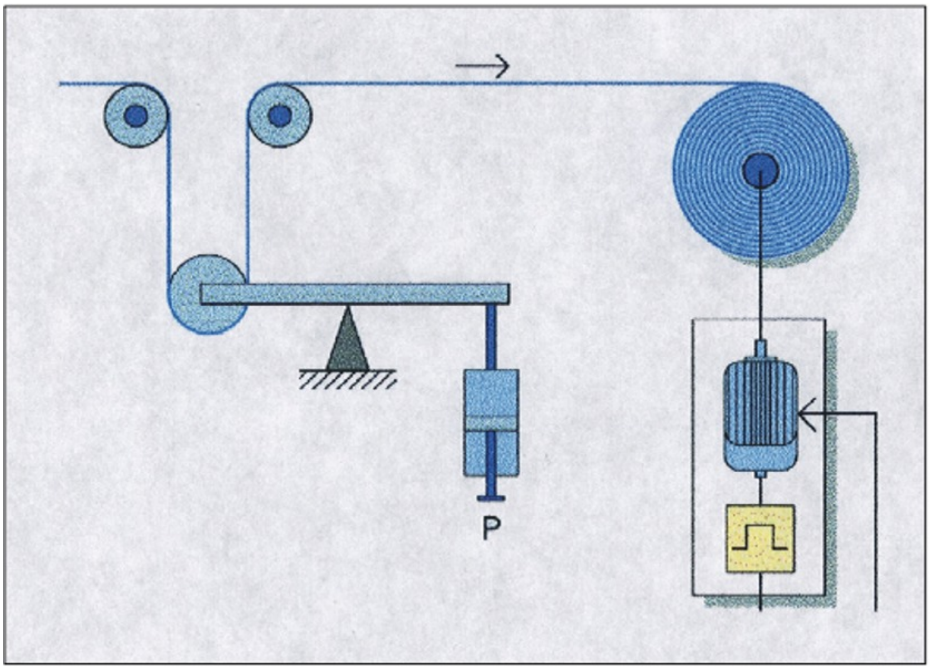
Application Winder with SIMOTION



applications & TOOLS

Standard Application Winder with SIMOTION V1.1

SIEMENS

Application No.: A4027118-N00124-A0404

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Reference regarding export codes

AL: N

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Foreword

This application involves the technological “Winder” function in the SIMOTION control system.

The central element is a parameterizable function block with which users can simply implement winder functionality.

Objective of the application

This application is based on the technological interaction between the SIMOTION motion control system and a drive system.

In order to demonstrate this as simply as possible and in-line with what is expected in practice, a technological function, that is frequently used in machines is used in a simple example with a link to an HMI system. This means that the application can also be used as a demonstration model.

The application should clearly demonstrate the following:

- How the components used operate with one another
- Which technological function is used
- The advantages of this solution
- How the technological function is programmed or parameterized
- How the example can be used as demonstration system

Knowledge base required

Basic know-how about SIMOTION SCOUT is required in order to understand this application example.

Further, some of the basic terminology and principles of winders should known.

Documentation structure

The documentation of this application is sub-divided into four parts:

Application description

Application example as demonstration system

Integration of the core function

Program description

The first section of the **application description** is intended for personnel that wish to obtain a fast overview. You do not have to read this section if you are knowledgeable in this area and you only wish to commission the application.

Part	Description	Note
Application description	You can read about everything you require to obtain an overview in Section A. You will learn about the components used (standard hardware and software components and the additional, developed software) and the principle of the technological core function. Further, you will be provided with engineering information and instructions in order to select the suitable closed-loop control concept	This Section will allow you to transfer the technology to other applications.

The second section – the **application example as demonstration system** – is intended for personnel that wish to use or present the examples supplied on a demonstration/presentation system.

Part	Description	Note
Application example as demonstration system	This Section navigates you step-by-step through the essential commissioning phases of the demonstration application. This Section then discusses how the demonstration application is used	

The third section – the **integration of the core function** – is intended for personnel that wish to go into the subject in far more detail in order to then be able to integrate the core function.

Part	Description	Note
Integration of the core function	Section “Integration of core function” navigates you step-by-step through the essential points to integrate the core function into your user program and through the commissioning of the application.	

The fourth Section – the **program description** – is intended for personnel that wish to commission the application or make changes to the program code.

Part	Description	Note
Program description	The individual functions of the winder block are discussed in more detail in this Section. Here you’ll find a precise description of the parameters and the mode of operation.	

Application description

Content

In Section “Application description” you’ll learn about everything to be able to obtain a complete overview. You will get to know the components used (standard hardware and software components and the additional, developed software) and the principle of function of the technological core function.

Further, you will be provided with engineering information and instructions in order to select the suitable closed-loop control concept.

1 Basic information and data

1.1 Prerequisites

1.1.1 Target group

The standard application is intended for all programming engineers and users that want to easily and quickly implement a winder function using SIMOTION.

1.1.2 Technical environment

This standard application can only be used – without having to make any changes – in conjunction with SIMOTION D and a SINAMICS demonstration case.

1.2 Objective and purpose of this standard application

1.2.1 Task

The standard winder application in SIMOTION was developed with the objective to be able to handle many of the known winder applications with one single application engineering package. When required, the application can be engineered or modified thanks to the openness of the application.

The standard winder application in SIMOTION allows, using the appropriate equipment and devices, a winder or unwinder to be engineered for the widest range of applications. These include, for example, foil machines, printing machines, coating systems, coilers for wire-drawing machines and textile machines.

In many technological processes, winders are an essential part of an overall system.

Depending on the particular plant or system, sometimes a finishing/conditioning process starts with an unwinder or ends with a winder.

Different winding techniques are used depending on the process and the material that is being wound.

1.3 Winder solution design and structure

1.3.1 General design and structure

Generally, a winder solution comprises a winder drive, a material web and possibly sensors. The function of a winder is to rewind or unwind a material web with a defined tension. When winding, the diameter changes. Depending on whether it involves a rewinder or unwinder, the material is wound or unwound. The motion control system calculates the actual diameter using several system variables and controls the motor speed so that the tension of the material web is kept constant. To do this, the actual velocity of the material web and the speed of the winder shaft must be known. If the system must fulfill higher demands regarding the performance and tension accuracy, then an appropriate range of sensors must be added to the winder solution. These can include a dancer roll or a load cell.

The **dancer roll** is a position-controlled measuring system. The material web is threaded through this dancer roll system. A cylinder with a deflection roll presses, with an adjustable force against the material web. If tension is established in the material web then this acts against the pressure from the dancer roll. If the dancer roll is at its center position, then the material web tension is the same as the selected dancer roll force. In order to control (closed-loop) the tension in the material web, the motion control system must ensure that the dancer roll remains at its center position. If the tension in the system changes, then the position of the dancer roll also changes – that is in turn coupled with the motion control system via a position detection function. If such a deviation is detected, then the system would respond, and e.g. change the drive speed.

The **tension measuring transducer** directly measures the tension in the system and transfers this signal to the motion control system. If the tension changes then this can either be compensated by changing the speed or by changing the motor torque.

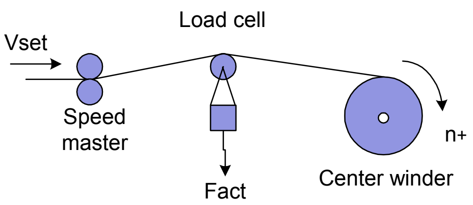
1.3.2 Winding and closed-loop control technique

Winding technique

A differentiation is always made between 2 winding techniques.

Central winder

Figure 1-1: Center winder

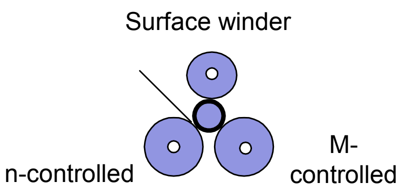


With a center winder, the roll is driven by a central shaft. The diameter range is an important factor when designing this winder type. The reason for this is that for a constant web velocity and constant tension, the speed is inversely proportional to the diameter. This means that the maximum required drive speed is defined by the minimum roll diameter – whereby the maximum required torque is defined by the maximum diameter.

The center winder is more complicated and from a closed-loop control perspective more difficult to handle than the surface winder; however it is still more widely established of the two winder types.

Surface winder

Figure 1-2: Surface winder



For a center winder, the roll is driven through one or several rolls that are in contact with the roll being wound. The drive speed and power depends on the diameter of the roll being wound. From a mechanical design perspective, this winder technique is more complicated than that of a center winder.

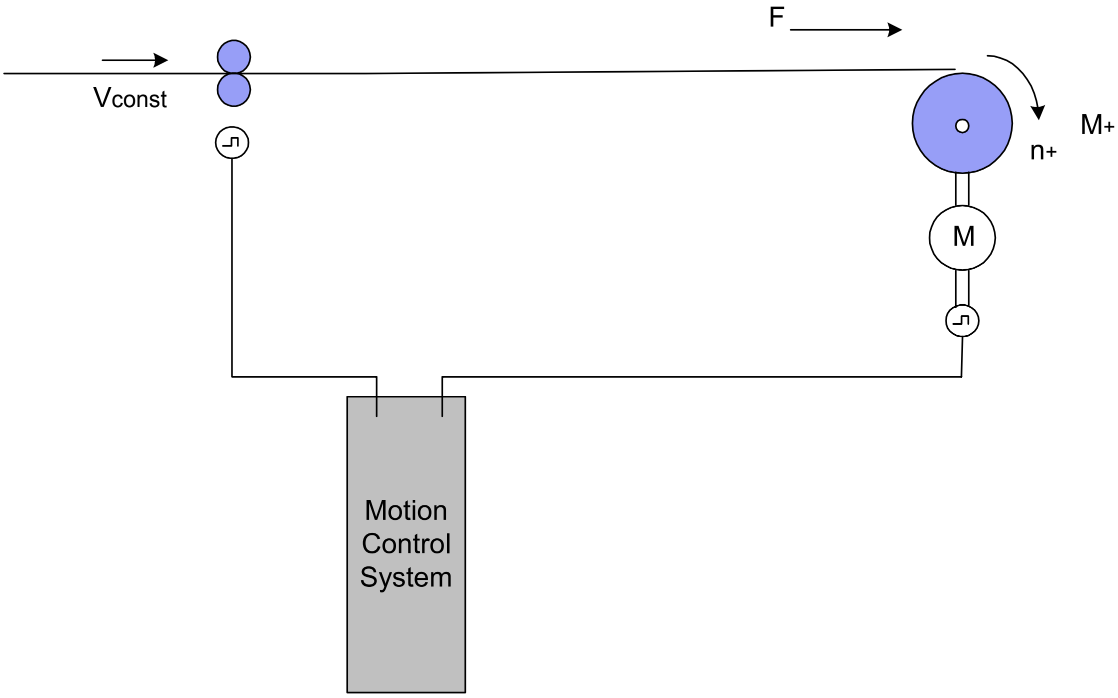
The contact winder (surface winder) is essentially used if there are no special requirements placed on the surface quality of the material being wound.

Closed-loop control techniques

3 closed-loop control techniques are mainly used for winders:

- Indirect closed-loop tension control (open-loop torque control)
- Closed-loop tension force control
- Closed-loop dancer roll control

Figure 1-3: Indirect closed-loop tension control

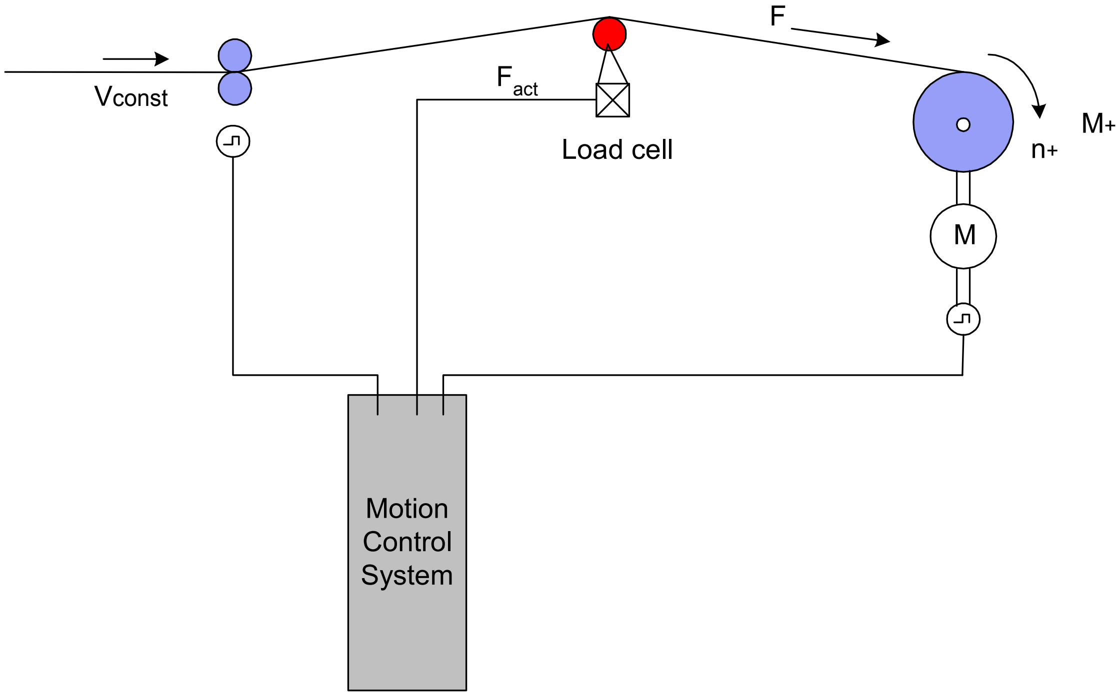


The **closed-loop indirect tension control** is very frequently used if a user does not want to use expensive sensor systems or there is no higher-level control loops. This technique must be able to operate without any tension feedback signal. This therefore places the highest requirements on the torque setpoint conditioning.

Indirect closed-loop tension control is based on the physical interrelationship between torque and tension of the material web. The motor torque is changed as a function of the diameter of the roll being wound so that a setpoint (reference) tension is obtained. For this closed-loop control technique, the tension cannot be corrected as there is no feedback. This has a negative impact on the precision of the tension. This means that the closed-loop indirect tension control is the simplest and most straightforward of the 3 control types and is not suitable for high-performance winders.

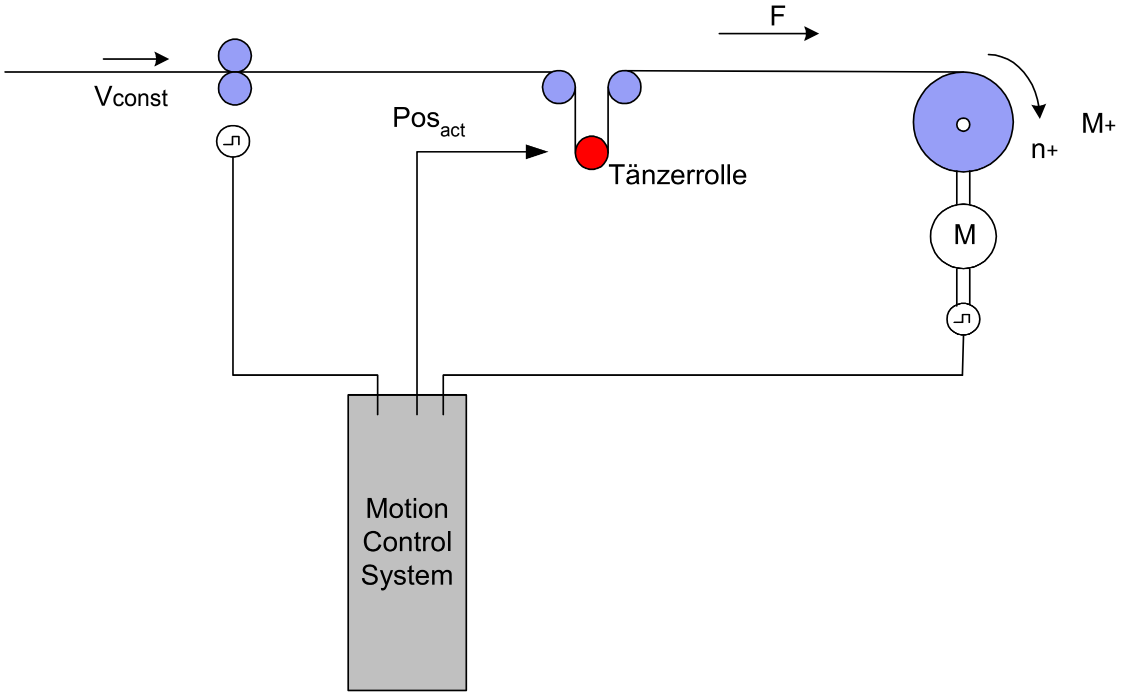
Winder

Figure 1-4: Closed-loop tension control



For the **closed-loop tension control**, the tension acting in the system is measured using a static measuring device and is compared with the tension setpoint (tension reference value) as measured quantity. The closed-loop tension control is used if the precision of the open-loop torque control is no longer sufficient. This can be the case if wide torque setting ranges are required or if the winder is subject to disturbing quantities and parameters.

Figure 1-5: Closed-loop dancer roll position control



A dancer roll is used for the **closed-loop dancer roll position control** – a position-controlled measuring system. The position of the dancer roll is determined using a suitable position encoder, which is then compared with the position setpoint (reference value). The tension is only determined using the dancer roll. If the tension changes, then the position of the dancer roll also changes. By changing the winder speed, the closed-loop dancer roll position control corrects this position offset. Although brief speed fluctuations have an effect on the position of the dancer roll, they hardly have any effects on the tension in the system. However, this only applies as long as the dancer roll does not reach its limits.

Advantage

The closed-loop dancer roll position control has the advantage that brief fluctuations in the tension can be absorbed due to the material web storage function of the dancer roll. Due to the mechanical requirement, it is also necessary to intervene in the material web.

Limits

The limits of the closed-loop dancer roll position control are predominantly defined by the mechanical implementation of the dancer roll and its dynamic characteristics.

1.3.3 Overview of the features of the winding techniques

Function

- Various winding functions, e.g. direct closed-loop tension control using speed correction or torque limiting and indirect closed-loop tension control are possible
- Overrides the speed controller (the tension controller acts on the torque limits) or speed correction technique (tension controller effects the speed setpoint) – either of these techniques can be selected
- The tension controller and speed controller gain are adapted as a function of the diameter
- Tension taper control is possible using a polygon, linear or hyperbolic characteristic
- Acceleration pre-control as a function of the roll moment of inertia
- Various techniques to calculate the diameter
- Load cell or dancer roll as measuring systems

1.3.4 Solution using the standard "winder" application

The standard "winder" application presented here helps to implement the functions shown and a functioning winder can be quickly developed.

The standard application includes, as a core function, pre-configured function blocks. The above mentioned functions are implemented in these function blocks and can be simply parameterized.

It is only necessary to control these function blocks via the user program and interconnect the output parameters of the function block corresponding to the existing drive system.

Depending on the required functionality of the winder, signal interconnections have to be parameterized in the drive – e.g. torque limits.

1.3.5 Advantages of the standard "winder" application

When the standard "winder" application is used, it offers users the following advantages:

Programs can be quickly generated

When the standard "winder" application is used, it is simple to quickly implement a comprehensive winder functionality when programming with SIMOTION. The core function can be integrated into the user program by simple parameterization.

The core functions in the standard application can be quickly and simply transferred by copying into the application to be generated. Additional engineering steps that are required are explained in this description of the standard application.

Possibility of making changes

The standard “winder” application includes all of the source codes in a commented form. This means that the core functions can be quickly and simply expanded using your own functions.

An explanation regarding background information that is required to expand the core functions is also included in this description.

1.4 Components included in the standard application

The standard “winder” application is implemented as SIMOTION project.

The project can, at the same time, be used for a (demonstration) machine for a SIMOTION D and PC with ProTool Pro RunTime demonstration case for visualization.

The program fulfills the following tasks:

- It controls the (demonstration) machine
- It simulates machine functions relevant for the demonstration case environment
- It displays the (demonstration) machine on the ProTool screen.

2 Functions of the winder application

2.1 Tasks that can be implemented using the core function

The winder application is used to control rotating mechanical equipment to wind or unwind a material web (film, paper, wire, foil, etc.)

The core function “winder” conditions the signals that are required to control the winder shaft – such as speed and torque. The functionality of the material web movement is implemented outside the core functions in the user program.

The core “winder” function comprises a function block, which generates the setpoints to control the winder shaft. These setpoints are the setpoint velocity and, depending on the closed-loop control mode, torque limits, additive torque setpoints as well as variables to control the controller gain adaptation function.

The block handles all of the essential functions of the winder open-loop control such as diameter calculation, moment of inertia calculation or setting the sign as a function of the winding direction.

The winder block can be simply changed-over to various closed-loop control modes by appropriately parameterizing it. It is not necessary to make any changes to the program in order to, for example, toggle between indirect and direct closed-loop tension control. However, it is possible to access the code of the winder block as this is not password protected.

2.2 Properties and features of the core “winder” functions

The following properties and features were taken into account when implementing the core functions and can even be used in user programs that you generate yourself:

Diameter calculator

3 different techniques are available to calculate the diameter of the roll being wound:

- The diameter is calculated using the ratio between the velocity of the material web and the winder speed
- The diameter is calculated by adding the material thickness
- The diameter is calculated from the ratio between the material length and the revolutions of the winder (integration)

Tension taper characteristic

A tension taper characteristic is required if the tension, with which the material is wound, is to be decreased as the diameter of the roll being wound increases. 3 different techniques are available to calculate the tension taper characteristic:

- Linear characteristic – the tension is linearly reduced as a function of the actual diameter
- Hyperbolic characteristic – the tension decreases according to a hyperbolic function/characteristic
- Interpolated characteristic using a table of points – 10 points can be entered to define the characteristic

Controller adaptation

- The gain of the tension controller can be adapted as a function of the diameter. This permits a higher controller gain at a large diameter
- The speed controller gain in the drive can be adapted as a function of the moment of inertia of the roll being wound. This is also necessary for a full roll so that this can be quickly moved

Inertia compensation

While the material web is being accelerated and decelerated, an additive torque can be switched to the drive in order to respond dynamically (quickly) to velocity changes.

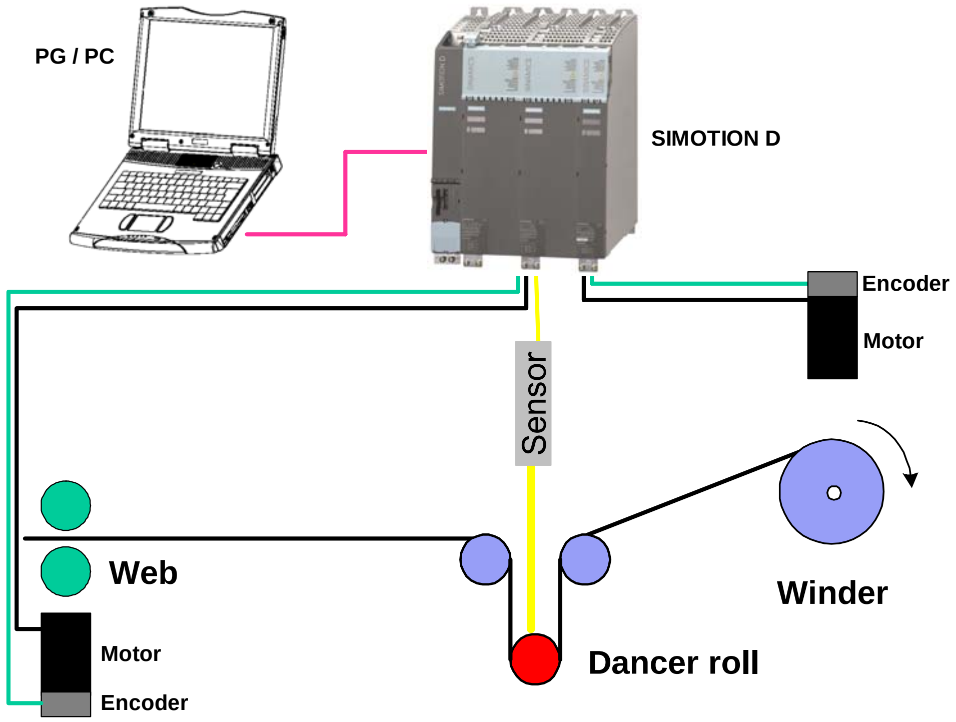
The inertia compensation avoids tension dips or tension increases due to the velocity change. This pre-control is required, especially for indirect closed-loop tension control but also for closed-loop tension control with a load cell.

The pre-control is made available to the user as an additive torque at the output of the winder function block. Instructions for making the appropriate interconnections are explained step-by-step in Section C using as an example, a SINAMICS drive.

3 Automation solution

Readers will obtain an overview of the hardware components required in this Chapter.

Figure 3-1: Automation solution



The material feed along the material web and the winder shaft are controlled by a SIMOTION D control

Hardware components

A SIMOTION platform (controller, PC or drive) is necessary to execute the winder functionality. A drive combination is also required (e.g. SINAMICS, SIMODRIVE or MASTERDRIVES). The application example has been designed for a 2-axis SIMOTION D435 demonstration case with firmware release V4.0. A PC with Ethernet interface and ProTool Runtime system are required for visualization and program control.

4 Selecting the closed-loop control concept

The standard winder application in SIMOTION allows the following closed-loop control concepts to be implemented:

- Indirect closed-loop tension control (without load cell)
- Direct closed-loop tension control with dancer roll or load cell

These control concepts will be briefly explained in the following. A Chapter with engineering examples is also included in Section C of the documentation. The *“Control_Mode”* parameter is used to toggle between the various closed-loop control concepts.

4.1.1 Indirect closed-loop tension control (“open-loop tension control”)

This technique does not require a device to measure the tension. The tension controller is not used – instead, the tension setpoint (reference value) is multiplied by the diameter and the result is directly pre-controlled as torque setpoint. This means that the motor current linearly increases with increasing diameter and the tension is kept constant. In this case it is important that the friction and accelerating torques are precisely compensated so that the pre-controlled torque setpoint results in the best possible approximation to the required material tension.

For this closed-loop control type it must be ensured that the mechanical losses are kept as low as possible. This means that worm gears may not be used, no open intermediate gear ratios - and if herringbone gearing is used, then the shaft should rotate in the direction of the herringbones. It is also important to ensure the lowest possible loss differences between gearboxes in the warm and cold states.

4.1.2 Direct closed-loop tension control with dancer roll

The material web is fed over a dancer roll. The dancer roll attempts to deflect the material web with a defined force. The deflection of the dancer roll (dancer roll position) is detected using a potentiometer – e.g. a field-plate potentiometer – and this serves as a measure of the material tension.

The material tension depends on the retraction force of the dancer roll suspension. Often, there are additional factors that influence the tension actual value as a result of the geometrical arrangement (distance to reversing rollers that maybe used) and the weight of the dancer roll itself. However, with a careful mechanical design, these effects can be eliminated or sufficiently minimized.

The controller that is at a higher-level to the speed controller (known as “tension controller” in this Manual) is used as dancer roll position controller and corrects the position actual value of the dancer roll in-line with the position reference value (position setpoint) (e.g. the dancer roll center position).

Normally, the position controller outputs a velocity correction setpoint to the speed controller.

Generally, the position reference value (position setpoint) is not entered from outside, but is parameterized as fixed value; the position reference value is entered using (*Controlled_Setvalue*).

For dancer rolls with a support force that cans either be pneumatically or hydraulically adjusted, decreasing tension taper can be implemented using the tension taper characteristic. To do this, the output signal (*Tension_Set*) of the winder block is output to an analog output and is used as setpoint for the dancer roll support function.

When a dancer roll is used as actual value transmitter, this has the advantage that the dancer roll (when the stroke is selected long enough) simultaneously serves as a storage element for the material web. This means that it already is a 'closed-loop tension controller'. Although closed-loop dancer roll controls are quite complex, they offer the best closed-loop control technique.

The material web storage function has a damping effect on

- Non-round (eccentric) material rolls (out of true)
- Jumps between layers – e.g. when winding cables
- At roll changes

4.1.3 Direct closed-loop tension control with load cell

A load cell (e.g. load cell from FAG Kugel-Fischer or Philips) directly senses the material tension. Its output signal is proportional to the tension and is fed to the tension controller as actual value signal (*Controlled_ActualValue*). This means that in this case the tension controller is effective and directly controls the tension of the material web. Just the same as for indirect closed-loop tension control, the speed controller in the drive operates in saturation (at its end limits). The drive is at one of the two torque limits and is controlled through these torque limits. The correction value from the tension controller acts additively on these torque limits. Supplementary torque setpoints – e.g. from the acceleration pre-control (inertia compensation) or the tension taper characteristic – are connected-up so they act additively to the torque limits.

For this technique, it is not necessary to intervene in the material web as is the case for a dancer roll system. However, in this case there is not the advantage of having a storage function for the material web.

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Comparison of the closed-loop control concepts

The most important criteria when selecting a suitable closed-loop control concept are summarized in the following table:

Table 4-1: Comparison of the closed-loop control concepts

Control concept	Indirect closed-loop control	Direct closed-loop tension control with dancer roll	Direct closed-loop tension control with load cell
Information on sensing the tension actual value	No tension actual value sensing required	Intervenes in the material web routing, ability to store material	Sensitive to overload, generally does not intervene in the web routing
Winding ratio D_{max}/D_{core}	Up to approx. 10:1, good compensation of dv/dt and friction required	Empirically up to approx. 15:1	Empirically up to approx. 15:1, precise dv/dt compensation required
Tension range Z_{max}/Z_{min}	Up to approx. 6:1 for good compensation of friction and dv/dt	Can only be set when the dancer roll support can be adjusted	Up to approx. 20:1 for precise dv/dt compensation
Winding ratio x tension range $\frac{D_{max}}{D_{core}} \cdot \frac{Z_{max}}{Z_{min}}$	Generally up to 40:1	Depends heavily on how the dancer roll support is implemented, up to approx. 40:1	Up to 100:1, essentially depends on the tension actual value signal
Friction force/tension that cannot be compensated	From experience, over the complete tension range < 1	-	-
Web velocity	Up to 600 m/min for good compensation	Up to over 2000 m/min	Up to 2000 m/min with precise dv/dt compensation
Closed-loop control concept, preferably used for	Sheet steel, textiles, paper	Rubber, cable, wire, textiles, foils, paper	Paper, thin foils
Nip position required	Yes	Yes	Yes
Web material tachometer required	-	-	-

5 Winder checklist

This checklist should be used to list customer requirements in order to investigate the feasibility of the winder application. The fields with white background must be completed; the fields with gray background can be calculated using the appropriate formulas.

Table 5-1: Winder checklist

Designation	Value	Units
Minimum diameter D_{min}		[m]
Maximum diameter D_{max}		[m]
→Diameter ratio D_{max} / D_{min}		[--]
Minimum tension F_{min}		[N]
Maximum tension F_{max}		[N]
→ Tension ratio F_{max} / F_{min}		[--]
→ Minimum torque M_{min}		[Nm]
→ Maximum torque M_{max}		[Nm]
→ Torque ratio M_{max} / M_{min}		[--]
Motor type (synchronous / induction)		[--]
Rated motor torque M_N		[Nm]
Rated motor frequency f_N		[Hz]
Rated motor speed n_N		[U/min]
Motor moment of inertia		[kg*m²]
Gearbox moment of inertia		[kg*m²]
Motor encoder system (resolver, pulse, encoder)		[--]
Maximum web velocity v_{max}		[m/min]
Maximum winder speed for v_{max}, D_{min}		[U/min]
Gearbox ratio $i=n_1/n_2$		[--]
Maximum motor speed for v_{max}, D_{min}		[U/min]
Maximum field weakening		[--]
Load cell (dancer roll/ load cell, measuring, control range)		[--]
Required tension accuracy $\Delta F/F_{max}$		[%]
Diameter sensor (yes/no)		[--]
Wound material width B		[m]
Wound material length L		[m]
Winding material thickness D		[m]
Winding material density		[kg/m³]

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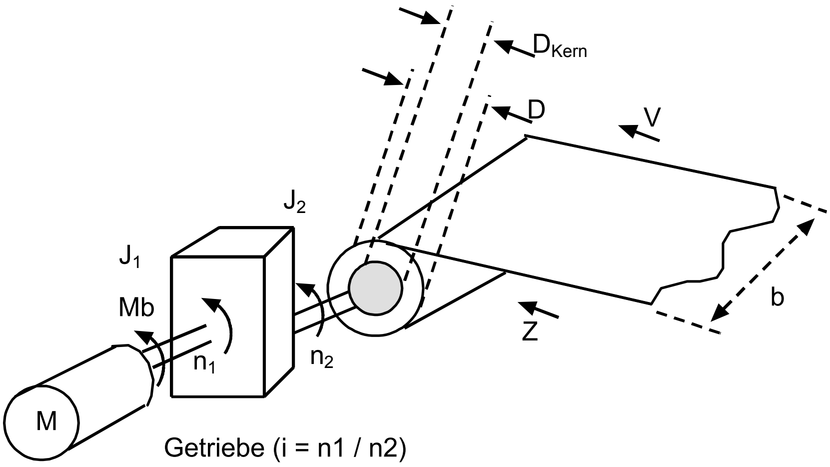
Designation	Value	Units
→ maximum moment of inertia of the wound roll		[kg*m²]
Flying roll change		[--]

Winder

6 Short collection of formulas

Figure 6-1: Schematic Diagram



(1) Winding ratio:

$$\boxed{q = \frac{D_{max}}{D_{Kern}}} \left[\frac{mm}{mm}\right]$$

(2) Speed [rpm]:

$$\boxed{n = \frac{V}{D \cdot \pi}} \left[\frac{1}{min}\right]$$

(3) Winding torque referred to the motor shaft [Nm]:

$$\boxed{M_W = \frac{Z \cdot D}{2000 \cdot i}} \left[\frac{Nmm}{1}\right]$$

(4) Winding power [kW:

$$\boxed{P_W = \frac{Z \cdot V}{60 \cdot 10^3}} \left[\frac{Nm/min}{1}\right]$$

(5) Gearbox ratio, max. motor speed / max. sleeve/ core speed:

$$\boxed{i = \frac{n_1}{n_2} = \frac{\pi \cdot D_{Kern} \cdot n_{max}}{1000 \cdot v_{max}}} \left[\frac{mm/min}{m/min}\right]$$

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(6) Moment of inertia, full cylinder [kg m^2]:

$$\boxed{J = \frac{m}{8 \cdot 10^6} \cdot D^2 = \frac{\pi}{32 \cdot 10^{12}} \cdot b \cdot \rho \cdot D^4} \left[\frac{mm \cdot kg \cdot mm^4}{dm^3}\right]$$

(7) Moment of inertia, hollow cylinder [kg m^2]:

$$\boxed{J = \frac{m}{8 \cdot 10^6} \cdot \left(D^4 - D_{Kern}^4\right) = \frac{\pi}{32 \cdot 10^{12}} \cdot b \cdot \rho \cdot \left(D^4 - D_{Kern}^4\right)}$$

(8) Moment of inertia reduction through a gearbox:

$$\boxed{J_1 = \frac{J_2}{i^2}}$$

(9) Fixed moment of inertia [kg m^2]
determined by the fixed parts and components of the winder (motor, gearbox and core) referred to the motor shaft

$$\boxed{J_F = J_{Motor} + J_{Getr} + \frac{J_{Kern}}{i^2}}$$

(10) Variable moment of inertia [kg m^2]

$$\boxed{J_V = \frac{\pi \cdot b \cdot \rho}{32 \cdot 10^{12} \cdot i^2} \cdot \left(D^4 - D_{Kern}^4\right)} \left[\frac{mm \cdot kg \cdot mm^4}{dm^3}\right]$$

(11) Accelerating torque referred to the motor shaft [Nm] for accelerating time t_b

$$\boxed{M_b = \frac{100 \cdot i}{3 \cdot D} \cdot \frac{\Delta V}{t_b}\left(J_f + J_V\right)}$$

(12) Accelerating power [kW]

$$\boxed{P_b = \frac{i \cdot V}{30 \cdot D} \cdot M_b = \frac{10 \cdot i^2 \cdot V}{9 \cdot D^2} \cdot \frac{\Delta V}{t_b} \cdot \left(J_f + J_V\right)}$$

(13) Rated motor torque [Nm]

$$\boxed{M_N = \frac{9549 \cdot P_M}{n_M}}$$

Winder

(14) Wound roll storage capacity for flat materials

$$\boxed{l = \frac{\pi}{4000 \cdot d} \cdot \left(D_{max}^2 - D_{Kern}^2\right)}$$

(15) Wound roll storage capacity for round materials

$$\boxed{l = \frac{\pi \cdot b}{2000 \cdot \sqrt{3} \cdot D_R^2} \cdot \left(D_{max}^2 - D_{Kern}^2\right)}$$

(16) Relative storage capability depending on the winding ratio:

q	2	3	4	5	6	7	8	9	10
$\frac{l}{l_{max}} = 1 - \frac{1}{q^2}$	75 %	88.9%	93.8%	96%	97.2%	98%	98.4%	98.8%	99%

(17) Winding time [s]:

$$\boxed{t = 60 \cdot \frac{l}{v}}$$

Formulas and dimensions used

b	=	material width [mm]
b_{max}	=	maximum material width of role being wound [mm],
d	=	material thickness [mm]
D	=	actual diameter [mm]
D_{core}	=	core or sleeve diameter [mm]
D_{Max}	=	maximum diameter [mm]
D_R	=	material diameter for round materials [mm]
i	=	gearbox ration (refer to (5))
J	=	moment of inertia [kgm^2]
J_F	=	fixed moment of inertia referred to the elements of the winder that do not change (motor, gearbox + wound roll core) referred to the motor shaft [kgm^2]
l	=	material length [m]
l_{max}	=	maximum material length (for core diameter 0 mm) [m]
J_{gear}	=	moment of inertia of the gear referred to the motor shaft [kgm^2]
J_{core}	=	moment of inertia of the core [kgm^2]
J_{motor}	=	motor moment of inertia [kgm^2]
J_V	=	variable moment of inertia caused by the wound material referred to the motor shaft [kgm^2] (refer to (10))
m	=	mass [kg]

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M_w	=	winding torque referred to the motor shaft [Nm]:
M_b	=	accelerating torque referred to the motor shaft [Nm]
M_{bF}%	=	percentage accelerating torque as a result of the fixed moment of inertia J_F at the minimum diameter [% of M_N] (refer to formula (1.2))
M_{bV}%	=	percentage accelerating torque due to the variable moment of inertia J_V at the maximum diameter and maximum width [% of M_N] (refer to formula (1.5))
M_N	=	rated motor torque [Nm] (refer to (13))
n	=	speed [RPM]
n_{max}	=	maximum motor speed [RPM] (no-load speed for maximum field weakening)
n_N	=	rated motor speed at the rated voltage and rated motor field current [RPM]
P_b	=	accelerating power [kW]
P_M	=	required motor power [kW]
P_N	=	rated motor power [kW]
P_w	=	winding power [kW]
q	=	winding ratio (refer to (1))
r	=	specific weight [kg/dm^3]
t	=	winding time [s]
t_b	=	accelerating time [s]
t_h	=	ramp-up (accelerating time) of the web velocity from 0 to V_{max} [s]
V	=	web velocity [m/min]
V_{max}	=	maximum web velocity [m/min]
Z	=	tension [N]
ΔV	=	velocity difference [m/min

6.1 Selecting the winding ratio (winding range

Winding operation is addressed in the following. The same essentially applies for unwinding.

Winding ratio is given by the following quotient:

$$\frac{D_{Max}}{D_{core}}$$

The winding quantity that can be used as a % is given by the following formula (14):

$$(D^2_{max} - D^2_{core}) \cdot \frac{\pi}{4}$$

This means that for a winding ratio of 6:1, the winding length that can be used is already $\approx$ 97 %.

6.2 Power and torque

The power required for winding is constant over the complete winding range if, for the selected web velocity, the selected winding tension is to be kept constant (also refer to the formula 4)). Winding power P_w:

$$P_W = \frac{Z_s \cdot b \cdot d \cdot V}{60 \cdot 10^3} \text{ kW}$$

b = operating width in mm
d = operating thickness in mm
V = web velocity in m/min
Z_s = specific material tension in [N/(mm^2 material cross-section surface)]

The torque required increases linearly with the diameter of the roll being wound.

6.3 Selecting the motor

The standard axial winder application is suitable for both synchronous as well as induction motors – without any differences in the control behavior. Because an induction motor can operate in the field-weakening mode, the motor can often be more favorably dimensioned a synchronous motor.

When selecting induction motors, we recommend that the following points are observed:

- An actual value encoder is already integrated in the motor
- Good field-weakening behavior allows a smaller motor to be selected
- The motors are force-ventilated as standard – which means adequate cooling at low speed and high torque. At field-weakening speeds, there is no increased fan noise when compared to non-ventilated motors.

Engineering information and instructions for synchronous and induction motors, refer to the PATH and SIZER engineering programs.

6.4 Dimensioning the gearbox

The gearbox is dimensioned together with the machinery construction company.

6.5 Selecting the drive converter

The drive converter is selected using PATH (Masterdrives) or SIZER (SINAMICS).

Application example as demonstration system

All of the steps necessary to commission the standard “winder” application as demonstration system are explained in this section.

Preparations and parameterizing operations are explained. Further, you are shown how to handle the ProTool Pro interface of the application example step-by-step.

Objectives

The Section of this document should provide the user with

- The necessary prerequisites to use this standard SIMOTION application as demonstration system
- The preparations and parameterizing operations
- The steps necessary when presenting this standard application
- Tips on how to use this standard application

7 Installing the hardware and software

7.1 Regarding your safety

7.1.1 Safety information and instructions

Pictograms, signal words and text

Every piece of safety information/instruction in this document is designated by text graphics – comprising pictogram and signal word, and supplemented by explanatory text. A clear classification according to the degree of the potential hazard is provided as a result of the combination of pictogram and signal word. Safety information/instructions are provided in front of the information regarding activities to be executed.

Classification

There are **three different stages** regarding safety information/instructions. These are designated **by the same pictogram**. They differ by the signal word.

! **Danger**	**This safety information/instruction indicates an immediate hazard. If the information/instruction is not carefully followed, this results in severe bodily injury or even death.**
! **Warning**	**This safety information/instruction indicates a potential hazard. If the information/instruction is not carefully followed, this can result in severe bodily injury or even death.**
! **Caution**	**This safety information/instruction indicates a potentially hazardous situation, which can result in slight to average bodily injury. This pictogram/text word can also warn about potential material damage.**

7.1.2 Responsibilities of the operator

Correct use

The correct use of the application components exclusively relates to the open-loop and closed-loop control of test set-ups that were adapted to the power/performance of the application components. In order that the application functions perfectly, the required standard SIMATIC components as well as also the necessary hardware and software components must be installed.

Misuse

The following are considered to be misuse:

- Inadmissible loads applied to the application components.
- Any application deviating from the use specified above, or applications that go beyond the specified use.
- Non-observance of the safety information and instructions.
- If faults that could have a negative impact on the safety are not immediately resolved/removed.
- Any changes/modifications to equipment/devices that are used to ensure perfect function and operation, unrestricted use as well as active or passive safety.
- If recommended hardware and software components are not used.
- If the application components are not in a perfect technical condition are not operated conscious of safety and hazards, and not taking into account all of the instructions provided in the documentation.

The manufacturer assumes no liability for incorrect use (misuse).

Responsible for monitoring

The company or person operating the system is responsible in continually monitoring the overall technical status of the application components (defects and damage that can be externally identified as well as changes in the operating behavior). The company/person operating the system is responsible in ensuring that the application is only operated in a perfect state. He must check the state of the application components before they are used and must ensure that any defect is removed before commissioning.

Qualification of personnel

The operating company/person may only deploy trained, authorized and reliable personnel. In so doing, all safety regulations must be carefully observed.

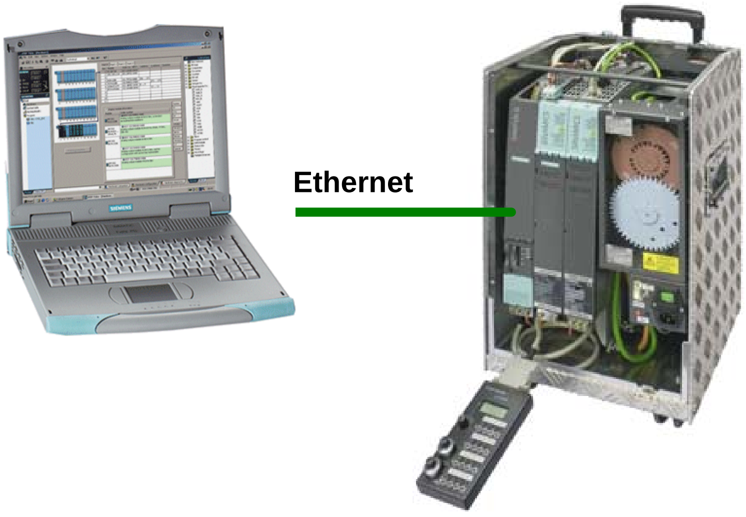
Personnel must receive special instructions regarding the hazards/dangers that can occur.

Winder

7.2 Hardware structure and mounting/installation

Overview

Figure 7-1: Hardware components (without power cable!)



The demonstration project can be commissioned using a conventional SIMOTION D435 demonstration case and a PC connected via Ethernet.

Winder

Table 7-1: Hardware components

Hardware element	Fig.	MRPD/Order No. and functions
Training case, SIMOTION D435 with SINAMICS S120		
SIMOTION D435 demonstration and training case		6ZB2 470-0AE00 The SIMOTION D training case comprises standard components (SIMOTION D435, two SINAMICS axes and motors)) and offers two axes. These are used to demonstrate the application. The case is already set-up and wired-up. It only has to be connected to the HMI system via ETHERNET.
Communications		
Ethernet cable		Ethernet Cross Link Cable!
HMI system		
PG/PC with Ethernet interface		- The PG/ PC is used to run the HMI operator interface.

Procedure

Proceed as follows to configure and mount the hardware components for the application example:

Table 7-2: Hardware configuration and mounting

Nr.	Action	Comment
1	Connect the Ethernet interface of your PG/PC with the lower Ethernet interface IE2 (contact X130) of SIMOTION D435 with a Ethernet cable.	It is absolutely necessary to use a cross-link Ethernet cable (twisted-pair) to connect the PG/PC and the SIMOTION D435. Otherwise, it is not possible to establish a communication.
	Connect the SIMOTION D training case to the power supply unit.	
	Switch on all devices.	

7.3 Installing the standard SIEMENS software

Note

If the application is only to be used for demonstrating and presenting, then it is only necessary to install Protool RT with 256 power tags.

Min. required Editions

Table 7-3: Versions

Component	Version.
STEP 7	V5.3 + HF1
SIMOTON SCOUT	V4.0
Protool/Pro	V6.0 + SP2

Table 7-4: Software components

Component	Order No. [MLFB]	Functions
STEP7 V5.3 SP3 HF1	6ES7810-4CC07-0YA5	STEP 7 is the basis package for the other software packages and is used to program SIMATIC S7
SIMOTION SCOUT V4.0.0	6AU1810-0BA40-0XA0	Tool to parameterize the SINAMICS drive and program SIMOTION controls
ProTool/Pro 6.0 + SP2 CS	6AV6581-3BX06-0DX0	Protool/Pro is used to program the HMI man-machine interface (screen). You cannot change the HMI man-machine interface without this software.
ProTool/Pro 6.0 + SP2 RT256	6AV6584-1AC06-0CX0	Protool/Pro RT allows you to use a PG/PC as operator panel.

Installation

1. Step 7 V5.3 incl. HF1
2. SIMOTION SCOUT V4.0
3. Protool/Pro CS V6.0 (with the option: **Integration in Step 7**)
4. Protool/Pro RT 256 V6.0 + SP2

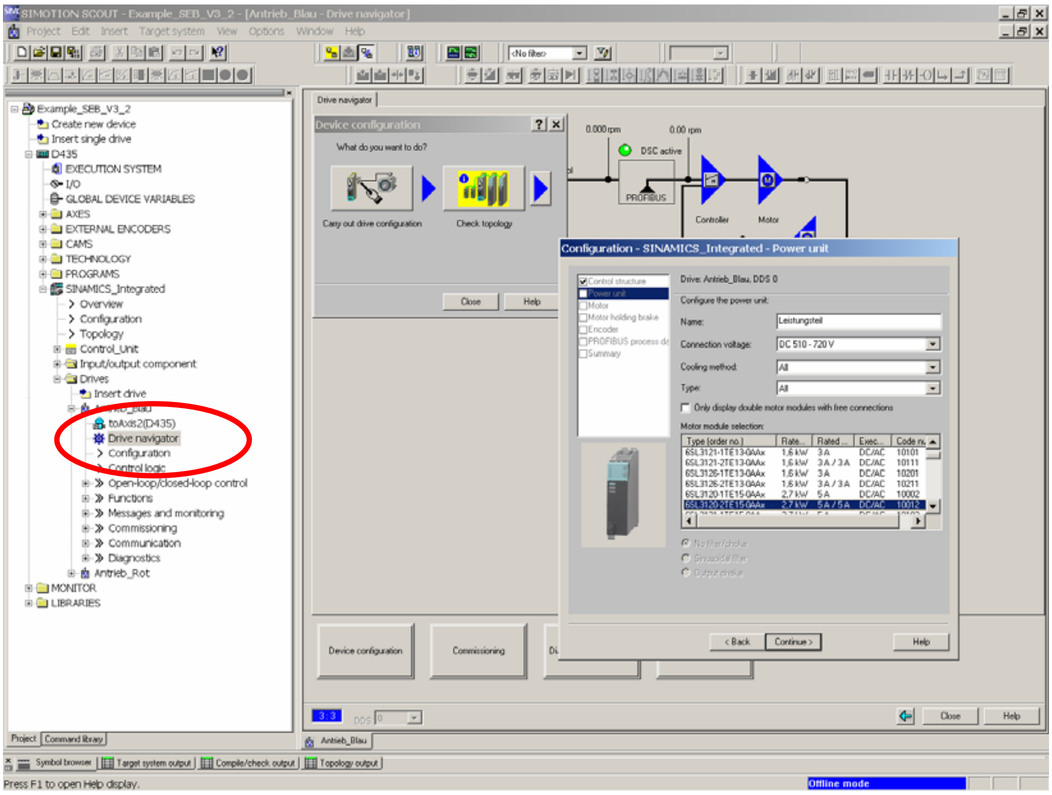
Then follow the instructions of the particular installation program.

7.3.1 Reconfiguration of double-axis motor module from 3A/3A to 5A/5A

This Standard Application is configured with a 3A/3A motor modul. If this project is used with demonstration racks of a different rated power, e.g. with double motor modules 5A/5A, the configuration in the project has to be changed accordingly:

- Change to offline mode
- Open the “drive navigator” in the project navigator window
- By pressing the button “device configuration” a new window opens
- Carry out drive configuration, by pressing the relevant button
- Press “continue” until you reach the window “configuration power unit”
- Select the used power unit in the list, compare serial number at front face of the motor module, e.g. 6SL3120-2TE15-0AA0 (5A/5A)
- Press “continue” and acknowledge warnings
- Press “continue” , without conducting any further changes, until the button “finish” appears and finish the configuration by pressing that button
- Close the window “device configuration”
- Reduce parameter p210 separately in both drives (Antrieb rot, Antrieb blau) from 600V to 345V by using the expert list (mark respective drive -> right mouse button -> expert -> expert list)
- Save and compile project, connect to target system and download your project

Figure 7-2: Reconfiguration of the motor module



7.4 Downloading the user program and the drive parameterization into the SIMOTION D demonstration case

7.4.1 De-archiving the SIMOTION project

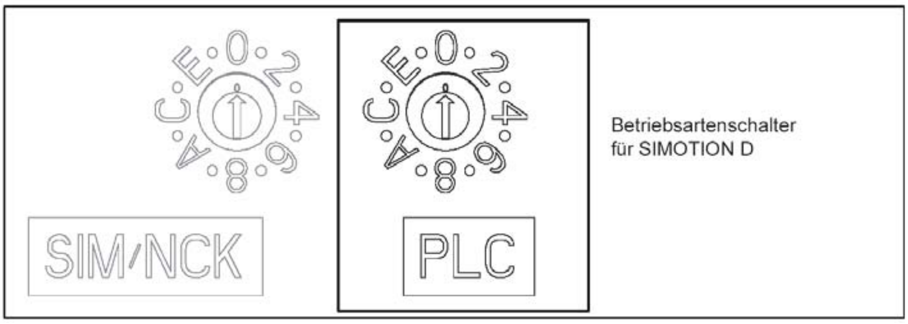
- Open SIMOTION SCOUT
- De-archive the SIMOTION project and open it with SIMOTION SCOUT

7.4.2 Resetting SIMOTION D435 to the factory settings

In order to have a fixed starting point for the description of the loading operation of the demonstration case, re-establish the factory setting at the demonstration case as described in the following:

- Power OFF the demonstration case
- Set the SIMOTION D435 operating mode switch to setting 3 (MRES)
- Power ON the demonstration case
- When RDY turns green and STOP turns orange, set the SIMOTION D435 operating mode switch to 0 (RUN)
- RDY and RUN are now green (lit)
- Once the factory setting has been established, SIMOTION D435 has PROFIBUS address 2 and the baud rate is 1.5 Mbit/s.

Figure 7-3: SIMOTION D435 operating mode switch

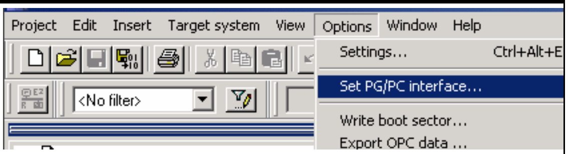
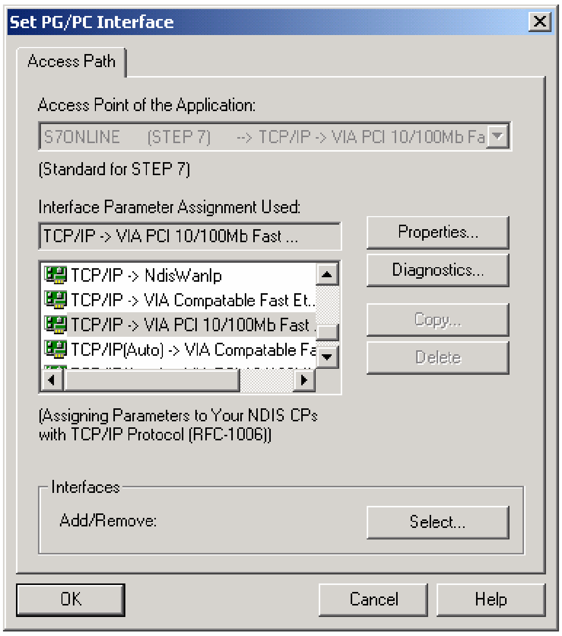
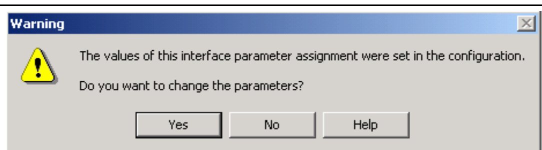


Winder

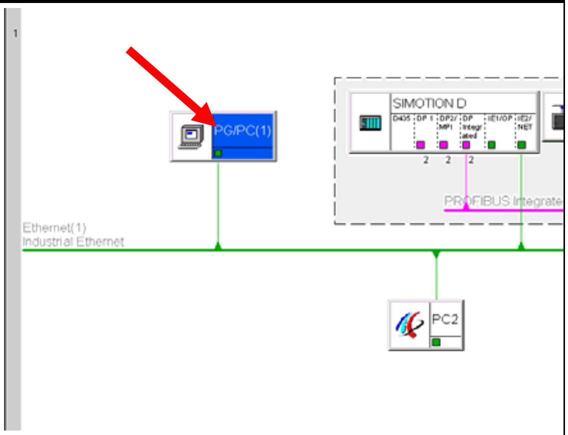
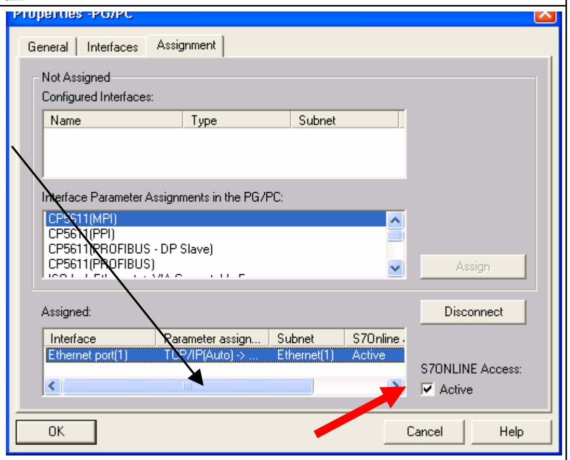
7.4.3 Configure Ethernet interface

Set PG/PC interface

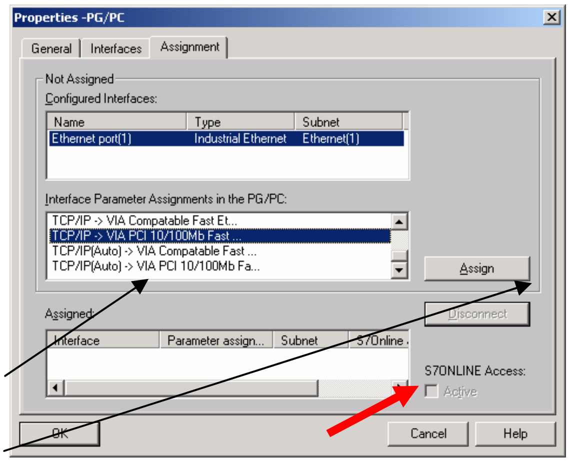
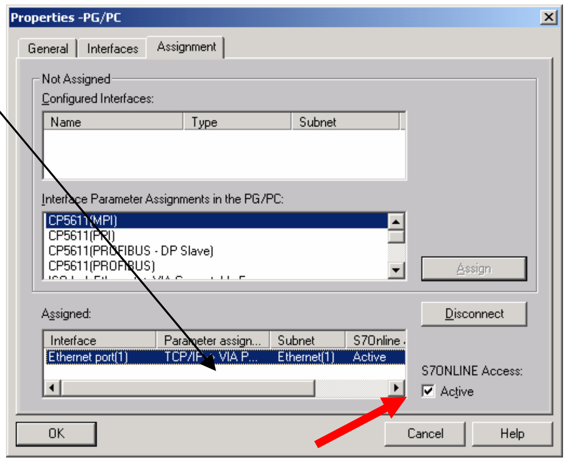
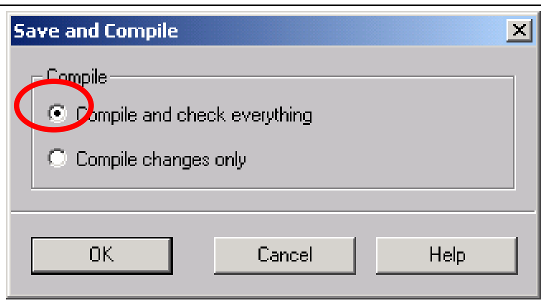
Table 7-5: PG/PC-interface configuration

No.	Action	Comment
1.	Open the interface configuration in SIMOTION SCOUT via **EXTRAS** → **SET PG/PC INTERFACE...**	
2.	Among the features by "Interface Parameter Assignment Used", please select your Ethernet card / interface of the PG/PC with „TCP/IP → ......" (e.g. „TCP/IP → VIA PCI 10/100I Fast Ethernet Adapter").	
3.	Confirm (possible) warning by **Yes**.	
4.	Confirm your changes with OK twice.	
5.	Return to SIMOTION SCOUT and open the net configuration **NETPRO** by using the button or by selecting the Menu **PROJECT** → **OPEN NETPRO**.	

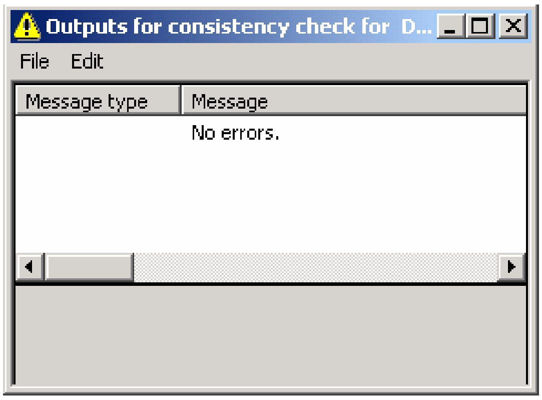
Winder

No.	Action	Comment
6.	Double-click on **PG/PC(1)** to open the properties.	
7.	Under the feature „Assignment“ (which has already been selected automatically), the applied ETHERNET interface has to be indicated under „Parameter assigned“. If this is already the case, you only have to select it and put the tick in the box marked ‘S7ONLINE Access: **active**’. **In this case, please skip the steps 8 and 9!** Confirm your entry with **OK.** After that, the Ethernet line of the PG/PC is marked in yellow.  **If the applied ETHERNET interface is not indicated under „parameter assigned“(but only in that case!), please execute the steps 8 and 9**	

Winder

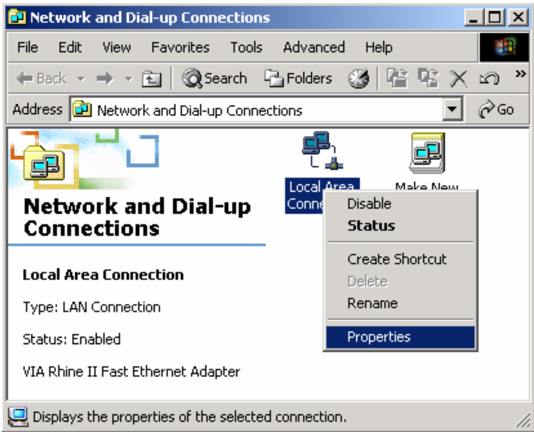
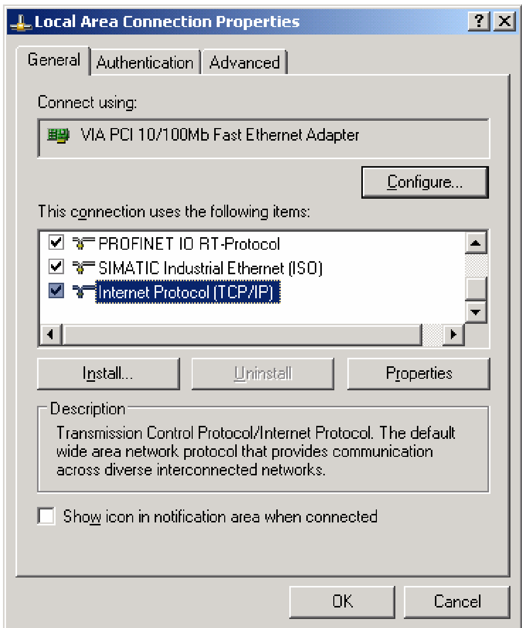
No.	Action	Comment
8.	ETHERNET has not been “assigned”, yet: You can find the configured interface of the control under „Configured Interfaces“ and all available interfaces in the PG/PC under „Interface Parameter Assignments in the PG/PC“. Select under „Interface Parameter Assignment“ the applied ETHERNET interface (like it has been set in „Set Interface in PG/PC“) and push the button **Assign**. If a warning appears, please, confirm it with OK.	
9.	After that, the interface of the control is assigned to the interface of the PG/PC. If this assignment has not been selected, yet, please do it now and put the tick in the box marked „S7ONLINE Access: **Active”**. Confirm your entry with **OK.** After that, the Ethernet line of the PG/PC is marked in yellow. 	
10.	Please, select „Compile and check everything”. Select the (button ) and confirm with **OK**.	

Winder

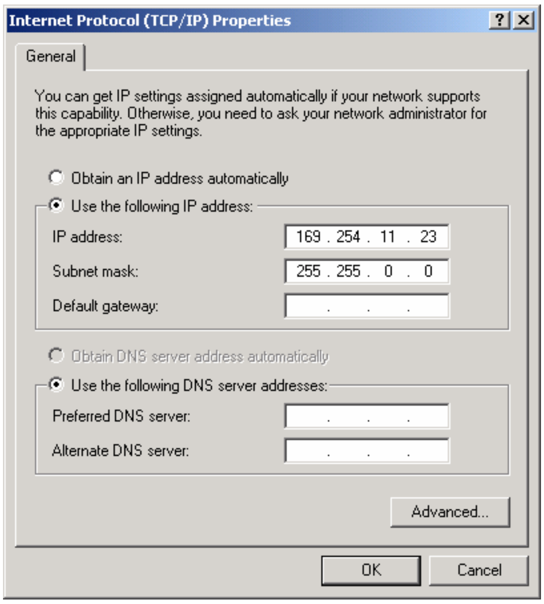
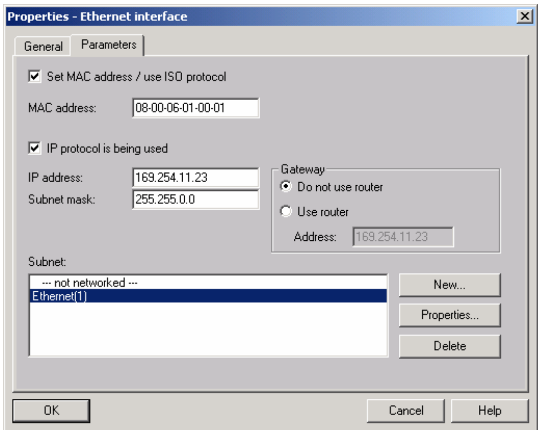
No.	Action	Comment
11.	Please close all possible appearing warnings.	
12.	Before you close the project of loading, please connect NETPRO and adjust the Ethernet address of your PG/PC. For this, please, see the next paragraph.	

7.4.4 Set the Ethernet address of the PG/PC

Table 7-6: Ethernet Address

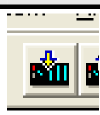
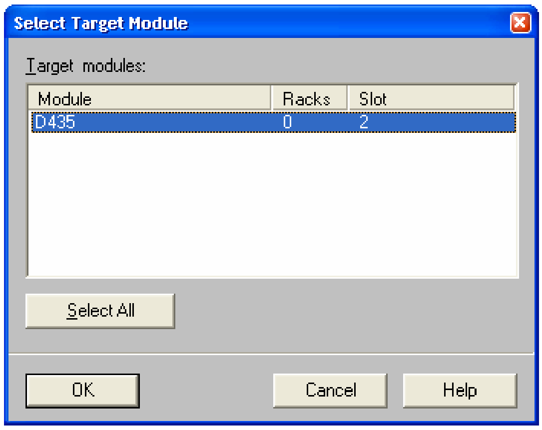
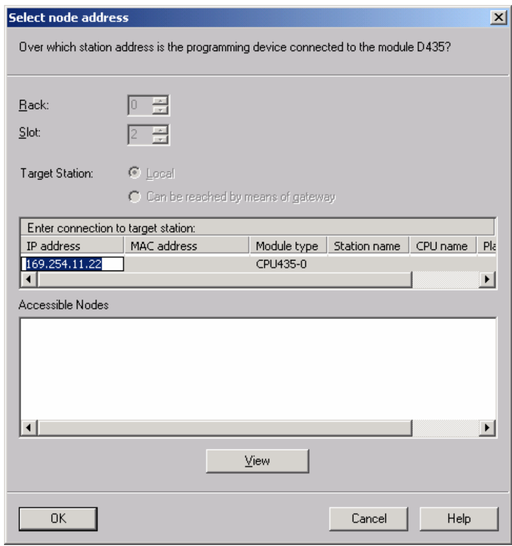
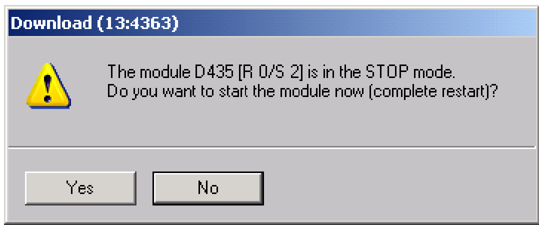
<table>
<tr><th>No.</th><th>Action</th><th>Comment</th></tr>
<tr><td>1.</td><td>Open the window NETWORK AND DIAL-UP CONNECTIONS of your PG/PC, select the applied network connection to SIMOTION D435, and open its properties.
(Right mouse click → mark properties or symbol and then FILE → PROPERTIES).</td><td>
</td></tr>
<tr><td>2.</td><td>In the area „Components checked are used by this connection“, please select the „Internet Protocol (TCP/IP)“ and open its properties.</td><td>
</td></tr>
</table>

Winder

No.	Action	Comment
3.	The standard IP address of the Ethernet interface IE2/OP (X130) for the SIMOTION D435 is 169.254.11.22. Please, select „Use the following IP address“ and enter the IP address **169.254.11.23**. Please, enter 255.255.0.0 in the „Subnet mask“.	
4.	The configured address need to be identical with the address of the PG/PC! Check the configured address in the properties of the PG/PC interface and change it if necessary.	
5.	Confirm your changes by pressing **OK** twice.	

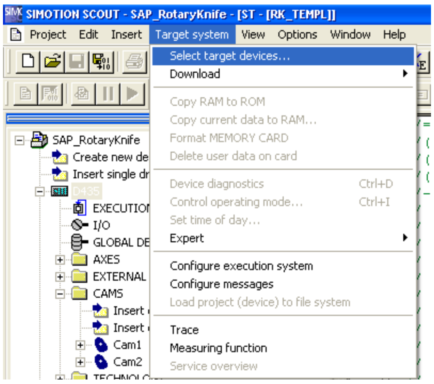
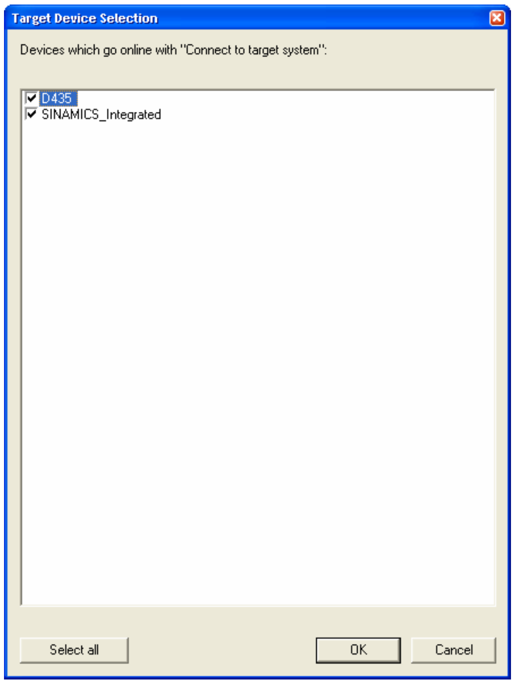
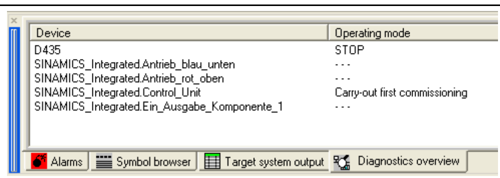
7.4.5 Loading the Hardware Configuration into the device

Table 7-7: Loading the Hardware Configuration into the device

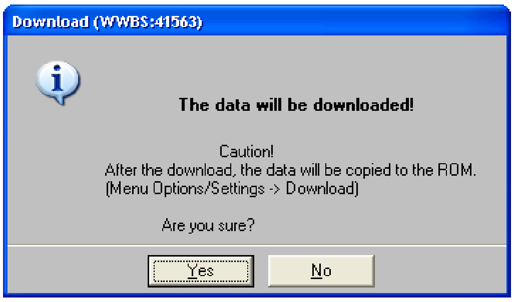
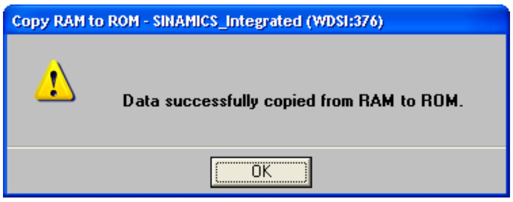
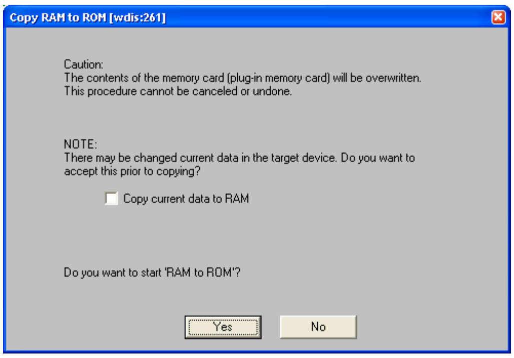
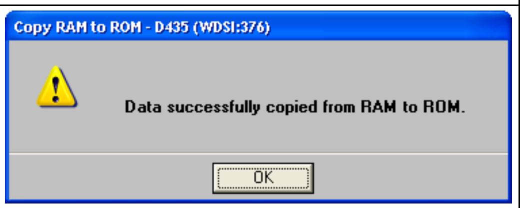
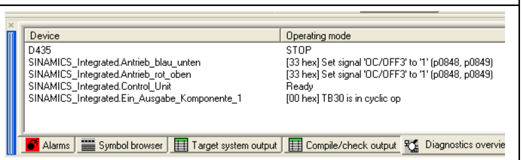
No.	Action	Comment
1.	Change to HW-Config and download the hardware configuration.	
2.	Confirm with **OK.**	
3.	Confirm with **OK**	
4.	Press no.	
5.	Close the HW-Config and change to SCOUT	

7.4.6 Load the SIMOTION part of the application

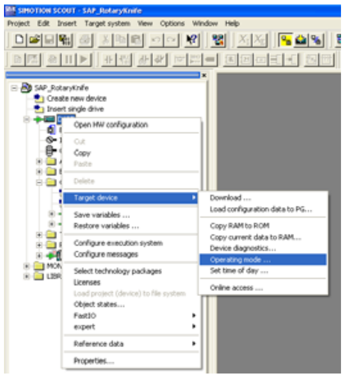
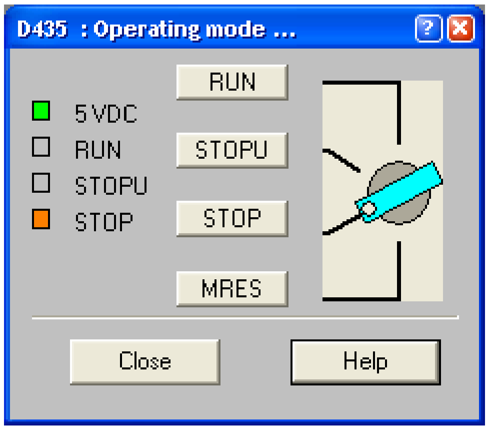
Table 7-8: Load the SIMOTION-Project

No.	Action	Comment
1.	Before you load the project, in the offline mode, please check under Target system/Select target devices.	
2.	Whether both SIMOTION D435 as well as also SINAMICS_Integrated are selected. Please acknowledge changes with **OK**.	
3.	After establishing the ONLINE connection, the operating states of the devices reached, are displayed in the diagnostics overview	

Winder

No.	Action	Comment
4.	After starting the download, you will be prompted as to whether you wish to “copy RAM to ROM“ after the download. Always answer this question with **Yes** as otherwise your program must be again loaded after power ON/OFF. This copy operation only refers to the SIMOTION part of the project.	
5.	Once the download has been completed, please acknowledge with **OK.**	
6.	Also acknowledge the message, copy RAM to ROM with **OK.**	
7.	The system now prompts you whether you wish to also copy the parameters of SINAMICS_Integrated from the RAM to the ROM. Also answer this with **Yes.**	
8.	Also acknowledge the data that has been successfully copied from the RAM to ROM with **OK**	
9.	After the download has been completed, you’ll see the adjacent diagnostics overview.	

Winder

No.	Action	Comment
10.	Now switch the SIMOTION D435 into the RUN state. To do this, click on the SIMOTION-CPU and with the right-hand mouse key and target device/operating state, go to the operating state display.	
11.	Here, click on the **RUN** button The SIMOTION D435 is then in RUN and the demonstration case is now ready to be used for the presentation!!	

8 Using the application example

The application can be used to present SIMOTION D with SINAMICS and get to know and test the functions of the CPU D435.

Brief instructions to demonstrate and present the application example are provided in the following Chapter 8.1 Brief instruction to demonstrate.

A detailed description of all operator screens is provided in Chapter 8.2. Detailed operating instructions.

8.1 Brief instructions to demonstrate

Here, in these instructions you will only be shown and explained the steps necessary to demonstrate the application. Not all of the operator screens will be discussed.

Prerequisites

The following prerequisites must be fulfilled in order to use the application example:

- The SIMOTION project is provided online in SIMOTION D435.
- SINAMICS has been loaded with the parameterization for the applications (also contained in the SIMOTION project!).
- All devices have been powered-up.
- The SIMOTION D435 has been switched into the “Run” state using the online function of SIMOTION SCOUT.
- At least Protool RT V6.0 + SP2 is installed on the PC/PG

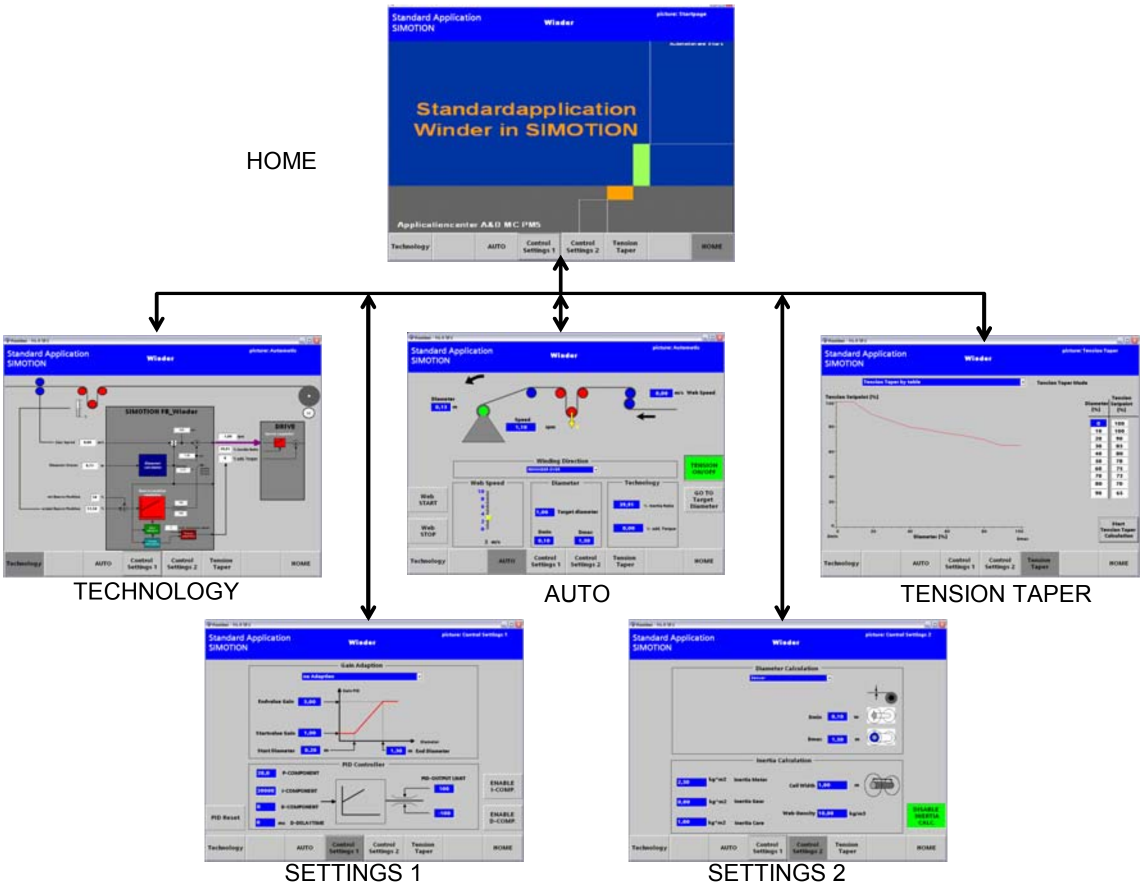
Note	Protool RT requires authorization. Authorization for at least 256 power tags is required. If there is no authorization, reference is made to this and can be acknowledged.

Winder

8.1.1 Overview of the structure

Please refer to the following diagram for the basic operator structure of the application.

Figure 8-1: Overview of the structure when demonstrating

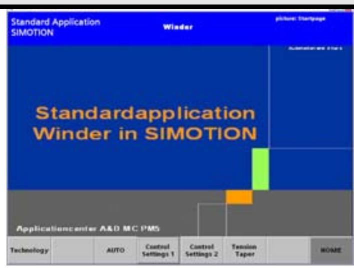
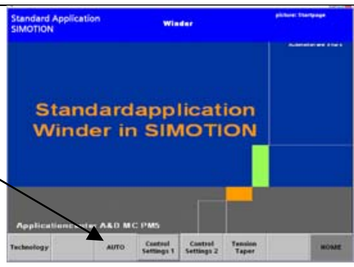
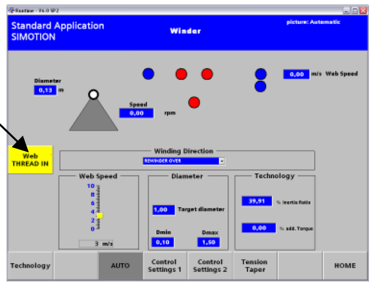
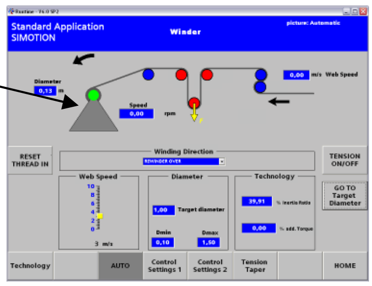
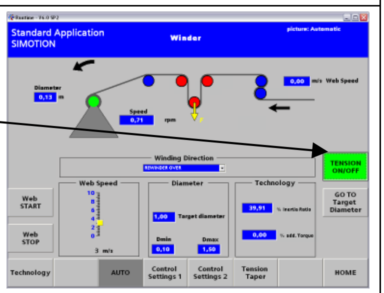


Winder

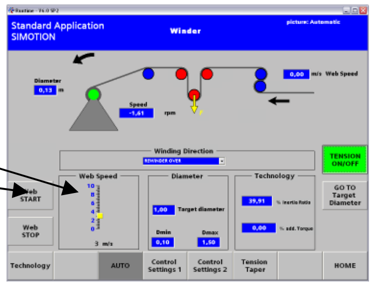
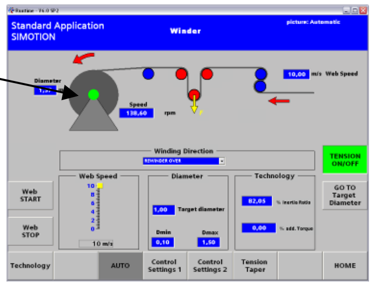
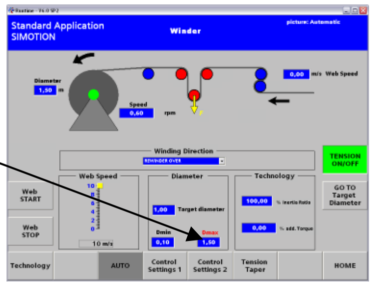
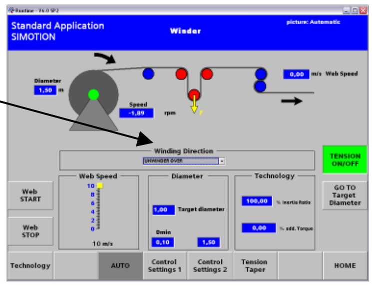
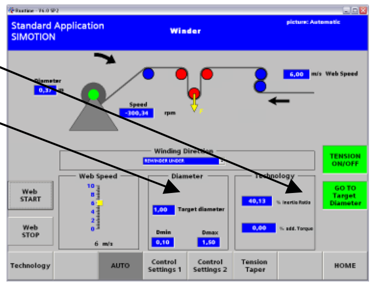
8.1.2 Brief instructions

Execute the steps in the sequence as listed in the following table to demonstrate the application example:

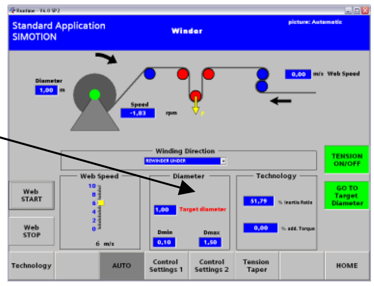
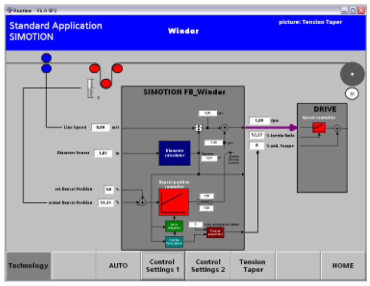
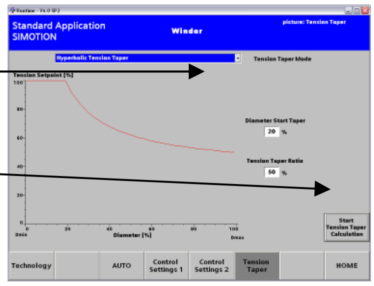
Table 8-1: Brief instructions to demonstrate the “Rotary Knife” application example

No.	Action	Comment
1	Call the file Winder.fwd. Alternatively, you can also call the operator panel via Step 7. To do this, in the SIMATIC Manager open the **Winder** project. You will find the HMI object **OP1** at the project level. Start the runtime system using the context menu (right-hand mouse key).	
2	At the bottom left, click on **AUTO** (3rd button from the left!).	
3	You are now in the AUTO mode. To start, you must thread the material. To do this, press the “**THREAD IN**“ key. The material will now be slowly thread-in. This is indicated by the rotating red disk, which signals that material is moving.	
4	Wait until the material has been completely thread-in and the winder signals this with green.	
5	The closed-loop tension control must now be switched-in (enabled). This is done by pressing the “TENSION ON/OFF“ button. The dancer roll rises to the center position and the lower, blue disk rotates. This disk simulates motion of the winder axis.	

Winder

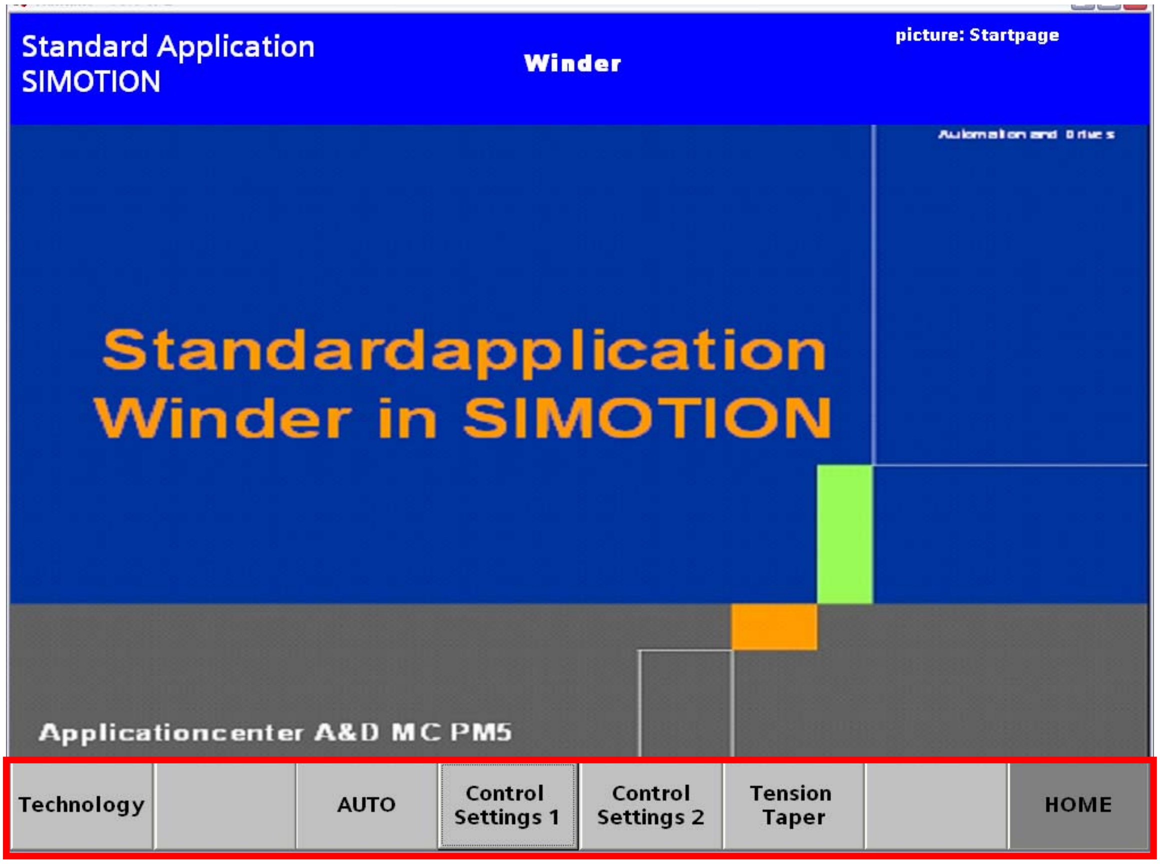
6	You can now start the material feed! Select the material speed using the **Web Speed** slider. Start the material feed using the **Web START** button	
7	The two shafts now start to rotate. On the HMI you can see how the diameter of the roll increases. The speed of the winder shaft decreases with increasing diameter.	
8	When the roll reaches the maximum diameter, the material velocity is slowly braked until both axes come to a standstill.	
9	The material has now been completely wound. In order to unwind it again, the winding direction “Winding Direction” must be changed to “Unwinding xx“. The winding can be restarted by pressing the “Web Start“ button until the minimum diameter is reached.	
10	A target diameter can be approached using the “GO TO Target Diameter“ button. The target diameter can be entered here. The axis only starts if “Web START“ is selected and if the correct winding direction to reach the target diameter was entered.	

Winder

11	The shafts move until the target diameter is reached.	
12	During the simulation, the quantities, generated by the winder function block, can be monitored in the technology mask.	
13	A tension taper characteristic can be calculated in the “Tension Taper“ screen. The characteristic is selected using the “Tension Taper Mode“. The characteristic is calculated and visualized with “Start Tension Taper Calculation“.	

8.2 Detailed operating instructions

Figure 8-2: Welcome screen



General screen areas

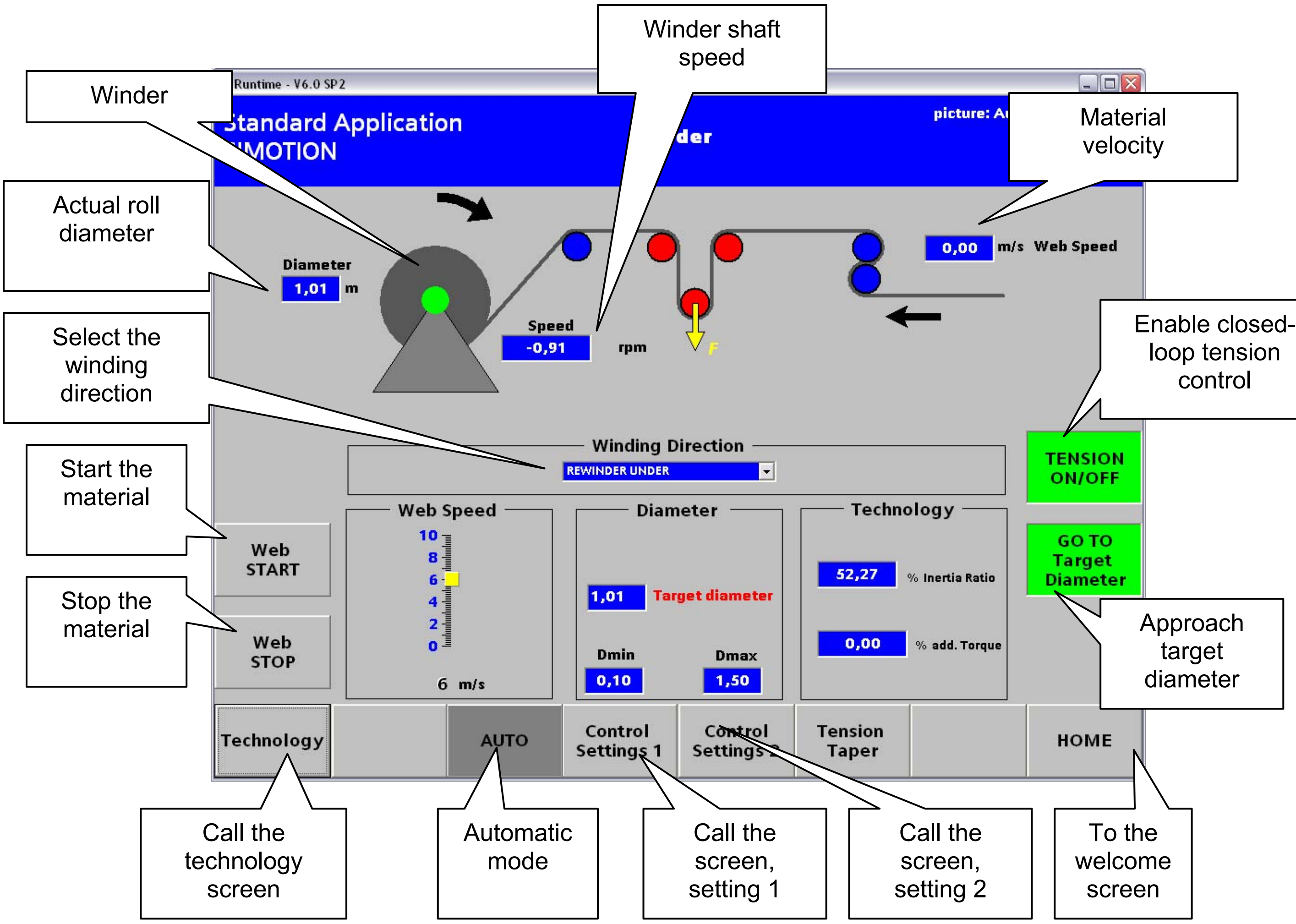
The application screens are handled using the buttons at the lower edge of the screens (these are highlighted in red in the diagram above) – and are provided on every screen.

Winder

8.2.1 Automatic screen

D The automatic screen is the main screen in the automatic mode of the application example on how to use the “winder“.

Figure 8-3: Automatic screen of the “winder”

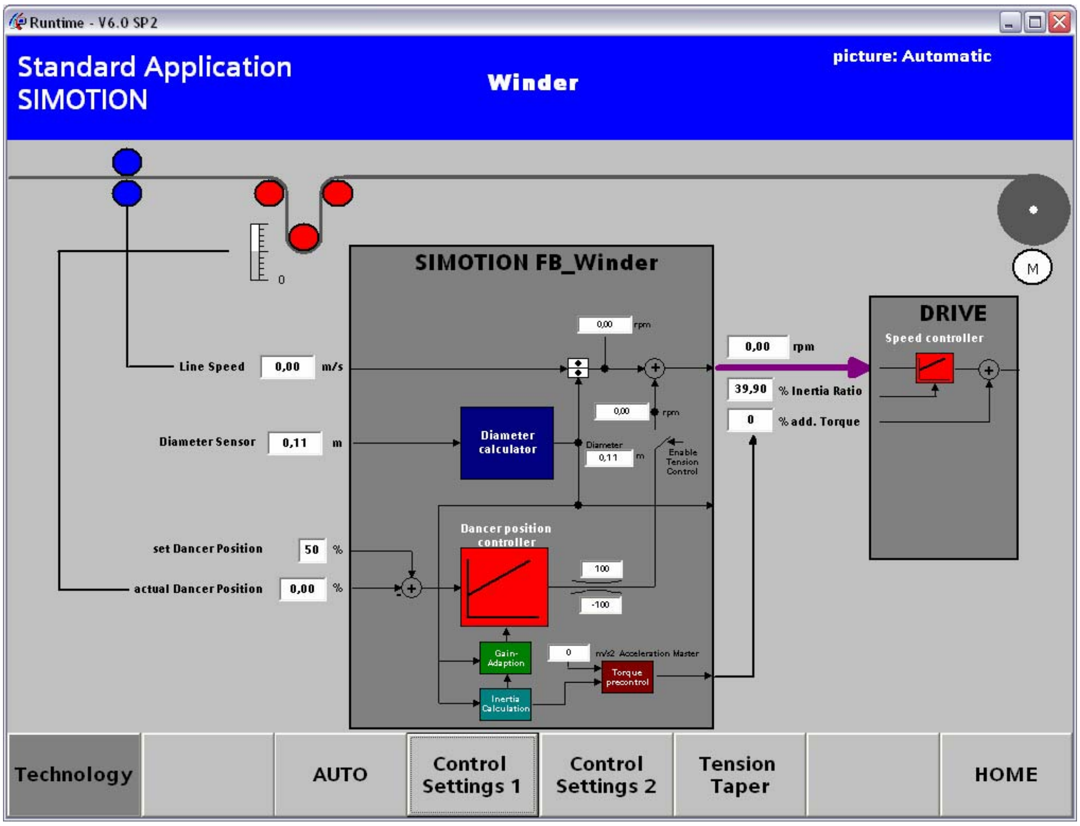


The application is handled/controlled in this automatic screen. The material can be started and stopped with the buttons on the left-hand side and the closed-loop tension control and the target diameter approached, using the buttons on the right-hand side.

Winder

8.2.2 Technology screen

Figure 8-4: Technology screen

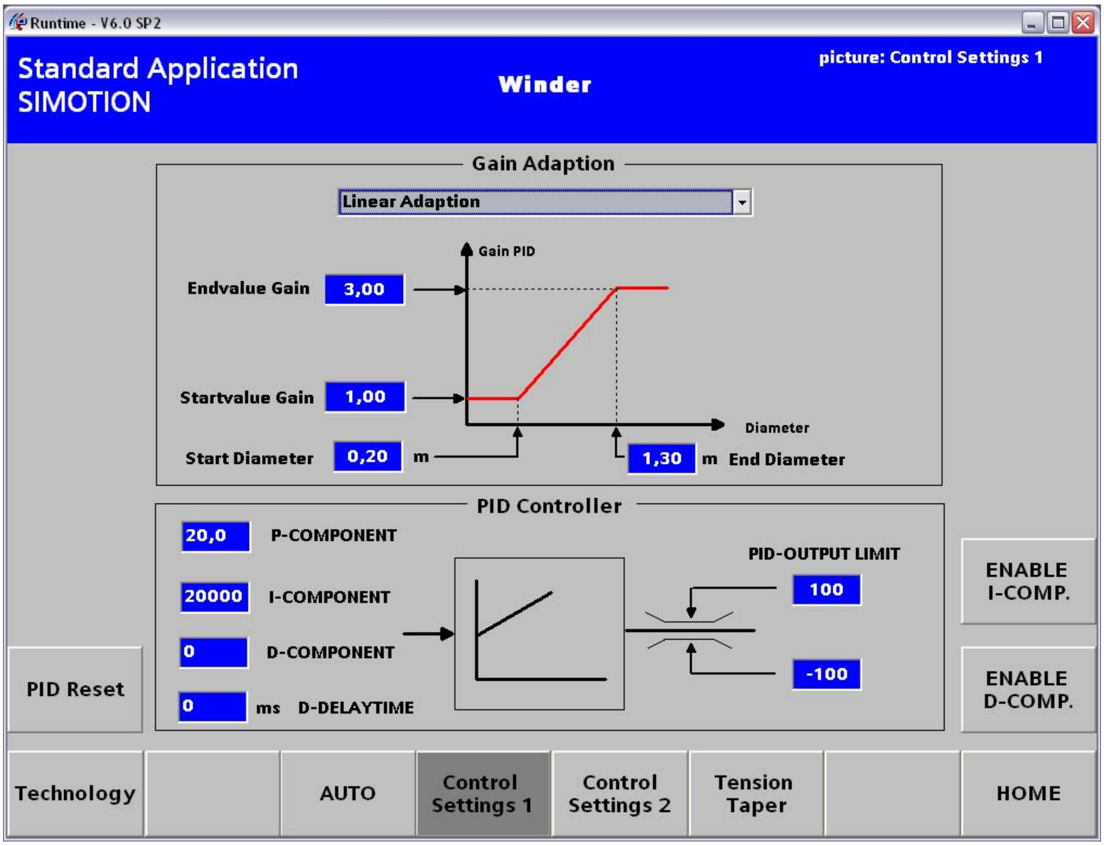


The technology screen is only set-up to display variables. This therefore shows the interaction between the FB_winder and the central variables – such as material velocity, dancer roll position, roll diameter and setpoint velocity of the winder.

The winder function block with several important input and output variables is shown in the center of the diagram. A symbolic graphic showing the drive is located next to it.

8.2.3 Control settings 1 screen

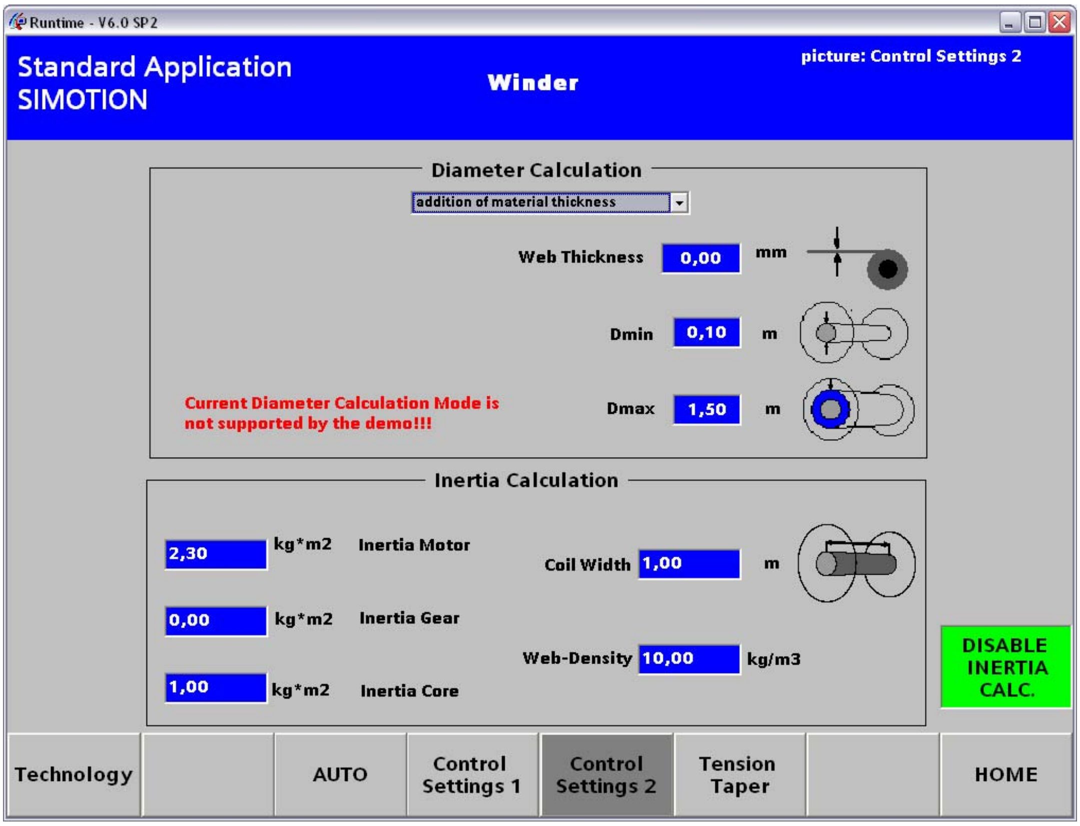
Figure 8-5: Control settings 1



The control settings 1 screen is used to enter parameters for the controller gain adaptation and the PID controller. The parameters that are to be set there act directly on the winder function block. However, the controller gain adaptation cannot be monitored/visualized as this is only effective within the FB. The parameters to set the PID controller also act directly and their effect can, in some cases, also be monitored/visualized. For instance, when enabling the differential component of the controller “Enable D_Comp.“ a significantly higher response of the winder motor can be monitored when the closed-loop tension control is switched-in (enabled) and the material is at a standstill. This can also be achieved by increasing the proportional component of the controller.

8.2.4 Control settings 2 screen

Figure 8-6: Control Settings 2

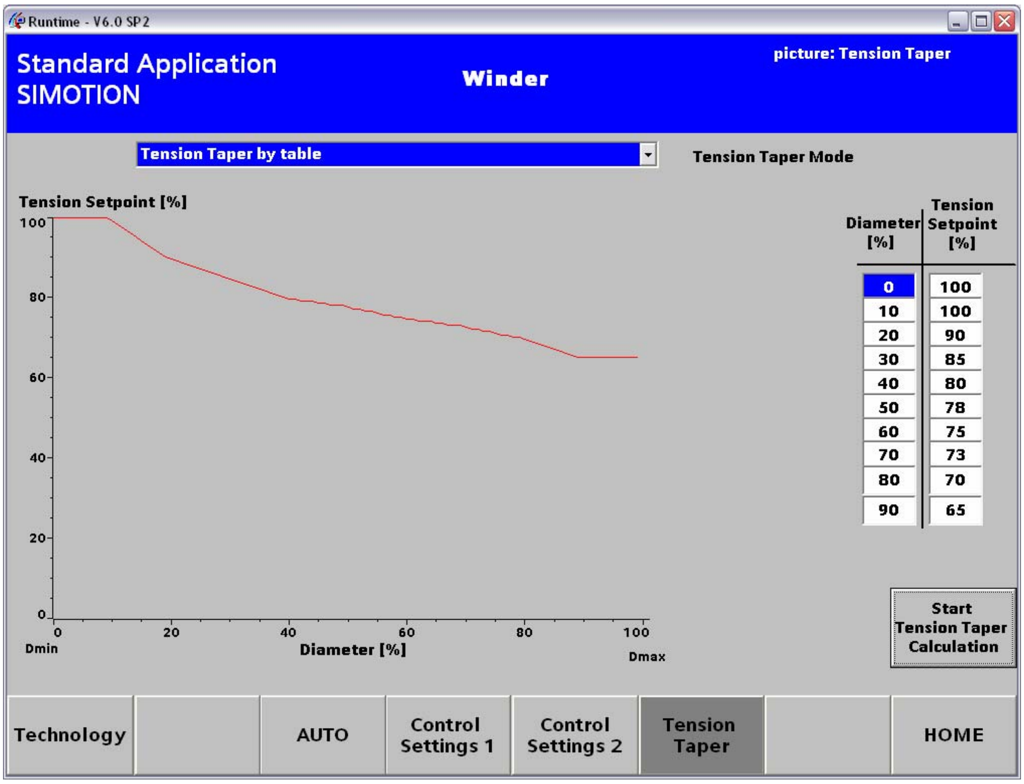


The “Control Settings 2“ screen allows the diameter calculation to be selected and the moment of inertia to be calculated. A mechanical system is not connected to the demonstration system. This is the reason that the varying diameter of the wound roll is simulated. This means that the selectable diameter calculation techniques are not effective. The diameter sensing via sensor mode is permanently set. However, various modes are connected to the HMI to show users that the possibility does exist. The variables are directly connected to the winder FB and can also be re-used for subsequent use at the machine.

In this case, the settings of the maximum and minimum roll diameter are important as well as the settings of the individual moments of inertia. The total moment of inertia is calculated from the moments of inertia of the mechanical system and load as a function of the diameter of the roll being wound. The torque pre-control is calculated as a function of this moment of inertia and is entered into the drive as additive torque setpoint. This calculation can be enabled using the selection field “ENABLE INERTIA CALC.“.

8.2.5 Tension taper screen

Figure 8-7: Tension Taper



A tension taper characteristic can be calculated using the “Tension taper“ screen. Using this tension taper characteristic, the tension with which the material is wound can be changed depending on the diameter. This is required in order to achieve a uniform, cylindrical structure of the roll being wound. To achieve this, a higher tension is used at a low diameter and as the diameter increases, the tension is reduced. It only makes sense to use the tension taper characteristic for winders. The tension setpoint, determined by the tension taper characteristic, either acts directly on the control of a suitable dancer roll (for the winding mode with dancer roll) – or internally on the torque limits of the drive.

3 different tension taper characteristics can be entered in the screen. Linear characteristic, hyperbolic characteristic as well as a characteristic that is interpolated using a table with 10 points. For the linear and hyperbolic characteristics, the starting diameter, the reduction as a % of the maximum diameter as well as the magnitude of the tension reduction as a % of the reference tension can be set.

The characteristic is only displayed after first pressing the button “start tension taper calculation”. This characteristic is only displayed as a dancer roll is not connected to the demonstration system.

Integrating the core function

Contents

The Section “Integrating the core function” guides you step-by-step through the set-up and commissioning of the application

9 Integrating into the user program

9.1 Technology objects required

The technology objects required according to their function are listed in the following

Master value

TO axis as speed, positioning or synchronous operation axis or TO external encoder

Winder

TO axis configured as speed axis or positioning axis

This means that licenses are not required to implement the winder functionality as the winder axis/shaft is designed as speed object

9.2 Preparation

De-archive and open the SIMOTION project “Winder in SIMOTION”. In parallel, open a second SIMOTION SCOUT project that contains your user program and copy the following sources by dragging & dropping them into your target project:

- WinderFB from the program container
- L_BaCtrl from the program library (basis control PID_controller)
- ToolLib from the program library (Low-Pass_Filter)

The velocity and acceleration values of the material web should be available using a technology object, external encoder or TO axis.

9.3 Integrating the core winder function

Overview

1. Call the winder function block in the IPO-synchronous task
2. Call a move command to move the winder shaft with the setpoint velocity generated by the winder FB

Additionally, when using the torque limits:

3. Connect the positive and negative torque limits B+ and B- for a closed-loop control with torque limiting and interconnect the additive torque setpoint when using this function
4. Enable the torque limits in a sequential task
5. Assign the setpoints generated from the winder FB and limits in the IPO-synchronous task

Additionally, when using the velocity controller adaptation:

6. Connect the moment of inertia ratio with the Kp adaptation of the drive

9.3.1 Calling the “winder FB” in the user program

The function block of the core winder function can be simply called after you have integrated your SIMOTION project into the program.

The “winder FB“ can be called from an MCC chart, an ST_program or a LAD/FBD program.

The FB must always be assigned an instance.

The program in which the “winder FB” is called must always be executed in clock-cycle synchronism. This is the reason that only a call may be used in a task that is in synchronism with the Ipo clock cycle (IPO synchronous task 1 or 2).

Now, the call parameters of the block must be interconnected corresponding to the function required in the user program.

The following parameters must always be interconnected:

Input

- Control_Structure (selects the closed-loop control mode)
- Winding_Direction (selects the winding direction)
- Sampling_Time (sampling time in which the FB is called [ms])
- Setvalue_Line_Speed_Master (reference/setpoint velocity, material web [m/min]
- Actual_Line_Speed_Master (actual velocity material web [m/min]
- Actual_Velocity_Winder (actual speed, winder [rpm])
- DiameterCalcMode (selects the diameter calculation mode)
- Diameter_min (minimum roll diameter)
- Diameter_max (maximum roll diameter)

Output

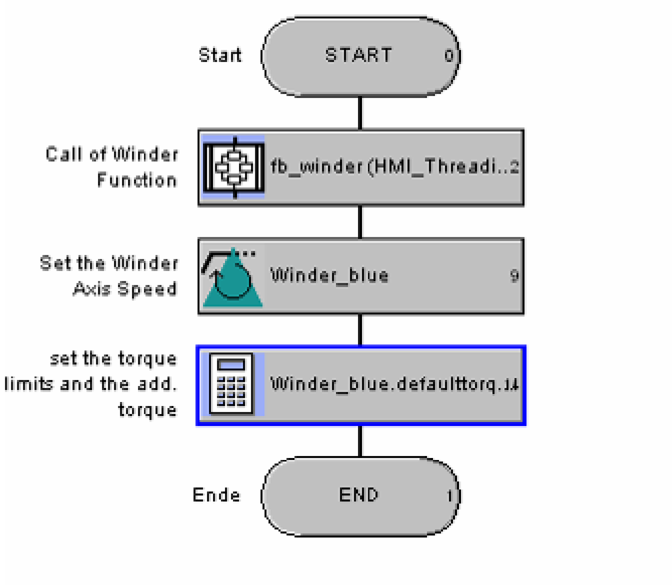
- Speedsetpoint_Winder (reference/setpoint velocity, winder [rpm]

A detailed description of all input and output parameters is provided in Section D of the document.

Winder

9.3.2 Calling the motion command for the winder shaft

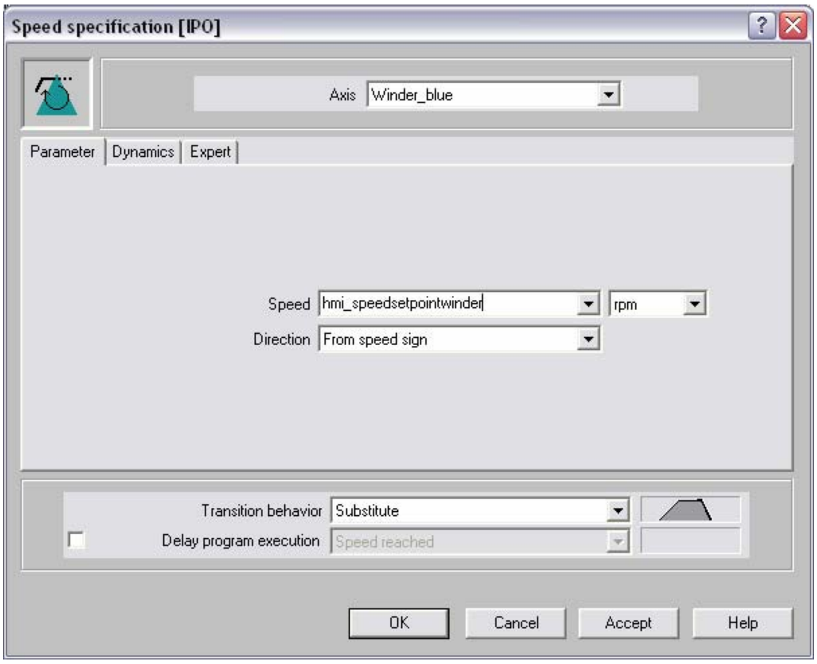
Figure 9-1: Calling motion command



The winder block generates setpoints to move the winder shaft. One of these setpoints is the setpoint velocity “*Speedsetpoint_Winder*“ – that is made available as output of the FB_Winder.

Winder

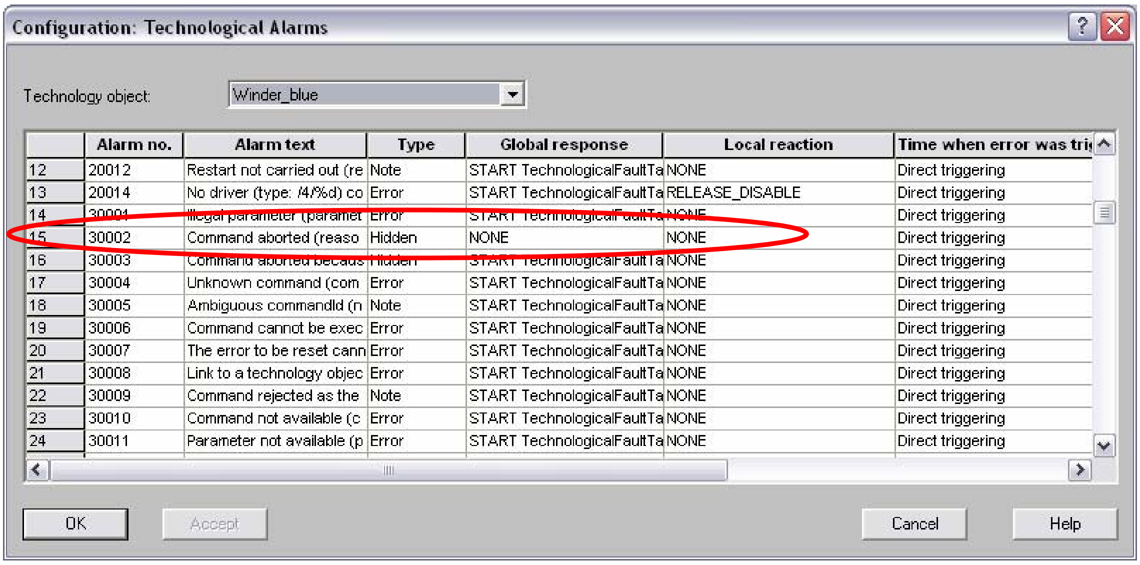
Figure 9-2: Speed Specification



This variable must be transferred to the winder shaft as setpoint velocity using a move command. This is the reason that the winder FB is called after a move command so that the setpoint velocity of the winder motor is cyclically updated. The dynamic values of the move command should be adapted depending on the mechanical system.

Winder

Figure 9-3: Technological Alarms



	Alarm no.	Alarm text	Type	Global response	Local reaction	Time when error was tri
12	20012	Restart not carried out (re	Note	START TechnologicalFaultTa	NONE	Direct triggering
13	20014	No driver (type: /4/%d) co	Error	START TechnologicalFaultTa	RELEASE_DISABLE	Direct triggering
14	30001	Illegal parameter (paramet	Error	START TechnologicalFaultTa	NONE	Direct triggering
15	30002	Command aborted (reaso	Hidden	NONE	NONE	Direct triggering
16	30003	Command aborted becaus	Hidden	START TechnologicalFaultTa	NONE	Direct triggering
17	30004	Unknown command (com	Error	START TechnologicalFaultTa	NONE	Direct triggering
18	30005	Ambiguous commandId (n	Note	START TechnologicalFaultTa	NONE	Direct triggering
19	30006	Command cannot be exec	Error	START TechnologicalFaultTa	NONE	Direct triggering
20	30007	The error to be reset cann	Error	START TechnologicalFaultTa	NONE	Direct triggering
21	30008	Link to a technology objec	Error	START TechnologicalFaultTa	NONE	Direct triggering
22	30009	Command rejected as the	Note	START TechnologicalFaultTa	NONE	Direct triggering
23	30010	Command not available (c	Error	START TechnologicalFaultTa	NONE	Direct triggering
24	30011	Parameter not available (p	Error	START TechnologicalFaultTa	NONE	Direct triggering

As a result of the cyclic call of the _move command, the system generates message 30002 (command interrupted).

In order to avoid that this message is displayed both in the alarm window and in the HMI, we recommend that you configure message 30002 in the alarm configuration (task system TechnologicalFaultTask-AlarmConfiguration) for the corresponding TO axis object so that the Technological Fault Task is not started and the message is suppressed (refer to Fig.)

9.3.3 Connecting torque limits B+/B- and the additive torque setpoint

None of the standard Profibus telegrams – torques and torque limits B+/B- can be transferred. This is the reason that the torque limits B+ (TorqueLimit_Pos) and B- (TorqueLimit_Neg) generated in the winder FB – as well as the additive torque setpoint (Add_Torque) should be connected to the drive.
To transfer this data SIMOTION offers system functions. These system functions transfer this data in an extended Profibus telegram (technology data block) that must be configured.

When activating the technology data block, technological data can be cyclically sent from the control to the drive or cyclically read.

This data must then be appropriately connected in the drive.

The connection of the torque limits is explained using as an example, the SIMOTION D435:

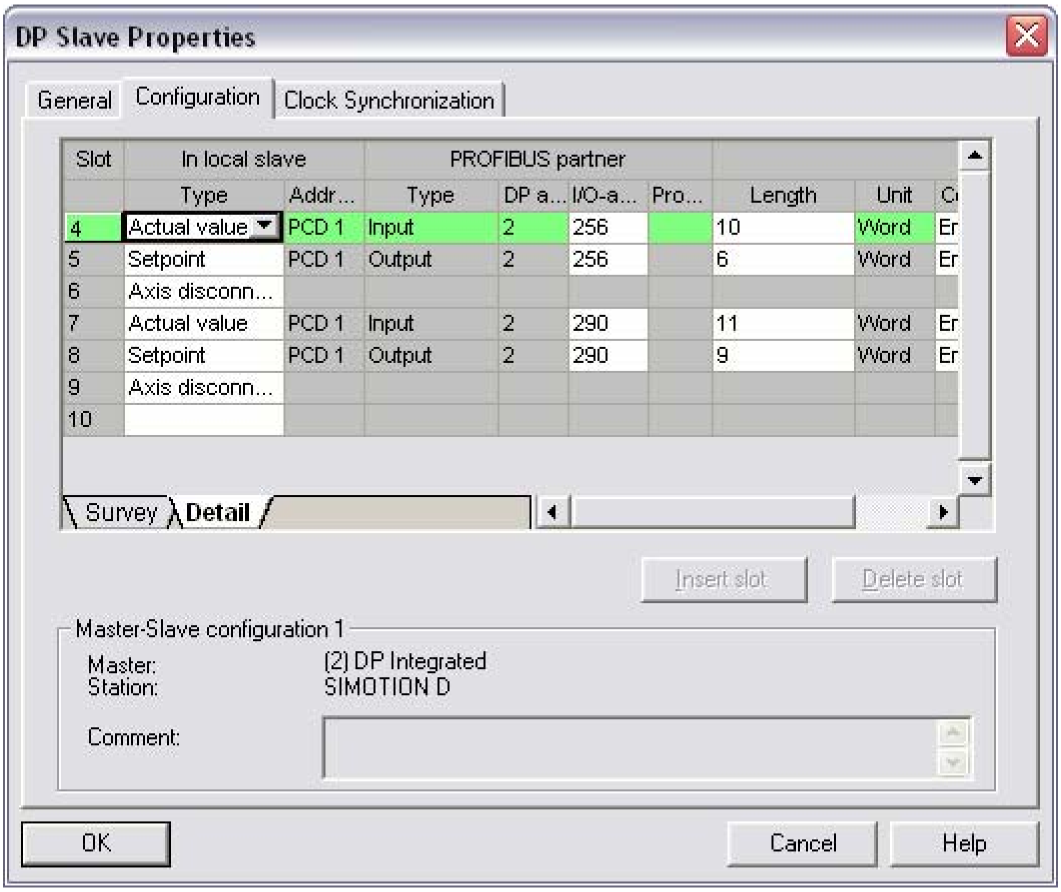
1. Manually extending the Profibus telegram in the hardware configuration

The standard telegram must be extended for the appropriate winder axis (shaft) in the hardware configuration – this can be selected under “Details”.

Input +1

Output +3

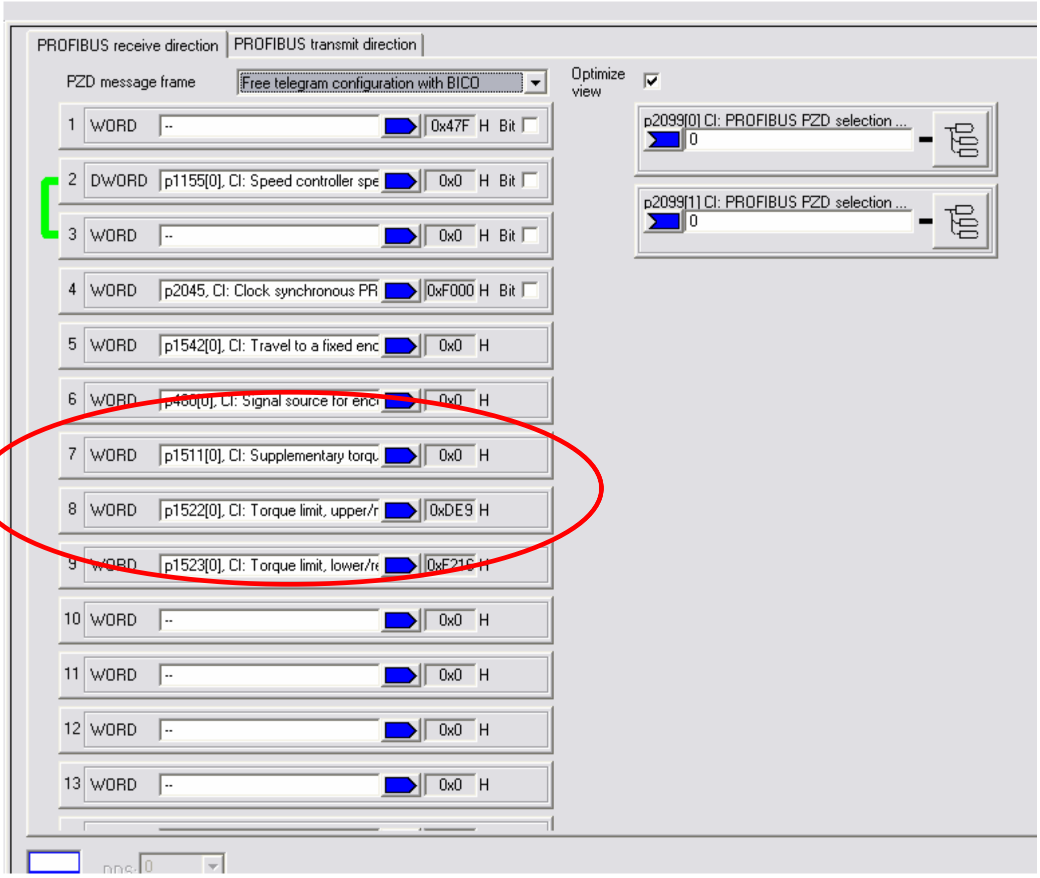
Figure 9-4: DP Slave Properties



In Fig. 9-4 it can be seen that the actual value of axis (shaft) 2 (slot 7) was extended by 1 word and the setpoint (slot 8) by 3 words.

2. Connecting variables in the drive (using SINAMICS as an example)

Figure 9-5 : Connecting variables



Data that is to be transferred using this extended Profibus protocol must now be linked-in to the drive using BiCo technology. Select the appropriate drive and under SINAMICS_Integrated – Drives – Drive_x – Communication – Profibus, select the communication screen.

Set the “Free telegram configuration with BiCO”.

Now configure the following connection to the standard telegram (do not change this, only attach it):

Profibus receive direction

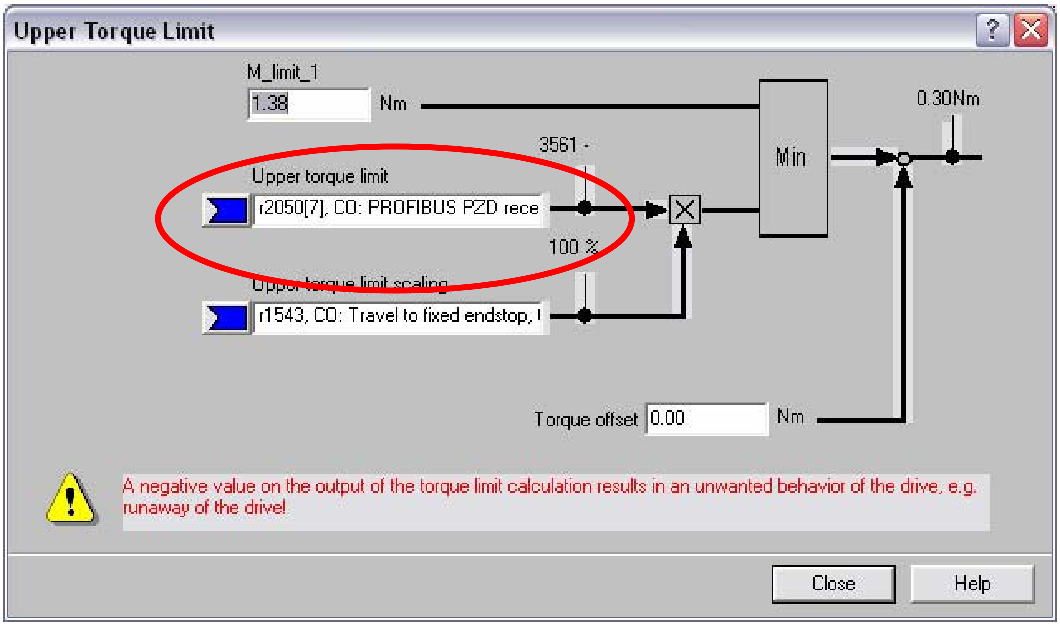
1. Additional PZD (M_Add) P1511
2. Additional PZD (B+) P1522
3. Additional PZD (B-) P1523

(set the weighting using P1522)

Profibus send direction (2nd tab)

1. Additional PZD (M_act) r80

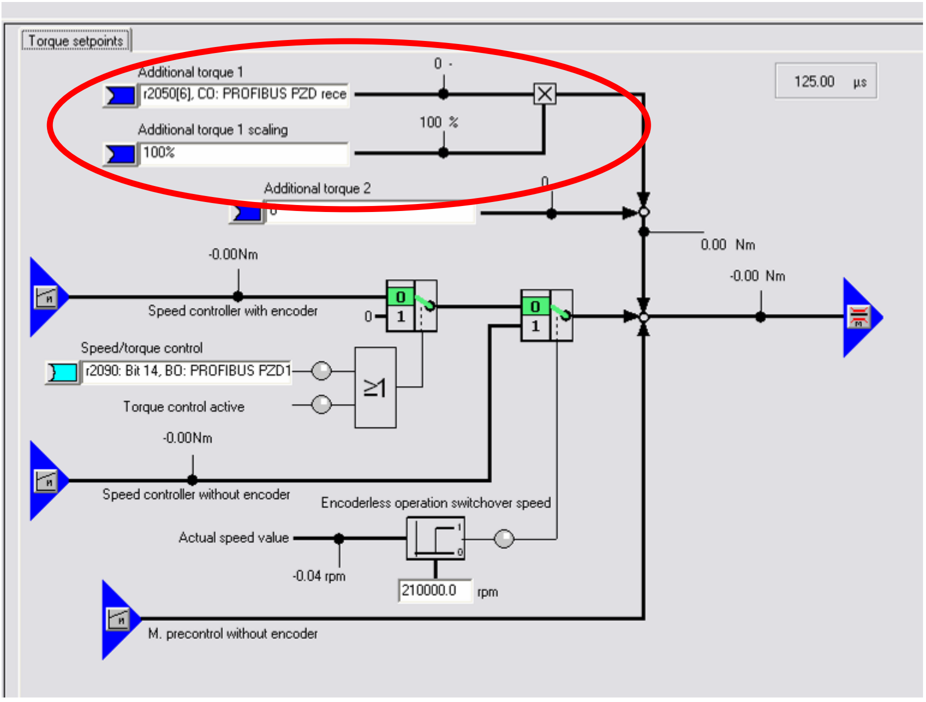
Figure 9-6: Profibus send direction



With this setting, data from the technological data block is transferred to the positive and negative torque limits (B+ / B-) and as additive torque setpoint (M_add).

Winder

Figure 9-7: Using additive torque

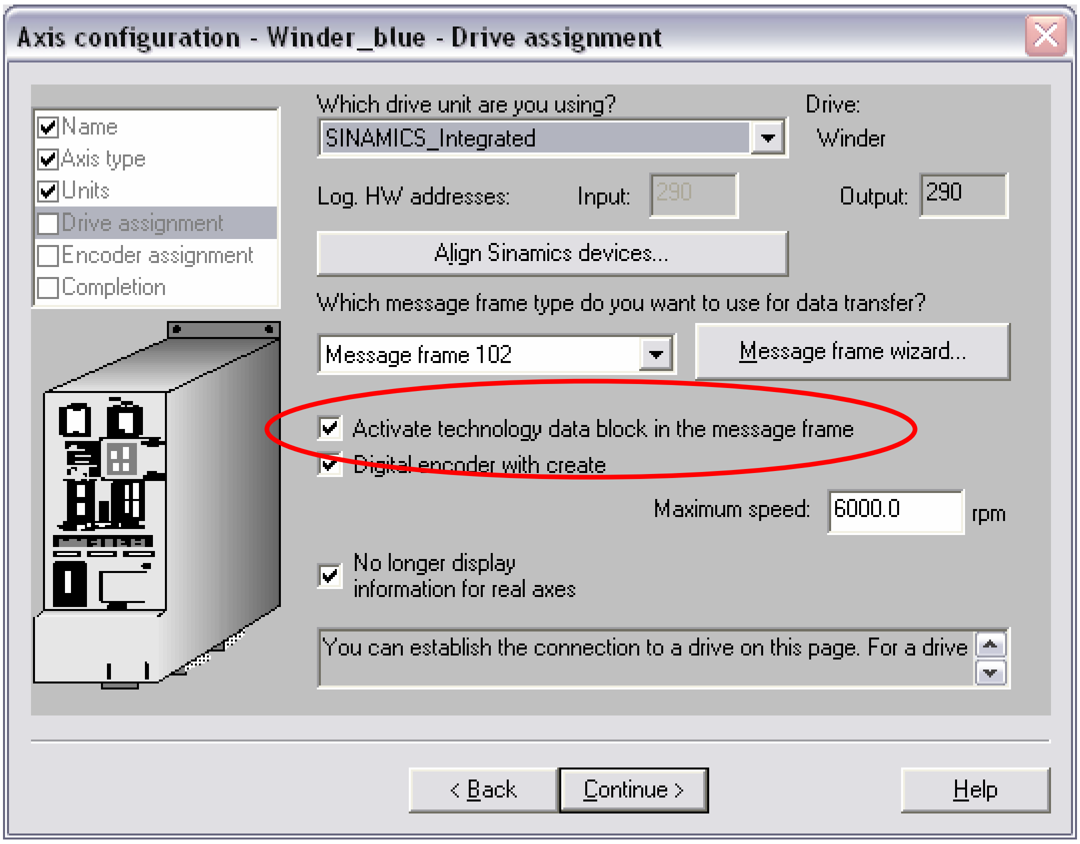


When using the additive torque, P1512 must be used to weight the additive torque setpoint!

Winder

1. Activating the technology data block

Figure 9-8: Activating technology data block



When setting-up the axis in SIMOTION, the “Technology data block” must now be activated.

2. Setting the reference torque

The reference torque must be entered in the expert list of the appropriate axis (shaft) under configuration data.

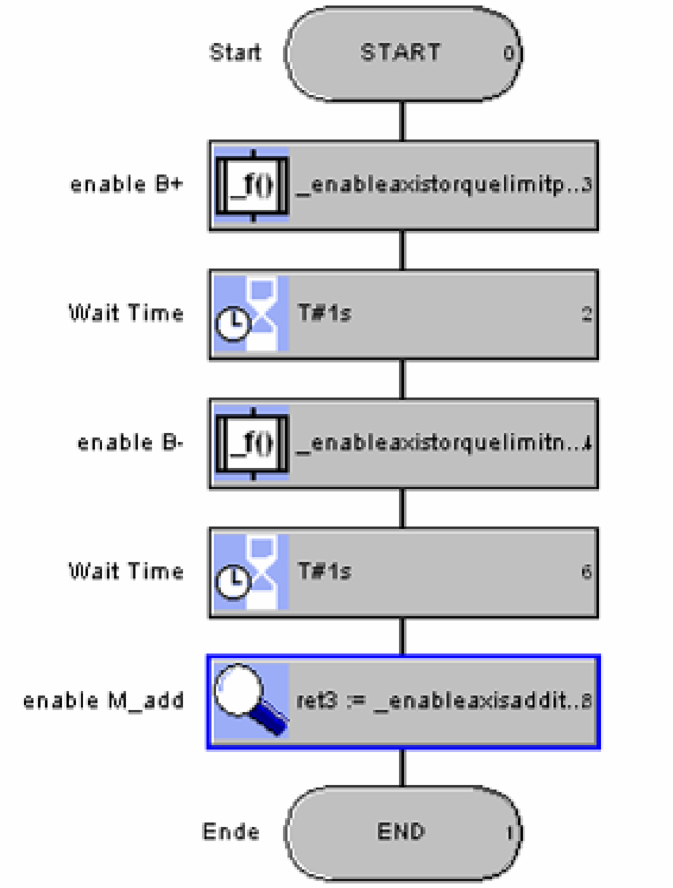
The value in the configuration data SetpointDriverInfo – maxTorque must be the same value as that is set under Sinamics parameter P1520 (torque limit).

9.3.4 Enabling torque limits and additive setpoint torque in the user program

B+, B- and M_Add are enabled using the system commands _enableaxistorquelimitpositive, _enableaxistorquelimitnegative and _enableadditivetorque. The commands _disableaxistorquelimitpositive, ..., de-activate the setting again.

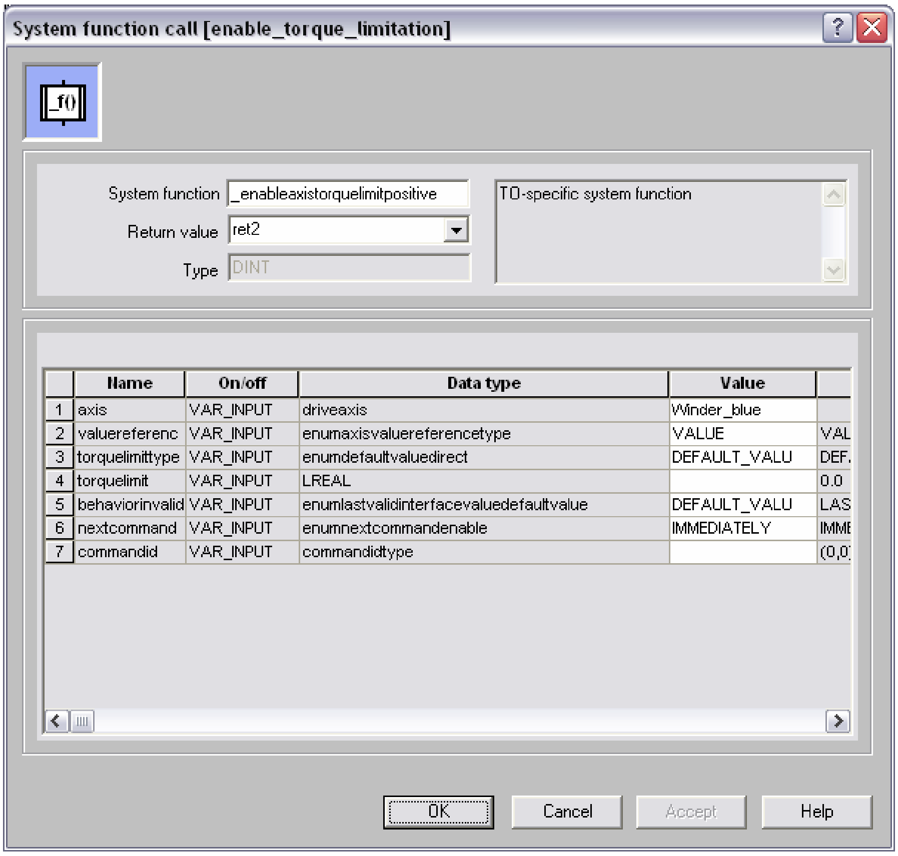
These commands must be issued once and may not be directly called one after the other. A delay time of e.g. 1 sec should be configured between the calls to take into account the command processing time.

Figure 9-9: Enabling torque limits and additive setpoint



Winder

Figure 9-10: Call commands



After start-up, the commands can be sequentially called in a motion task.

The commands should be parameterized as follows:

EnumAxisValueReferenceType:	VALUE
EnumDefaultValueDirect:	DEFAULT_VALUE

9.3.5 Cyclically changing B+, B- and M_add

Figure 9-11: B+, B-, M_add cyclically changing

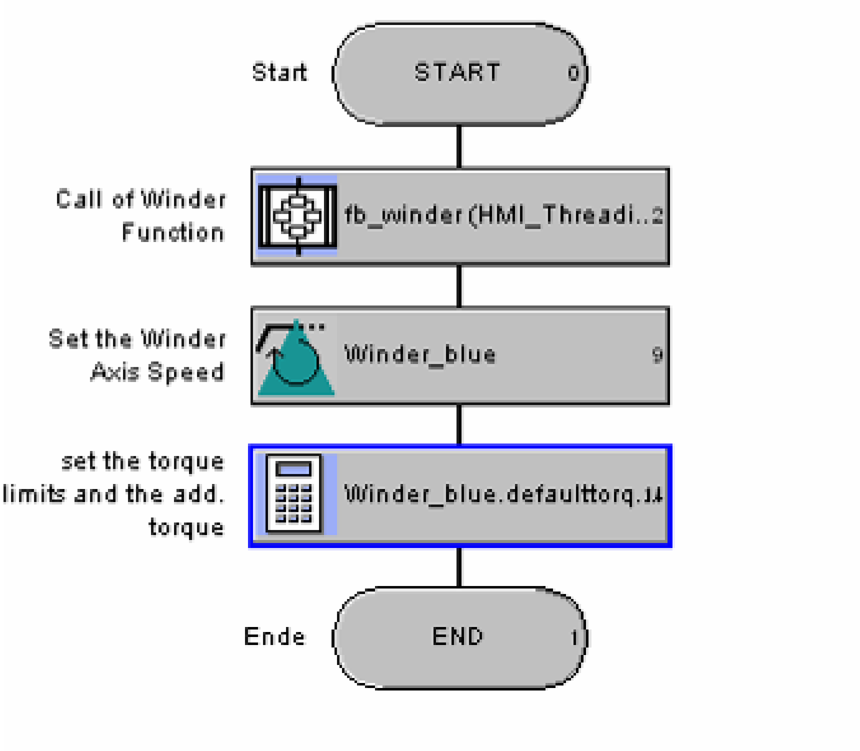
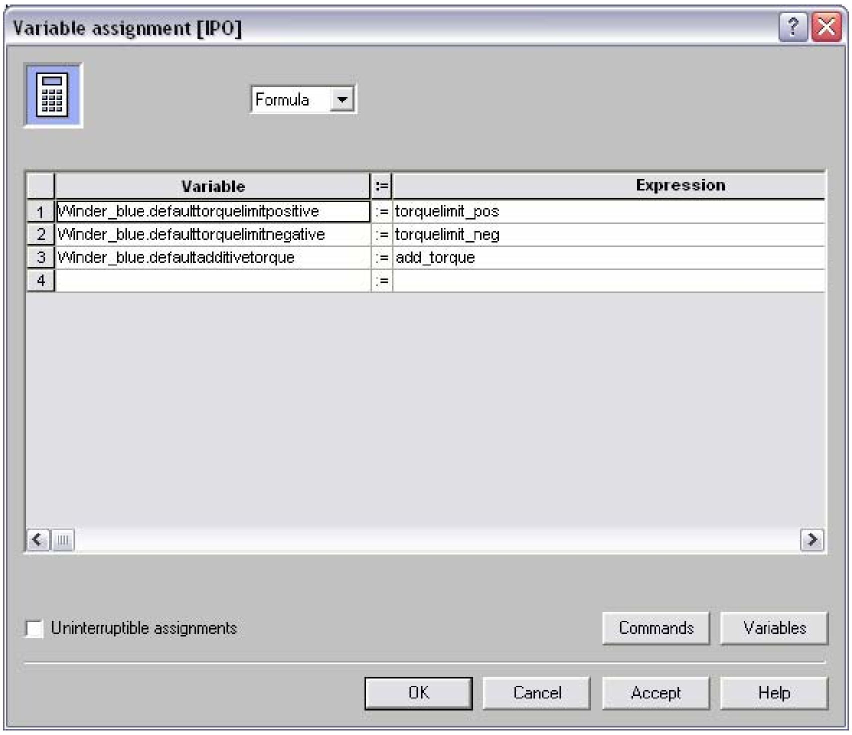


Figure 9-12: Variable assignment



If you now wish to cyclically change the technological data, then the data axis_x.defaulttorquelimitpositve / negative and axis_x.defaultadditivetorque must be written into cyclically. The FB winder cyclically generate the data and outputs them at output torquelimit_pos, toruelimit_neg and add_torque.

The data generated by the winder FB should therefore be assigned a variable after the winder is called.

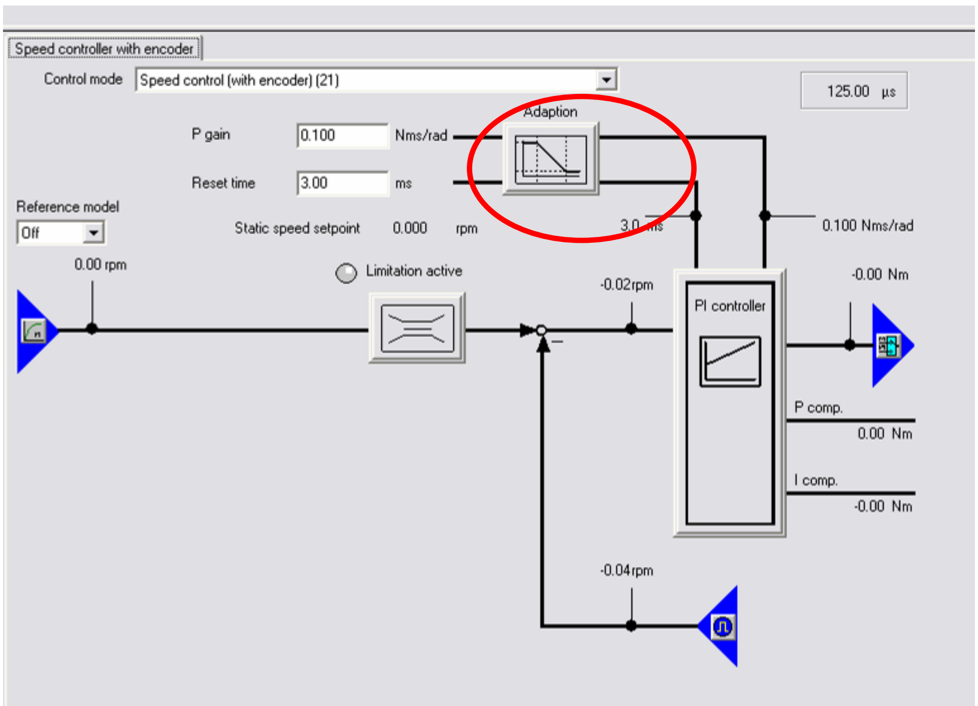
9.3.6 Connecting the moment of inertia ratio for Kp adaptation

The winder block generates the actual ratio from the actual moment of inertia and the maximum moment of inertia of the roll being wound. The moment of inertia comprises a fixed component – determined by the motor, possibly the gearbox and roll core as well as a variable component. This variable component depends on the diameter of the roll being wound and therefore the material being wound. The maximum diameter (D_{max}) is used to derive the maximum moment of inertia; the actual diameter is used to derive the actual moment of inertia.

The ratio between the actual moment of inertia and the maximum moment of inertia is output using output parameter *Inertia_Ratio* as a %.
In order to implement Kp adaptation, this value can be connected to the drive. The necessary steps to do this will be explained using a SINAMICS drive as example in the following.

1. Extend the Profibus telegram:
   The Profibus telegram must be extended by one word (setpoint), by the value – which is generated using the output parameter *Inertia_Ratio* – and then transferred to the drive
2. The output parameter *Inertia_Ratio* is connected to the appropriate Profibus address
3. Connection in the drive

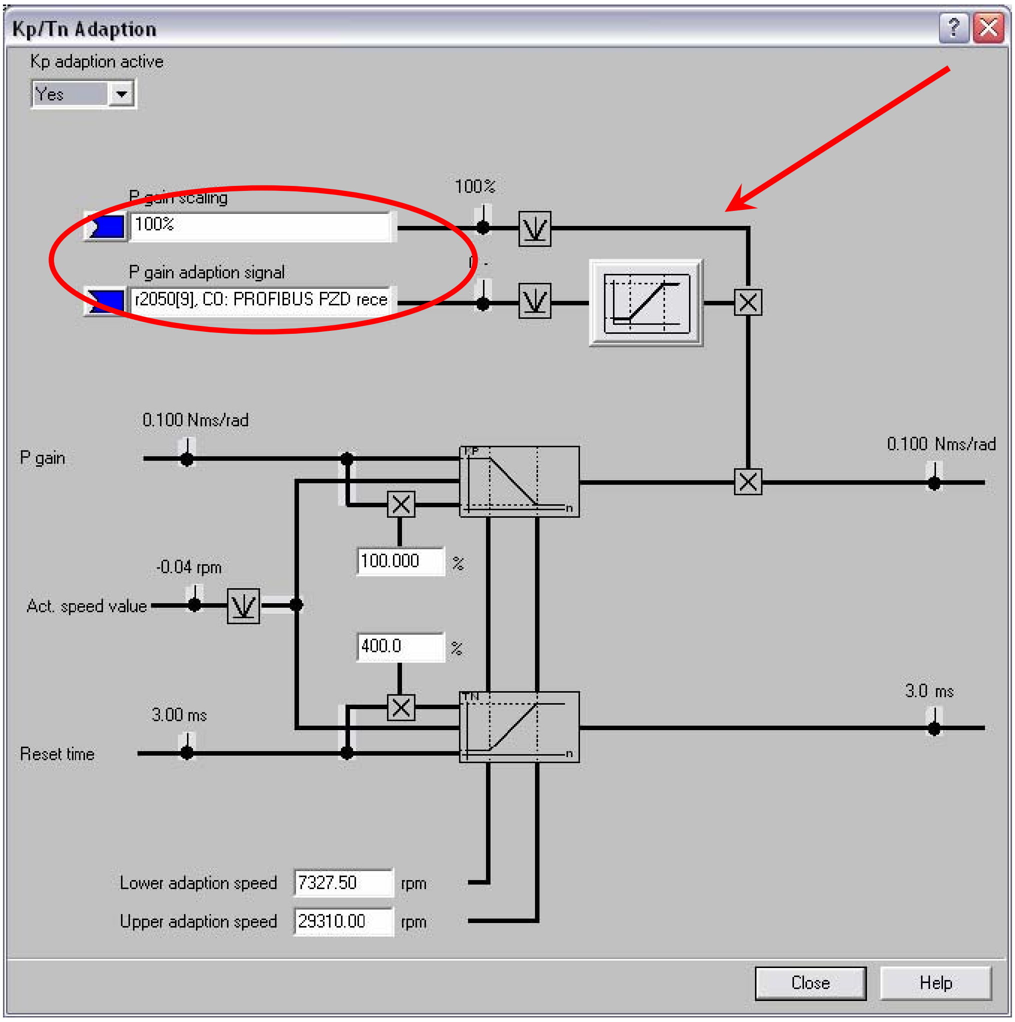
Figure 9-13: setting screen speed controller



Winder

Select the adaptation in the setting screen for the speed controller.

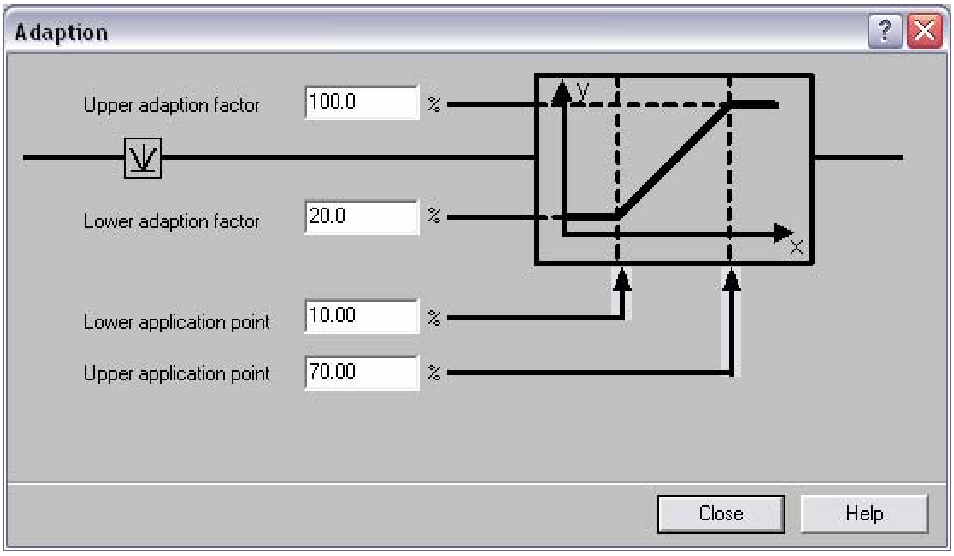
Figure 9-14: speed controller adaptation



In the speed controller adaptation, connect the Profibus signal to P1455 (speed controller P gain adaptation) and set the adaptation values in the last step. In so doing, the x axis mirrors the moment of inertia ratio and the y axis, the controller gain adaptation. These must be parameterized corresponding to your particular application.

Winder

Figure 9-15: Adaption



9.4 Engineering examples

9.4.1 Direct closed-loop tension control, winder with dancer roll, speed correction

Closed-loop control mode:

The control mode is selected using the FB input *Control_Structure*. The input must be set to 0 for the closed-loop control mode winder with dancer roll and speed correction

Winding direction:

Either 0 or 1 is connected to the *Winding-Direction* input (winder, top / bottom)

Web velocity setpoint and actual value:

The web velocity and actual value are entered at the FB input *Setvalue_Line_Speed_Master* and *Actual_Line_Speed_Master* in [m/min].

Winder speed:

The actual speed of the winder motor is connected to the input *Actual_Velocity_Winder*

Dancer roll actual value:

The dancer roll position actual value is read-in (downloaded) via the system and should be entered, filtered at the FB input *Controlled_Actualvalue*. The center position of the dancer roll should correspond to the value at the input *Controlled_Setvalue* (dancer roll position setpoint).

In this case, the PID tension controller operates as position controller for the dancer roll position and generates a supplementary velocity setpoint that is entered with a positive sign at the speed controller. This means that the dancer roll position actual value tracks the entered position setpoint (position reference value). The output of the tension controller is limited with *PID_Output_Limit_pos* and *PID_Output_Limit_neg*.

Selecting the diameter calculation

If you are using a sensor to sense the diameter, then connect a 0 to the input *DiameterCalcMode*. The measured value is read-in in m with input *Diameter_Sensor*.

Diameter limits

Connect the diameter limits of the roll being wound in m at inputs *Diameter_min* and *Diameter_max*

Sampling time

Connect the sampling time of the task, in which you call the winder FB at input *SamplingTime* (clock cycle time IPO1 or 2, in ms)

Enabling the closed-loop tension control

The closed-loop tension control is enabled by setting the input *Enable_TensionControl*. The position actual value of the dancer roll tracks the setpoint.

Setpoint, winder axis

The setpoint speed for the winder drive is available at the output *Speedsetpoint_Winder*. This must be output using a command for speed input (_Move).

9.4.2 Direct closed-loop tension control, unwinder with load cell, torque limiting

Closed-loop control mode:

The closed-loop control mode is selected using the FB input *Control_Structure*. The input must be set to 2 for the control mode unwinder with load cell and torque limiting

Winding direction:

Either 2 or 3 is connected to the input *Winding-Direction* (unwinder, top / bottom)

Web velocity setpoint and actual value:

The web velocity setpoint and speed are entered at the FB input *Setvalue_Line_Speed_Master* and *Actual_Line_Speed_Master* in [m/min].

Winder speed:

Connect the actual speed of the winder motor to the input *Actual_Velocity_Winder*

Tension actual value:

The tension actual value is read-in via the system and should then be entered, filtered at FB input *Controlled_Actualvalue*. The tension setpoint is entered at the input *Controlled_Setvalu*e. The tension controller output is limited with *PID_Output_Limit_pos* and *PID_Output_Limit_neg*.

Selecting the diameter calculation

Connect a 1 to the input *DiameterCalcMode* if the diameter is to be calculated from the ratio between the web velocity / winder speed. The winder velocity is specified as a percentage using *Start_Calc_Ratio*, from where the calculation should start. An initial diameter value can be entered with *Diameter_InputValue* and set with *Diameter_Set*.

Diameter limits

Connect the diameter limits of the roll being wound in m to inputs *Diameter_min* and *Diameter_max*

Sampling time

Assign the sampling time of the task in which you call the winder FB (clock cycle time IPO1 or 2, in ms) to input *SamplingTime*

Enabling the closed-loop tension control

The closed-loop tension control is enabled by setting the input *Enable_TensionControl*. The dancer roll position actual value tracks the setpoint.

Setpoint, winder axis

The setpoint speed for the winder drive is available at the output *Speedsetpoint_Winde*r. This must be issued using a command to input speed (_Move). This setpoint comprises the actual web velocity weighted with the diameter and an overcontrol setpoint. This overcontrol setpoint is entered at input *Override_Ratio* as a % of the rated winder speed (typically 5-10%). The limited velocity setpoint and the overcontrol provides protection against the web speed increasing in an uncontrolled fashion.

Torque limits

The torque limit values B+ and B- are provided at output *TorqueLimit_Pos* and *TorqueLimit_Neg*. These are considered not as reduction, but as weighting. The values must be connected as torque limits to the drive and act in absolute term in Nm (refer to Chapter 11.2.3).

9.4.3 Indirect closed-loop tension control, unwinder, torque limiting

Closed-loop control mode:

The closed-loop control mode is selected using the FB input *Control_Structure*. The input must be set to 3 for the control mode unwinder with load cell and torque limiting

Winding direction:

Either 2 or 3 is connected to the input *Winding-Direction* (unwinder, top / bottom)

Web velocity setpoint and actual value:

The web velocity setpoint and actual value are entered at the FB input *Setvalue_Line_Speed_Master* and *Actual_Line_Speed_Master* in [m/min].

Winder speed:

The actual speed of the winder motor is connected to input *Actual_Velocity_Winder*

Selecting the diameter calculation

Connect a 1 to the input *DiameterCalcMode* if the diameter is to be calculated from the ratio between the web velocity / winder speed. The winder velocity is specified as a percentage using *Start_Calc_Ratio*, from where the calculation should start. An initial diameter value can be entered with *Diameter_InputValue* and set with *Diameter_Set*.

Diameter limits

Connect the diameter limits of the roll being wound in m at inputs *Diameter_min* and *Diameter_max*

Sampling time

Assign the sampling time of the task in which you call the winder FB (clock cycle time IPO1 or 2, in ms) to input *SamplingTime*

Setpoint, winder axis

The setpoint speed for the winder drive is available at the output *Speedsetpoint_Winder*. This must be issued using a command to input speed (_Move). This setpoint comprises the actual web velocity evaluated/weighted with the diameter and an overcontrol setpoint. This overcontrol setpoint is entered at input *Override_Ratio* as a % of the rated winder speed (typically 5-10%). The limited velocity setpoint and the overcontrol provides protection against the web speed increasing in an uncontrollable fashion.

Torque limits

The torque limit values B+ and B- are provided at output *TorqueLimit_Pos* and *TorqueLimit_Neg*. These are not considered as a reduction, but as weighting. The values must be connected as torque limits to the drive and act in absolute term in Nm (refer to Kap. 11.2.3)

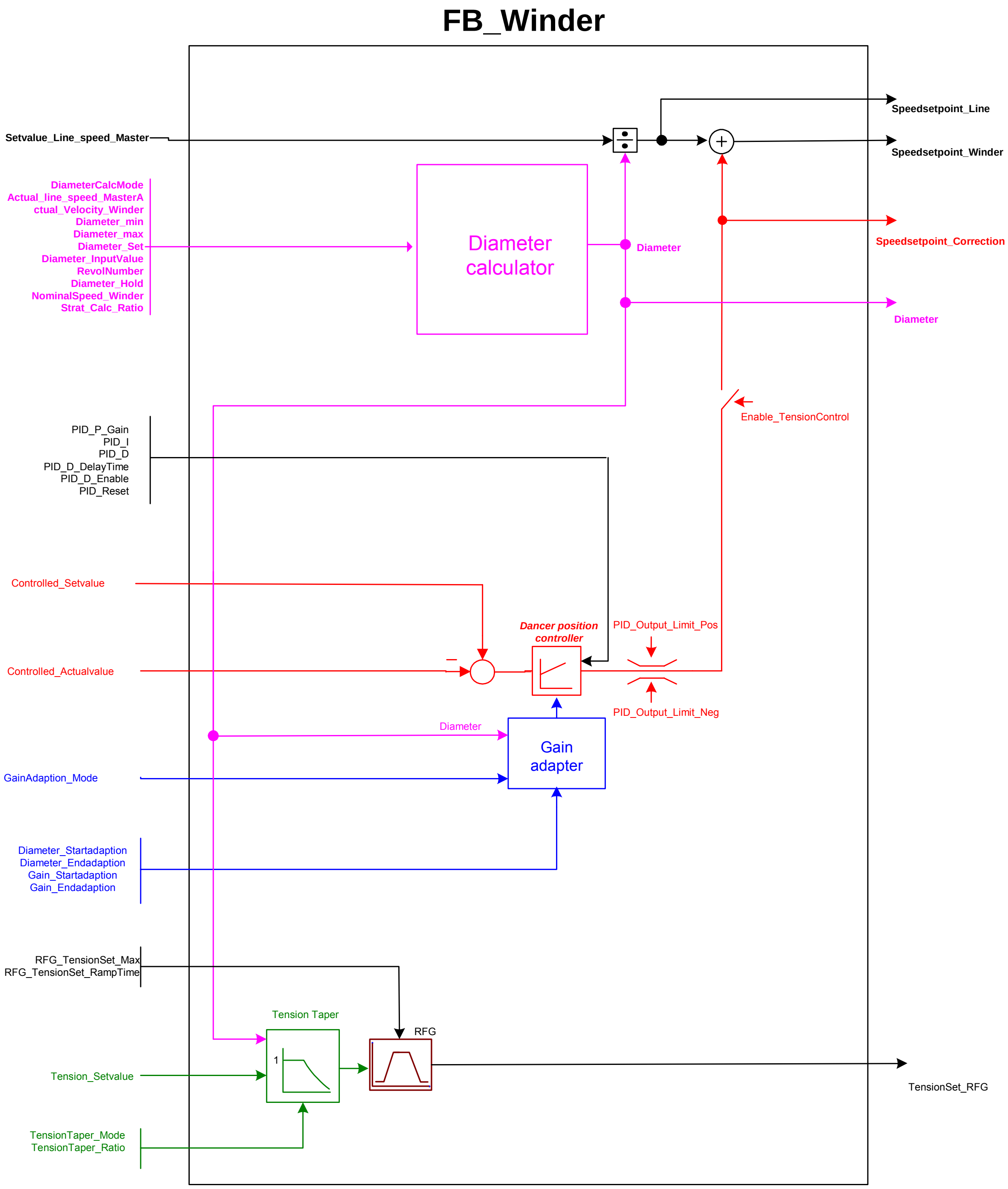
Program description

Section “Program description” describes, in more detail, the functions of the winder block. Here you will find parameter lists, diagrams and function descriptions of the core winder function

Winder

10 Program and function description

10.1 Block diagram for direct closed-loop tension control with a dancer roll



Winder

10.2 Input and output parameters of the function block

Group	Type	IN	OUT	Type
General variables	BOOL	Execute	Inertia_Ratio	LREAL
	INT	Control_Structure	Speedsetpoint_Winder	LREAL
	INT	Winding_Direction	Speedsetpoint_Correction	LREAL
	BOOL	Enable_TensionControl	Speedsetpoint_Line	LREAL
	LREAL	SamplingTime	TorqueLimit_Pos	LREAL
	LREAL	Controlled_Setvalue	TorqueLimit_Neg	LREAL
	LREAL	Controlled_Actualvalue	TensionSet_RFG	LREAL
	LREAL	Setvalue_Line_speed_Master	Add_Torque	LREAL
	LREAL	Actual_Line_speed_Master	Diameter	LREAL
	LREAL	Actual_Velocity_Winder	PID_Output	LREAL
	INT	DiameterCalcMode		
Diameter sensing	LREAL	Diameter_Sensor		
	LREAL	Diameter_min		
	LREAL	Diameter_max		
	BOOL	Diameter_Set		
	LREAL	Diameter_StartValue		
	LREAL	WebThickness		
	INT	RevolNumber		
	BOOL	Diameter_Hold		
	LREAL	NominalSpeed_Winder		
	INT	Start_Calc_Ratio		
	LREAL	DiameterScalingFactor		
Moment of inertia calculation	LREAL	Inertia_Motor		
	LREAL	Inertia_Gear		
	LREAL	Inertia_Core		
	LREAL	Coil_Width		
	LREAL	Density_WoundMaterial		
	LREAL	Diameter_Core		
	LREAL	Gear_Ratio		
	BOOL	Enable_InertiaCalculation		
Pre-control	LREAL	Accel_Master		
	LREAL	NominalTorque_Winder		
Controller gain	INT	GainAdaption_Mode		
	LREAL	Diameter_StartAdaption		
	LREAL	Diameter_EndAdaption		
	LREAL	Gain_StartAdaption		
	LREAL	Gain_EndtAdaption		
	LREAL	GainAdaption_Diameter_Tuned		
	LREAL	GainAdaption_Gain_Tuned		
Tension taper characteristic	INT	TensionTaper_Mode		
	LREAL	TensionTaper_Ratio		
	LREAL	Tension_Setvalue		
	ARRAY	TensionTaper_Diameter_Tab		
	ARRAY	TensionTaper_Setpoint_Tab		
Ramp-function generator	LREAL	RFG_TensionSet_Max		
	LREAL	RFG_TensionSet_RampTime		
Tension controller	LREAL	PID_P_Gain		
	DINT	PID_I		
	BOOL	PID_I_Enable		
	DINT	PID_D		
	DINT	PID_D_DelayTime		
	BOOL	PID_D_Enable		
	BOOL	PID_Reset		
	LREAL	PID_Output_Limit_Pos		
	LREAL	PID_Output_Limit_Neg		
	LREAL	Override_Ratio		

10.3 Description of the input parameters

10.3.1 General parameters

Table 10-1: General parameters

Name	Data type	Initial. value	Description
Execute	BOOL	FALSE	Enables the calculation of the FB
Control_Sructure	BOOL	0	Selects the control mode: 0: Direct closed-loop tension control using speed correction and dancer roll 1: Direct closed-loop tension control using speed correction and load cell 2: Direct closed-loop tension control using torque limiting and load cell 3: Indirect closed-loop tension control using torque limiting (open-loop controlled mode)
Winding_Direction	INT	0	Selects the winding direction The winding direction is selected using this parameter. 0: Winder, top 1: Winder, bottom 2: Unwinder, top 3: Unwinder, bottom
Enable_TensionControl	BOOL	FALSE	Enables the closed-loop tension control. For TRUE, the closed-loop tension control is activated (not effective for indirect closed-loop tension control))
SamplingTime	LREAL	2	Sampling time of the task in which the FB is called [ms], generally 1-9 ms, clock cycle time (IPO1 or IPO2)
Controlled_Setvalue	LREAL	0	Setpoint for the closed-loop control [%] Dancer roll position setpoint for closed-loop control with dancer roll Tension setpoint for closed-loop control with load cell
Controlled_Actualvalue	LREAL	0	Actual value for the closed-loop control [%] Dancer roll position actual value for closed-loop control with dancer roll Tension actual value for closed-loop control with load cell
Setvalue_Line_Speed_Master	LREAL	-	Material web setpoint velocity [m/min]
Actual_Line_Speed_Master	LREAL	-	Material web actual velocity [m/min]
Actual_Velocity_Winder	LREAL	-	Actual speed, winder [rpm]

10.3.2 Description of the input parameters, diameter sensing

Table 10-2: Input parameters, diameter sensing

Name	Data type	Initial. value	Description
DiameterCalcMode	INT	0	Selects the diameter sensing 0: Sensing via sensor 1: Calculated from the ratio between the web velocity and the winder speed 2: Calculated by adding the material thickness 3: Calculated by integrating the distance over the number of revolutions
Diameter_Sensor	LREAL	-	Selects the diameter sensing 0: Sensing via sensor 1: Calculated from the ratio between the web velocity and the winder speed 2: Calculated by adding the material thickness 3: Calculated by integrating the distance over the number

Name	Data type	Initial. value	Description
			of revolutions
Diameter_min	LREAL	0	Minimum diameter [m]
Diameter_max	LREAL	5	Maximum diameter [m]
Diameter_Set	BOOL	FALSE	Sets the diameter from par. Diameter_Startvalue for diameter modes 1 and 3. This is only effective if the closed-loop tension control is not active
Diameter_StartValue	LREAL		Starting (initial) value for the diameter calculation in [m] – is set by Diameter_Set
WebThickness	LREAL	1	Material thickness is only used in diameter mode 2 [mm]
RevolNumber	INT	5	Number of revolutions is used for the calculation using the integration technique – only active for mode 3
Diameter_Hold	BOOL	FALSE	Freezes the actual diameter value
Nominalspeed_Winder	LREAL	3000	Rated speed of the winder motor [rpm]
Start_Calc_Ratio	INT	10	Relative speed of the winder referred to the rated speed as [%] at which the diameter calculation should start in mode 1
DiameterScalingFactor	LREAL	1	Scaling /Correction Factor for Diameter

10.3.3 Input parameters to calculate the moment of inertia

Table 10-3: Input parameters to calculate the moment of inertia

Name	Data type	Initial value	Description
Inertia_Motor	LREAL	0	Motor moment of inertia [kg*m^2]
Inertia_Gear	LREAL	0	Gearbox moment of inertia [kg*m^2]
Inertia_Core	LREAL	0	Moment of inertia, winder core [kg*m^2]
Coil_Width	LREAL	1	Wound roll width [m]
Density_WoundMaterial	LREAL	1	Wound material density [kg/m^3]
Diameter_Core	LREAL	0.1	Diameter of the roll core [m]
Gear_Ratio	LREAL	1	Gearbox factor
Enable_InertiaCalculation	BOOL	FALSE	Enable moment of inertia calculation

10.3.4 Input parameters to pre-control the acceleration

Table 10-4: Input parameters to pre-control the acceleration

Name	Data type	Initial value	Description
Accel_Master	LREAL	0	Acceleration, material web [m/s^2]
NominalTorque_Winder	LREAL	10	Rated torque, winder motor [Nm]

10.3.5 Input parameters for the controller gain adaptation, tension controller

Table 10-5: Input parameters, controller gain adaptation, tension controller

Name	Data type	Initial value	Description
GainAdaption_Mode	INT	0	Selects the controller gain adaptation 0: No adaptation 1: Linear adaptation 2: Inverse adaptation
Diameter_StartAdaption	LREAL	0	Diameter, starting value for adaptation [m]
Diameter_EndAdaption	LREAL	0	Diameter, final value for adaptation [m]
Gain_StartAdaption	LREAL	0	Starting value, gain (this is only effective for linear adaptation)

Winder

Name	Data type	Initial value	Description
Gain_EndAdaption	LREAL	0	Final value, gain (this is only effective for linear adaptation)
GainAdaption_Diameter_Tuned	LREAL	0	Set diameter (only effective for inverse adaptation)
GainAdaption_Gain_Tuned	LREAL	0	Set P gain (only effective for inverse adaptation)

10.3.6 Input parameters for the tension taper characteristic and ramp-function generator

Table 10-6: Input parameters, tension taper characteristic and ramp-function generator

Name	Data type	Initial value	Description
TensionTaper_Mode	INT		Selects the tension taper characteristic mode 0: No tension taper characteristic 1: Hyperbolic characteristic 2: Linear characteristic 3: Linear interpolation from a 10 point table
TensionTaper_Ratio	LREAL		Tension reduction [%]
Diameter_StartTaper	LREAL		Diameter starting value for the tension reduction [m]
Tension_Setvalue	LREAL		Tension setpoint [N]
TensionTaper_Diameter_Tab	ARRAY		Tabular values diameter [m] (only effective for interpolation from the table of points)
TensionTaper_Setpoint_Tab	ARRAY		Tabular values tension setpoints [m] (only effective for interpolation from the table of points)
RFG_TensionSet_Max	LREAL		Maximum tension setpoint [N]
RFG_TensionSet_RampTime	LREAL		Ramp-up (accelerating) time [s]

10.3.7 Input parameters, tension controller

Table 10-7: Input parameters, tension controller

Name	Data type	Initial value	Description
PID_P_Gain	LREAL		P_gain, tension controller
PID_I	DINT		Integration time, tension controller [s] (this is only effective when the I component is enabled)
PID_I_Enable	BOOL	FALSE	Enables the integral component, tension controller
PID_D	DINT		D component, tension controller (this is only effective when the D component is enabled)
PID_D_DelayTime	DINT		Delay time D component [s] (filter of the D component of the tension controller, is only effective when the D component is enabled)
PID_D_Enable	BOOL		Enables the D component
PID_Reset	BOOL		Resets the controller output (deletes the I_component)
PID_Output_Limit_Pos	REAL		Positive limit, controller output (depending on the closed-loop control mode [rpm] or [N])
PID_Output_Limit_Neg	REAL		Negative limit, controller output (depending on the closed-loop control mode [rpm] or [N])
Override_Ratio	LREAL	5	Override of Windermotor relative to nominal speed in [%] for override of the speedcontroller for Control_Mode 2 and 3 (Torue Limitation)

10.4 Output parameters

Table 10-8: Output parameters

Name	Data type	Initial value	Description
Inertia_Ratio	LREAL	-	Ratio between the actual moment of inertia and the maximum moment of inertia [%]
Speedsetpoint_Winder	LREAL	-	Speed setpoint for the winder axis (shaft) [rpm]
Speedsetpoint_Correction	LREAL	-	Percentage component, correction speed for the winder axis (shaft) from the tension controller [rpm]

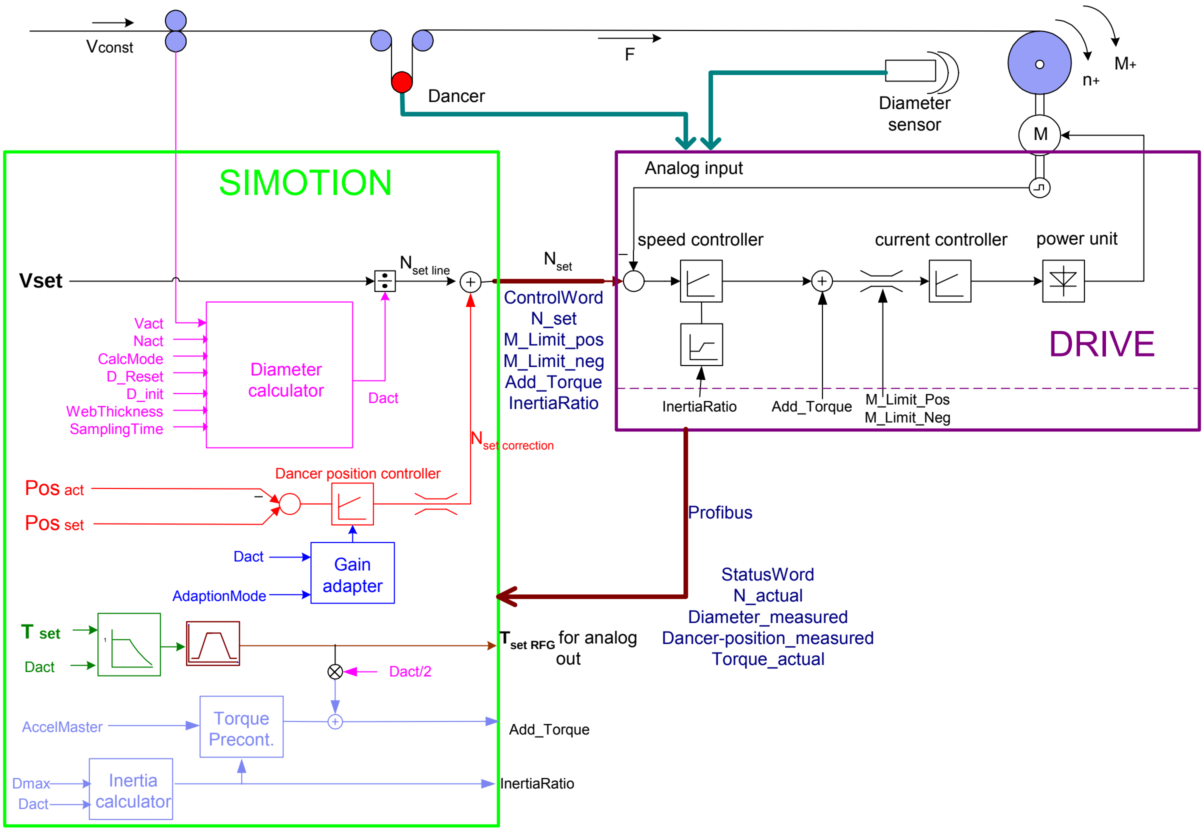
Winder

Speedsetpoint_Line	LREAL	-	Percentage component of the base speed for the winder axis (shaft) calculated from the material web velocity [rpm]
TorqueLimit_Pos	LREAL	-	Positive torque limit for the winder axis [Nm]
TorqueLimit_Neg	LREAL	-	Positive torque limit for the winder axis (shaft) [Nm]
Add_Torque	LREAL	-	Supplementary torque for the winder axis (shaft) [Nm]
TensionSet_RFG	LREAL	-	Tension setpoint for the dancer roll [%]
Diameter	LREAL	-	Actual diameter of the winder roll [m]

11 Function description

11.1 Direct closed-loop tension control with dancer roll using speed correction

Figure 11-1: Direct closed-loop tension control with dancer roll using speed correction



For direct closed-loop tension control with dancer roll, the tension is adjusted using the dancer roll. This means that the tension in the material web depends on the selected operating point of the dancer roll. If you wish to change the material web tension, then the counter-pressure of the dancer roll must be also changed.

The SIMOTION control reads-in the position of the dancer roll.

When the dancer roll moves in the direction of too little tension, then the unwinder must get slower or the winder must get faster.

This ensures that the dancer roll is always operated in the operating range and is not pressed against the end stop.

Generally, the position controller is operated as P controller with D component. Under certain circumstances, the controller can also be set-up as PID controller; however, this can result in oscillations due to several integral components in the system!

The resulting web velocity setpoint is converted into a speed setpoint using the actual diameter.

A controller gain adaptation can be carried-out in order to adapt the controller to different roll diameters (gain adapter).

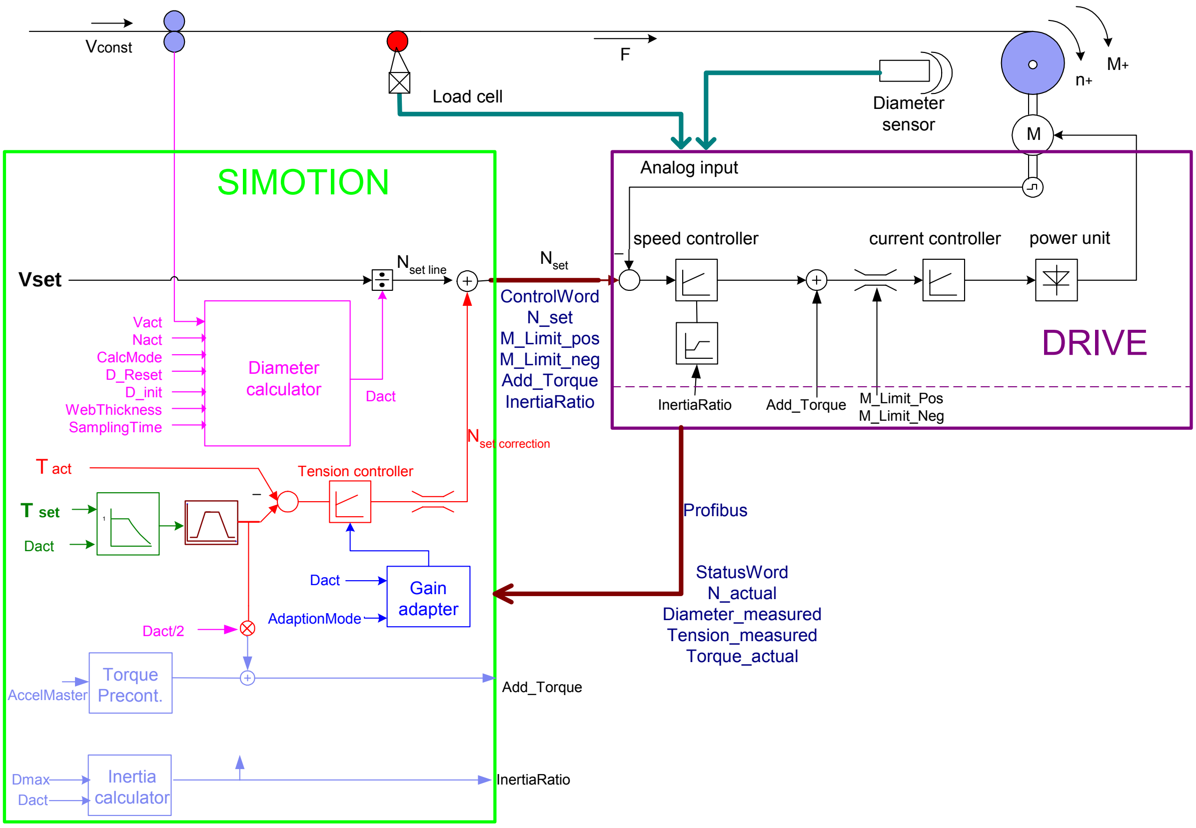
The tension taper while winding can be influenced using a tension taper characteristic function. The characteristic can, for example, be provided as setpoint at an analog output; this then determines the counter pressure of the dancer roll (this is generally a pneumatic system). A downstream ramp-function generator prevents setpoint steps in the system. Further, the moment of inertia of the roll can be calculated that then influences the torque pre-control.

In addition to the reference velocity, the torque ratio between an empty and a wound roll, the positive and negative limit torque and the additional input torque are also transferred to the drive. The drive receives the actual velocity and the actual torque. Depending on the application, sensors for the roll diameter and the dancer roll position can be connected to the controls – either via the drive or directly.

Winder

11.2 Direct closed-loop tension control using speed correction and a tension measuring transducer

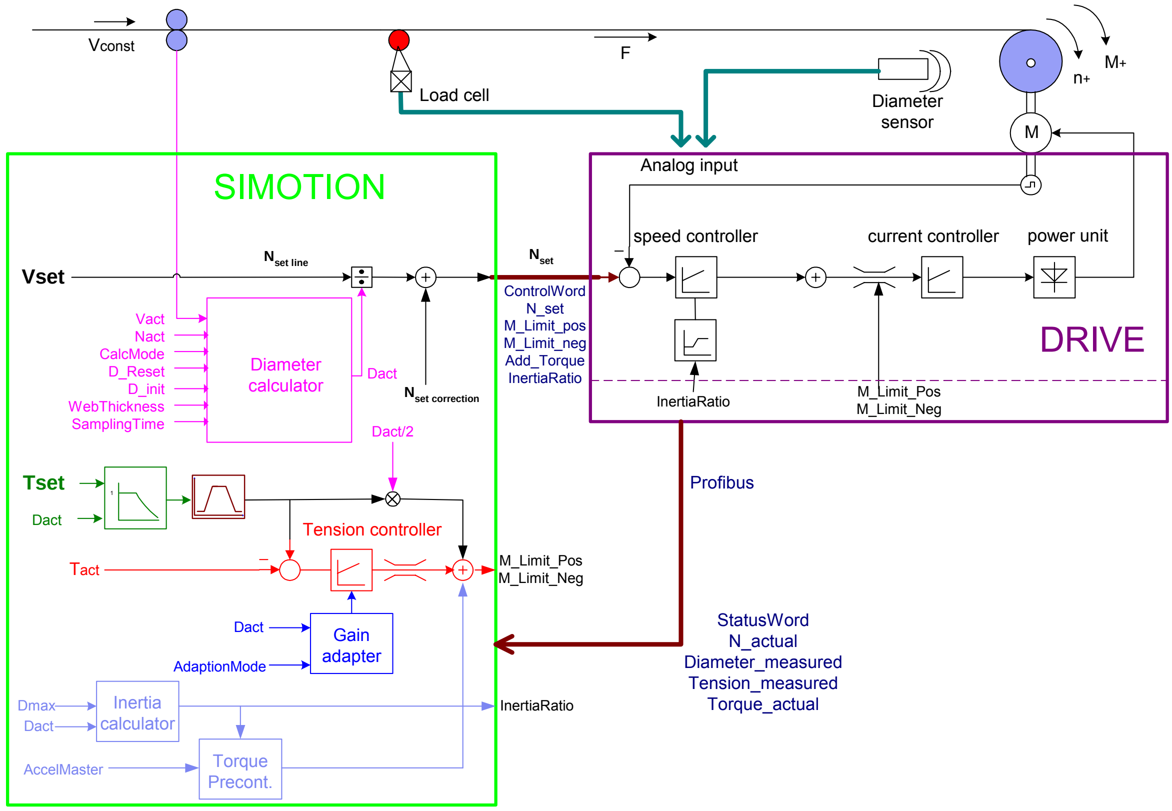
Figure 11-2: Direct closed-loop tension control using speed correction and a tension measuring transducer



For the “direct closed-loop tension control using speed correction and load cell” winding mode, instead of the dancer roll position, the tension of the material web, determined using the transducer, is directly entered. In this case, the PID controller in the SIMOTION no longer operates as position controller – as was the case with the dancer roll – but as tension controller. The controller P gain must be selected so that the controller output can be used as correction velocity. Also here, the tension in the system is adjusted by modifying the speed of the winder axis (shaft). In this case, the tension setpoint – and therefore the tension taper characteristic – act directly in the system on the tension controller.

11.3 Direct closed-loop tension control using torque limiting and load cell

Figure 11-3: Direct closed-loop tension control using torque limiting and load cell



With this closed-loop control method, the material tension is measured using a load cell. The tension controller regulates and compensates any deviations from the specified tension setpoint. The tension controller is configured as PI controller. The tension setpoint can be influenced using the tension taper characteristic while winding as a function of the diameter. The tension controller component obtained is added to the tension setpoint and is weighted with diameter D.

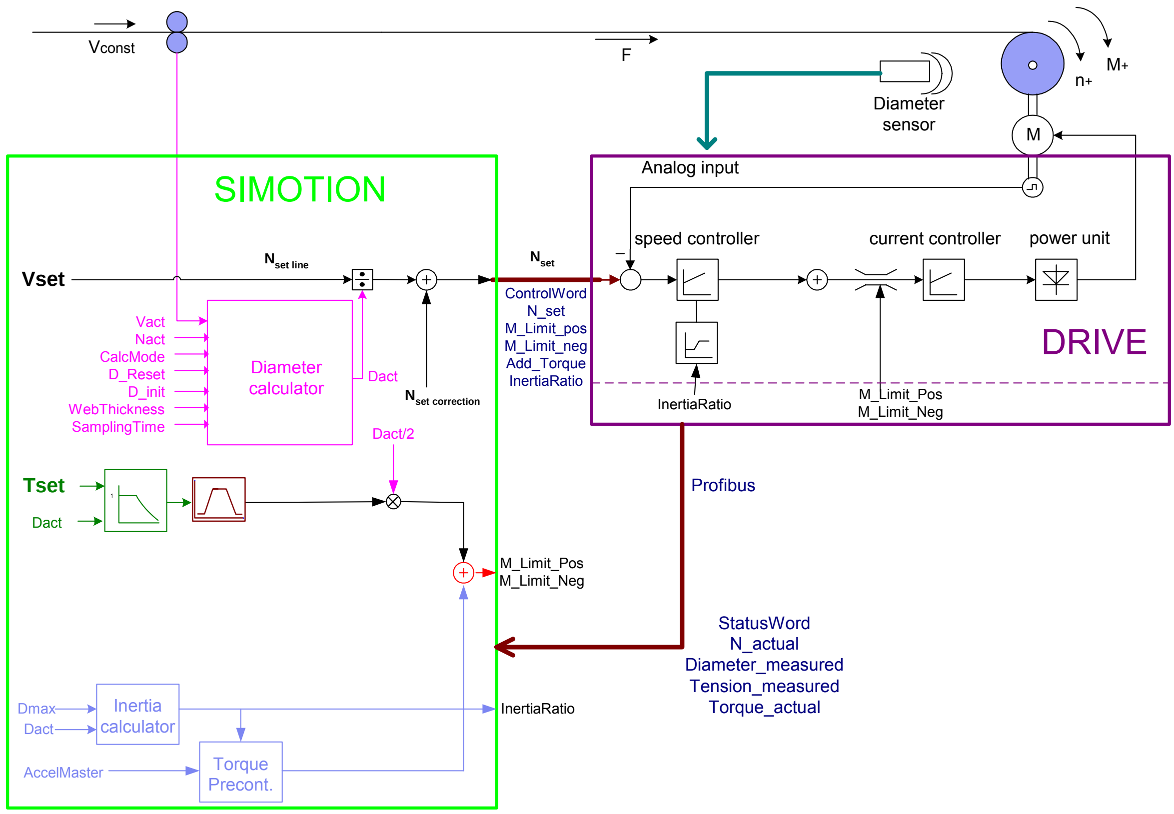
The resulting torque acts as limiting torque at the speed output. The web velocity setpoint is converted into the appropriate speed using the actual diameter. In order that the torque limiting is effective in the tension mode, an additional web velocity setpoint is entered that results in the speed controller being overcontrolled (i.e. it goes to its limit). A lower overcontrol value should be selected in order to slowly establish the tension in the material. The tension is directly set using the torque limit.

In this case, the tension taper characteristic acts directly in the system as this tension setpoint is directly compared with the tension actual value. Torque limits are defined by the tension pre-control, the tension controller and the acceleration compensation (inertia compensation).

For the direct closed-loop tension control using torque limiting, the same data is sent to the drive as for closed-loop tension control with a dancer roll.

11.4 Indirect closed-loop tension control

Figure 11-4: Indirect closed-loop tension control



The indirect closed-loop tension control functions principally the same as the direct closed-loop tension control using torque limiting. However, for this technique, the tension is not closed-loop controlled, but only open-loop controlled. This is the reason that this mode is occasionally known as open-loop tension control. A sensor is not used that detects the tension or the position of a dancer roll. This is the reason that there is also no PID controller – and is known as open-loop controlled mode as there is no feedback signal regarding the actual tension in the system. As for the closed-loop tension control using torque limiting, the drive operates at one of the torque limits that is entered via SIMOTION.

11.5 Description of the individual functions of the winder FB

11.5.1 Diameter calculation

The diameter calculation mode is selected using the DiameterCalcMode variables:

Various techniques are available to determine the roll diameter:

1. From the sensor:

The analog sensor signal detects the roll diameter. This value can be connected using the *Diameter_Sensor* input variables. Generally, the sensor must be calibrated. We generally recommend that the signal is filtered.

2. From the relationship between the actual speed and the circumferential velocity (V/N):

In this mode, the diameter is calculated from the ratio of the speed of the winder and the material web velocity. The speed of the winder must be connected to the parameter *Actual_Velocity_Winder* and the material web velocity with the parameter *Actual_line_speed_Master*. The signals are internally filtered.

In this mode, while accelerating and decelerating, the diameter calculation is not reliable. Further, the diameter calculation is only enabled after a certain minimum speed has been reached. The minimum speed is specified as a ratio to the rated speed with *Start_Calc_Ratio* as a %.

3. By incrementally adding the material thickness at the specified speed:

The results with this particular mode are extremely accurate if the precise material thickness is known, the tension taper does not influence the thickness of the material, and no significant voids can occur in the material. The web thickness parameter must be connected to the material thickness.

4. By the ratio between the web length for one or several revolutions of the winder:

With this calculation mode, the ratio between the winder speed and the material web velocity is generated – however, over several revolutions.

The RevolNumber parameter defines the number of revolutions from which the diameter is calculated. An interpolation is made between the old and new values.

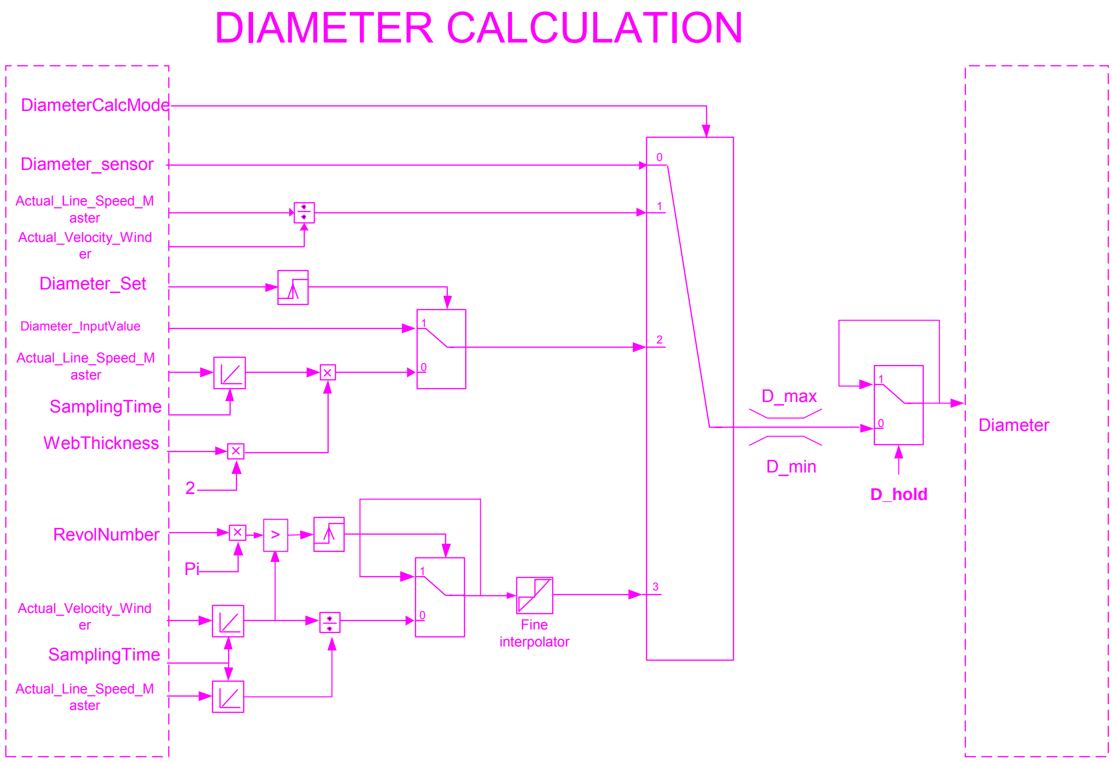
Especially while accelerating and decelerating, as well as at low speeds, this mode is still more accurate than the V/N mode.

If the input bit *Diameter_hold* is set to TRUE, then the last calculated diameter value is held. This can be selected at any time independently of the selected calculation mode.

At any time it is possible to toggle between the modes. This means, for example, the starting diameter can be detected using a sensor or can be entered at the HMI. When required, it can also be changed-over in operation.

A starting diameter can also be entered with Diameter_Inputvalue, which is set with Diameter_Set.

Figure 11-5: Diameter Calculation



11.5.2 Calculating the moment of inertia

The moment of inertia calculation is necessary in order to be able to operate with significantly differing moments of inertia while winding.

The varying moments of inertia occur due to the varying component of wound material on the winder.

The moment of inertia can be used for the K_P adaptation and the torque pre-control. For the K_p adaptation, a ratio between the actual torque and the maximum torque at the full roll is sent to the drive using the Profibus protocol. This means that the speed controller gain can be adapted as a function of the moment of inertia situation. The torque pre-control requires this calculation in order to generate additive torque setpoints for the drive while the drive is accelerating and decelerating.

Further, the torque ratio can be used to modify the gain of the PID controller of the winder FB that then controls/compensates for the position of the dancer roll or the tension.

The calculation comprises a fixed component made up of the moment of inertia of the motor, moment of inertia of the gearbox and the empty roll (*Inertia_Motor, Inertia_Gear, Inertia_Core, Diameter_Core, Gear_ratio*) as well as a variable component. This is made up of the material that is calculated using the material density, roll core width and diameter (*Density_Woundmaterial, Coil_Width, Diameter_Core*).

The moment of inertia calculation can be activated using the parameter *Enable_InertiaCalculation*.

The *Inertia_Ratio* parameter specifies the ratio between the empty roll and the full roll as a %.

Figure 11-6: Inertia calculation

Inertia_Motor
Inertia_Gear
Inertia_Core
Diameter
D_max
D_core
Coil_Width
Density_Woundmaterial
GearRatio

```
EmptyInertia          := Inertia_Motor+Inertia_Gear+Inertia_Core/GearRatio**2;
FullMaterialinertia   := PI*rWidth*rDensity*(Diameter_Max**4-rDiameterCore**4)/32/GearRatio**2;
Materialinertia       := PI*rWidth*rDensity*(Diameter**4-rDiameterCore**4)/32/GearRatio**2;
Inertia               := (Emptyinertia + Materialinertia);
InertiaRatio          :=(Emptyinertia + Materialinertia)/(Emptyinertia + FullMaterialinertia)*100.0 ;
```

Inertia (kgm2)
InertiaRatio (%)

AccelMaster (m/s)
Inertia
Diameter

$$TorquePrecontrol = Inertia \frac{AccelMaster}{\frac{D\_Actual}{2}}$$

TorquePrecontrol (Nm)

11.5.3 Torque pre-control

The torque pre-control can be activated to keep the deviation of the material web tension as low as possible while accelerating and decelerating.
In the speed correction mode, an additional torque pre-control value is generated using the add-torque output parameter. This can be sent to the drive via Profibus.
In the closed-loop tension control mode with torque limiting, the pre-control is added to the torque limit value that was calculated from the PID controller.

To calculate the torque pre-control, the actual acceleration of the material web (*Accel_Master*) and the rated torque of the winder motor are required (*NominalTorque_Winder*).

11.5.4 Calculating the controller gain adaptation

While winding, the roll diameter changes. The change in the diameter has an impact on the tension or the effectiveness of the dancer roll position or tension closed-loop control. In order to compensate for this change in the diameter, a variable controller gain can be used. One of two different adaptation techniques can be selected.

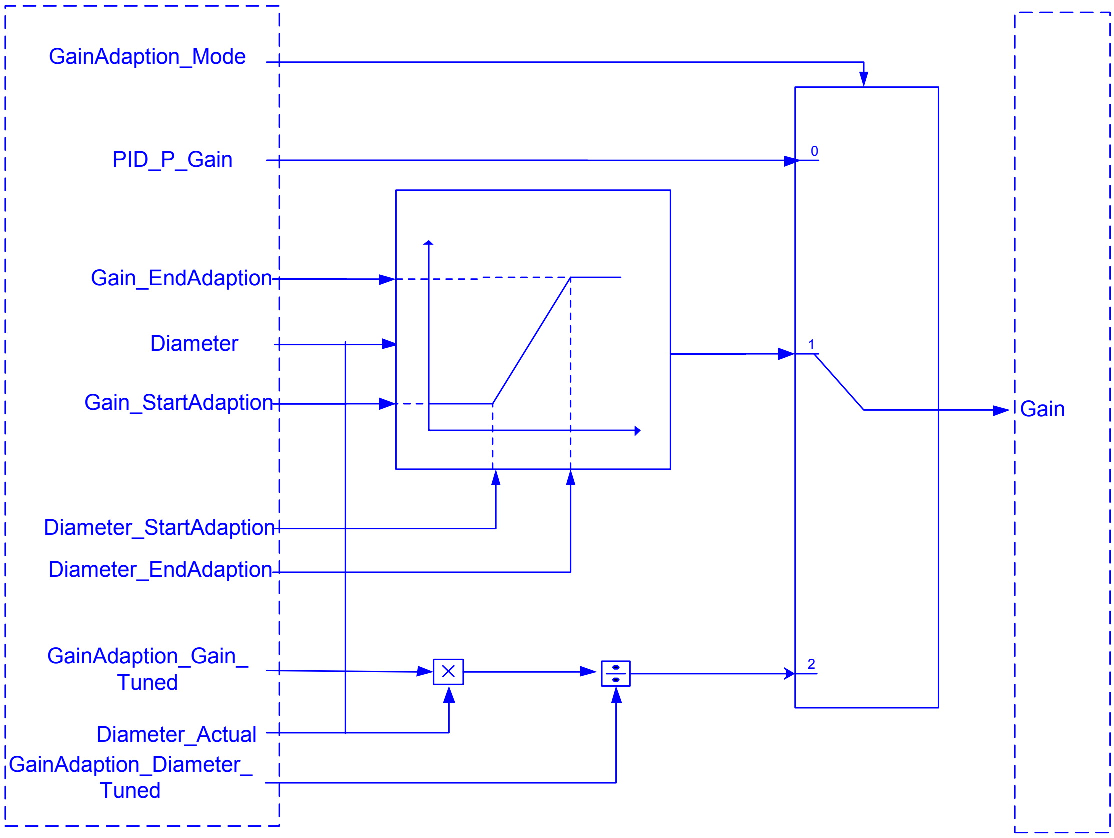
1. Linear adaptation: A table with 4 points specifies the gain as a function of the diameter (*Diameter_StartAdaption, Diameter_EndAdaption, Gain_StartAdaption, Gain_EndAdaption*).
2. Inverse adaptation: Normally, the controller gain is set to a specific diameter (G_{tuned} at D_{tuned}). Using the minimum and maximum diameter of the roll, and the linear interdependency of the quantities with respect to one another, gain G_{act} can be calculated (*GainAdaption_Diameter_Tuned, GainAdaption_Gain_Tuned*).

$$\frac{G_{act}}{D_{act}} = \frac{G_{tuned}}{D_{tuned}} \Rightarrow G_{act} = G_{tuned} \cdot \frac{D_{act}}{D_{tuned}}$$

The calculation mode is set using parameter *GainAdaption_Mode*.

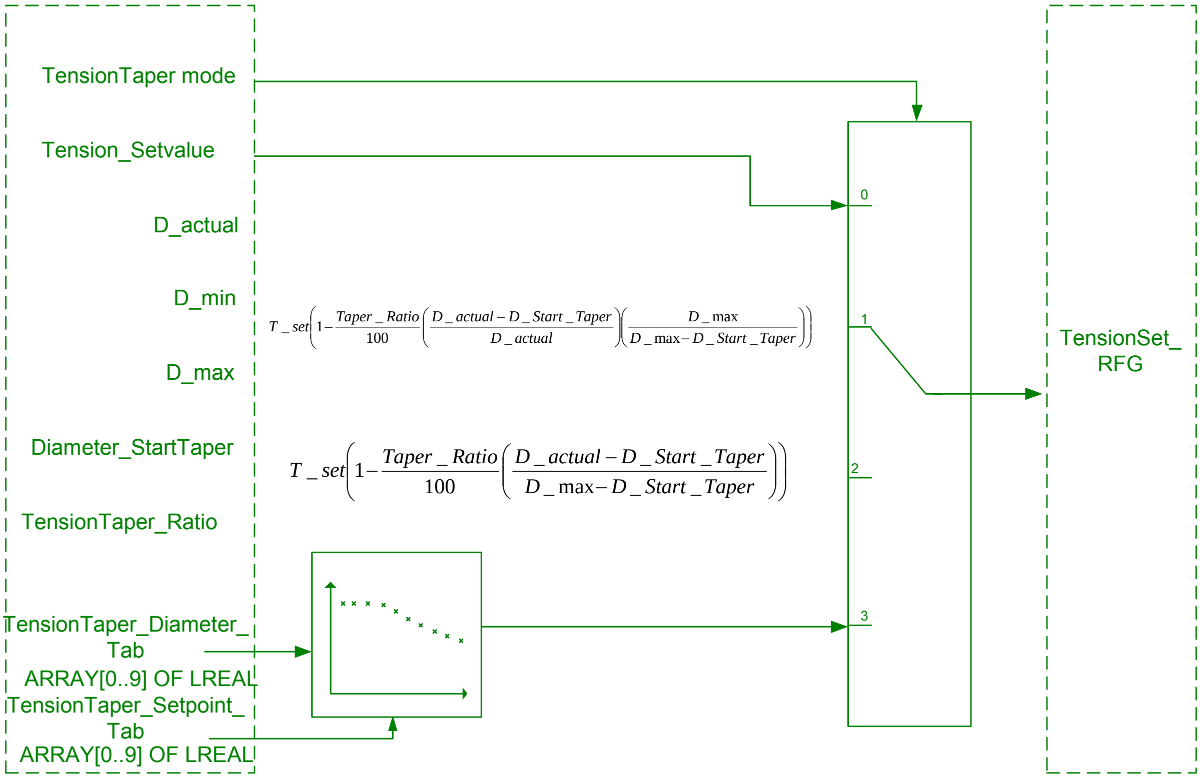
Winder

Figure 11-7: GainAdaption_Mode



11.5.5 Calculating the tension taper characteristic

Figure 11-8: Calculating the tension taper characteristic



The tension taper characteristic can be used to define with which tension the material is to be wound in the process as a function of the roll diameter.

The tension taper characteristic only makes sense while actually winding. The characteristic depends on the actual roll diameter. Various modes can be called (*TensionTaper_Mode*):

1. The selected tension setpoint is switched-through, independent of the diameter
2. Hyperbolic tension taper characteristic
3. Linear tension taper characteristic
4. Linear interpolation in a table with 10 points

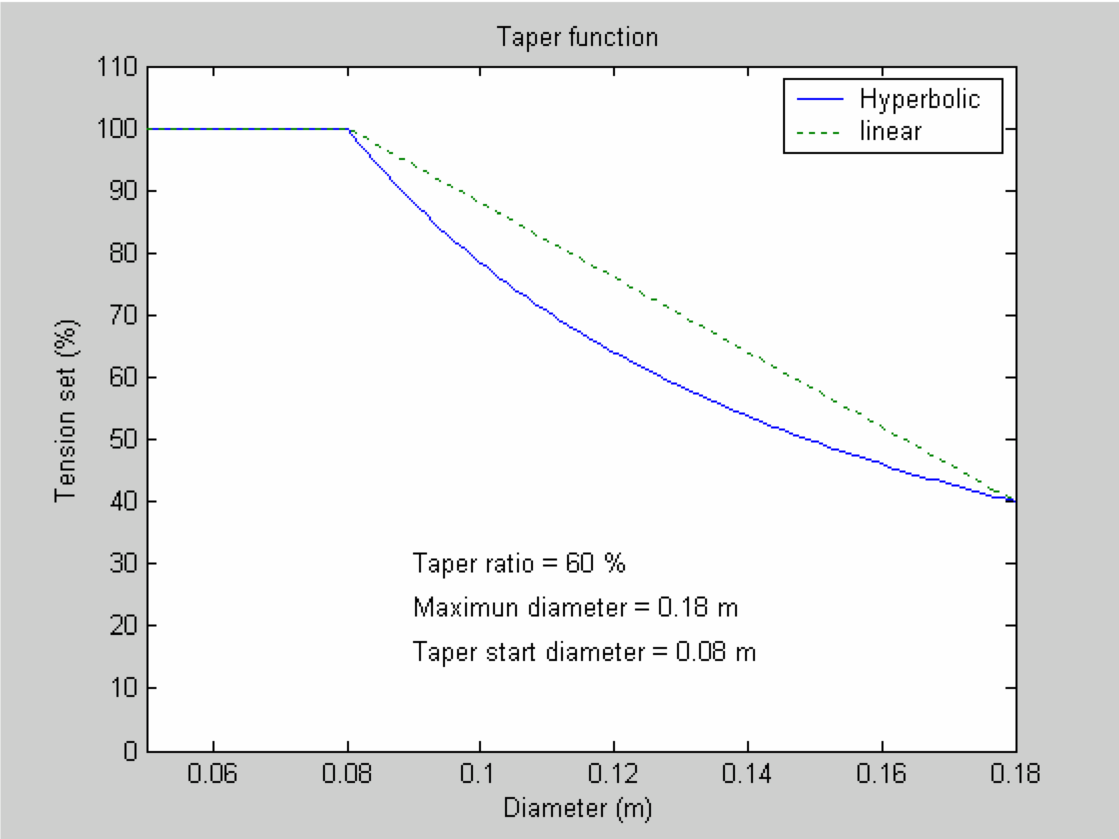
Using the *Diameter_StartTaper* variables, it is possible to determine from which diameter onwards the tension taper characteristic should apply. Then, as a function of the mode (*TensionTaperMode*), the input value is reduced, either as hyperbolic function, linear function or interpolated according to a table of values. This reduction is made until the entered maximum diameter is reached (*Diameter_max*). If the diameter of the roll is at its maximum, then the input setpoint is reduced by the factor *TensionTaperRatio*.

In order to avoid steps (jumps) in the tension, the tension taper characteristic is followed by a ramp-function generator. The time is selected, using *RFG_TensionSet_RampTime*, with which the new tension value should be approached. This quantity is limited by *RFG_TensionSet_Max*.

Depending on the particular operating mode, the tension setpoint is processed differently. For a system with dancer roll, Simotion generates the tension setpoint and outputs it. This value can then be used to adjust the tension at the dancer roll.

For systems with torque limiting, the tension acts on the torque limits and is therefore internally connected.

Figure 11-9: Comparison between linear and hyperbolic tension taper characteristics



12 Commissioning the winder function

12.1 Checking the speed actual value calibration

Principle

The maximum speed occurs at the maximum web velocity and minimum diameter.

Procedure

- Set the actual diameter the same as the core diameter of the roll to be wound (Diameter_Inputvalue and Diameter_Set)
- Enter the web velocity setpoint (approx. 20% of V_{Max}) (*Setvalue_Line_Speed_Master*)
- Operate the winder with an empty roll and with the closed-loop tension control switched-out
- Using a handheld tachometer, check the circumferential velocity at the roll – this must be the same as the web velocity
- If required, check the axis setting, gearbox factor and units
- Secure the wound roll so that the material cannot fly off, measure, enter, set and inhibit the diameter (*Diameter_Inputvalue, Diameter_Set, Diamater_hold*)
- Repeat this operation with a larger diameter and higher material web velocity

12.2 Compensating the accelerating torque

Applications

If the accelerating torque is not negligibly low when compared to the other torque, then the inertia compensation for the winder with indirect closed-loop tension control and for direct closed-loop tension control with load cell should be set. For the closed-loop dancer control, under certain circumstances, it is not necessary to compensate the accelerating torque.

12.2.1 Compensating the constant moment of inertia

Principle

The fixed moment of inertia does not depend on the diameter of the roll. At the minimum diameter ($D_{min} = D_{core}$), the total moment of inertia is equal to the fixed moment of inertia.

Procedure

- Measure, enter and inhibit the core diameter (*Diameter_Inputvalue, Diameter_Set, Diamater_hold*)
- Enable the calculation of the moment of inertia (Enable_Inertia_Calc)
- Connect the variables to calculate the moment of inertia (Inertia_Motor, Inertia_Gear, Inertia_Core, etc)
- Accelerate and decelerate the winder with the machine ramp
- The speed controller output (monitor in the drive) must be at a minimum.

The speed controller output while accelerating must be minimum. If this is not the case, the values for the fixed moment of inertia must be checked (*Inertia_Motor, Inertia_Gear, Gera_Ratio, Inertia_Core*).

12.2.2 Compensating the variable moment of inertia

Principle

The variable component of the moment of inertia is defined by the wound material and therefore depends on the diameter of the roll being wound.

For gearboxes with high ratios, frequently, the component of the variable moment of inertia can be neglected.

Procedure

Carry-out the steps described above in the general procedure for a half, full and completely unwound roll. It is important that the roll is tied and secure and cannot accidentally unwind!

The speed controller output must be at a minimum while accelerating. If this is not the case, the values for the variable moment of inertia must be checked (*Coil_Width, Density*).

Repeat the measurement with a full wound roll.

12.3 Setting the Kp adaptation for the closed-loop speed control

Measure required

The proportional gain of the speed controller should be generally adapted to the variable moment of inertia. For a ratio $D_{max}/D_{min} > 3$, it is absolutely necessary to optimize the Kp adaptation for good winding characteristics and fast commissioning.

Procedure

Set the actual diameter of the roll using the command *Diameter_InputValue* and *Diameter_Set*, with which the speed controller is to be optimized. Generally, this is the minimum and maximum diameter of the roll.

The adaptation is carried-out using a polygon characteristic with 2 points along the characteristic in the drive. The actual moment of inertia is the input quantity for the characteristic – that is provided from the winder FB in the output variables *Inertia_Ratio* and can be transferred to the drive via the extended Profibus telegram. The adaptation is set in the drive using parameters P1456 to P1459 (Sinamics S120). The output of the adaptation acts as weighting on the selected Kp. This means that the Kp is set for the full wound roll and then is reduced to the Kp determined for an empty roll along the adaptation characteristic.

12.4 Checking the tension pre-control

With a load cell

- Check the control sense – if the sign is incorrect, invert the analog input
- Filter the tension actual value signal; we recommend that you use the analog inputs of the SINAMICS drive or a fast I/O module (TB30/TM31) as this can be appropriately quickly sampled. Depending on the dynamic response of the application, the actual value signal of the load cell should be appropriately scaled and filtered.
- De-activate the closed-loop tension control (*Enable_TensionControl* = FALSE), thread the material web and clamp
- Check the diameter and if required correct it
- Switch-in the closed-loop tension control at standstill
- The pre-control must set the required tension

For dancer rolls

- Check the control sense – if the sign is incorrect, invert the analog input
- Filter the position actual value signal; we recommend that you use the analog inputs of the SINAMICS drive or a fast I/O module (TB30/TM31), as this can be appropriately quickly sampled. Depending on the dynamic response of the application, the actual value signal of the dancer roll position should be appropriately scaled and filtered.
- De-activate the closed-loop tension control (*Enable_TensionControl* = FALSE), thread the material web and clamp
- Check the diameter and if required correct it
- Enter a fixed position setpoint (reference value) at *Controlled_Setvalue*; the setpoint (reference value) corresponds to the dancer roll position actual value at the center position
- Switch-in the closed-loop tension control at standstill
- The setpoint (reference) position of the dancer roll is approached (*Controlled_Setvalue*) (check: *Controlled_Setvalue* = *Controlled_Actualvalue*)

12.5 Setting and optimizing the tension controller, Kp adaptation

For closed-loop torque limit control with direct tension measurement it is necessary to adapt to the variable moment of inertia (*Control_Structure*=2). Indirect closed-loop tension control does not require any adaptation and also the tension controller does not have to be set (as it is not used).

For closed-loop speed correction control, it is not permissible that the adaptation is set; in this case, the Kp value of *PID_P_Gain* is valid for the complete range.

Optimizing the tension controller

The tension controller is optimized according to the usual technique; this is done, for example, by entering a low supplementary tension setpoint and monitoring the tension actual value. A dampened stabilizing sequence must always be able to be monitored. The optimization should be carried-out at various diameter values. While optimizing, a start should be made with extremely slow controller settings and the controller output limited (PID_OutputLimit_pos and PID_Out*putLimit_neg*).

12.6 Setting the overcontrol value

Note

For closed-loop speed correction control, the overcontrol (override) factor *Override_Ratio* is not active.

For closed-loop torque limiting control, the value should be selected so that the speed controller, under normal operating conditions, is always at its limit. It only leaves this when the web breaks and prevents the winder from accelerating in an uncontrolled fashion.

Appendix

13 General information on the application

13.1 Scope of supply

The package “Standard winder application in SIMOTION” comprises the following:

- 1x SIMATIC project with SIMOTION SCOUT program and ProTool HMI program
- 1x documentation package (detailed commissioning instructions, detailed application structure, function charts)

13.2 Revision

Table 13-1: Revision

Version	Date/Revision
V1.0	31.01.2005 / first edition
V1.1	13.06.2005 / Communication via Ethernet Add-On Inputs Add-On Outputs
V1.2	03/15/06/ Changes “General Notes”
V1.3	04/12/06 / Scout 4.0

14 Literature/references

Literature/references

This list is in no way complete and only reflects a selection of suitable literature.

	Subject	Title
1	Standard axial winder engineering	Axial winder SPW420 – SIMADYN Manual

15 Contact partners

Application Center

SIEMENS

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16 Please help us to become better

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Sender:
Name:
Department:
City:
Telephone:
E-Mail:

Evaluation of the article

Is this subject helpful/ beneficial for you? ❑ Yes ❑ No

How high are the benefits of this application for you in the following working phases?

	Very high					Very low
– own training/ information	❑	❑	❑	❑	❑	❑
– conceptual phase	❑	❑	❑	❑	❑	❑
– engineering/coding	❑	❑	❑	❑	❑	❑
– commissioning	❑	❑	❑	❑	❑	❑

How is this application from the didactic perspective?

	Very good					Very poor
– scope	❑	❑	❑	❑	❑	❑
– layout/design	❑	❑	❑	❑	❑	❑
– clarity	❑	❑	❑	❑	❑	❑

Can the application be transferred to your own application?

Very easily					Not easily
❑	❑	❑	❑	❑	❑

Do you require support for this application? ❑ Yes ❑ No

Other comments: ....

....