The Drive & Control Company

Rexroth
Bosch Group

Rexroth IndraMotion MLC 14VRS

Winder Function Application

Application Description
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Edition 01

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Winder Function Application

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1 About this documentation

1.1 Validity of the documentation

Target group

In the following illustration, the framed activities, product phases and target groups refer to the present documentation.

Example: In the product phase "Commissioning", the target group "Programmer" can execute the activities "Optimize" and "Test" using this documentation.

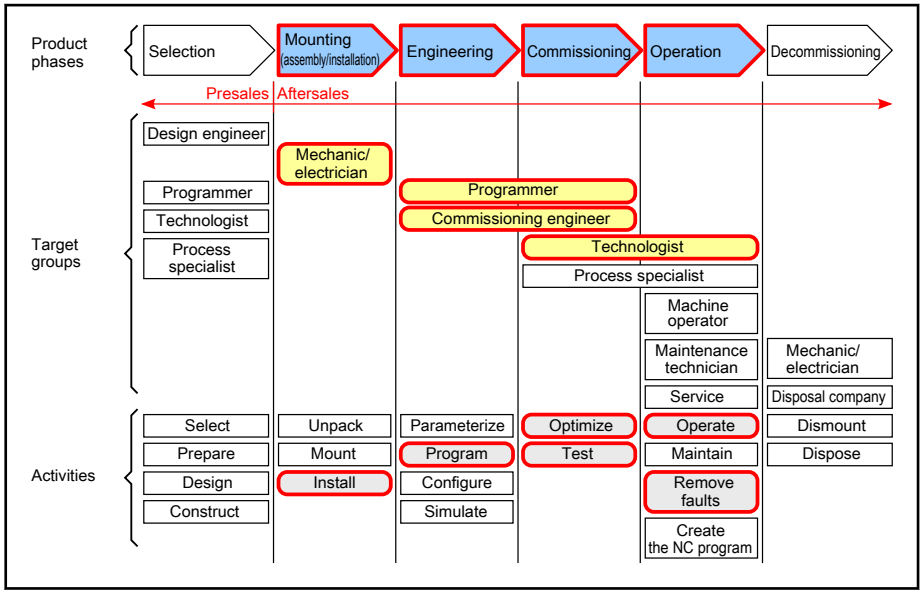

Fig. 1-1: Assigning this documentation to the target groups, product phases and target group activities

1.2 Required and supplementing documentation

Documentation titles with type codes and part numbers

System overview
Rexroth IndraLogic XLC 14VRS System Overview DOK-XLC***-SYSTEM**V14-PRRS-EN-P, R911341483 This documentation provides an overview on the possible hardware/software components of the automation system IndraLogic XLC of the mentioned version. The documentation facilitates assembling a system.
Rexroth IndraMotion MLC 14VRS System Overview DOK-MLC***-SYSTEM**V14-PRRS-EN-P, R911341504 This documentation provides an overview of the hardware/software components of the automation system IndraMotion MLC in the mentioned version. The documentation facilitates assembling a system.

Tab. 1-1: XCL/MLC documentation overview - System overview

About this documentation

First steps
Rexroth IndraMotion MLC 14VRS First Steps
DOK-MLC***-F*STEP**V14-CORS-EN-P, R911341517
This documentation describes the first steps of the IndraMotion MLC and the RobotControl. It includes the hardware and software prerequisites as well as the creation of a project.
Rexroth IndraLogic XLC 14VRS First Steps
DOK-XLC***-F*STEP**V14-CORS-EN-P, R911341489
This documentation describes the first steps of the IndraLogic XLC. It includes the hardware and software prerequisites as well as the creation of a project.
Rexroth IndraMotion MLC 14VRS Project Conversion
DOK-XLCMLC-PROCONV*V14-APRS-EN-P, R911341494
This documentation describes the project conversion of the IndraMotion MLC.

Tab. 1-2: XCL/MLC documentation overview - First steps

Engineering
Rexroth IndraWorks 14VRS Software Installation
DOK-IWORKS-SOFTINS*V14-CORS-EN-P, R911344286
This documentation describes the IndraWorks installation.
Rexroth IndraWorks 14VRS Engineering
DOK-IWORKS-ENGINEE*V14-APRS-EN-P, R911343566
This documentation describes the application of IndraWorks in which the Rexroth Engineering tools are integrated. It includes instructions on how to work with IndraWorks and how to operate the oscilloscope function.
Rexroth IndraLogic XLC IndraMotion MLC 14VRS Function Description
DOK-XLCMLC-FUNC****V14-APRS-DE-P, R911341700
This documentation describes wizards, context menus, dialogs, control commissioning, device configuration and functionalities of the IndraMotion MLC.

Tab. 1-3: XCL/MLC documentation overview - Engineering

Diagnostics and service
Rexroth IndraLogic XLC IndraMotion MLC 14VRS Diagnostics
DOK-XLCMLC-DIAG****V14-RERS-EN-P, R911341481
This documentation includes all control parameters implemented in the control systems IndraLogic XLC and IndraMotion MLC.
Rexroth IndraLogic XLC IndraMotion MLC 14VRS Parameters
DOK-XLCMLC-PARAM***V14-RERS-EN-P, R911341479
This documentation describes the parameters of the XLC/MLC systems as well as the interaction between parameterization and programming. It includes the axis parameters, control parameters, kinematic parameters, touch probe parameters and programmable limit switch parameters.

Diagnostics and service
Rexroth IndraLogic XLC IndraMotion MLC 14VRS Commissioning
DOK-XLCMLC-STARTUP*V14-CORS-EN-P, R911341502
This documentation describes the steps to commission and service the IndraMotion MLC and IndraLogic XLC systems. It includes checklists for frequent tasks and a detailed description of the steps.
Rexroth IndraWorks IndraMotion Service Tool
DOK-IWORKS-IMST*******-APRS-DE-P, R911341383
This documentation describes the IndraMotion Service Tool (IMST). IMST is a web-based diagnostic tool used to access a control system via an Ethernet high-speed connection. The IMST allows OEMs, end users and service engineers to access and remotely diagnose a system. The PC has to use at least Internet Explorer 8, Firefox 3.5 or a higher version. The following control variants are supported: • IndraMotion MLC L25/L45/L65 • IndraLogic XLC L25/L45/L65/VEP

Tab. 1-4: XLC/MLC documentation overview - Diagnostics and service

Drive controllers
Rexroth IndraDrive Firmware for Drive Controllers MPH-, MPB-, MPD-, MPC-08
DOK-INDRV*-MP*-08VRS**-APxx-EN-P-DE-P, R911332643
This documentation describes all functional properties of the IndraDrive firmware in the variants MPH-08, MPB-08, MPD-08 and MPC-08.
Rexroth IndraDrive Drive Controllers MPx-02 to MPx-08
DOK-INDRV*-GEN-**VRS**-PAxx-EN-P, R911297317
This documentation describes all parameters implemented in the firmware for drive controllers of the IndraDrive family. It supports the parameterization of the drive controllers.
Rexroth IndraDrive MPx-02 to MPx-08 and HMV
DOK-INDRV*-GEN-**VRS**-WAxx-EN-P, R911297319
This documentation describes all diagnostics implemented in the following firmwares: • Drive controller firmwares from MPx-02 to MPx-08 and • firmwares of the supply devices of the type "HMV". It supports the operating crew as well as the programmer during troubleshooting.
Rexroth IndraDrive Control Units CSB02, CSE02, CSH02, CDB02
DOK-INDRV*-CXX02******-PRRS-EN-P, R911338962
Rexroth IndraDrive MPx-18 Functions
DOK-INDRV*-MP*-18VRS**-APRS-EN-P, R911338673
This documentation describes all functional properties of the IndraDrive firmware in the variants MPB-18, MPM-18, MPC-18 and MPE-18.

xx Corresponding edition

Tab. 1-5: XCL/MLC documentation overview - Drive controllers

About this documentation

PLC
Rexroth IndraWorks 14VRS IndraLogic 2G PLC Programming System
DOK-IWORKS-IL2GPRO*V14-APRS-EN-P, R911343571
This documentation describes the PLC programming tool IndraLogic 2G and its usage. It includes the basic use, first steps, visualization, menu items and editors.
Rexroth IndraWorks 14VRS Basic Libraries IndraLogic 2G
DOK-IL*2G*-BASLIB**V14-LIRS-EN-P, R911343920
This documentation describes the system-comprehensive PLC libraries.
Rexroth IndraLogic XLC IndraMotion MLC 14VRS PLCopen Libraries
DOK-XLCMLC-FUNLIB**V14-LIRS-EN-P, R911341491
This documentation describes the function blocks, functions and data types of the RIL_CommonTypes, ML_Base and ML_PLCopen libraries for the IndraLogic XLC/IndraMotion MLC. It also includes the error reactions of function blocks.

Tab. 1-6: XCL/MLC documentation overview - PLC

Field buses
Rexroth IndraWorks 14VRS Field Buses
DOK-IWORKS-FB******V14-APRS-EN-P, R911341485
This documentation describes the field bus and local periphery connections supported by the IndraLogic XLC, IndraMotion MLC and IndraMotion MTX systems. The focus of this documentation is on the configuration, parameterization, commissioning and the diagnostics of the different periphery connections. This documentation is the basis for the online help.
Rexroth IndraWorks 14VRS Field Buses Libraries
DOK-IWORKS-FB*LIB**V14-LIRS-EN-P, R911343575
This documentation describes the field bus libraries: RIL_ProfibusDP_02, RIL_ProfibusDPSlave, RIL_ProfinetIO, RIL_ProfinetIODevice, RIL_EtherNetIPAdapter, RIL_MappingList, RIL_SERCOSIII, RIL_Inline including their diagnostics and error reactions of the function blocks.
Rexroth IndraWorks 12VRS FDT Container
DOK-IWORKS-FDT*CON*V12-APRS-EN-P, R911334398
This documentation describes the IndraWorks FDT Container functionality. It includes the activation of the functionality in the project and working with DTMs.
SERCOS System Manual for I/O Devices
DOK-CONTRL-ILS3*******-APxx-EN-P, R911333512
This documentation describes the configuration, parameterization, commissioning and diagnostics of I/O devices with a SERCOS interface.

xx Corresponding edition

Tab. 1-7: XCL/MLC documentation overview - Field buses

HMI
Rexroth IndraWorks 14VRS HMI
DOK-IWORKS-HMI*****V14-APRS-EN-P, R911343569
This documentation describes the functions, configuration and operation of the user interfaces IndraWorks HMI Engineering and IndraWorks HMI Operation.
Rexroth IndraWorks 14VRS WinStudio
DOK-IWORKS-WINSTUD*V14-APRS-EN-P, R911341585
This "User Manual and Technical Reference Book" facilitates working with the "Rexroth WinStudio" software for optimal results. This document provides technical information and step-by-step instructions to create web-enabled HMI/SCADA programs.
Rexroth IndraLogic XLC IndraMotion MLC 14VRS HMI Connection
DOK-XLCMLC-HMI*****V14-APRS-EN-P, R911341497
This documentation describes the visualization systems supported by the IndraLogic XLC and IndraMotion MLC and their connection.

Tab. 1-8: XCL/MLC documentation overview - HMI

Technology
Rexroth IndraLogic XLC IndraMotion MLC 14VRS Generic Application Template
DOK-XLCMLC-TF*GAT**V14-APRS-EN-P, R911341487
This documentation provides a structured template to the IndraLogic PLC programmer. This template can be used to add and edit the PLC programming code. It includes the template, the template wizard and example applications.
Rexroth IndraMotion MLC 14VRS Technology Libraries
DOK-MLC***-TF*LIB**V14-LIRS-EN-P, R911341511
This documentation describes the function blocks, functions and data types of the "ML_TechInterface.library", "ML_TechMotion.library", "RMB_TechCam.library" and "ML_TechBase.library". It also includes libraries for the winder functionality, register controller functionality and CrossCutter functionality.
Rexroth IndraWorks Energy Efficiency Management 14VRS
DOK-IWORKS-4EE*****V14-APRS-EN-P, R911339229
This documentation describes the HMI connection of the energy management system and the function blocks, functions and data types of the "RIL_4EE " library. The documentation also includes the error reactions of the function blocks.
Rexroth IndraMotion MLC 14VRS RegisterControl (Library)
DOK-MLC***-REGI*CO*V14-LIRS-EN-P, R911341509
This documentation describes the inputs and outputs of the individual function blocks and provides notes on their use.
Rexroth IndraMotion MLC 14VRS RegisterControl (Application Description)
DOK-MLC***-REGI*CO*V14-APRS-EN-P, R911341507
This documentation describes the application of the integrated register control for a rotogravure printing machine. The components of the mark stream sensor, the HMI application and the error recovery options are described. This instruction provides information on how to operate the register control, react to errors and query diagnostics. This documentation is written for machine setters and machine operators.
Rexroth IndraMotion MLC 14VRS Winder Function Application
DOK-MLC***-TF*WIND*V14-APRS-EN-P, R911341513
This application-related system documentation describes the application of the winder technology functions.

About this documentation

Technology
Rexroth IndraWorks 13VRS CamBuilder
DOK-IWORKS-CAMBUIL*V13-APRS-EN-P, R911336291
This documentation describes the basic principles and operation of the CamBuilder, the cam editing tool.
Rexroth IndraMotion MLC 14VRS Robot Control V2
DOK-MLC***-ROCO****V14-RERS-EN-P, R911341588
This documentation provides information about the Robot Control V2. The focus is on PLCopen programming. The program structure, variables, functions, motion statements and the required system parameters are described. This documentation also includes the description of the "ML_Robot" library. Robot Control V2 is supported by a kinematic interface. The components of this interface are described in the "ML_KinTech" library.

Tab. 1-9: XCL/MLC documentation overview - Technology

Open Core Engineering - OCE
Rexroth IndraLogic XLC IndraMotion MLC 14VRS First Steps MLPI
DOK-XLCMLC-MLPI****V14-CORS-EN-P, R911341033
This document describes the installation and the commissioning of the MLPI interface.
Rexroth IndraLogic XLC IndraMotion MLC 14VRS Automation Interface
DOK-XLCMLC-AUT*INT*V14-APRS-EN-P, R911341499
This documentation describes the script-based access to IndraWorks project data via the interface of the Automation Interface.

Tab. 1-10: XCL/MLC documentation overview - Open Core Engineering - OCE

SafeLogic
Rexroth IndraWorks SafeLogic 14VRS First Steps
DOK-IWORKS-SL*STEP*V14-CORS-EN-P, R911341520
This documentation describes the initial commissioning of the Safety function module and its external Safety periphery. Taking the example of a project, all required steps to commission a simple Safety application are executed.
Rexroth IndraMotion MLC IndraLogic XLC 14VRS SafeLogic System Overview
DOK-XLCMLC-SL**SYS*V14-PRRS-EN-P, R911341696
This documentation describes the project planning, configuration, creation and commissioning of safety-related devices.
Rexroth IndraWorks 14VRS SafeLogic Project Configuration
DOK-IWORKS-SL**PRJ*V14-APRS-EN-P, R911341694
This documentation describes the configuration of Safety applications.
Rexroth IndraControl SafeLogic Function Module
DOK-CONTRL-SL**FM*****-ITRS-DE-P, R911336576
This documentation is provided with the hardware and describes the commissioning, the installation, the decommissioning and disposal of the hardware.

Tab. 1-11: XCL/MLC documentation overview - SafeLogic

Hardware
Rexroth IndraControl L45/L65/L85 Control
DOK-CONTRL-ICL45L65L85-PRxx-EN-P, R911332116
This documentation describes the IndraControl L45/L65/L85 controls.
Rexroth IndraControl L25
DOK-CONTRL-IC*L25*****-PRxx-EN-P, R911328474
This documentation describes the IndraControl L25 controls.
Rexroth IndraControl Lxx 14VRS Function Modules
DOK-CONTRL-FM*LXX**V14-APRS-EN-P, R911341583
This documentation describes all function modules of the Lxx controls including engineering and diagnostics.

xx Corresponding edition

Tab. 1-12: XCL/MLC documentation overview - Hardware

Hydraulics
Rexroth IndraLogic XLC IndraMotion MLC 14VRS Sequential Programming
DOK-XLCML-SEQPROG*V14-LIRS-ENE-P, R911341909
This documentation includes the library for the sequential programming.
Rexroth IndraMotion MLC 13VRS MH_TechHydrBase
DOK-MLC***-TF*HBASEV13-LIRS-EN-P, R911336312
This documentation describes the function blocks, functions and data types of the MH_TechHydrBase libraries. The documentation also includes the error reactions of the function blocks.
Rexroth IndraMotion MLC 14VRS MH_TechHydrMotion
DOK-MLC***-TF*HMOT*V14-LIRS-EN-P, R911341906
This documentation describes the function blocks, functions and data types of the MH_TechHydrMotion libraries. The documentation also includes the error reactions of the function blocks.
Rexroth IndraMotion MLC 13VRS MH_HydrControl
DOK-MLC***-TFHCLIB*V13-LIRS-EN-P, R911336328
This documentation describes the function blocks, functions and data types of the MH_HydrControl library. The documentation also includes the error reactions of the function blocks.
Rexroth IndraMotion MLC 14VRS MH_SynchControl
DOK-MLC***-TFHSLIB*V14-LIRS-EN-P, R911341911
This documentation describes the function blocks, functions and data types of the MH_SynchControl library. The documentation also includes the error reactions of the function blocks.

Tab. 1-13: XCL/MLC documentation overview - Hydraulics

1.3 Information representation

1.3.1 Safety instructions

If there are safety instructions, they contain certain signal words (Danger, Warning, Caution, Notice) and if applicable, signal alert symbols (acc. to ANSI Z535.6-2006).

The signal word draws attention to the safety instruction and indicates the risk potential.

The signal alert symbol (warning triangle with exclamation mark) positioned in front of the signal words Danger, Warning and Caution indicates hazards for individuals.

⚠ DANGER

In case of non-compliance with this safety instruction, death or serious injury **will** occur.

⚠ WARNING

In case of non-compliance with this safety instruction, death or serious injury **can** occur.

⚠ CAUTION

In case of non-compliance with this safety instruction, minor or moderate injury can occur.

NOTICE

In case of non-compliance with this safety instruction, material damage can occur.

1.3.2 Symbols used

Note Notes are represented as follows:

This is a note for the user.

Tip Tips are represented as follows:

This is a tip for the user.

1.3.3 Names and abbreviations

Term	Explanation
CANopen	Field bus
DeviceNet	Field bus
Ethernet	Communication interface
IWE	IndraWorks Engineering
IWO	IndraWorks Operation
OWG	Optical waveguide
MLC	Motion Logic Control
MLD	Motion Logic Drive Control
NC	Numerical Control
OEM	Original Equipment Manufacturer

PROFIBUS-DP	Field bus
Sercos	Sercos (SErial Realtime COmmunication System) interface is a world-wide standardized interface for the communication between controls and drives

Tab. 1-14: Names and abbreviations used

1.3.4 Customer feedback

Customer requests, comments or suggestions for improvement are of great importance to us. Please email your feedback on the documentations to Feedback.Documentation@boschrexroth.de. Directly insert comments in the electronic PDF document and send the PDF file to Bosch Rexroth.

2 Important directions for use

2.1 Appropriate use

2.1.1 Introduction

Bosch Rexroth products represent state-of-the-art developments and manufacturing. They are tested prior to delivery to ensure operating safety and reliability.

⚠ WARNING **Personal injury and property damage caused by inappropriate use of the products!**

The products may only be used in the manner that is defined as appropriate. If they are used in an inappropriate manner, then situations can develop that may lead to property damage or injury to personnel.

☞ Bosch Rexroth, as manufacturer, is not liable for any damages resulting from inappropriate use. In such cases, the guarantee and the right to payment of damages resulting from inappropriate use are forfeited. The user alone carries all responsibility of the risks.

Before using Bosch Rexroth products, make sure that all the pre-requisites for appropriate use of the products are satisfied:

- Personnel that in any way, shape or form uses our products must first read and understand the relevant safety instructions and be familiar with appropriate use.
- If the product takes the form of hardware, then they must remain in their original state, in other words, no structural changes are permitted. It is not permitted to decompile software products or alter source codes.
- Do not mount damaged or faulty products or use them in operation.
- Make sure that the products have been installed in the manner described in the relevant documentation.

2.1.2 Areas of use and application

The IndraControl of Bosch Rexroth and its function modules are suitable for motion/logic applications.

☞ The IndraControl and its function modules may only be used with the accessories and parts specified in this document. If a component has not been specifically named, then it may not be either mounted or connected. The same applies to cables and lines.

Operation is only permitted in the specified configurations and combinations of components using the software and firmware as specified in the relevant function descriptions.

IndraControl and its function modules have been developed for use in single or multiple-axis drives and control tasks.

To ensure an application-specific use, the machine operator and visualization panels are available with differing equipment and different interfaces.

Typical applications of IndraControl and its function modules are:

- [Handling and assembly systems]

Important directions for use

- [Packaging and foodstuff machines]
- [Printing and paper processing machines]
- [Machine tools]

IndraControl and its function modules may only be operated under the assembly, installation and ambient conditions as described here (temperature, system of protection, humidity, EMC requirements, etc.) and in the position specified.

2.2 Inappropriate use

Using IndraControl and its function modules outside of the above-referenced areas of application or under operating conditions other than described in the document and the technical data specified is defined as "inappropriate use".

IndraControl and its function modules may not be used if

- they are subject to operating conditions that do not meet the above specified ambient conditions. This includes, for example, operation under water, in the case of extreme temperature fluctuations or extremely high maximum temperatures or if
- Bosch Rexroth has not specifically released them for that intended purpose. Please note the specifications outlined in the general safety instructions!

3 Project planning and configuration

3.1 General information

The winder functions are described from the user point of view. For more details on the winder function blocks, the library description is required for the TechWinder library.

3.2 System configuration

3.2.1 MLC control

General information

The MLC control is a rack-based control connecting Motion and control functionality. The Motion functionality is mostly realized by a fix firmware. The control functionality is freely programmable with the Engineering Suite IndraWorks and the PLC programming environment IndraLogic 2G.

Hardware

- IndraControl L25 (lower performance segment)
- IndraControl XM21 (lower performance segment) with TEC (technology) function package
- IndraControl L45 (medium performance segment)
- IndraControl XM22 (medium performance segment) with TEC (technology) function package
- IndraControl L65 (upper performance segment)

Firmware

- from FWA-CML25*-MLC-11VRS-D0
- from FWA-XM2sss-MLC-14VRS
- from FWA-CML45*-MLC-11VRS-D0
- from FWA-XM2sss-MLC-14VRS
- from FWA-CML65*-MLC-11VRS-D0

The control variant XLC cannot be used with the RMB_TechWinder library/the TEC function package.

Software

IndraWorks 14VRS for IndraMotion MLC

3.2.2 MLD control

General information

The IndraMotion MLD is an "onboard" control integrated into the hardware of the IndraDrive control section. The PLC firmware is part of the drive firmware. In contrast to the IndraMotion MLC, the PLC engineering environment is the IndraLogic 1.x. (up to the drive firmware MPX08).

Hardware

- The control section CSH01.1 is required for the single-axis control MLD-S
- The control section CSH01.3 is required for the multi-axis control MLD-M

Firmware

Drive firmware from 07VRS:

- MPC firmware: Multi-axis MotionControl IndraMotion MLD-M for up to eight axes
- MPH firmware: Single-axis control IndraMotion MLD-S for one axis

Function packages:

The drive firmware functionality is divided into several function packages. The function packages have to be ordered and licensed according to the application. The required function packages are then enabled.

Project planning and configuration

The "IndraMotion MLD" function packages has to be enabled for the IndraMotion MLD.

The additional package "IndraMotion MLD Advanced" ("MA") has to be enabled for extended technology function blocks.

The additional package "IndraMotion MLD Advanced" is only available for MPC firmware and MPH firmware (not for MPB firmware).

Software

IndraWorks 14VRS for IndraMotion MLD

Special parameterization for the MLD control

The "AxisData structure" of the drive has to be parameterized (P-0-1367 "PLC configuration", bit 6 is set or the dialog "PLC Configuration")

For the multiple axis control, set additionally in the PLC configuration that the PLC "permanently control" (P-0-1367 "PLC configuration", bit 4 set or dialog for the "PLC Configuration") the drive.

For the MLD control, the virtual axis is realized using a master axis generator.

Configuring the virtual master axis generator:

The configuration of the virtual master axis generator comprises the following three parameterizations:

- Operating modes of the virtual master axis

  Setting the positioning mode

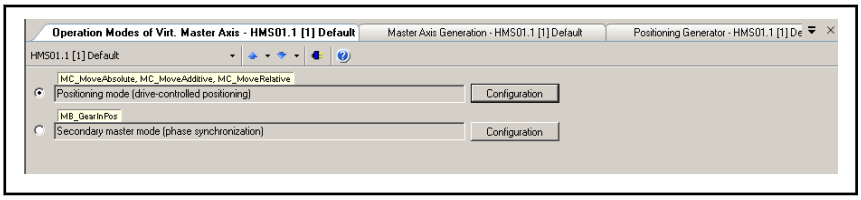

Fig. 3-1: Operation modes of the virtual master axis

- Master axis generation

  Entering the parameter P-0-0758 "Virtual master axis, actual position value"

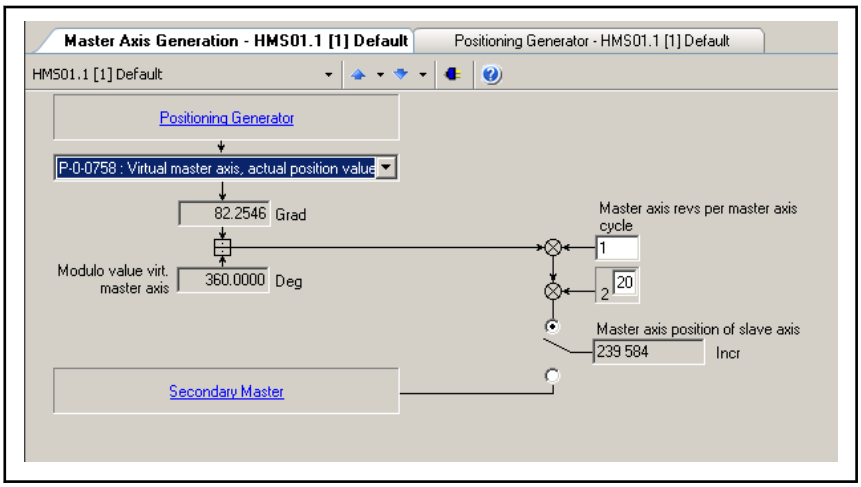

Fig. 3-2: Master axis generation

- Positioning generator

  Enabling position command value

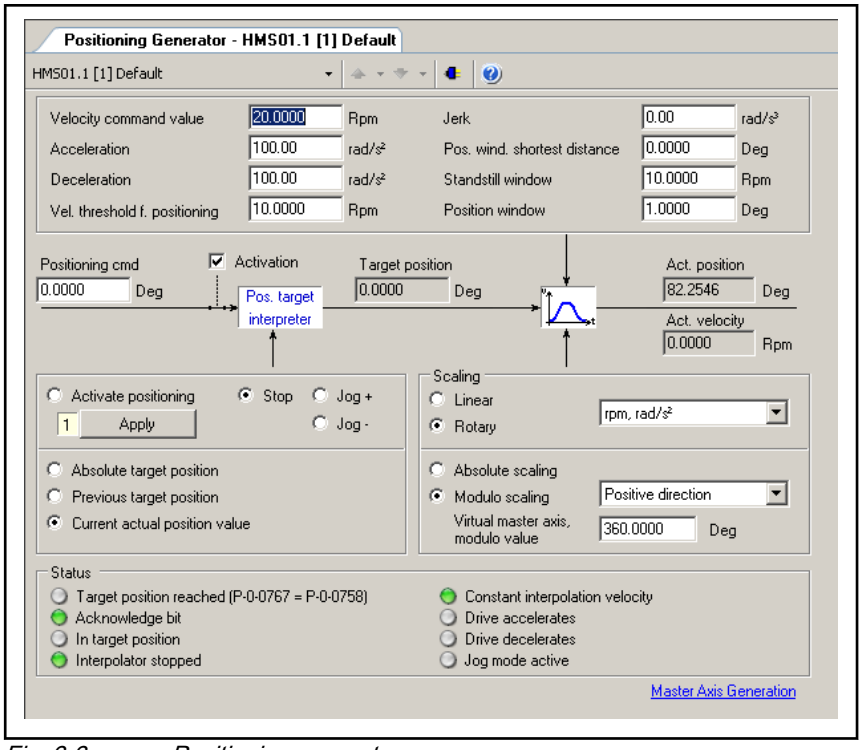

Fig. 3-3: Positioning generator

3.3 Order information/reference lists

3.3.1 IndraMotion MLC control

Description	Hardware type code	Firmware type codes
IndraMotion MLC based on IndraControl L25		
IndraControl CML25.1	CML25.1-3N-400-NN-NNC1-NW	FWA-CML25*-MLC-11VRS-D0
IndraMotion MLC based on IndraControl L45		
IndraControl CML45.1	CML45.1-3P-500-NA-NNNN-N	FWA-CML45*-MLC-13VRS-D0
IndraControl CML45.1 (with 8 MB S-RAM)	CML45.1-3P-504-NA-NNNN-N	
IndraMotion MLC based on IndraControl L65		
IndraControl CML65.1	CML65.1-3P-500-NA-NNNN-N	FWA-CML65*-MLC-13VRS-D0
IndraControl CML65.1 (with 8 MB S-RAM)	CML65.1-3P-504-NA-NNNN-N	

Tab. 3-1: Firmware for the control hardware variants

3.3.2 IndraDrive

The following firmware versions of the drives are supported by the MLC system:

- FWA-INDRV*-MPH-06VRS-D5-1-SNC-NN
- FWA-INDRV*-MPD-06VRS-D5-1-SNC-NN
- FWA-INDRV*-MPB-06VRS-D5-1-SNC-NN
- FWA-INDRV*-MPC-06VRS-D5-1-SNC-NN

- FWA-INDRV*-MPH-07VRS-D5-1-SNC-NN
- FWA-INDRV*-MPD-07VRS-D5-1-SNC-NN
- FWA-INDRV*-MPB-07VRS-D5-1-SNC-NN
- FWA-INDRV*-MPC-07VRS-D5-1-SNC-NN
- FWA-INDRV*-MPH-08VRS-D5-1-SNC-NN
- FWA-INDRV*-MPD-08VRS-D5-1-SNC-NN
- FWA-INDRV*-MPB-08VRS-D5-1-SNC-NN
- FWA-INDRV*-MPC-08VRS-D5-1-SNC-NN
- FWA-INDRV*-MPB-17VRS-D5-1-SNC-NN
- FWA-INDRV*-MPM-17VRS-D5-1-SNC-NN
- FWA-INDRV*-MPC-17VRS-D5-1-SNC-NN
- FWA-INDRV*-MPB-18VRS-D5-1-SNC-NN
- FWA-INDRV*-MPM-18VRS-D5-1-SNC-NN
- FWA-INDRV*-MPC-18VRS-D5-1-SNC-NN
- FWA-INDRV*-MPB-19VRS-D5-1-SNC-NN
- FWA-INDRV*-MPC-19VRS-D5-1-SNC-NN

3.3.3 MLD control

The multi-axis control MLD-M are supported for the following versions:

- FWA-INDRV*-MPC-07VRS-D5-1-SNC-NN
- FWA-INDRV*-MPC-08VRS-D5-1-SNC-NN
- FWA-INDRV*-MPC-17VRS-D5-1-SNC-NN

The following versions are supported for the single-axis control MLC-S:

- FWA-INDRV*-MPH-07VRS-D5-1-SNC-NN
- FWA-INDRV*-MPH-08VRS-D5-1-SNC-NN
- FWA-INDRV*-MPM-17VRS-D5-1-SNC-NN

4 Functional description

4.1 Overview on winder functions

A winder application normally consists of a control, a winding drive, a material web and sensors if necessary. The web should be wound or unwound with a defined tension. The winding diameter changes continuously. The control calculates the current diameter using multiple system variables and controls the motor speed so that the web tension remains constant. If higher performance and tension accuracy or tension constancy are demanded, use additional sensors such as a dancer roll or a tension load cell.

The center-driven winder is the state-of-art today. That means a motor drives the central shaft of the winder. With regard to control technology, this is more difficult to be controlled than the so-called surface-driven winder (drive shaft at the circumference of the winder), but it is the more effective and, mechanically, the more simple variant.

There are different control methods for the center-driven winder:

1. Winder with closed-loop dancer position control and dancer roll
2. Winder with open-loop tension control (without sensor)
3. Winder with closed-loop tension control and torque limitation
4. Winder with closed-loop tension control and speed correction

Each control method has advantages and disadvantages.

Criteria to select the suitable control concept

Control concept	Open-loop tension control (without sensor)	Closed-loop tension control and torque limitation	Closed-loop tension control and speed correction	Closed-loop dancer position control with dancer roll
Note on the actual tension value detection	No actual tension value detection required	Sensitive to overload, Does not interfere with the web characteristics	Sensitive to overload Does not interfere with the web characteristics	Does interfere with the web characteristics Material storing capacity
Winding ratio D_{max}/ D_{core}	Up to approx. 10:1, Good compensation of changes in velocity and friction required	Up to approx. 15:1 Good compensation of changes in velocity and friction required	Up to approx. 15:1	Up to approx. 15:1
Tension range F_{max}/F_{min}	Up to approx. 6:1 Good compensation of changes in velocity and friction required	Up to approx. 20:1	Up to approx. 20:1	Can only be changed via active force on the dancer roll
Winding ratio of the tension range $D_{max}/ D_{core} * F_{max}/F_{min}$	Up to approx. 40:1	Up to approx. 100:1 Depends mostly on the quality of the actual tension value signal	Up to approx. 100:1 Depends mostly on the quality of the actual tension value signal	Depends on the structure of the dancer Up to approx. 40:1

Functional description

Control concept	Open-loop tension control (without sensor)	Closed-loop tension control and torque limitation	Closed-loop tension control and speed correction	Closed-loop dancer position control with dancer roll
Web velocity	Up to 600 m/min At good compensation	Up to approx. 2000 m/min At good compensation of changes in velocity	Up to above 2000 m/min	Up to above 2000 m/min
Control procedure preferably used for:	Sheet metal, textile, paper	Paper, thin foils	Elastic, expandable material	Rubber, cable, wire, textile, foils, paper

Tab. 4-1: Criteria to select the suitable control concept

☞ When designing the drive, avoid overdimensioning for winders with torque limitation (winder with open-loop tension control (without sensor) and closed-loop tension control.

Consider the tension range (F_{max}/F_{min}) as well as the winding ratio (D_{max}/D_{core})!

4.2 Winder with dancer position controller

4.2.1 Introduction and overview

The diameter calculator with dancer is used for center-driven winders. The tension is specified by a force which acts upon the movable part of the dancer. Apply this force by a weight, a spring or a pneumatic element. The closed-loop control of the dancer position is performed in the dancer position controller. The actual value of the dancer position is recorded for example via an analog channel and is transferred to the closed-loop control.

The current winding diameter is calculated by an internally integrated diameter calculator. The velocity of the winding axis is adjusted using the calculated winding diameter. Thus, the calculated winding diameter replaces an actual diameter recorded via a sensor system.

The diameter calculator with dancer thus represents a combination of a winder (represented by the winding axis and the diameter calculator) and a dancer position controller. The diameter calculator influences the gear fine adjustment and the dancer position controller influences the additive speed command value.

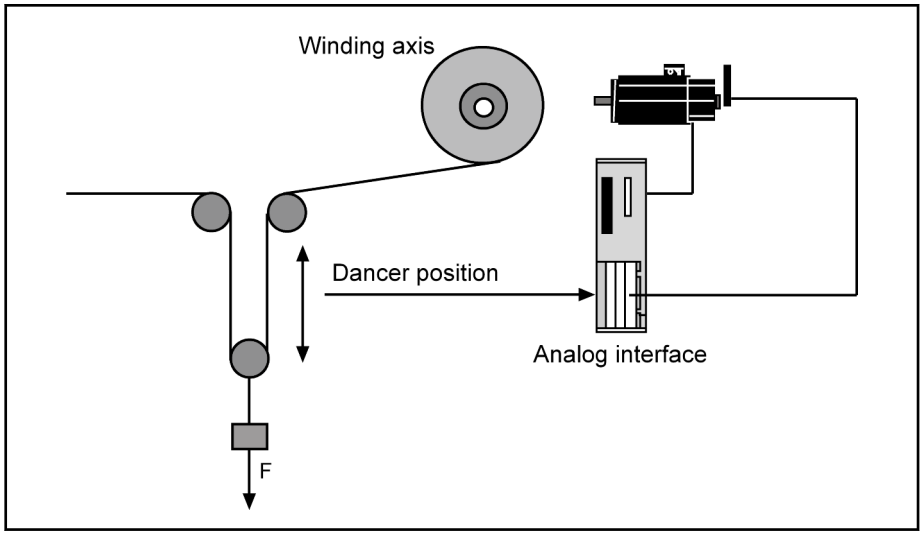

Fig. 4-1: Principle of the diameter calculator with dancer position controller

4.2.2 Interfaces of the winder with dancer

Interface description

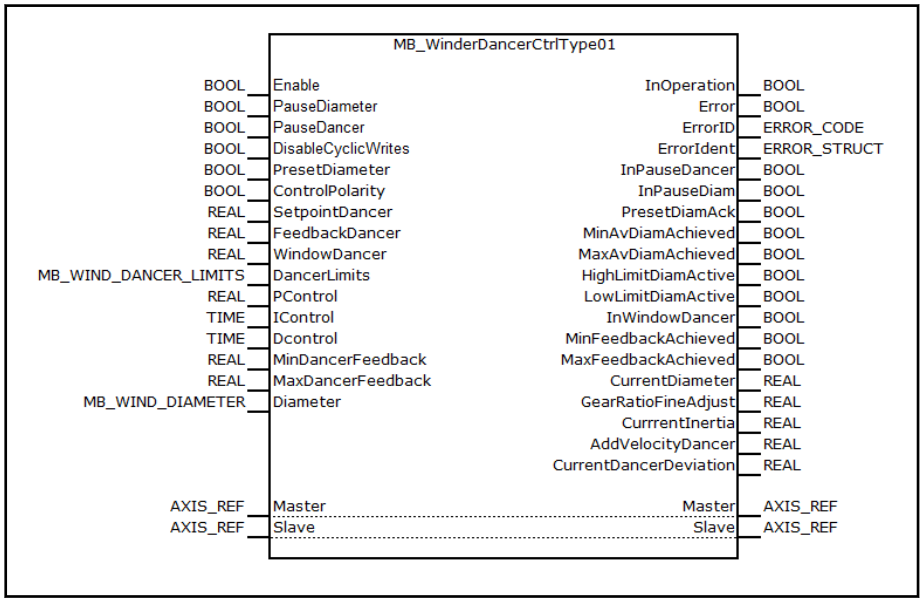

Fig. 4-2: MB_WinderDancerCtrlType01 function block

I/O type	Name	Type	Comment
VAR_INPUT	Enable	BOOL	Processing of function block enabled (level-controlled)
	PauseDiameter	BOOL	Diameter calculator paused; no further diameter calculation and velocity adjustment (level-controlled)
	PauseDancer	BOOL	Dancer controller paused (level-controlled)
	DisableCyclicWrites	BOOL	If this input is set, the cyclic data is not written directly to the optional cyclic data container, but only displayed at the output
	PresetDiameter	BOOL	CurrentDiameter is set to PresetVal. GearRatioFineAdj is adjusted accordingly (edge-controlled)
	ControlPolarity	BOOL	Polarity of the closed-loop dancer control is inverted (applied at a positive edge of "Enable")

Functional description

I/O type	Name	Type	Comment
	SetpointDancer	REAL	Command value (setpoint) for the closed-loop dancer control
	FeedbackDancer	REAL	Actual value (feedback) for the dancer position
	WindowDancer	REAL	Window to monitor the actual dancer position value [%] with regard to the command dancer position value. If the dancer position deviates from the command value by more than the given value, the function block reports this deviation by resetting the "InWindow" output
	DancerLimits	MB_WIND_DANCER_LIMITS	Structure for the automatic control variable limitation of the dancer
	PControl	REAL	Value for the Kp-gain of the closed-loop dancer control
	IControl	TIME	Value for the integral action time of the closed-loop dancer control
	DControl	TIME	Value for the derivative time of the closed-loop dancer control
	MinDancerFeedback	REAL	Lower threshold for the actual dancer value (only for a display with binary output).
	MaxDancerFeedback	REAL	Upper threshold for the actual dancer value (only for a display with binary output).
	Diameter	MB_WIND_DIAMETER	Structure for diameter calculator
VAR_OUTPUT	InOperation	BOOL	Function block is operating
	Error	BOOL	Processing completed with error
	ErrorID	ERROR_CODE	Diagnostic description in the event of an error
	ErrorIdent	ERROR_STRUCT	Detailed diagnostics
	InPauseDancer	BOOL	Dancer controller pausing
	InPauseDiam	BOOL	Diameter calculator paused
	PresetDiamAck	BOOL	Preset diameter was applied (is set provided "Preset" is pending)
	MinAvDiamAchieved	BOOL	Minimum diameter reached (based on the averaged diameter)
	MaxAvDiamAchieved	BOOL	Maximum diameter reached (based on the averaged diameter)
	HighLimitDiamActive	BOOL	Currently calculated diameter has reached the upper limit (Diameter value is discarded)
	LowLimitDiamActive	BOOL	Currently calculated diameter has reached the lower limit (diameter value is discarded)
	InWindowDancer	BOOL	Actual dancer value within dancer window

I/O type	Name	Type	Comment
	MinFeedbackAchieved	BOOL	Actual value of the dancer position is below the input "MinDancerFeedback"
	MaxFeedbackA-chieved	BOOL	Actual value of the dancer position is above the input "MaxDancerFeedback"
	CurrentDiameter	REAL	Current winding diameter
	GearRatioFineAdjust	REAL	Fine gear adjustment for speed tracing of the drive [%]
	CurrentInertia	REAL	Current moment of inertia of the winding material + mechanics (based on the motor side) [kg m^2]
	AddVelocityDancer	REAL	Speed offset for the winding drive [rpm]
	CurrentDancerDevia-tion	REAL	Current control deviation of the dancer controller
VAR_IN_OUT CONSTANT	Master	AXIS_REF	Reference to master axis
	Slave	AXIS_REF	Reference to the slave axis (winding axis)

Tab. 4-2: Interface variables of the MB_WinderDancerCtrlType01 function block

Another function block

Another function block is additionally available for the winder with dancer. The standardization of the dancer position controller does not depend on the diameter calculator. Additional diagnostic outputs are also available for the dancer position controller.

Interface description

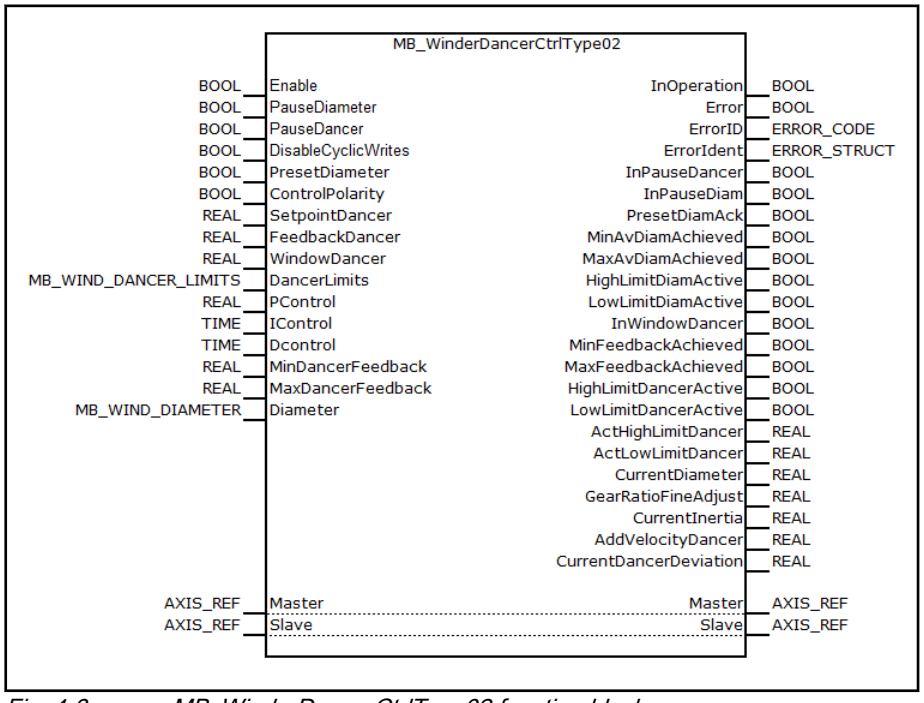

Fig. 4-3: MB_WinderDancerCtrlType02 function block

Functional description

I/O type	Name	Type	Comment
VAR_INPUT	Enable	BOOL	Processing of function block enabled (level-controlled)
	PauseDiameter	BOOL	Diameter calculator paused; no further diameter calculation and velocity adjustment (level-controlled)
	PauseDancer	BOOL	Dancer controller paused (level-controlled)
	DisableCyclicWrites	BOOL	If this input is set, the cyclic data is not written directly to the optional cyclic data container, but only displayed at the output
	PresetDiameter	BOOL	CurrentDiameter is set to PresetVal. GearRatioFineAdj is adjusted accordingly (edge-controlled)
	ControlPolarity	BOOL	Polarity of the closed-loop dancer control is inverted (applied at a positive edge of "Enable")
	SetpointDancer	REAL	Command value (setpoint) for the closed-loop dancer control
	FeedbackDancer	REAL	Actual value (feedback) for the dancer position
	WindowDancer	REAL	Window to monitor the actual dancer position value [%] with regard to the command dancer position value. If the dancer position deviates from the command value by more than the given value, the function block reports this deviation by resetting the "InWindow" output
	DancerLimits	MB_WIND_DANCER_LIMITS	Structure for the automatic control variable limitation of the dancer
	PControl	REAL	Value for the Kp-gain of the closed-loop dancer control
	IControl	TIME	Value for the integral action time of the closed-loop dancer control
	DControl	TIME	Value for the derivative time of the closed-loop dancer control
	MinDancerFeedback	REAL	Lower threshold for the actual dancer value (only for a display with binary output).
	MaxDancerFeedback	REAL	Upper threshold for the actual dancer value (only for a display with binary output).
	Diameter	MB_WIND_DIAMETER	Structure for diameter calculator
VAR_OUTPUT	InOperation	BOOL	Function block is operating
	Error	BOOL	Processing completed with error
	ErrorID	ERROR_CODE	Diagnostic description in the event of an error
	ErrorIdent	ERROR_STRUCT	Detailed diagnostics
	InPauseDancer	BOOL	Dancer controller pausing
	InPauseDiam	BOOL	Diameter calculator paused
	PresetDiamAck	BOOL	Preset diameter was applied (is set provided "Preset" is pending)

I/O type	Name	Type	Comment
	MinAvDiamAchieved	BOOL	Minimum diameter reached (based on the averaged diameter)
	MaxAvDiamAchieved	BOOL	Maximum diameter reached (based on the averaged diameter)
	HighLimitDiamActive	BOOL	Currently calculated diameter has reached the upper limit (Diameter value is discarded)
	LowLimitDiamActive	BOOL	Currently calculated diameter has reached the lower limit (diameter value is discarded)
	InWindowDancer	BOOL	Actual dancer value within dancer window
	MinFeedbackAchieved	BOOL	Actual value of the dancer position is below the input "MinDancerFeedback"
	MaxFeedbackA-chieved	BOOL	Actual value of the dancer position is above the input "MaxDancerFeedback"
	HighLimitDancerActive	BOOL	Limit of speed offset "HighLimit " is active
	LowLimitDancerActive	BOOL	Limit of speed offset "LowLimit " is active
	ActHighLimitDancer	REAL	Current value for the upper limit of the speed offset
	ActLowLimitDancer	REAL	Current value for the lower limit of the speed offset
	CurrentDiameter	REAL	Current winding diameter
	GearRatioFineAdjust	REAL	Fine gear adjustment for speed tracing of the drive [%]
	CurrentInertia	REAL	Current moment of inertia of the winding material + mechanics (based on the motor side) [kg m^2]
	AddVelocityDancer	REAL	Speed offset for the winding drive [rpm]
	CurrentDancerDevia-tion	REAL	Current control deviation of the dancer controller
VAR_IN_OUT CONSTANT	Master	AXIS_REF	Reference to master axis
	Slave	AXIS_REF	Reference to the slave axis (winding axis)

Tab. 4-3: Interface variables of the MB_WinderDancerCtrlType02 function block

Functional description

Functional diagram:

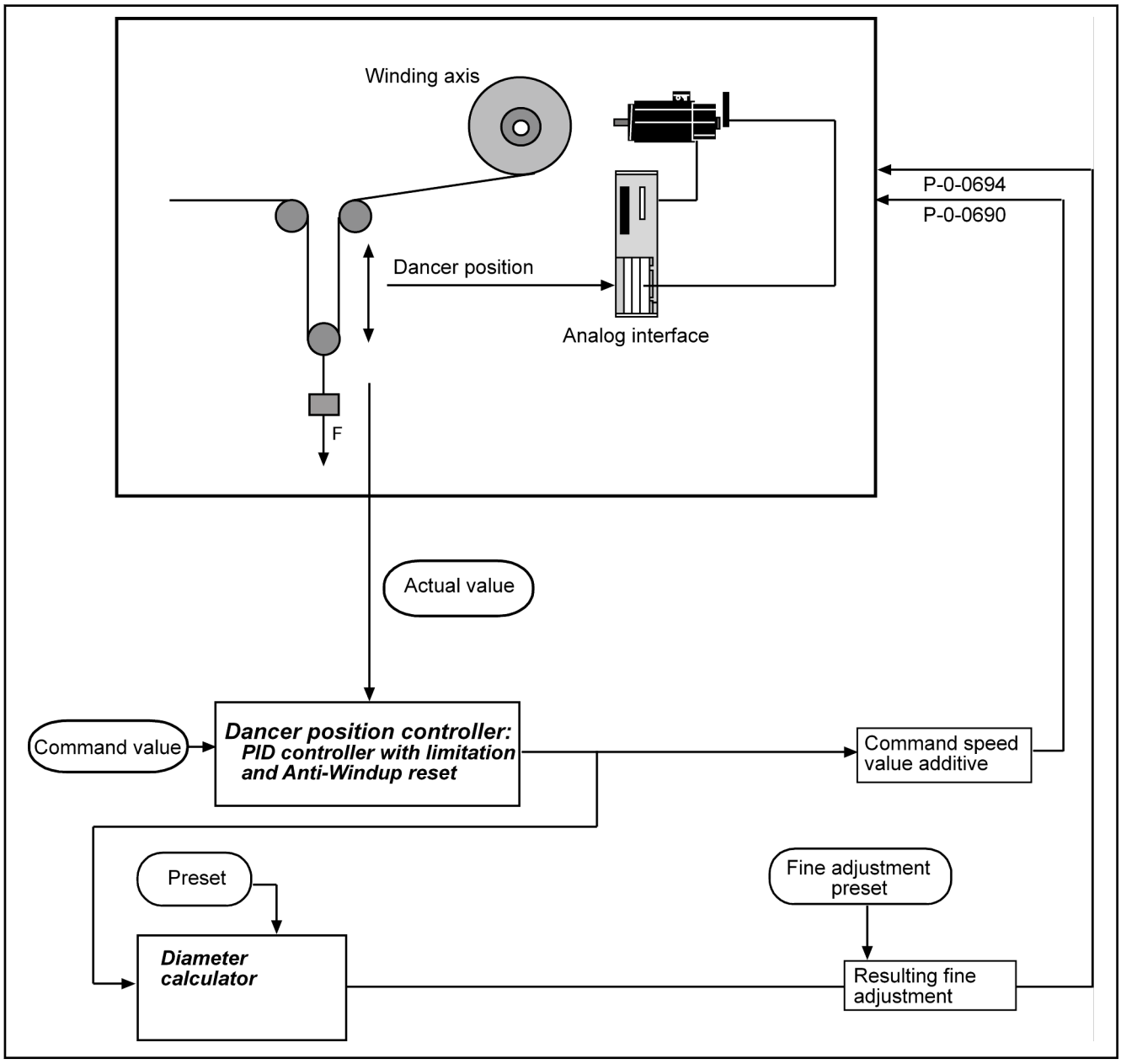

Fig. 4-4: Functional diagram of the diameter calculator with dancer

4.2.3 Commissioning the winder with dancer

General settings

Mechanical gear

An actual existing mechanical gear ratio from the drive axis to the winding axis has to be written to the parameters S-0-0121 ("Input revolutions of load gear") and S-0-0122 ("Output revolutions of load gear").

Operation mode of the winding drive (commanding)

Set the correct operation mode "Speed Synchronization" of the drive and the drive enabled for the winding axis. There are two ways:

- Set the "ModeSyncVel" operation mode using the AxisInterface (recommended)
- Use the PLCopen "MC_Power", "MC_GearIn", "MC_Stop" function blocks to command the axis

Set the electronic gear between master and winding axis to 1:1 for the winding axis (A-0-2720 "ELS, master axis gear, input revolutions" or P-0-0156 "Electronic gear input revolutions" and A-0-2721 "ELS, master axis gear, output revolutions" or P-0-0157 "Electronic gear, output revolutions").

Setting the speed control loop

Perform the following for an empty and full roll:

- Set Tn to 0 and let the winding axis rotate freely at low speed.
- The parameter S-0-0100 "Velocity controller proportional gain" starts slowly from the default value until an oscillation of the velocity control deviation is detected at the oscilloscope.
- If the oscillation frequency is significantly higher than 500 Hz, the parameter P-0-0004 "Smoothing time constant - speed controller" is increased until the oscillation decreases again.

  In general, set the parameter P-0-0004 "Smoothing time constant - speed controller" to a minimum value of 1000.
- In this case, increase the parameter S-0-0100 "Velocity controller, proportional gain" until the control loop becomes instable again and then reduce it until the oscillation decays. Set the P-gain to the half of the last value set to be sufficiently far away from the stability limit.
- Decrease S-0-0101 "Velocity controller integral action time" starting from a relative high value (e.g. 1000 ms) until the control loop becomes instable and then increase it until the oscillation decreases. Enter twice the value as value for the parameter S-0-0101 "Velocity controller integral action time". The integral action time should not be lower than 150 ms.

Select the control loop setting of the drives accordingly to ensure that both extreme cases (minimum diameter and maximum diameter) can be operated with stability.

Otherwise, these two values can be linearly adapted to each other depending on the current diameter (function block MB_WindSpeedAdaptionType01).

Determining the direction of rotation of the winding axis

Set the direction of rotation of the tension or winding axis using the axis parameter A-0-2798 "Polarity of master axis position" or the drive parameter P-0-0108 "Master drive polarity". If the winding axis does not rotate in the desired direction, set the axis parameter A-0-2798 or the drive parameter P-0-0108 accordingly.

When inverting the drive direction of rotation, it might also be required to invert the control direction of the dancer position controller ("ControlPolarity" input).

The following figure shows the principal relations between rewinders and unwinders

Functional description

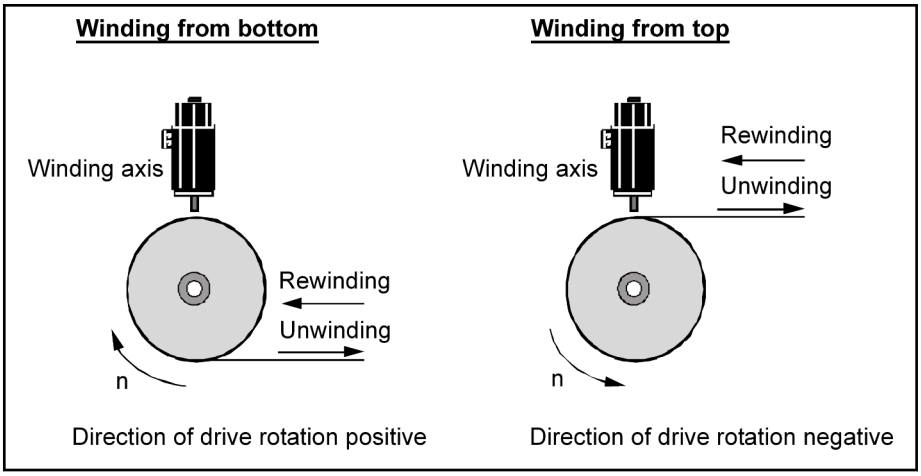

Fig. 4-5: Principles of rewinders and unwinders

Actual value detection of the dancer position

The dancer position is generally read in via an analog input. The analog input can either be read in at the drive (onboard analog input or via an MA1 extension card) or via an Inline analog input module of the control.

The actual value detection only processes positive actual values. It might be required to add an offset to the read value to ensure this over the complete range (e.g. offset is 0.1 volt). If the command value is specified in volt, a standardization factor is not required. If the command value is specified in mm, a standardization factor from volt to mm is required (e.g. 10 volt correspond to 200 mm; that is a standardization factor of 20 mm/V).

Filter this actual value in case of strong variation using a PT1-filter (e.g. 20 ms). If the analog input is read in at the drive, the filter in the drive is to be preferably used. For analog input 1, this is set in the parameter P-0-0217 "Analog input 1, time constant input filter". If the analog input is read in at the control, a PT1-filter function block can be used in the PLC library "RIL_LoopControl.library".

Basic settings of the function block

Axis assignment

The axis reference (AXIS_REF) of the winding axis is connected to the "Slave" input.

The axis reference (AXIS_REF) of the master axis is connected to the "Master" input. This is the axis that provides the web velocity of the machine.

The scaling type has to be identical for the master and the slave axis. Rotary and preference scaling are recommended.

For the winding axis, the interpolation in the drive has to be enabled for the MLC control.

Setting rewinders or unwinders

There is no separate input to set rewinders and unwinders. It is switched between rewinders or unwinders via the "ControlPolarity" input. See also "Determining the direction of rotation".

Determining the dancer command value

The "SetpointDancer" input is specified in such a way that the dancer roll is located in the center position if the control deviation of the dancer "CurrentDancerDeviation" is approximately zero.

The unit of the dancer command value is identical to the actual dancer value. That means that if the actual value is read in in volt, the command value is also read in in volt. If the actual value is read in in mm, the command value is also read in in mm.

Settings for the diameter calculator

The settings for the diameter calculator are summarized in the "MB_Wind_Diameter" structure.

To calculate the diameter, set the structure variable "DiamSource" to "FALSE". To read the diameter externally, set the structure variable "DiamSource" to "TRUE".

The core diameter of the winder (in mm) is written to the variable "CoreDiameter".

Enter the variable "RepeatLength" (in mm) for the diameter calculation. This corresponds to the circumference of the master axis.

The limitations ("HighLimit", "LowLimit") can additionally be entered for the diameter calculation. This limits the diameter to a minimum (e.g. core diameter) and to a maximum value (e.g. maximum winding roll possible).

Set the standstill window of the master axis (parameter A-0-0222 "Standstill window" or S-0-0124 "Standstill window") to the lowest value possible (e.g. 0.1 rpm). When there is a standstill message of the master or reference axis, the diameter calculator does not calculate!

Furthermore, enter the web width "WebWidth" (in mm) and the density "Density" (in kg/dm^3) of the material web.

The diameter calculation can be influenced via the calculation range "CalcRange" and an average value filter "AverageValue". At the beginning, there is a "CalcRange" of 360 degrees. Thus, **one calculation per winding axis revolution** and an "AverageValue" of 1 (an averaging) is not reasonable.

The diameter is only calculated if the material web is tensioned. That means that the binary output "DiameterEngaged" has to be set.

The ratio "RepeatLength"/"CoreDiameter" may not be greater than 25.

Otherwise, the gear adjustment via the gear fine adjustment is insufficient!

A relative motion of a dancer roll (applies only to winders with dancer) is considered when calculating the diameter using the "DancerConstant" variables. Determine this dancer constant once for a winder with dancer.

First, set the dancer constant "DancerConstant" to zero (default)

Set the "DancerConstant" value always to zero for the winders with open-loop and closed-loop tension control.

Control variable limitation for the dancer position controller

To avoid higher deflection of the dancer roll (e.g. switch-on procedure of the dancer controller, chop at the flying splice), set a velocity-dependent limitation for the dancer position controller.

The limitations are summarized in the MB_WIND_DIAMETER structure. A value (in rpm) for the lower limitation of the dancer controller output (e.g.10 rpm) has to be written to the variable "LowLimitControl". This value is the decisive factor for the limitation of the switch-on process. A value (in rpm) for the upper limitation of the dancer controller output (e.g. 200 rpm) has to be written to the variable "HighLimitControl". There is also a master axis velocity "VelocityHighLimit" (e.g. setup velocity of the machine) belonging to this value. There is linear interpolation between "LowLimitControl" and "HighLimitControl".

Functional description

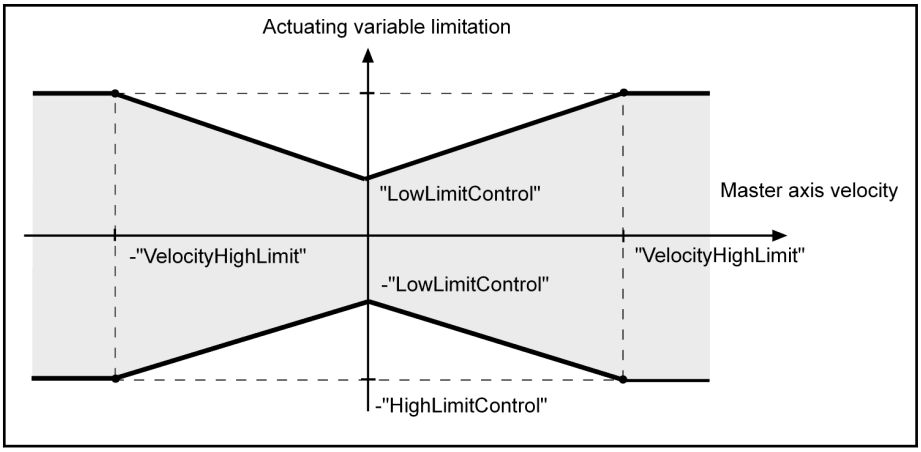

Fig. 4-6: Control variable limitation of the dancer position controller

Control variable limitation

The control variable can be limited in both the following function block types:

- MB_WindDancerCtrlType01
- MB_WindDancerCtrlType02

The both function blocks applies:

The control variable limitation of the dancer position controller is dynamically adjusted according to the reference axis velocity and the diameter ratio. This means that at higher velocity, the limitation of the additive velocity of the dancer position controller is automatically higher than at lower velocity. The consideration of the diameter ratio causes the limitation for winding applications being automatically adapted to the changing winding diameter.

MB_WindDancerCtrlType01

For the diameter ratio, the following calculation applies:

RepeatLength / (Pi * CurrentDiameter)

MB_WindDancerCtrlType02

For the diameter ratio, the following calculation applies:

MinRefDiameter / CurrentDiameter

Additionally, the binary outputs "ActHighLimitVal" and "ActLowLimitVal" show the current values for the limitation.

Cyclic data channels for the winding drive

Interpolation in the drive:

Write the **parameters P-0-0694 ("Gear ratio fine adjustment, process controller")** and **P-0-0690 ("Additive velocity command value, process controller"**) to the cyclic Sercos channel of the respective drive ("UserCmdDataX"). The real axes are parameterized in the parameterization mode in IndraWorks.

Interpolation in the control:

No parameter may have been written to the cyclic Sercos channel of the respective drive. The target variables are the control parameters **A-0-2605 "ELS, gear ratio fine adjustment, process controller"** and **A-0-2615 "ELS, additive velocity command value, process controller"**.

The function block automatically sets these two parameters. If this is not desired, switch it off via the "DisableCyclicWrites" input. In this case, set the outputs "GearRatioFineAdjust" and "AddVelocityDancer" manually to the corresponding parameters.

Final basic settings

Set the P-gain of the dancer position controller "PControl" to 1.0 for the initial commissioning.

Set the process variable window "WindowDancer" to 20 % for example. If the actual dancer value is within the range of the dancer command value +/- 20%, this is displayed at the "InWindowDancer" output.

Set the minimum and maximum thresholds "MinDancerFeedback" and "MaxDancerFeedback" for the actual dancer value to the values permitted for the

dancer roll (absolute values in the dancer command value unit). Exceeding or falling below the actual dancer value is then displayed in the binary outputs "MinFeedbackAchieved" and "MaxFeedbackAchieved".

The moment of inertia of mechanics and winding shaft "MechanicInertia" can be set to 0 at the beginning.

Operating the function block

Initial startup of the winding axis

1. "Enable" of the function block for the winder with dancer. "Preset" of the diameter to the desired value

   (with the binary signal "PresetDiameter" and the value "Diameter.PresetVal").
2. Switch on the synchronous operation modes of all axes participating in the web process (for the winding axis "Speed synchronization" and "ModeSyncVel").
3. The dancer roll has to move into the direction of the center position and the web has to be tensioned.

   Otherwise, check the dancer command value "DancerSetpoint" and the input "ControlPolarity".
4. Synchronous run of the machine via specification of a velocity command value for the master axis (MoveVelocity for the master axis with 20 rpm for example). The web has to remain tensioned.
5. Check the calculated winding diameter after several winding axis revolutions.

   If the calculated diameter deviates more than 5 % from the actual diameter, check the mechanical gear and the "RepeatLength" of the master.
6. Stop the machine by setting the master axis command value to zero.

Setting the dancer control loop

1. "Enable" of the function block for the winder with dancer.
2. Switch on the synchronous operation modes of all axes participating in the web process (for the winding axis "Speed synchronization" and "ModeSyncVel").
3. The dancer roll has to move into the direction of the center position and the web has to be tensioned.
4. **Open the dancer limitations**, that means "LowLimitControl" and "HighLimitControl" to 1000 rpm.
5. Increase the p-gain "PControl" of the dancer position controller until the dancer roll starts oscillating (excitation of the oscillation might be required). Subsequently, reduce the p-gain until the oscillation decays again. Reduce this critical "PControl" by approximately 50 %. Subsequently, add command value jumps to the dancer command value "DancerSetpoint" and observe the oscillation behavior (recording with oscilloscope or trace if required). Optimize "PControl" accordingly later on if required.

   Enter a lead time "DControl" if required. The minimum value is the cycle time for the MB_WinderDancerCtrlType01 function block. The higher the "DControl" value, the more powerful the controller.

   Enter an integral action time "IControl", if required. A value within the range of seconds (e.g. one second).

   Optimize these values later on if necessary using a jump response (command value jump) and an oscilloscope recording.
6. Enter these values again for the **dancer limitations**.

Functional description

7. Check the values determined at a rotating machine or master axis. Travel along the velocity profile of the master axis and correct the controller values if required.

Setting the dancer constant

1. In case of dancer deflection from one end position to the other end position, determine the required web distance (in mm).
2. Determine the difference between the two actual dancer values of the respective end position.
3. Calculate the quotient of both values.
4. Determine the sign of the dancer constant by conducting a practical test. For this purpose, the diameter calculation is observed at a slowly rotating winding axis and reference axis. Command value jumps to the dancer command value should not have a significant influence on the calculation of the diameter if the sign is correct.
5. "Subsequently optimize" the calculated value for the dancer constant as described in step 4 if required.

Basic sequence of a "flying splice"

A so-called "flying splice" is a change from a roll to a new roll when the material web is still moving which can be performed according to the following basic diagram:

(two winding axes and two winding function blocks are required).

1. Currently unwinding roll reaches critical diameter for chopping.
2. Switch on the respective winding function block for the new roll and preset the diameter with the diameter of the new roll. Subsequently, set the "Pause" input.
3. Command the winding axis of the new roll and accelerate to the current web velocity.
4. Perform the material chopping (separating the unwinding roll from the web) and stick the new roll.
5. Disable the "Pause" input of the winding function block for the new roll.

   The function block can be switched off for the old roll.

4.2.4 Diagnostics for the winder with dancer

The following error codes can result for the winder with open-loop tension control (without sensor):

ErrorID	Additional1	Additional2	Text
STATE_MACHINE_ERROR	16#1160	16#0020	Error in state machine
INPUT_RANGE_ERROR	16#1161	16#0002	HighLimit < LowLimit
		16#0003	FormatLength < 0.0
		16#0004	ReferenceDiameter < 0.0
		16#0005	ProcessWindow < 0.0
		16#0006	HighLimit < 0.0
		16#0007	LowLimit < 0.0
		16#0008	VelocityHighLimit < 0.0
		16#0009	P-Gain < 0.0
		16#000A	Setpoint < 0.0
		16#000B	MinFeedback < 0.0
		16#000C	MaxFeedback < 0.0
		16#000D	MaxFeedback < MinFeedback
		16#000E	Number of slave axis incorrect
		16#000F	Number of master axis incorrect
DEVICE_ERROR	16#1162	16#0001	Axis not in operating mode
RESSOURCE_ERROR	16#0004	16#0000	Incorrect drive firmware
RESSOURCE_ERROR	16#000F	16#0003	Drive function package "MA" not enabled

Tab. 4-4: Error codes of the MB_DancerControlType03 function block

ErrorID	Additional1	Additional2	Text
STATE_MACHINE_ERROR	16#1100	16#0020	Error in state machine
INPUT_RANGE_ERROR	16#1101	16#0001	HighLimitDiameter < LowLimitDiameter
		16#0002	FormatLength < 0.0
		16#0003	WebWidth < 0.0
		16#0004	Density < 0.0
		16#0005	Core diameter < 0.0
		16#0006	DiamCalcRange < 0.0
		16#0007	Preset diameter < 0.0
		16#0008	Minimum diameter < 0.0
		16#0009	Maximum diameter < 0.0
		16#000A	HighLimitDiameter < 0.0
		16#000B	LowLimitDiameter < 0.0
		16#000C	DiamCalcMode invalid
		16#000D	Number of slave axis incorrect
		16#000E	Number of master axis incorrect
DEVICE_ERROR	16#1102	16#0001	No operating mode (no sercos phase 4)

Functional description

ErrorID	Additional1	Additional2	Text
RESSOURCE_ERROR	16#0004	16#0000	Incorrect drive firmware
RESSOURCE_ERROR	16#000F	16#0003	Drive function package "MA" not enabled

Tab. 4-5: Error codes of the MB_DiameterCalculatorType03 function block

4.3 Winders with open-loop tension control (without sensor)

4.3.1 Introduction and overview

Diameter calculator with open-loop tension control

The diameter calculator with open-loop tension control is used for center-driven winders. The drive of the winding axis generally operates at its torque limit. The torque limit depends on the current winding diameter and the tension set.

The tension is generated by adjusting the torque of the winding axis. Additional measuring elements are not required.

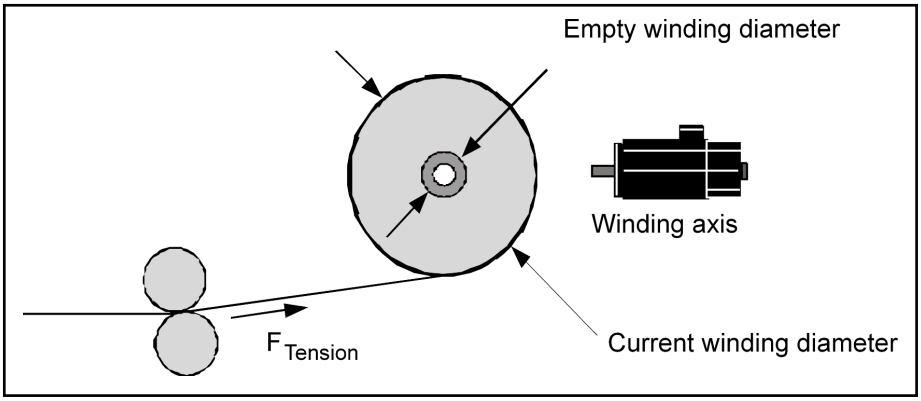

Fig. 4-7: Diameter calculator with open-loop tension control

4.3.2 Interfaces of the winder with open-loop tension control (without sensor)

Interface description

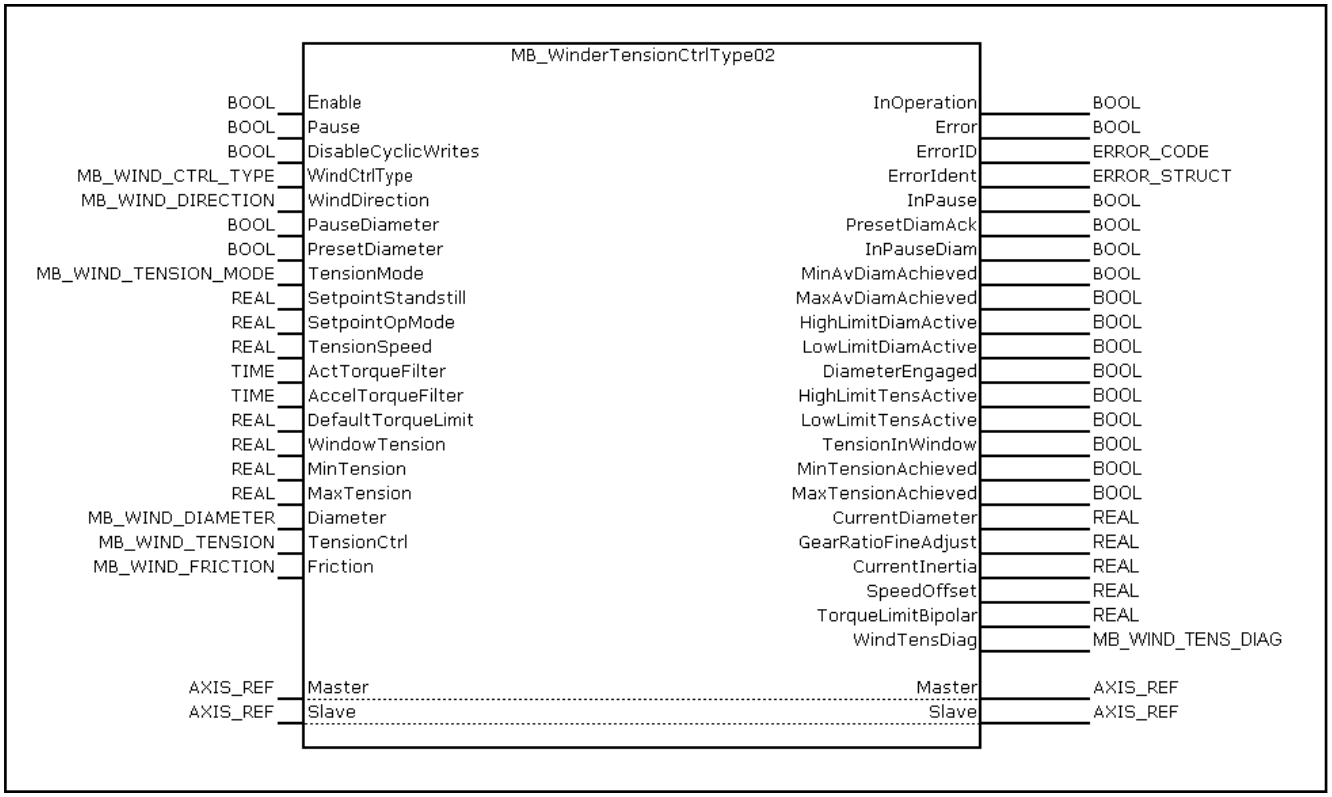

Fig. 4-8: MB_WinderTensionCtrlType02 function block

I/O type	Name	Type	Comment
VAR_INPUT	Enable	BOOL	Processing of function block enabled (level-controlled)
	Pause	BOOL	Pausing the tension controller and the diameter calculator (values are frozen)
	DisableCyclicWrites	BOOL	If this input is set, the cyclic data is not written directly to the optional cyclic data container, but only displayed at the output
	WindCtrlType	MB_WIND_CTRL_TYPE	Winding structure Open-loop tension control (without sensor) OPEN_LOOP (16#0000) Closed-loop tension control (load cell) CLOSED_LOOP (16#0001)
	WindDirection	MB_WIND_DIRECTION	Winding direction Rewinder REWIND (16#0000) Unwinder UNWIND (16#0001)
	PauseDiameter	BOOL	Pausing the diameter calculation Closed-loop/open-loop control of the torque limit remains active
	PresetDiameter	BOOL	CurrentDiameter is set to PresetVal. GearRatioFineAdj is adjusted accordingly (edge-controlled)

Functional description

I/O type	Name	Type	Comment
	TensionMode	MB_WIND_TEN-SION_MODE	Mode to tension the material web Tensioning at constant speed CONST_SPEED Tensioning at constant web velocity CONST_WEB_VEL
	SetpointStandstill	REAL	Specification of the standstill tension [N] (Switching between standstill tension and operating tension by means of the standstill message from the drive).
	SetpointOpMode	REAL	Specification of the operating tension [N] (Switching between standstill tension and operating tension by means of the standstill message from the drive).
	TensionSpeed	REAL	Tensioning speed at an empty winder [min^{-1}]
	ActTorqueFilter	TIME	Filter time constant for the actual torque S-0-0084 "Actual torque/force value"
	AccelTorqueFilter	TIME	Filter time constant for acceleration torque
	DefaultTorqueLimit	REAL	Value for the bipolar torque limit after deactivation of "Enable" [%]
	WindowTension	REAL	Window for the actual tension value [%] related to the tension command value (output "TensionInWindow")
	MinTension	REAL	Lower threshold for the actual tension value (only for the display with binary output "MinTensionAck")
	MaxTension	REAL	Upper threshold for the actual tension value (only for the display with binary output "MaxTensionAck")
	Diameter	MB_WIND_DIAMETER	Structure for diameter calculator
	TensionCtrl	MB_WIND_TENSION	Structure for tension controller
	Friction	MB_WIND_FRICTION	Structure for friction torque
VAR_OUTPUT	InOperation	BOOL	Function block is operating
	Error	BOOL	Processing completed with error
	ErrorID	ERROR_CODE	Diagnostic description in the event of an error
	ErrorIdent	ERROR_STRUCT	Detailed diagnostics
	InPause	BOOL	Tension controller and diameter calculator pause
	PresetDiamAck	BOOL	Preset diameter was applied (is set as long as "Pre-set" is pending)
	InPauseDiam	BOOL	Diameter calculator pauses
	MinAvDiamAchieved	BOOL	Minimum diameter reached (based on the averaged diameter)
	MaxAvDiamAchieved	BOOL	Maximum diameter reached (based on the averaged diameter)
	HighLimitDiamActive	BOOL	Currently calculated diameter has reached the upper limit (diameter value is discarded)

I/O type	Name	Type	Comment
	LowLimitDiamActive	BOOL	Currently calculated diameter has reached the lower limit (diameter value is discarded)
	DiameterEngaged	BOOL	Diameter "engaged" TRUE: engaged FALSE: disengaged
	HighLimitTensActive	BOOL	Output of the tension controller reached upper limit
	LowLimitTensActive	BOOL	Output of the tension controller reached lower limit
	TensionInWindow	BOOL	Actual tension value is within the tension window
	MinTensionAchieved	BOOL	Tension is below the "MinTension" input
	MaxTensionAchieved	BOOL	Tension is above the input "MaxTension"
	CurrentDiameter	REAL	Currently calculated diameter [mm]
	GearRatioFineAdjust	REAL	Resulting fine adjustment of the gear for speed tracing of the drive [%]
	CurrentInertia	REAL	Current moment of inertia of the winding material + mechanics (based on the motor side [kg m^2]
	SpeedOffset	REAL	Tensioning speed [rpm]
	TorqueLimitBiploar	REAL	Bipolar torque limit [%]
	WindTensDiag	MB_WIND_TENS_DIAG	Current control deviation of the dancer controller
VAR_IN_OUT CONSTANT	Master	AXIS_REF	Reference to master axis
	Slave	AXIS_REF	Reference to the slave axis (winding axis)

Tab. 4-6: Interface variables of the MB_WinderTensionCtrlType02 function block

Functional description

Functional diagram:

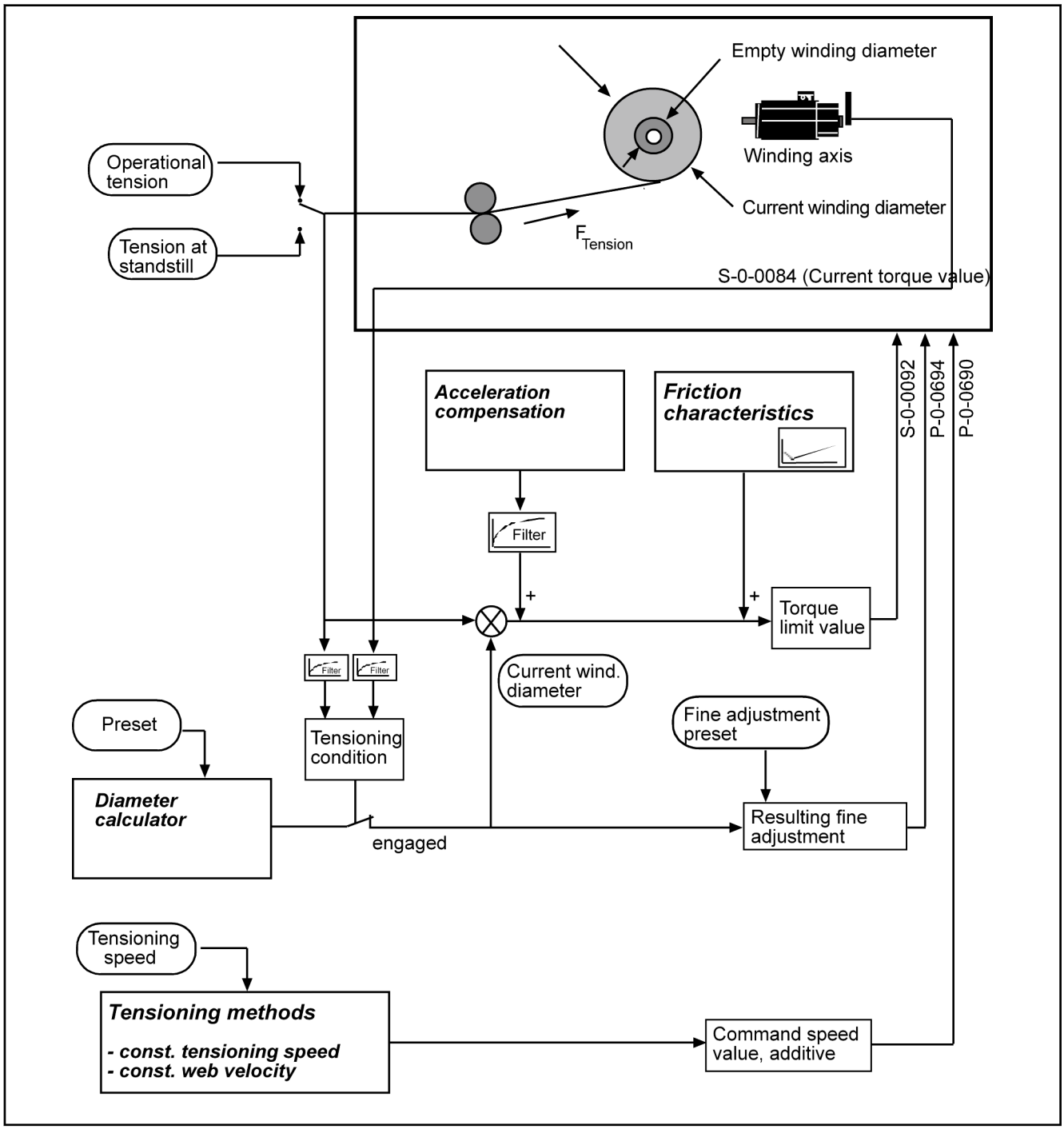

Fig. 4-9: Functional diagram of the winder with open-loop tension control

4.3.3 Commissioning the winder with open-loop tension control (without sensor)

General settings

Mechanical gear An actually existing mechanical gear ratio from the drive axis to the winding axis has to be written to the parameters S-0-0121 ("Input revolutions of load gear") and S-0-0122 ("Output revolutions of load gear").

Operation mode of the winding drive (commanding)

Set the correct operation mode "Speed Synchronization" of the drive and the drive enabled for the winding axis.

There are two ways:

- Set the "ModeSyncVel" operation mode using the AxisInterface (recommended)
- Use the PLCopen "MC_Power", "MC_GearIn", "MC_Stop" function blocks to command the axis

Set the electronic gear between master and winding axis to 1:1 for the winding axis (A-0-2720 "ELS, master axis gear, input revolutions" or P-0-0156 "Electronic gear input revolutions" and A-0-2721 "ELS, master axis gear, output revolutions" or P-0-0157 "Electronic gear, output revolutions").

Setting the speed control loop

Perform the following for an empty and full roll:

- Set Tn to 0 and let the winding axis rotate freely at low speed.
- The parameter S-0-0100 "Velocity controller proportional gain" starts slowly from the default value until an oscillation of the velocity control deviation is detected at the oscilloscope.
- If the oscillation frequency is significantly higher than 500 Hz, the parameter P-0-0004 "Smoothing time constant - speed controller" is increased until the oscillation decreases again.

  In general, set the parameter P-0-0004 "Smoothing time constant - speed controller" to a minimum value of 1000.
- In this case, increase the parameter S-0-0100 "Velocity controller, proportional gain" until the control loop becomes instable again and then reduce it until the oscillation decays. Set the P-gain to the half of the last value set to be sufficiently far away from the stability limit.
- Decrease S-0-0101 "Velocity controller integral action time" starting from a relative high value (e.g. 1000 ms) until the control loop becomes instable and then increase it until the oscillation decreases. Enter twice the value as value for the parameter S-0-0101 "Velocity controller integral action time". The integral action time should not be lower than 150 ms.

Select the control loop setting of the drives accordingly to ensure that both extreme cases (minimum diameter and maximum diameter) can be operated with stability.

Otherwise, these two values can be linearly adapted to each other depending on the current diameter (function block MB_WindSpeedAdaptionType01).

Determining the direction of rotation of the winding axis

Set the direction of rotation of the tension or winding axis using the axis parameter A-0-2798 "Polarity of master axis position" or the drive parameter P-0-0108 "Master drive polarity". If the winding axis does not rotate in the desired direction, set the axis parameter A-0-2798 or the drive parameter P-0-0108 accordingly.

The following figure shows the principal relations between rewinders and unwinders

Functional description

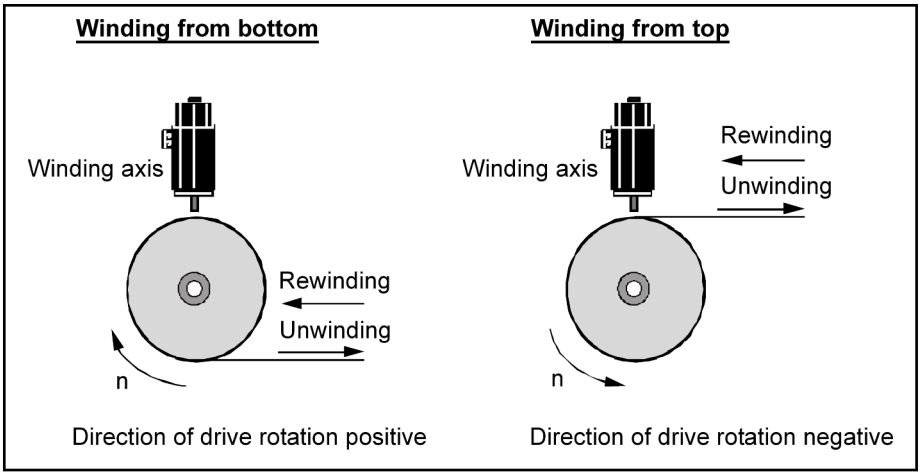

Fig. 4-10: Principles of rewinders and unwinders

Actual tension value

The actual tension value is automatically calculated by the function block (when setting MB_WIND_CTRL_MODE with "OPEN_LOOP").

Additional leading and lagging of the winding axis

Set an additional leading or lagging via the gear fine adjustment (presetting gear fine adjustment "FineAdjust") using the structure variable "qrAxisCtrl[AxisNumber].Admin.SyncMode.FineAdjust" of the "MB_AXIS_SYNCHRONISATION" data structure of the "ML_TechInterface" library. A low **positive value** (e.g. 5 %) should be set for a **rewinder** and a low **negative value** for an **unwinder**. This results in an improved startup reaction for the respective winding direction.

If the winding axis is not commanded using the AxisInterface, but with the PLCopen function blocks, use the "MasterFineAdjust" input of the "MC_GearIn" function block.

Monitoring torque limit values

At the initial control startup, a drive warning "E2056 Torque limit value = 0" can be output if the winder function block is not yet enabled.

In order to prevent this, write a value unequal to zero (e.g. 100%) to the respective cyclic data container during the startup phase of the PLC program (e.g. warm start). The value of the parameter S-0-0092 "Bipolar torque/force" is written to the mentioned data container.

If the warning "E8260 Torque - force command value limit active" is output when the function block is enabled, clear this warning by setting bit 4 of the parameter P-0-0556, "Axis controller configuration".

In some cases (e.g. multiple F8078 "Error in the speed control loop") it might be necessary to disable the velocity controller monitoring (set bit 1 of the parameter P-0-0556 "Axis controller configuration").

Enabling the correction of the torque constant at synchronous motors

The torque resulting from a motor is determined at the drive using the motor current and a so-called torque constant P-0-0051 "Torque/force constant". However, this so-called "torque or force constant" is a physical but not a static value.

It depends on:

1. the level of the actual motor current flow

   (the constant reduces at currents higher than I_{Nom})

2. the temperature of the motor winding and rotor

   (the constant reduces with rising temperature)

A corrected torque constant can be used for the **synchronous motor**. This constant can be enabled in the parameter **P-0-0556 "Axis controller configuration" bit 11 (set)**.

Thus, the following influences on the torque/force constant are considered:

1. Magnetic field weakening by magnetic saturation due to increased motor current compared to nominal current.
2. Magnetic field weakening due to increased motor winding temperature.
3. Magnetic field weakening due to increased rotor temperature depending on the average speed.

The torque constant effective in this case can be read in the parameter P-0-0450 "Torque/force constant, current".

A significant deviation from the torque constant P-0-0051 is only caused if the current load increases to 100% (or higher) of the nominal current S-0-0111 "Standstill current motor". That means the higher the motor load, the better the impact of correction. For a motor loaded at low level, only a minimum or no correction results.

A correction of the torque constant is automatically enabled for an asynchronous motor and does thus not need to be set separately in the parameter P-0-0556.

Also refer to the functional description of the respective IndraDrive drive.

Basic settings of the function block

Axis assignment

The axis reference (AXIS_REF) of the winding axis is connected to the "Slave" input.

The axis reference (AXIS_REF) of the master axis is connected to the "Master" input. This is the axis that provides the web velocity of the machine.

The scaling type has to be identical for the master and the slave axis. Rotary and preference scaling are recommended.

For the MLC control, "Interpolation in the drive" has to be enabled for the winding axis.

Setting the control method

Set the "WindCtrlType" input to the "OPEN_LOOP" mode using the enumeration MB_WIND_CTRL_MODE.

Setting rewinders or unwinders

Differentiate between rewinders or unwinders using the "WindDirection" input.

Specifying the tension command values

There is one tension command value available for the standstill "Setpoint-Standstill" and one for the normal operation mode "SetpointOpMode". Switching between these two command values is performed automatically using the standstill message of the master axis.

Set the standstill window of the master axis (parameter A-0-0222 "Standstill window" or S-0-0124 "Standstill window") to the lowest value possible (e.g. 0.1 rpm).

The two tension values can be set to the same value for the initial commissioning.

Settings for the diameter calculator

The settings for the diameter calculator are summarized in the "MB_Wind_Diameter" structure.

To calculate the diameter, set the structure variable "DiamSource" to "FALSE". To read the diameter externally, set the structure variable "DiamSource" to "TRUE".

The core diameter of the winder (in mm) is written to the variable "CoreDiameter".

Functional description

Enter the variable "RepeatLength" (in mm) for the diameter calculation. This corresponds to the circumference of the master axis.

The limitations ("HighLimit", "LowLimit") can additionally be entered for the diameter calculation. This limits the diameter to a minimum (e.g. core diameter) and to a maximum value (e.g. maximum winding roll possible).

Set the standstill window of the master axis (parameter A-0-0222 "Standstill window" or S-0-0124 "Standstill window") to the lowest value possible (e.g. 0.1 rpm). When there is a standstill message of the master or reference axis, the diameter calculator does not calculate!

Furthermore, enter the web width "WebWidth" (in mm) and the density "Density" (in kg/dm^3) of the material web.

The diameter calculation can be influenced via the calculation range "CalcRange" and an average value filter "AverageValue". At the beginning, there is a "CalcRange" of 360 degrees. Thus, **one calculation per winding axis revolution** and an "AverageValue" of 1 (an averaging) is not reasonable.

The diameter is only calculated if the material web is tensioned. That means that the binary output "DiameterEngaged" has to be set.

☞ The ratio "RepeatLength"/"CoreDiameter" may not be greater than 25.

Otherwise, the gear adjustment via the gear fine adjustment is insufficient!

A relative motion of a dancer roll (applies only to winders with dancer) is considered when calculating the diameter using the "DancerConstant" variables. Determine this dancer constant once for a winder with dancer.

First, set the dancer constant "DancerConstant" to zero (default)

Set the "DancerConstant" value always to zero for the winders with open-loop and closed-loop tension control.

Tensioning method (TensionMode) and tensioning speed

Enter a tensioning speed "TensionSpeed" for the tensioning method at standstill (e.g. 10 rpm).

Select between tensioning with constant tensioning speed ("TensionMode" input to "CONST_SPEED") and tensioning with constant web velocity ("TensionMode" input to "CONST_WEB_VEL").

For the initial commissioning of tensioning with constant web velocity, set the "TensionMode" input to "CONST_WEB_VEL".

Torque limit value, DefaultTorqueLimit

If the function block is enabled, the torque of the winding drive is limited to a calculated value. This calculated value corresponds to the torque required for the set tension command value. When disabling the function block, the torque is set to the value of the "DefaultTorqueLimit" input.

Entering a value at the "DefaultTorqueLimit" input (e.g. 100 %).

Filtering the actual torque value

To determine whether the web is tensioned, the torque limit value S-0-0092 "Torque/force limit value, bipolar" and the actual torque value S-0-0084 "Actual torque/force value" are compared with each other. If the two values differ from each other more than 25 %, the web is considered as untensioned (diameter calculator does not calculate anymore).

At low tensions, the diameter calculator can disengage due to an unfiltered actual torque. Thus, a filtering of this value can be set at the function block ("ActTorqueFilter" input) to achieve a constant tensioning condition "DiameterEngaged".

For this purpose, a value of 20 ms for example can be set at the "ActTorque-Filter" input.

Filtering the acceleration compensation

To compensate acceleration and deceleration processes, an additional acceleration torque is added. This acceleration torque can be increased using a filter.

For this purpose, enter a filter time (e.g. 20 ms) at the "AccelTorqueFilter" input.

Diagnostic settings

To monitor the tension, several binary diagnostic outputs can be evaluated. The "WindowTension" input (in %) is used to put a window - related to the actual tension value - on the tension command value. If the actual tension value is in the window, this is displayed at the "TensionInWindow" output (e.g. "TensionInWindow" 30 %).

To display if maximum threshold values have been exceeded or if the values were fallen below these thresholds, a "MinTension" (in N) and "MaxTension" (in N) can be entered.

Determining the friction characteristic

Friction torque at standstill:

1. The "friction torque at standstill" ("StandstillTorque" variable in the data structure MB_WIND_TENSION) is determined when the master axis is at standstill and the winder is empty (core only). The winding function block is disabled. For the winding axis (slave axis), select the operating mode "Velocity control" (select in AxisInterface of the ML_TechInterface "MODE_VEL" library). Optionally, the axis can be controlled using the PLCopen function block MC_MoveVelocity. 10 rpm can be set as command value.
2. The value of the parameter P-0-0109 "Peak torque/force limit" is set to zero. The axis has to stop now. The value for this parameter is incremented until the drive starts to rotate. The last value corresponds to the friction torque at standstill.
3. The axis enabled "MODE_VEL" is canceled (also by using the PLCopen function block "MC_Stop").

   The parameter P-0-0109 "Peak torque/force limit" is reset to its previous value (e.g. 400 %).

   The friction torque setting at standstill is thus completed.

Friction torque at maximum speed:

The "friction torque at maximum speed" ("MaxTorque" variable in the data structure MB_WIND_TENSION) is determined when the master axis is at standstill and with an empty winder (core only). The function block is disabled.

1. Select the operation mode "Velocity control" for the winding axis (slave axis) (in the AxisInterface of the ML_TechInterface "MODE_VEL", also the PLCopen function block).

   Increase the command value for the selected operation mode incrementally up to the value of the parameter S-0-0091 "Bipolar velocity limit value". Enter the value for the parameter S-0-0091 "Bipolar velocity limit value" according to application and motor data.

2. In the next step, the value of the parameter P-0-0109 "Peak torque/force limit" is decreased incrementally (e.g. from 100% towards 0%) until the drive speed also starts to decrease. The speed of the drive can be traced using the drive parameter S-0-0040 "Actual velocity value" or the axis parameter A-0-0102 "Actual velocity value". The last value of

P-0-0109 "Peak torque/force limit" corresponds to the maximum friction torque at maximum speed.

3. The axis enabled "MODE_VEL" is canceled (also by using the PLCopen function block "MC_Stop").

   The parameter P-0-0109 "Peak torque/force limit" is reset to its previous value (e.g. 400 %).

   Setting the friction torque at maximum speed "MaxTorque" is thus completed.

Determining the minimum friction torque:

The minimum friction torque is determined using the deceleration test with an empty winder. The winding drive is decelerated from a constant velocity (e.g. 50 min^{-1}) to standstill (by setting the operation mode "Mode_AH" of the AxisInterface or by using the PLCopen function block "MC_Stop"). At the same time, the drive parameters P-0-0049 "Effective torque/force command value" (axis parameter A-0-0038 "Torque/force limit value, bipolar") and S-0-0040 "Actual velocity value" (axis parameter A-0-0102 "Actual velocity value") are recorded with an oscilloscope or with the trace function in IndraWorks.

The minimum value is read from the torque curve and can be transferred to the structure MB_WIND_FRICTION as "MinTorque". The corresponding speed is entered as "MinTorqueVelocity" in MB_WIND_FRICTION.

Cyclic data channels for the winding drive

Interpolation in the drive:

Write the **parameters P-0-0694 ("Gear ratio fine adjustment, process controller")**, **P-0-0690 ("Additive velocity command value, process controller"** and **S-0-0092 "Bipolar torque/force limit value"** to the cyclic Sercos channel of the corresponding drive ("UserCmdDataX"). The real axes are parameterized in the parameterization mode in IndraWorks.

Interpolation in the control:

The target variables are the control parameters **A-0-2605 "ELS, gear ratio fine adjustment, process controller"** and **A-0-2615 "ELS, additive velocity command value, process controller"** and **S-0-0092 "Bipolar torque and force limit value"**.

Write the parameter **S-0-0092 "Bipolar torque and force limit value"** to the cyclic Sercos channel of the respective drive.

The function block sets these parameters automatically. If this is not desired, switch it off via the "DisableCyclicWrites" input. In this case, set the outputs "GearRatioFineAdjust", "SpeedOffset" and "TorqueLimitBipolar" manually to the corresponding parameters.

Final basic settings

The moment of inertia of mechanics and winding shaft "MechanicInertia" can be set to 0 at the beginning.

Set the process variable window "WindowTension" to 30 % for example. If the actual tension value is within the range of the tension command value +/- 30%, this is displayed at the "InWindowTension" output.

Set the minimum and maximum thresholds "MinTension" and "MaxTension" to the desired threshold values for the actual tension value (absolute values in the unit of the tension command value). Exceeding or falling below the actual tension value is displayed in the binary outputs "MinTensionAchieved" and "MaxTensionAchieved".

Operating the function block

Initial startup of the winding axis

1. "Enable" of the function block for the winder with open-loop tension control. Set the diameter preset to the desired value (using the binary signal "PresetDiameter" and the value "Diameter.PresetVal").
2. Switch on the synchronous operation modes of all axes participating in the web process (for the winding axis "Speed synchronization" and "ModeSyncVel").
3. The winding axis has to tension the web.

   If the winding axis rotates in the wrong direction, check the direction of the winding axis without winder function block and winder type (rewinder or unwinder).
4. Synchronous run of the machine via specification of a velocity command value for the master axis (MoveVelocity for the master axis with 20 rpm for example). The web has to remain tensioned.
5. Check the calculated winding diameter after several winding axis revolutions.

   If the calculated diameter deviates more than 5 % from the actual diameter, check the mechanical gear and the "RepeatLength" of the master.
6. Stop the machine by setting the master axis command value to zero.

Specifics for a torque-limited unwinder

An unwinder should always be operated with a generator; that means in decelerating operation.

Since the actual torque is proportional to the current winding radius, the desired tension F, the mechanic friction $M_{Friction}$ and the acceleration torque M_{accel}, the following dependencies result for the actual torque or torque limit M_{Limit}:

$$M_{Limit} \sim F_{Tension} * r_{Winder} + M_{accel} + M_{Friction}$$

Fig. 4-11: Torque limitation

Since tension torque and friction torque are opposite to each other while unwinding, the following condition results when not considering the acceleration torque and the mechanical drive i (S-0-0121 "Load gear, input revolutions" / S-0-0122 "Load gear, output revolutions"):

$$M_{Friction} \leq \frac{F_{Tension} * r_{winder}}{i_{mechanical}}$$

Fig. 4-12: Unwinder, condition for the friction torque

To obtain a value in percent, divide by S-0-0111 "Standstill current, motor" and the torque constant P-0-0051 "Torque/force constant".

$$M_{Friction} \leq \frac{F_{Tension} * r_{Winder}}{S-0-0111 * P-0-0051 * i_{mechanical}}$$

Fig. 4-13: Unwinder, condition for the friction torque in percent

Functional description

☞ If the friction torque is higher than this condition (consideration with minimum tension and minimum winding diameter!), the unwinder goes into motor operation.

This case is more difficult to control with regard to its process and should thus be avoided.

Basic sequence of a "flying splice"

A so-called "flying splice" is a change from a roll to a new roll when the material web is still moving which can be performed according to the following basic diagram:

(two winding axes and two winding function blocks are required).

1. Currently unwinding roll reaches critical diameter for chopping.
2. Switch on the respective winding function block for the new roll and preset the diameter with the diameter of the new roll. Subsequently, set the "Pause" input.
3. Command the winding axis of the new roll and accelerate to the current web velocity.
4. Perform the material chopping (separating the unwinding roll from the web) and stick the new roll.
5. Disable the "Pause" input of the winding function block for the new roll.

   The function block can be switched off for the old roll.

4.3.4 Diagnostics for the winder with open-loop tension control (without sensor)

The following error codes can result for the winder with open-loop tension control (without sensor):

ErrorID	Additional1	Additional2	Text
STATE_MACHINE_ERROR	16#1100	16#0020	Error in state machine
INPUT_RANGE_ERROR	16#1101	16#0001	HighLimitDiameter < LowLimitDiameter
		16#0002	FormatLength < 0.0
		16#0003	WebWidth < 0.0
		16#0004	Density < 0.0
		16#0005	Core diameter < 0.0
		16#0006	DiamCalcRange < 0.0
		16#0007	Preset diameter < 0.0
		16#0008	Minimum diameter < 0.0
		16#0009	Maximum diameter < 0.0
		16#000A	HighLimitDiameter < 0.0
		16#000B	LowLimitDiameter < 0.0
		16#000C	DiamCalcMode invalid
		16#000D	Number of slave axis incorrect
		16#000E	Number of master axis incorrect
DEVICE_ERROR	16#1102	16#0001	No operating mode (no sercos phase 4)

ErrorID	Additional1	Additional2	Text
RESSOURCE_ERROR	16#0004	16#0000	Incorrect drive firmware
RESSOURCE_ERROR	16#000F	16#0003	Drive function package "MA" not enabled

Tab. 4-7: Error codes of the MB_DiameterCalculatorType03 function block

ErrorID	Additional1	Additional2	Text
STATE_MACHINE_ERROR	16#1180	16#0020	Error in state machine
INPUT_RANGE_ERROR	16#1181	16#0001	HighLimit < LowLimit
INPUT_RANGE_ERROR	16#1181	16#0002	FormatLength < 0.0
INPUT_RANGE_ERROR	16#1181	16#0003	WebWidth < 0.0
INPUT_RANGE_ERROR	16#1181	16#0004	Density < 0.0
INPUT_RANGE_ERROR	16#1181	16#0005	CoreDiameter < 0.0
INPUT_RANGE_ERROR	16#1181	16#0008	MinDiameter < 0.0
INPUT_RANGE_ERROR	16#1181	16#0009	MaxDiameter < 0.0
INPUT_RANGE_ERROR	16#1181	16#000A	HighLimit < 0.0
INPUT_RANGE_ERROR	16#1181	16#000B	Lowlimit < 0.0
INPUT_RANGE_ERROR	16#1181	16#000C	Incorrect slave axis number
DEVICE_ERROR	16#1182	16#0001	No operating mode (sercos phase 4)
RESSOURCE_ERROR	16#0004	16#0000	Incorrect drive firmware
RESSOURCE_ERROR	16#000F	16#0003	Drive function package "MA" not enabled

Tab. 4-8: Error codes of the MB_DiameterMeasurementType01 function block

ErrorID	Additional1	Additional2	Description
STATE_MACHINE_ERROR	16#1120	16#20	Error in state machine
INPUT_RANGE_ERROR	16#1121	16#01	Diameter.MechanicInertia < 0.0
INPUT_RANGE_ERROR	16#1121	16#02	TensionCtrl.PreControlWeighting < 0.0
INPUT_RANGE_ERROR	16#1121	16#03	MaxTension < 0.0
INPUT_RANGE_ERROR	16#1121	16#04	TensionHighLimit < TensionLowLimit
INPUT_RANGE_ERROR	16#1121	16#05	Friction.StandstillTorque < 0.0
INPUT_RANGE_ERROR	16#1121	16#06	Friction.MaxTorque < 0.0
INPUT_RANGE_ERROR	16#1121	16#07	Friction.MinTorque < 0.0
INPUT_RANGE_ERROR	16#1121	16#08	Friction.MinVelocity < 0.0
INPUT_RANGE_ERROR	16#1121	16#09	WindowTension < 0.0
INPUT_RANGE_ERROR	16#1121	16#0A	MinTension < 0.0
INPUT_RANGE_ERROR	16#1121	16#0B	MaxTension < 0.0
INPUT_RANGE_ERROR	16#1121	16#0C	Winding axis not in "BB"
INPUT_RANGE_ERROR	16#1121	16#0D	Incorrect torque scaling (A-0-0050) Scaling for the motor torque has to be based on the motor side

Functional description

ErrorID	Additional1	Additional2	Description
INPUT_RANGE_ERROR	16#1121	16#0E	Axis number of the slave axis incorrect
INPUT_RANGE_ERROR	16#1121	16#0F	Axis number of the master axis incorrect
RESOURCE_ERROR	16#0004	16#0000	Incorrect drive firmware
RESOURCE_ERROR	16#000F	16#0003	Drive function package "MA" not enabled
RESOURCE_ERROR	16#0012	16#00xx	wrong local cntrl number for local cntrl xx
RESOURCE_ERROR	16#001C	16#00xx	wrong Axistype for Axis xx

Tab. 4-9: Error codes of the MB_WinderTensionCtrlType02 function block

4.4 Winder with closed-loop tension control

4.4.1 Introduction and overview

Diameter calculator with closed-loop tension control

The diameter calculator with closed-loop tension control is used on center-driven winders. The drive of the winding axis generally operates at its torque limit. The torque limit depends on the current winding diameter and the tension set. The torque limit corresponds to the value of the motor torque required to rotate the winder at the defined speed. It consists of load torque, friction torque and acceleration torque.

The tension controller is provided as PI-controller. It contains the function block "IL_PIDType01" from the "RIL_LoopControl" library. The control variable of the controller and the current winding diameter determine the torque limit value of the drive. The command value of the tension should also be scaled and transferred to the controller output ("PreControlWeighting" not equal to zero). When the scaling is not zero, the tension for the torque creation consists of the controller output variable added to the scaled command value. Scaling to zero means that only the tension controller is active. Thus, the tension controller should only be operated additively (e.g. with a scaling of 1.0).

The actual tension value is measured directly with the help of a load cell and transferred to the tension controller as actual value via an analog channel or field bus. With the web tensioned, the diameter calculator can calculate the current winding diameter.

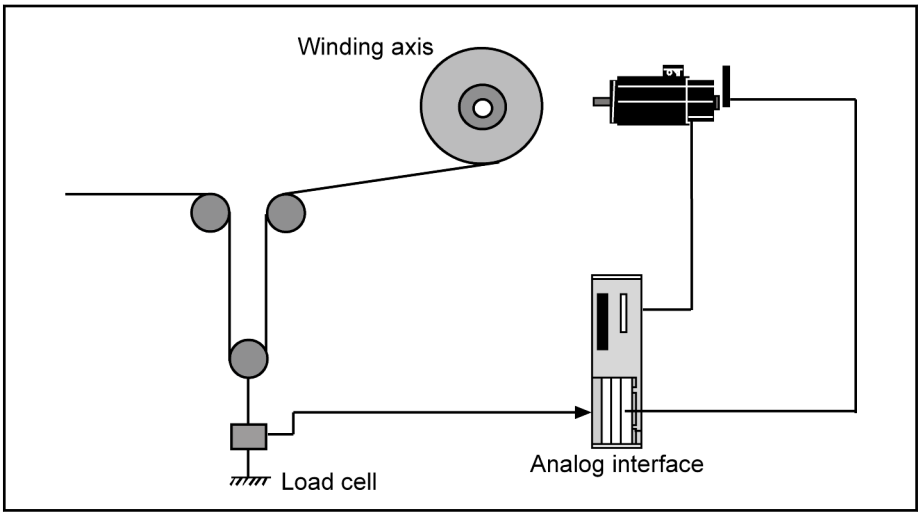

Fig. 4-14: Diameter calculator with closed-loop tension control

4.4.2 Interface of the winder with closed-loop tension control

Interface description

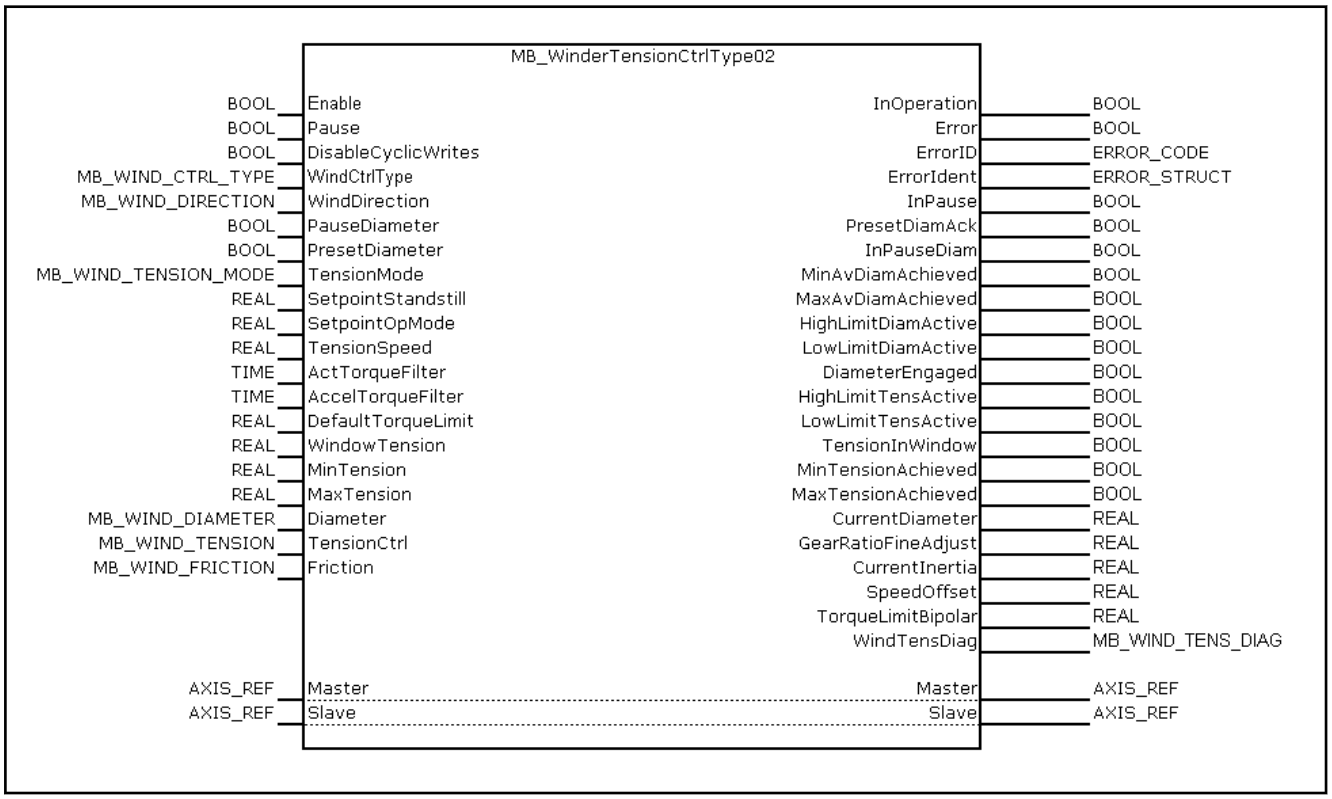

Fig. 4-15: MB_WinderTensionCtrlType02 function block

I/O type	Name	Type	Comment
VAR_INPUT	Enable	BOOL	Processing of function block enabled (level-controlled)
	Pause	BOOL	Pausing the tension controller and the diameter calculator (values are frozen)
	DisableCyclicWrites	BOOL	If this input is set, the cyclic data is not written directly to the optional cyclic data container, but only displayed at the output
	WindCtrlType	MB_WIND_CTRL_TYPE	Winding structure Open-loop tension control (without sensor) OPEN_LOOP (16#0000) Closed-loop tension control (load cell) CLOSED_LOOP (16#0001)
	WindDirection	MB_WIND_DIRECTION	Winding direction Rewinder REWIND (16#0000) Unwinder UNWIND (16#0001)
	PauseDiameter	BOOL	Pausing the diameter calculation Closed-loop/open-loop control of the torque limit remains active
	PresetDiameter	BOOL	CurrentDiameter is set to PresetVal. GearRatioFineAdj is adjusted accordingly (edge-controlled)

Functional description

I/O type	Name	Type	Comment
	TensionMode	MB_WIND_TEN-SION_MODE	Mode to tension the material web Tensioning at constant speed CONST_SPEED Tensioning at constant web velocity CONST_WEB_VEL
	SetpointStandstill	REAL	Specification of the standstill tension [N] (Switching between standstill tension and operating tension by means of the standstill message from the drive).
	SetpointOpMode	REAL	Specification of the operating tension [N] (Switching between standstill tension and operating tension by means of the standstill message from the drive).
	TensionSpeed	REAL	Tensioning speed at an empty winder [min^{-1}]
	ActTorqueFilter	TIME	Filter time constant for the actual torque S-0-0084 "Actual torque/force value"
	AccelTorqueFilter	TIME	Filter time constant for acceleration torque
	DefaultTorqueLimit	REAL	Value for the bipolar torque limit after deactivation of "Enable" [%]
	WindowTension	REAL	Window for the actual tension value [%] related to the tension command value (output "TensionInWindow")
	MinTension	REAL	Lower threshold for the actual tension value (only for the display with binary output "MinTensionAck")
	MaxTension	REAL	Upper threshold for the actual tension value (only for the display with binary output "MaxTensionAck")
	Diameter	MB_WIND_DIAMETER	Structure for diameter calculator
	TensionCtrl	MB_WIND_TENSION	Structure for tension controller
	Friction	MB_WIND_FRICTION	Structure for friction torque
VAR_OUTPUT	InOperation	BOOL	Function block is operating
	Error	BOOL	Processing completed with error
	ErrorID	ERROR_CODE	Diagnostic description in the event of an error
	ErrorIdent	ERROR_STRUCT	Detailed diagnostics
	InPause	BOOL	Tension controller and diameter calculator pause
	PresetDiamAck	BOOL	Preset diameter was applied (is set as long as "Pre-set" is pending)
	InPauseDiam	BOOL	Diameter calculator pauses
	MinAvDiamAchieved	BOOL	Minimum diameter reached (based on the averaged diameter)
	MaxAvDiamAchieved	BOOL	Maximum diameter reached (based on the averaged diameter)
	HighLimitDiamActive	BOOL	Currently calculated diameter has reached the upper limit (diameter value is discarded)

I/O type	Name	Type	Comment
	LowLimitDiamActive	BOOL	Currently calculated diameter has reached the lower limit (diameter value is discarded)
	DiameterEngaged	BOOL	Diameter "engaged" TRUE: engaged FALSE: disengaged
	HighLimitTensActive	BOOL	Output of the tension controller reached upper limit
	LowLimitTensActive	BOOL	Output of the tension controller reached lower limit
	TensionInWindow	BOOL	Actual tension value is within the tension window
	MinTensionAchieved	BOOL	Tension is below the "MinTension" input
	MaxTensionAchieved	BOOL	Tension is above the input "MaxTension"
	CurrentDiameter	REAL	Currently calculated diameter [mm]
	GearRatioFineAdjust	REAL	Resulting fine adjustment of the gear for speed tracing of the drive [%]
	CurrentInertia	REAL	Current moment of inertia of the winding material + mechanics (based on the motor side [kg m^2]
	SpeedOffset	REAL	Tensioning speed [rpm]
	TorqueLimitBiploar	REAL	Bipolar torque limit [%]
	WindTensDiag	MB_WIND_TENS_DIAG	Current control deviation of the dancer controller
VAR_IN_OUT CONSTANT	Master	AXIS_REF	Reference to master axis
	Slave	AXIS_REF	Reference to the slave axis (winding axis)

Tab. 4-10: Interface variables of the MB_WinderTensionCtrlType02 function block

Functional description

Functional diagram:

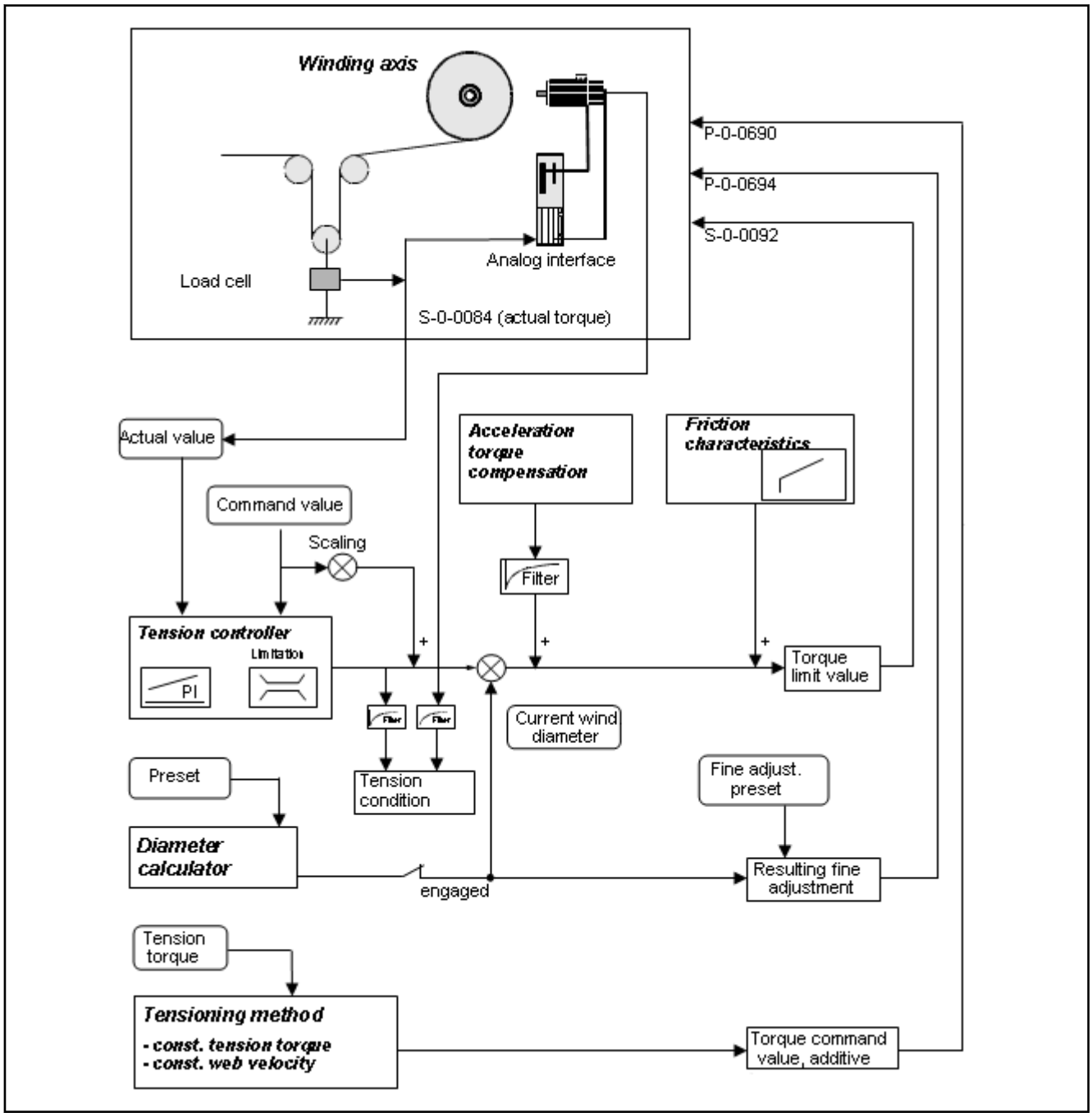

Fig. 4-16: Functional diagram of the winder with closed-loop tension control

4.4.3 Commissioning the winder with closed-loop tension control

General settings

Mechanical gear

An actually existing mechanical gear ratio from the drive axis to the winding axis has to be written to the parameters S-0-0121 ("Input revolutions of load gear") and S-0-0122 ("Output revolutions of load gear").

Operation mode of the winding drive (commanding)

Set the correct operation mode "Speed Synchronization" of the drive and the drive enabled for the winding axis. There are two ways:

- Set the "ModeSyncVel" operation mode using the AxisInterface (recommended)
- Use the PLCopen "MC_Power", "MC_GearIn", "MC_Stop" function blocks to command the axis

The electronic gear between master axis and winding axis is to be set to 1:1 for the winding axis (A-0-2720 "ELS, master axis gear, input revolutions" or P-0-0156 "Electronic gear input revolutions" and A-0-2721 "ELS, master axis gear, output revolutions" or P-0-0157 "Electronic gear, output revolutions").

Setting the speed control loop

Perform the following for an empty and full roll:

- Set Tn to 0 and let the winding axis rotate freely at low speed.
- The parameter S-0-0100 "Velocity controller proportional gain" starts slowly from the default value until an oscillation of the velocity control deviation is detected at the oscilloscope.
- If the oscillation frequency is significantly higher than 500 Hz, the parameter P-0-0004 "Smoothing time constant - speed controller" is increased until the oscillation decreases again.

  In general, set the parameter P-0-0004 "Smoothing time constant - speed controller" to a minimum value of 1000.
- In this case, increase the parameter S-0-0100 "Velocity controller, proportional gain" until the control loop becomes instable again and then reduce it until the oscillation decays. Set the P-gain to the half of the last value set to be sufficiently far away from the stability limit.
- Decrease S-0-0101 "Velocity controller integral action time" starting from a relative high value (e.g. 1000 ms) until the control loop becomes instable and then increase it until the oscillation decreases. Enter twice the value as value for the parameter S-0-0101 "Velocity controller integral action time". The integral action time should not be lower than 150 ms.

Select the control loop setting of the drives accordingly to ensure that both extreme cases (minimum diameter and maximum diameter) can be operated with stability.

Otherwise, these two values can be linearly adapted to each other depending on the current diameter (function block MB_WindSpeedAdaptionType01).

Determining the direction of rotation of the winding axis

Set the direction of rotation of the tension or winding axis using the axis parameter A-0-2798 "Polarity of master axis position" or the drive parameter P-0-0108 "Master drive polarity". If the winding axis does not rotate in the desired direction, set the axis parameter A-0-2798 or the drive parameter P-0-0108 accordingly.

The following figure shows the general relations between rewinders and unwinders.

Functional description

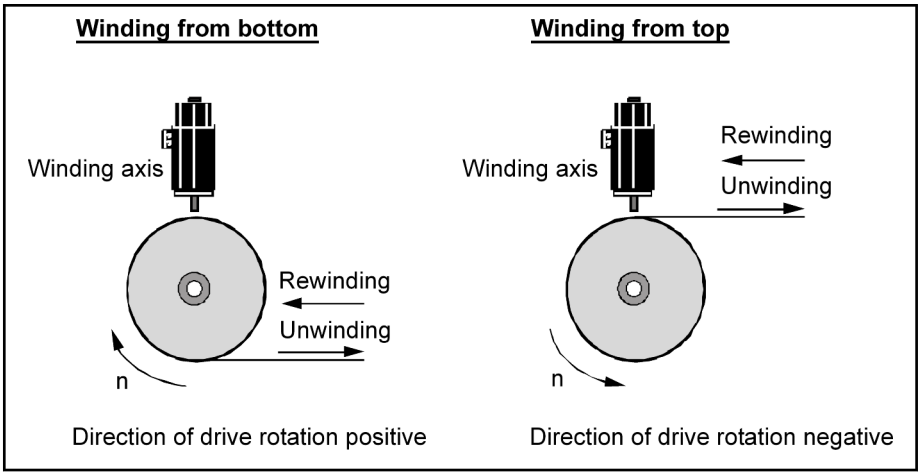

Fig. 4-17: Principles of rewinders and unwinders

Detecting the actual tension value

The actual tension value is generally read in via an analog input. The analog input can either be read in at the drive (onboard analog input or via an MA1 extension card) or via an Inline analog input module of the control.

The actual value detection only processes positive actual values. It might be required to add an offset to the read value to ensure this over the complete range (e.g. offset is 0.1 volt).

If the actual tension value is read in as analog voltage (volt), it has to be standardized to the unit Newton in the PLC using a a standardization factor (e.g. 10 volt correspond to 200 N, that is a standardization factor of 20 N/V).

Filter this actual value in case of strong variation using a PT1-filter (e.g. 20 ms). If the analog input is read in at the drive, the filter in the drive is to be preferably used. For analog input 1, this is set in the parameter P-0-0217 "Analog input 1, time constant input filter". If the analog input is read in at the control, a PT1-filter function block can be used in the PLC library "RIL_Loop-Control".

The actual value is connected to the "TensionCtrl.FeedbackVal" input.

Additional leading and lagging of the winding axis

Set an additional leading or lagging via the gear fine adjustment (presetting gear fine adjustment "FineAdjust") using the structure variable "qrAxisCtrl[AxisNumber].Admin.SyncMode.FineAdjust" of the "MB_AXIS_SYNCHRONISATION" data structure of the "ML_TechInterface" library. A low **positive value** (e.g. 5 %) should be set for a **rewinder** and a low **negative value** for an **unwinder**. This results in an improved startup reaction for the respective winding direction.

If the winding axis is not commanded using the AxisInterface, but with the PLCopen function blocks, use the "MasterFineAdjust" input of the "MC_GearIn" function block.

Monitoring torque limit values

At the initial control startup, a drive warning "E2056 Torque limit value = 0" can be output if the winder function block is not yet enabled.

In order to prevent this, write a value unequal to zero (e.g. 100%) to the respective cyclic data container during the startup phase of the PLC program (e.g. warm start). The value of the parameter S-0-0092 "Bipolar torque/force" is written to the mentioned data container.

If the warning "E8260 Torque - force command value limit active" is output when the function block is enabled, clear this warning by setting bit 4 of the parameter P-0-0556, "Axis controller configuration".

In rare cases (e.g. multiple F8078 "Error in the speed control loop") it might be necessary to disable the velocity controller monitoring (set bit 1 of the parameter P-0-0556 "Axis controller configuration").

Enabling the correction of the torque constant at synchronous motors

The torque resulting from a motor is determined at the drive using the motor current and a so-called torque constant P-0-0051 "Torque/force constant". However, this so-called "torque or force constant" is a physical but not a static value.

It depends on:

1. the level of the actual motor current flow

   (the constant reduces at currents higher than I_{Nom})

2. the temperature of the motor winding and rotor

   (the constant reduces with rising temperature)

A corrected torque constant can be used for the **synchronous motor**. This constant can be enabled in the parameter **P-0-0556 "Axis controller configuration" bit 11 (set)**.

Thus, the following influences on the torque/force constant are considered:

1. Magnetic field weakening by magnetic saturation due to increased motor current compared to nominal current.
2. Magnetic field weakening due to increased motor winding temperature.
3. Magnetic field weakening due to increased rotor temperature depending on the average speed.

The torque constant effective in this case can be read in the parameter P-0-0450 "Torque/force constant, current".

A significant deviation from the torque constant P-0-0051 is only caused if the current load increases to 100% (or higher) of the nominal current S-0-0111 "Standstill current motor". That means the higher the motor load, the better the impact of correction. For a motor loaded at low level, only a minimum or no correction results.

A correction of the torque constant is automatically enabled for an asynchronous motor and does thus not need to be set separately in the parameter P-0-0556.

Also refer to the functional description of the respective IndraDrive drive.

Basic settings of the function block

Axis assignment

The axis reference (AXIS_REF) of the winding axis is connected to the "Slave" input.

The axis reference (AXIS_REF) of the master axis is connected to the "Master" input. This is the axis that provides the web velocity of the machine.

The scaling type has to be identical for the master and the slave axis. Rotary and preference scaling are recommended.

For the MLC control, "Interpolation in the drive" has to be enabled for the winding axis.

Setting the control method

Set the "WindCtrlType" input set to the "CLOSED_LOOP" mode using the enumeration MB_WIND_CTRL_MODE.

Setting rewinders or unwinders

Differentiate between rewinders or unwinders using the "WindDirection" input.

Functional description

Specifying the tension command values

There is one tension command value available for the standstill "Setpoint-Standstill" and one for the normal operation mode "SetpointOpMode". Switching between these two command values is performed automatically using the standstill message of the master axis.

Set the standstill window of the master axis (parameter A-0-0222 "Standstill window" or S-0-0124 "Standstill window") to the lowest value possible (e.g. 0.1 rpm).

The two tension values can be set to the same value for the initial commissioning.

Settings for the diameter calculator

The settings for the diameter calculator are summarized in the "MB_Wind_Diameter" structure.

To calculate the diameter, set the structure variable "DiamSource" to "FALSE". To read the diameter externally, set the structure variable "DiamSource" to "TRUE".

The core diameter of the winder (in mm) is written to the variable "CoreDiameter".

Enter the variable "RepeatLength" (in mm) for the diameter calculation. This corresponds to the circumference of the master axis.

The limitations ("HighLimit", "LowLimit") can additionally be entered for the diameter calculation. This limits the diameter to a minimum (e.g. core diameter) and to a maximum value (e.g. maximum winding roll possible).

Set the standstill window of the master axis (parameter A-0-0222 "Standstill window" or S-0-0124 "Standstill window") to the lowest value possible (e.g. 0.1 rpm). When there is a standstill message of the master or reference axis, the diameter calculator does not calculate!

Furthermore, enter the web width "WebWidth" (in mm) and the density "Density" (in kg/dm^3) of the material web.

The diameter calculation can be influenced via the calculation range "CalcRange" and an average value filter "AverageValue". At the beginning, there is a "CalcRange" of 360 degrees. Thus, **one calculation per winding axis revolution** and an "AverageValue" of 1 (an averaging) is not reasonable.

The diameter is only calculated if the material web is tensioned. That means that the binary output "DiameterEngaged" has to be set.

☞ The ratio "RepeatLength"/"CoreDiameter" may not be greater than 25.

Otherwise, the gear adjustment via the gear fine adjustment is insufficient!

A relative motion of a dancer roll (applies only to winders with dancer) is considered when calculating the diameter using the "DancerConstant" variables. Determine this dancer constant once for a winder with dancer.

First, set the dancer constant "DancerConstant" to zero (default)

Set the "DancerConstant" value always to zero for the winders with open-loop and closed-loop tension control.

Tensioning method (TensionMode) and tensioning speed

Enter a tensioning speed "TensionSpeed" for the tensioning method at standstill (e.g. 10 rpm).

Select between tensioning with constant tensioning speed ("TensionMode" input to "CONST_SPEED") and tensioning with constant web velocity ("TensionMode" input to "CONST_WEB_VEL").

For the initial commissioning of tensioning with constant web velocity, set the "TensionMode" input to "CONST_WEB_VEL".

Torque limit value, DefaultTorqueLimit

If the function block is enabled, the torque of the winding drive is limited to a calculated value. This calculated value corresponds to the torque required for the set tension command value. When disabling the function block, the torque is set to the value of the "DefaultTorqueLimit" input.

Entering a value at the "DefaultTorqueLimit" input (e.g. 100 %).

Filtering the actual torque value

To determine whether the web is tensioned, the torque limit value S-0-0092 "Torque/force limit value, bipolar" and the actual torque value S-0-0084 "Actual torque/force value" are compared with each other. If the two values differ from each other more than 25 %, the web is considered as untensioned (diameter calculator does not calculate anymore).

At low tensions, the diameter calculator can disengage due to an unfiltered actual torque. Thus, a filtering of this value can be set at the function block ("ActTorqueFilter" input) to achieve a constant tensioning condition "DiameterEngaged".

For this purpose, a value of 20 ms for example can be set at the "ActTorqueFilter" input.

Filtering the acceleration compensation

To compensate acceleration and deceleration processes, an additional acceleration torque is added. This acceleration torque can be increased using a filter.

For this purpose, enter a filter time (e.g. 20 ms) at the "AccelTorqueFilter" input.

Diagnostic settings

To monitor the tension, several binary diagnostic outputs can be evaluated. The "WindowTension" input (in %) is used to put a window around the tension command value. If the actual tension value is in the window, this is displayed at the "TensionInWindow" output (e.g. "TensionInWindow" 30 %)

To display the falling below or exceeding of the minimum and maximum threshold values, a "MinTension" (in N) and "MaxTension" (in N) can be entered.

Determining the friction characteristic

Friction torque at standstill:

1. The "friction torque at standstill" ("StandstillTorque" variable in the data structure MB_WIND_TENSION) is determined when the master axis is at standstill and the winder is empty (core only). The winding function block is disabled. For the winding axis (slave axis), select the operating mode "Velocity control" (select in AxisInterface of the ML_TechInterface "MODE_VEL" library). Optionally, the axis can be controlled using the PLCopen function block MC_MoveVelocity. 10 rpm can be set as command value.
2. The value of the parameter P-0-0109 "Peak torque/force limit" is set to zero. The axis has to stop now. The value for this parameter is incremented until the drive starts to rotate. The last value corresponds to the friction torque at standstill.
3. The axis enabled "MODE_VEL" is canceled (also by using the PLCopen function block "MC_Stop").

   The parameter P-0-0109 "Peak torque/force limit" is reset to its previous value (e.g. 400 %).

   The friction torque setting at standstill is thus completed.

Friction torque at maximum speed:

Functional description

The "friction torque at maximum speed" ("MaxTorque" variable in the data structure MB_WIND_TENSION) is determined when the master axis is at standstill and with an empty winder (core only). The function block is disabled.

1. Select the operation mode "Velocity control" for the winding axis (slave axis) (in the AxisInterface of the ML_TechInterface "MODE_VEL", also the PLCopen function block).

   Increase the command value for the selected operation mode incrementally up to the value of the parameter S-0-0091 "Bipolar velocity limit value". Enter the value for the parameter S-0-0091 "Bipolar velocity limit value" according to application and motor data.

2. In the next step, the value of the parameter P-0-0109 "Peak torque/force limit" is decreased incrementally (e.g. from 100% towards 0%) until the drive speed also starts to decrease. The speed of the drive can be traced using the drive parameter S-0-0040 "Actual velocity value" or the axis parameter A-0-0102 "Actual velocity value". The last value of P-0-0109 "Peak torque/force limit" corresponds to the maximum friction torque at maximum speed.
3. The axis enabled "MODE_VEL" is canceled (also by using the PLCopen function block "MC_Stop").

   The parameter P-0-0109 "Peak torque/force limit" is reset to its previous value (e.g. 400 %).

   Setting the friction torque at maximum speed "MaxTorque" is thus completed.

Determining the minimum friction torque:

The minimum friction torque is determined using the deceleration test with an empty winder. The winding drive is decelerated from a constant velocity (e.g. 50 min^{-1}) to standstill (by setting the operation mode "Mode_AH" of the AxisInterface or by using the PLCopen function block "MC_Stop"). At the same time, the drive parameters P-0-0049 "Effective torque/force command value" (axis parameter A-0-0038 "Torque/force limit value, bipolar") and S-0-0040 "Actual velocity value" (axis parameter A-0-0102 "Actual velocity value") are recorded with an oscilloscope or with the trace function in IndraWorks.

The minimum value is read from the torque curve and can be transferred to the structure MB_WIND_FRICTION as "MinTorque". The corresponding speed is entered as "MinTorqueVelocity" in MB_WIND_FRICTION.

Cyclic data channels for the winding drive

Interpolation in the drive:

Write the **parameters P-0-0694 ("Gear ratio fine adjustment, process controller")**, **P-0-0690 ("Additive velocity command value, process controller"** and **S-0-0092 "Bipolar torque/force limit value"** to the cyclic Sercos channel of the corresponding drive ("UserCmdDataX"). The real axes are parameterized in the parameterization mode in IndraWorks.

Interpolation in the control:

The target variables are the control parameters **A-0-2605 "ELS, gear ratio fine adjustment, process controller"** and **A-0-2615 "ELS, additive velocity command value, process controller"** and **S-0-0092 "Bipolar torque and force limit value"**.

Write the parameter **S-0-0092 "Bipolar torque and force limit value"** to the cyclic Sercos channel of the respective drive.

The function block sets these parameters automatically. If this is not desired, switch it off via the "DisableCyclicWrites" input. In this case, set the outputs "GearRatioFineAdjust", "SpeedOffset" and "TorqueLimitBipolar" manually to the corresponding parameters.

Final basic settings

Set the P-gain of the tension controller "TensionCtrl.PControl" to 0.1 for the initial commissioning.

Set the command value precontrol "TensionCtrl.PreControlWeighting" to 1.0 (default).

Set the limitations "TensionCtrl.HighLimit" and "TensionCtrl.LowLimit" (e.g. five times the tension command value).

Set the process variable window "WindowTension" to 30 % for example. If the actual tension value is within the range of the tension command value +/- 30%, this is displayed at the "InWindowTension" output.

Set the minimum or maximum thresholds "MinTension" and "MaxTension" to the desired threshold values for the actual tension value (absolute values in the unit of the tension command value). Exceeding or falling below the actual tension value is displayed in the binary outputs "MinTensionAchieved" and "MaxTensionAchieved".

The moment of inertia of mechanics and winding shaft "MechanicInertia" can be set to 0 at the beginning.

Operating the function block

Initial startup of the winding axis

1. "Enable" of the function block for the winder with closed-loop tension control. Set the diameter preset to the desired value (using the binary signal "PresetDiameter" and the value "Diameter.PresetVal").
2. Switch on the synchronous operation modes of all axes participating in the web process (for the winding axis "Speed synchronization" and "ModeSyncVel").
3. The winding axis has to tension the web.

   If the winding axis rotates in the wrong direction, check the direction of the winding axis without winder function block and winder type (rewinder or unwinder).
4. Synchronous run of the machine via specification of a velocity command value for the master axis (MoveVelocity for the master axis with 20 rpm for example). The web has to remain tensioned.
5. Check the calculated winding diameter after several winding axis revolutions.

   If the calculated diameter deviates more than 5 % from the actual diameter, check the mechanical gear and the "RepeatLength" of the master.
6. Stop the machine by setting the master axis command value to zero.

Setting the tension control loop

1. "Enable" of the function block for the winder with closed-loop tension control.
2. Switch on the synchronous operation modes of all axes participating in the web process (for the winding axis "Speed synchronization" and "ModeSyncVel").
3. The winding axis has to move into this direction to tension the web.
4. **Open the limitations for the tension controller**. That means set "LowLimitControl" and "HighLimitControl" at least to a value twenty times as high as the tension command value (N).

5. Synchronous run of the machine via specification of a velocity command value for the master axis (MoveVelocity for the master axis with 20 rpm for example). The web has to remain tensioned.

   Increase the Kp-gain "PControl" incrementally and oscillograph the actual tension value and the torque limit "TorqueLimitBipolar" until these signals are located in the desired accuracy range.

   Determine the critical Kp-gain "PControl" alternatively (increase Kp-gain step by step until the actual tension value oscillates. Subsequently, decrease the Kp-gain until the oscillation decays and halves the Kp-gain.

   Enter the integral action time "IControl". A value within the range of seconds (e.g. two seconds). (A significantly lower value can be entered for "IControl" at standstill). Increase the integral action time "IControl" step by step and oscillograph the actual tension value and the torque limit "TorqueLimitBipolar" until these signals are located in the desired accuracy range.

6. Enter the values again for the **limitations of the tension controller**.
7. Check the values determined at higher machine velocities or master axis velocities. If necessary, travel along the velocity profile of the master axis and correct controller values if required.

Specifics for a torque-limited unwinder

An unwinder should always be operated with a generator; that means in decelerating operation.

Since the actual torque is proportional to the current winding radius, the desired tension F, the mechanic friction $M_{Friction}$ and the acceleration torque M_{accel}, the following dependencies result for the actual torque or torque limit M_{Limit}:

$$M_{Limit} \sim F_{Tension} * r_{Winder} + M_{accel} + M_{Friction}$$

Fig. 4-18: Torque limitation

Since tension torque and friction torque are opposite to each other while unwinding, the following condition results when not considering the acceleration torque and the mechanical drive i (S-0-0121 "Load gear, input revolutions" / S-0-0122 "Load gear, output revolutions"):

$$M_{Friction} \leq \frac{F_{Tension} * r_{winder}}{i_{mechanical}}$$

Fig. 4-19: Unwinder, condition for the friction torque

To obtain a value in percent, divide by S-0-0111 "Standstill current, motor" and the torque constant P-0-0051 "Torque/force constant".

$$M_{Friction} \leq \frac{F_{Tension} * r_{Winder}}{S-0-0111 * P-0-0051 * i_{mechanical}}$$

Fig. 4-20: Unwinder, condition for the friction torque in percent

☞ If the friction torque is higher than this condition (consideration with minimum tension and minimum winding diameter!), the unwinder goes into motor operation.

This case is more difficult to control with regard to its process and should thus be avoided.

Basic sequence of a "flying splice"

A so-called "flying splice" is a change from a roll to a new roll when the material web is still moving which can be performed according to the following basic diagram:

(two winding axes and two winding function blocks are required).

1. Currently unwinding roll reaches critical diameter for chopping.
2. Switch on the respective winding function block for the new roll and preset the diameter with the diameter of the new roll. Subsequently, set the "Pause" input.
3. Command the winding axis of the new roll and accelerate to the current web velocity.
4. Perform the material chopping (separating the unwinding roll from the web) and stick the new roll.
5. Disable the "Pause" input of the winding function block for the new roll.

   The function block can be switched off for the old roll.

4.4.4 Diagnostics for the winder with closed-loop tension control

The following error codes can occur for the winder with closed-loop tension control:

ErrorID	Additional1	Additional2	Text
STATE_MACHINE_ERROR	16#1100	16#0020	Error in state machine
INPUT_RANGE_ERROR	16#1101	16#0001	HighLimitDiameter < LowLimitDiameter
		16#0002	FormatLength < 0.0
		16#0003	WebWidth < 0.0
		16#0004	Density < 0.0
		16#0005	Core diameter < 0.0
		16#0006	DiamCalcRange < 0.0
		16#0007	Preset diameter < 0.0
		16#0008	Minimum diameter < 0.0
		16#0009	Maximum diameter < 0.0
		16#000A	HighLimitDiameter < 0.0
		16#000B	LowLimitDiameter < 0.0
		16#000C	DiamCalcMode invalid
		16#000D	Number of slave axis incorrect
		16#000E	Number of master axis incorrect
DEVICE_ERROR	16#1102	16#0001	No operating mode (no sercos phase 4)
RESSOURCE_ERROR	16#0004	16#0000	Incorrect drive firmware
RESSOURCE_ERROR	16#000F	16#0003	Drive function package "MA" not enabled

Tab. 4-11: Error codes of the MB_DiameterCalculatorType03 function block

ErrorID	Additional1	Additional2	Text
STATE_MACHINE_ERROR	16#1180	16#0020	Error in state machine
INPUT_RANGE_ERROR	16#1181	16#0001	HighLimit < LowLimit

Functional description

ErrorID	Additional1	Additional2	Text
INPUT_RANGE_ERROR	16#1181	16#0002	FormatLength < 0.0
INPUT_RANGE_ERROR	16#1181	16#0003	WebWidth < 0.0
INPUT_RANGE_ERROR	16#1181	16#0004	Density < 0.0
INPUT_RANGE_ERROR	16#1181	16#0005	CoreDiameter < 0.0
INPUT_RANGE_ERROR	16#1181	16#0008	MinDiameter < 0.0
INPUT_RANGE_ERROR	16#1181	16#0009	MaxDiameter < 0.0
INPUT_RANGE_ERROR	16#1181	16#000A	HighLimit < 0.0
INPUT_RANGE_ERROR	16#1181	16#000B	Lowlimit < 0.0
INPUT_RANGE_ERROR	16#1181	16#000C	Incorrect slave axis number
DEVICE_ERROR	16#1182	16#0001	No operating mode (sercos phase 4)
RESSOURCE_ERROR	16#0004	16#0000	Incorrect drive firmware
RESSOURCE_ERROR	16#000F	16#0003	Drive function package "MA" not enabled

Tab. 4-12: Error codes of the MB_DiameterMeasurementType01 function block

ErrorID	Additional1	Additional2	Description
STATE_MACHINE_ERROR	16#1120	16#20	Error in state machine
INPUT_RANGE_ERROR	16#1121	16#01	Diameter.MechanicInertia < 0.0
INPUT_RANGE_ERROR	16#1121	16#02	TensionCtrl.PreControlWeighting < 0.0
INPUT_RANGE_ERROR	16#1121	16#03	MaxTension < 0.0
INPUT_RANGE_ERROR	16#1121	16#04	TensionHighLimit < TensionLowLimit
INPUT_RANGE_ERROR	16#1121	16#05	Friction.StandstillTorque < 0.0
INPUT_RANGE_ERROR	16#1121	16#06	Friction.MaxTorque < 0.0
INPUT_RANGE_ERROR	16#1121	16#07	Friction.MinTorque < 0.0
INPUT_RANGE_ERROR	16#1121	16#08	Friction.MinVelocity < 0.0
INPUT_RANGE_ERROR	16#1121	16#09	WindowTension < 0.0
INPUT_RANGE_ERROR	16#1121	16#0A	MinTension < 0.0
INPUT_RANGE_ERROR	16#1121	16#0B	MaxTension < 0.0
INPUT_RANGE_ERROR	16#1121	16#0C	Winding axis not in "BB"
INPUT_RANGE_ERROR	16#1121	16#0D	Incorrect torque scaling (A-0-0050) Scaling for the motor torque has to be based on the motor side
INPUT_RANGE_ERROR	16#1121	16#0E	Axis number of the slave axis incorrect
INPUT_RANGE_ERROR	16#1121	16#0F	Axis number of the master axis incorrect
RESOURCE_ERROR	16#0004	16#0000	Incorrect drive firmware
RESOURCE_ERROR	16#000F	16#0003	Drive function package "MA" not enabled
RESOURCE_ERROR	16#0012	16#00xx	wrong local cntrl number for local cntrl xx
RESOURCE_ERROR	16#001C	16#00xx	wrong Axistype for Axis xx

Tab. 4-13: Error codes of the MB_WinderTensionCtrlType02 function block

4.5 Winder with closed-loop tension control and speed correction

4.5.1 Introduction and overview

The diameter calculator with closed-loop tension control and speed correction is used on center-driven winders. The drive of the winding axis generally **DOES NOT** operates at its torque limit. Due to safety reasons, a torque limit is calculated that can additionally be set (the limit should be above the required motor torque and should not limit the drive in normal operation).

This winder is mainly used for elastic, expandable material.

The actual tension value is measured directly with the help of a load cell and transferred to the tension controller as actual value via an analog channel or field bus. With the web tensioned, the diameter calculator can calculate the current winding diameter.

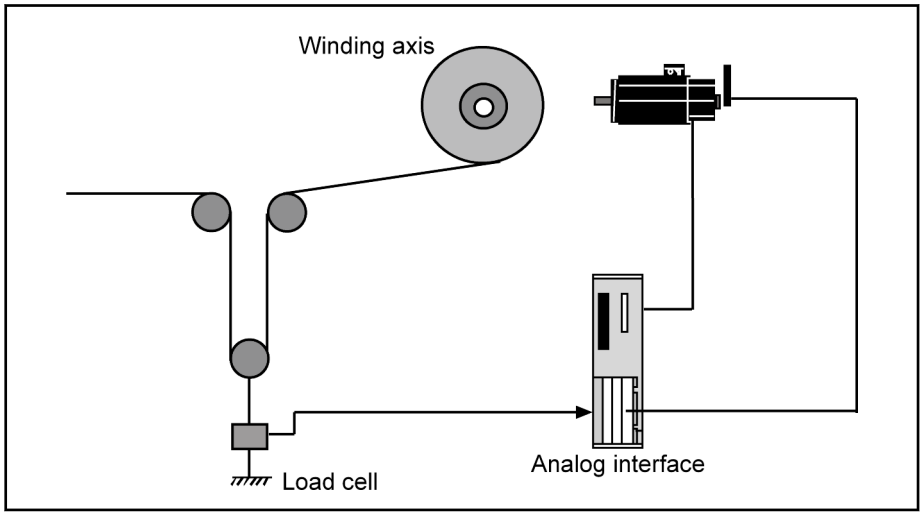

Fig. 4-21: Diameter calculator with closed-loop tension control

4.5.2 Interfaces of the winder with closed-loop tension control and speed correction

Interface description

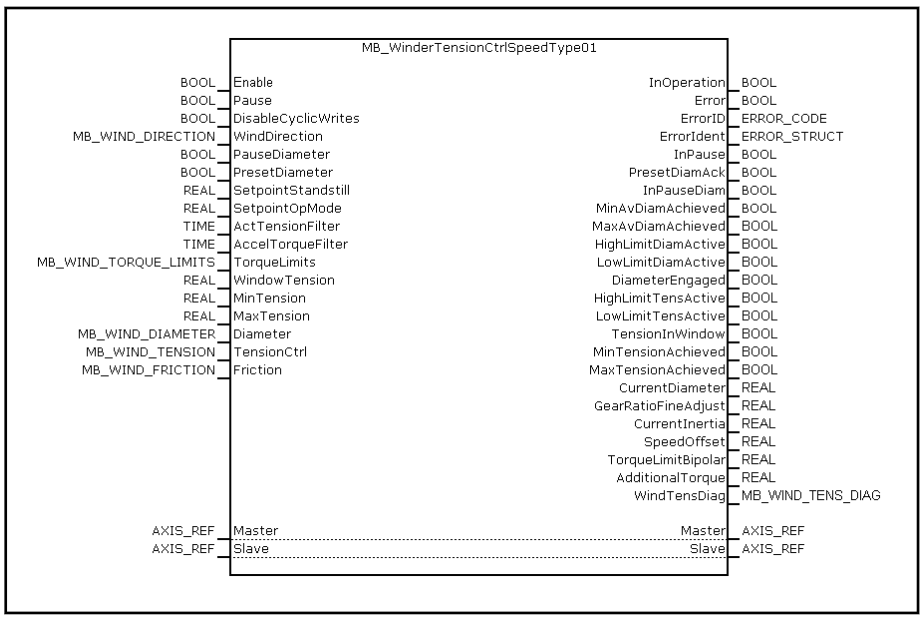

Fig. 4-22: MB_WinderTensionCtrlSpeedType01 function block

Functional description

I/O type	Name	Type	Comment
VAR_INPUT	Enable	BOOL	Processing of function block enabled (level-controlled)
	Pause	BOOL	Pausing the tension controller and the diameter calculator (values are frozen)
	DisableCyclicWrites	BOOL	If this input is set, the cyclic data is not written directly to the optional cyclic data container, but only displayed at the output
	WindDirection	MB_WIND_DIRECTION	Winding direction Rewinder REWIND (16#0000) Unwinder UNWIND (16#0001)
	PauseDiameter	BOOL	Pausing the diameter calculation
	PresetDiameter	BOOL	CurrentDiameter is set to PresetVal, GearRatioFineAdjust is adjusted accordingly (edge-controlled)
	SetpointStandstill	REAL	Specification of the standstill tension [N] (Switching between standstill tension and operating tension by means of the standstill message from the drive).
	SetpointOpMode	REAL	Specification of the operating tension [N] (Switching between standstill tension and operating tension by means of the standstill message from the drive).
	ActTensionFilter	TIME	Filter time constant for actual tension control
	AccelTorqueFilter	TIME	Filter time constant for acceleration torque
	TorqueLimits	MB_WIND_TORQUE_LIMITS	Structure for bipolar torque limit (S-0-0092)
	WindowTension	REAL	Window for the actual tension control value [%] in relation to the tension command value ("TensionInWindow")
	MinTension	REAL	Lower threshold for the actual tension value (only for a display with the binary output "MinTensionAck")
	MaxTension	REAL	Upper threshold for the actual tension control value (only for a display with binary output "MaxTensionAck")
	Diameter	MB_WIND_DIAMETER	Structure for diameter calculator
	TensionCtrl	MB_WIND_TENSION	Structure for tension controller
	Friction	MB_WIND_FRICTION	Structure for friction torque
VAR_OUTPUT	InOperation	BOOL	Function block is operating
	Error	BOOL	Processing completed with error
	ErrorID	ERROR_CODE	Diagnostic description in the event of an error
	ErrorIdent	ERROR_STRUCT	Detailed diagnostics
	InPause	BOOL	Tension controller and diameter calculator pause

I/O type	Name	Type	Comment
	PresetDiamAck	BOOL	Preset diameter was applied (is set as long as "Preset" is pending)
	InPauseDiam	BOOL	Diameter calculator pauses
	MinAvDiamAck	BOOL	Minimum diameter reached (relates to the averaged diameter)
	MaxAvDiamAck	BOOL	Maximum diameter reached (relates to the averaged diameter)
	HighLimitDiamAck	BOOL	Currently calculated diameter has reached the upper limit (diameter value is discarded)
	LowLimitDiamAck	BOOL	Currently calculated diameter has reached the lower limit (diameter value is discarded)
	DiameterEngaged	BOOL	Diameter "engaged" TRUE: engaged FALSE: disengaged
	HighLimitTensActive	BOOL	Output of the tension controller reached upper limit
	LowLimitTensActive	BOOL	Output of the tension controller reached lower limit
	TensionInWindow	BOOL	Actual tension value is within the tension window
	MinTensionAchieved	BOOL	Tension is below the "MinTension" input
	MaxTensionAchieved	BOOL	Tension is above the input "MaxTension"
	CurrentDiameter	REAL	Currently calculated diameter [mm]
	GearRatioFineAdjust	REAL	Resulting fine adjustment of the gear for speed tracing of the drive [%]
	CurrentInertia	REAL	Current total moment of inertia (based on the motor side [kg/m^2]
	SpeedOffset	REAL	Tensioning speed [rpm]
	TorqueLimitBipolar	REAL	Bipolar torque limit [%]
	AdditionalTorque	REAL	Additive torque [%]
	WindTensDiag	MB_WIND_TENS_DIAG	Diagnostic structure
VAR_IN_OUT CONSTANT	Master	AXIS_REF	Reference to master axis
	Slave	AXIS_REF	Reference to the slave axis (winding axis)

Tab. 4-14: Interface variables of the MB_WinderTensionCtrlSpeedType01 function block

Functional description

Functional diagram:

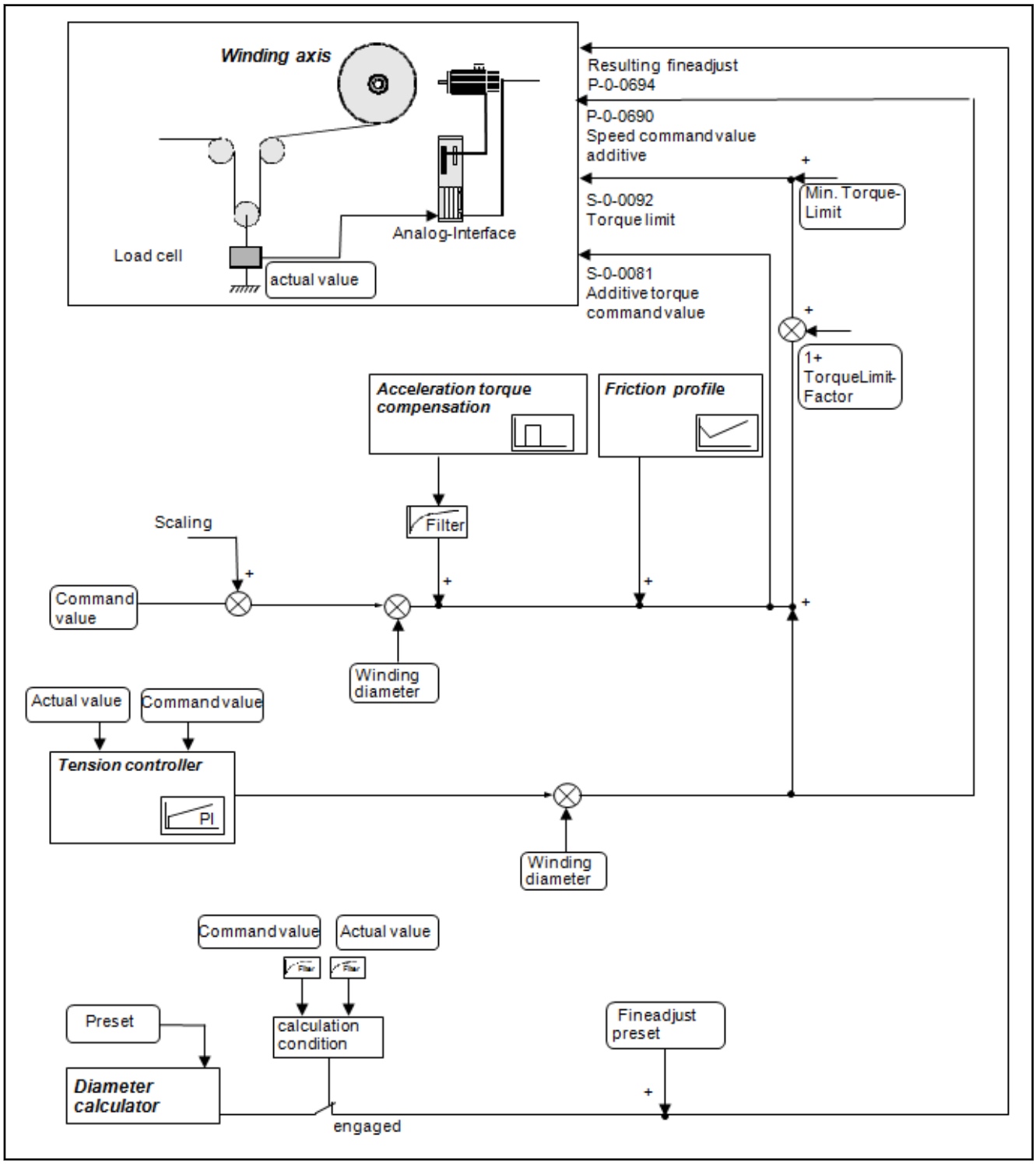

Fig. 4-23: Functional diagram of the winder with tension control and speed correction

4.5.3 Commissioning of the winder with closed-loop tension control and speed correction

General settings

Mechanical gear

An actually existing mechanical gear ratio from the drive axis to the winding axis has to be written to the parameters S-0-0121 ("Input revolutions of load gear") and S-0-0122 ("Output revolutions of load gear").

Operation mode of the winding drive (commanding)

Set the correct operation mode "Speed Synchronization" of the drive and the drive enabled for the winding axis.

There are two ways:

- Set the "ModeSyncVel" operation mode using the AxisInterface (recommended)
- Use the PLCopen "MC_Power", "MC_GearIn", "MC_Stop" function blocks to command the axis

The electronic gear between master axis and winding axis is to be set to 1:1 for the winding axis (A-0-2720 "ELS, master axis gear, input revolutions" or P-0-0156 "Electronic gear input revolutions" and A-0-2721 "ELS, master axis gear, output revolutions" or P-0-0157 "Electronic gear, output revolutions").

Setting the speed control loop

Perform the following for an empty and full roll:

- Set Tn to 0 and let the winding axis rotate freely at low speed.
- The parameter S-0-0100 "Velocity controller proportional gain" starts slowly from the default value until an oscillation of the velocity control deviation is detected at the oscilloscope.
- If the oscillation frequency is significantly higher than 500 Hz, the parameter P-0-0004 "Smoothing time constant - speed controller" is increased until the oscillation decreases again.

  In general, set the parameter P-0-0004 "Smoothing time constant - speed controller" to a minimum value of 1000.
- In this case, increase the parameter S-0-0100 "Velocity controller, proportional gain" until the control loop becomes instable again and then reduce it until the oscillation decays. Set the P-gain to the half of the last value set to be sufficiently far away from the stability limit.
- Decrease S-0-0101 "Velocity controller integral action time" starting from a relative high value (e.g. 1000 ms) until the control loop becomes instable and then increase it until the oscillation decreases. Enter twice the value as value for the parameter S-0-0101 "Velocity controller integral action time". The integral action time should not be lower than 150 ms.

Select the control loop setting of the drives accordingly to ensure that both extreme cases (minimum diameter and maximum diameter) can be operated with stability.

Otherwise, these two values can be linearly adapted to each other depending on the current diameter (function block MB_WindSpeedAdaptionType01).

Determining the direction of rotation of the winding axis

Set the direction of rotation of the tension or winding axis using the axis parameter A-0-2798 "Polarity of master axis position" or the drive parameter P-0-0108 "Master drive polarity". If the winding axis does not rotate in the desired direction, set the axis parameter A-0-2798 or the drive parameter P-0-0108 accordingly.

The following figure shows the general relations between rewinders and unwinders.

Functional description

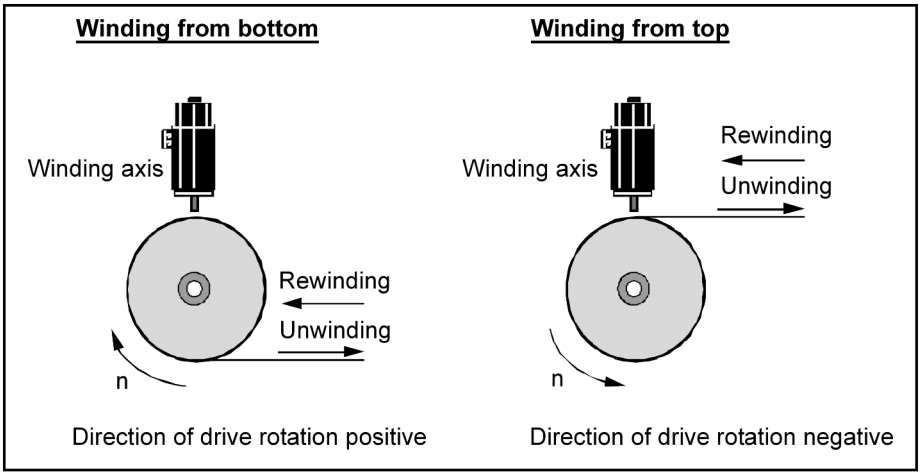

Fig. 4-24: Principles of rewinders and unwinders

Detecting the actual tension value

The actual tension value is generally read in via an analog input. The analog input can either be read in at the drive (onboard analog input or via an MA1 extension card) or via an Inline analog input module of the control.

The actual value detection only processes positive actual values. It might be required to add an offset to the read value to ensure this over the complete range (e.g. offset is 0.1 volt).

If the actual tension value is read in as analog voltage (volt), it has to be standardized to the unit Newton in the PLC using a a standardization factor (e.g. 10 volt correspond to 200 N, that is a standardization factor of 20 N/V).

Filter this actual value in case of strong variation using a PT1-filter (e.g. 20 ms). If the analog input is read in at the drive, the filter in the drive is to be preferably used. For analog input 1, this is set in the parameter P-0-0217 "Analog input 1, time constant input filter". If the analog input is read in at the control, a PT1-filter function block can be used in the PLC library "RIL_Loop-Control".

The actual value is connected to the "TensionCtrl.FeedbackVal" input.

Monitoring torque limit values

At the initial control startup, a drive warning "E2056 Torque limit value = 0" can be output if the winder function block is not yet enabled.

In order to prevent this, write a value unequal to zero (e.g. 100%) to the respective cyclic data container during the startup phase of the PLC program (e.g. warm start). The value of the parameter S-0-0092 "Bipolar torque/force" is written to the mentioned data container.

If the warning "E8260 Torque - force command value limit active" is output when the function block is enabled, clear this warning by setting bit 4 of the parameter P-0-0556, "Axis controller configuration".

In rare cases (e.g. multiple F8078 "Error in the speed control loop") it might be necessary to disable the velocity controller monitoring (set bit 1 of the parameter P-0-0556 "Axis controller configuration").

Enabling the correction of the torque constant at synchronous motors

The torque resulting from a motor is determined at the drive using the motor current and a so-called torque constant P-0-0051 "Torque/force constant". However, this so-called "torque or force constant" is a physical but not a static value.

It depends on:

1. the level of the actual motor current flow

   (the constant reduces at currents higher than I_{Nom})

2. the temperature of the motor winding and rotor

   (the constant reduces with rising temperature)

A corrected torque constant can be used for the **synchronous motor**. This constant can be enabled in the parameter **P-0-0556 "Axis controller configuration" bit 11 (set)**.

Thus, the following influences on the torque/force constant are considered:

1. Magnetic field weakening by magnetic saturation due to increased motor current compared to nominal current.
2. Magnetic field weakening due to increased motor winding temperature.
3. Magnetic field weakening due to increased rotor temperature depending on the average speed.

The torque constant effective in this case can be read in the parameter P-0-0450 "Torque/force constant, current".

A significant deviation from the torque constant P-0-0051 is only caused if the current load increases to 100% (or higher) of the nominal current S-0-0111 "Standstill current motor". That means the higher the motor load, the better the impact of correction. For a motor loaded at low level, only a minimum or no correction results.

A correction of the torque constant is automatically enabled for an asynchronous motor and does thus not need to be set separately in the parameter P-0-0556.

Also refer to the functional description of the respective IndraDrive drive.

Basic settings of the function block

Axis assignment

The axis reference (AXIS_REF) of the winding axis is connected to the "Slave" input.

The axis reference (AXIS_REF) of the master axis is connected to the "Master" input. This is the axis that provides the web velocity of the machine.

The scaling type has to be identical for the master and the slave axis. Rotary and preference scaling are recommended.

For the winding axis, the interpolation in the drive has to be enabled for the MLC control.

Setting rewinders or unwinders

Differentiate between rewinders or unwinders using the "WindDirection" input.

Specifying the tension command values

There is one tension command value available for the standstill "Setpoint-Standstill" and one for the normal operation mode "SetpointOpMode". Switching between these two command values is performed automatically using the standstill message of the master axis.

Set the standstill window of the master axis (parameter A-0-0222 "Standstill window" or S-0-0124 "Standstill window") to the lowest value possible (e.g. 0.1 rpm).

The two tension values can be set to the same value for the initial commissioning.

Settings for the diameter calculator

The settings for the diameter calculator are summarized in the "MB_Wind_Diameter" structure.

To calculate the diameter, set the structure variable "DiamSource" to "FALSE". To read the diameter externally, set the structure variable "DiamSource" to "TRUE".

Functional description

The core diameter of the winder (in mm) is written to the variable "CoreDiameter".

Enter the variable "RepeatLength" (in mm) for the diameter calculation. This corresponds to the circumference of the master axis.

The limitations ("HighLimit", "LowLimit") can additionally be entered for the diameter calculation. This limits the diameter to a minimum (e.g. core diameter) and to a maximum value (e.g. maximum winding roll possible).

Set the standstill window of the master axis (parameter A-0-0222 "Standstill window" or S-0-0124 "Standstill window") to the lowest value possible (e.g. 0.1 rpm). When there is a standstill message of the master or reference axis, the diameter calculator does not calculate!

Furthermore, enter the web width "WebWidth" (in mm) and the density "Density" (in kg/dm^3) of the material web.

The diameter calculation can be influenced via the calculation range "CalcRange" and an average value filter "AverageValue". At the beginning, there is a "CalcRange" of 360 degrees. Thus, **one calculation per winding axis revolution** and an "AverageValue" of 1 (an averaging) is not reasonable.

The diameter is only calculated if the material web is tensioned. That means that the binary output "DiameterEngaged" has to be set.

☞ The ratio "RepeatLength"/"CoreDiameter" may not be greater than 25.

Otherwise, the gear adjustment via the gear fine adjustment is insufficient!

A relative motion of a dancer roll (applies only to winders with dancer) is considered when calculating the diameter using the "DancerConstant" variables. Determine this dancer constant once for a winder with dancer.

First, set the dancer constant "DancerConstant" to zero (default)

Set the "DancerConstant" value always to zero for the winders with open-loop and closed-loop tension control.

Torque limit value, precontrol, DefaultTorqueLimit

The drive of the winding axis generally **DOES NOT** operates at its torque limit.

Due to safety reasons, the calculated torque is set as value for the torque limit, in addition to a variable additive value (this value should be above the required motor torque and should not limit the drive in normal operation).

A torque limit proportional to the tension and the respective radius of the winder r is calculated cyclically.

$$M_{Limit} \sim F_{Tension} * r_{Winder} + M_{Accel.} + M_{Friction}$$

Fig. 4-25: Torque limit

This cyclic value for the torque limit is precontrolled as additive torque command value.

Furthermore, this value can be increased by a proportional ratio (TorqueLimitFactor) and an additive ratio (MinTorqueLimit) so that the torque limit does not become active during normal winder operation.

$$M_{ResLimit} \sim M_{Limit} * (1 + TorqueLimitFactor) + MinTorqueLimit$$

Fig. 4-26: Resulting torque limit

Set the "TorqueLimits.TorqueLimitFactor" input to approximately 20 %.

Set the "TorqueLimits.MinTorqueLimit" input to approximately 10 %.

When switching off the function block, the torque is set to the value of the "TorqueLimits.DefaultTorqueLimit" input.

Enter a value (e.g. 100 %) at the "DefaultTorqueLimit" input.

Filtering the actual tension value

To determine whether the web is tensioned, the tension command value and the actual tension value are compared with each other. If the two values differ from each other more than 25 %, the web is considered as untensioned (diameter calculator does not calculate anymore).

At low tensions, an unfiltered actual tension value can cause the diameter calculator to engage. Thus, a filtering of this value can be set at the function block ("ActTensionFilter" input) to achieve a constant tensioning condition "DiameterEngaged".

For this purpose, a value of 20 ms for example can be set at the "ActTensionFilter" input.

Filtering the acceleration compensation

To compensate acceleration and deceleration processes, an additional acceleration torque is added. This acceleration torque can be increased using a filter.

For this purpose, enter a filter time (e.g. 20 ms) at the "AccelTorqueFilter" input.

Diagnostic settings

To monitor the tension, several binary diagnostic outputs can be evaluated. The "WindowTension" input (in %) is used to put a window around the tension command value. If the actual tension value is in the window, this is displayed at the "TensionInWindow" output (e.g. "TensionInWindow" 30 %).

To display if maximum threshold values have been exceeded or if the values were fallen below these thresholds, a "MinTension" (in N) and "MaxTension" (in N) can be entered.

Determining the friction characteristic

Friction torque at standstill:

1. The "friction torque at standstill" ("StandstillTorque" variable in the data structure MB_WIND_TENSION) is determined when the master axis is at standstill and the winder is empty (core only). The winding function block is disabled. For the winding axis (slave axis), select the operating mode "Velocity control" (select in AxisInterface of the ML_TechInterface "MODE_VEL" library). Optionally, the axis can be controlled using the PLCopen function block MC_MoveVelocity. 10 rpm can be set as command value.
2. The value of the parameter P-0-0109 "Peak torque/force limit" is set to zero. The axis has to stop now. The value for this parameter is incremented until the drive starts to rotate. The last value corresponds to the friction torque at standstill.
3. The axis enabled "MODE_VEL" is canceled (also by using the PLCopen function block "MC_Stop").

   The parameter P-0-0109 "Peak torque/force limit" is reset to its previous value (e.g. 400 %).

   The friction torque setting at standstill is thus completed.

Friction torque at maximum speed:

The "friction torque at maximum speed" ("MaxTorque" variable in the data structure MB_WIND_TENSION) is determined when the master axis is at standstill and with an empty winder (core only). The function block is disabled.

Functional description

1. Select the operation mode "Velocity control" for the winding axis (slave axis) (in the AxisInterface of the ML_TechInterface "MODE_VEL", also the PLCopen function block).

   Increase the command value for the selected operation mode incrementally up to the value of the parameter S-0-0091 "Bipolar velocity limit value". Enter the value for the parameter S-0-0091 "Bipolar velocity limit value" according to application and motor data.

2. In the next step, the value of the parameter P-0-0109 "Peak torque/force limit" is decreased incrementally (e.g. from 100% towards 0%) until the drive speed also starts to decrease. The speed of the drive can be traced using the drive parameter S-0-0040 "Actual velocity value" or the axis parameter A-0-0102 "Actual velocity value". The last value of P-0-0109 "Peak torque/force limit" corresponds to the maximum friction torque at maximum speed.
3. The axis enabled "MODE_VEL" is canceled (also by using the PLCopen function block "MC_Stop").

   The parameter P-0-0109 "Peak torque/force limit" is reset to its previous value (e.g. 400 %).

   Setting the friction torque at maximum speed "MaxTorque" is thus completed.

Determining the minimum friction torque:

The minimum friction torque is determined using the deceleration test with an empty winder. The winding drive is decelerated from a constant velocity (e.g. 50 min^{-1}) to standstill (by setting the operation mode "Mode_AH" of the AxisInterface or by using the PLCopen function block "MC_Stop"). At the same time, the drive parameters P-0-0049 "Effective torque/force command value" (axis parameter A-0-0038 "Torque/force limit value, bipolar") and S-0-0040 "Actual velocity value" (axis parameter A-0-0102 "Actual velocity value") are recorded with an oscilloscope or with the trace function in IndraWorks.

The minimum value is read from the torque curve and can be transferred to the structure MB_WIND_FRICTION as "MinTorque". The corresponding speed is entered as "MinTorqueVelocity" in MB_WIND_FRICTION.

Cyclic data channels for the winding drive

Interpolation in the drive:

Write the **parameters P-0-0694 ("Gear ratio fine adjustment, process controller")**, **P-0-0690 ("Additive velocity command value, process controller"**, **S-0-0092 "Bipolar torque/force limit value"** and **S-0-0081 "Additive velocity command value, process controller"** to the cyclic Sercos channel of the corresponding drive ("UserCmdDataX"). The real axes are parameterized in the parameterization mode in IndraWorks.

Interpolation in the control:

The target variables are the control parameters **A-0-2605 "ELS, gear ratio fine adjustment, process controller"**, **A-0-2615 "ELS, additive velocity command value, process controller"**, **S-0-0092 "Bipolar torque and force limit value"** and **S-0-0081 "Additive torque/force command value"**.

Write the parameters **S-0-0092 "Bipolar torque and force limit value"** and **S-0-0081 "Additive torque/force command value"** to the cyclic Sercos channel of the respective drive.

The function block sets these parameters automatically. If this is not desired, switch it off via the "DisableCyclicWrites" input. In this case, set the outputs

"GearRatioFineAdjust", "SpeedOffset", "TorqueLimitBipolar" and "AdditionalTorque" manually to the corresponding parameters.

Final basic settings

Set the P-gain of the tension controller "TensionCtrl.PControl" to 0.1 for the initial commissioning.

Set the command value precontrol "TensionCtrl.PreControlWeighting" to 1.0 (default).

Set the limitations "TensionCtrl.HighLimit" and "TensionCtrl.LowLimit" (e.g. five times the tension command value).

Set the process variable window "WindowTension" to 30 % for example. If the actual tension value is within the range of the tension command value +/- 30%, this is displayed at the "InWindowTension" output.

Set the minimum and maximum thresholds "MinTension" and "MaxTension" to the desired threshold values for the actual tension value (absolute values in the unit of the tension command value). Exceeding or falling below the actual tension value is displayed in the binary outputs "MinTensionAchieved" and "MaxTensionAchieved".

The moment of inertia of mechanics and winding shaft "MechanicInertia" can be set to 0 at the beginning.

Operating the function block

Initial startup of the winding axis

1. "Enable" of the function block for the winder with open-loop tension control. Set the diameter preset to the desired value (using the binary signal "PresetDiameter" and the value "Diameter.PresetVal").
2. Switch on the synchronous operation modes of all axes participating in the web process (for the winding axis "Speed synchronization" and "ModeSyncVel").
3. The winding axis has to tension the web.

   If the winding axis rotates in the wrong direction, check the direction of the winding axis without winder function block and winder type (rewinder or unwinder).
4. Synchronous run of the machine via specification of a velocity command value for the master axis (MoveVelocity for the master axis with 20 rpm for example). The web has to remain tensioned.
5. Check the calculated winding diameter after several winding axis revolutions.

   If the calculated diameter deviates more than 5 % from the actual diameter, check the mechanical gear and the "RepeatLength" of the master.
6. Stop the machine by setting the master axis command value to zero.

Setting the tension control loop

1. "Enable" of the function block for the winder with closed-loop tension control.
2. Switch on the synchronous operation modes of all axes participating in the web process (for the winding axis "Speed synchronization" and "ModeSyncVel").
3. The winding axis has to move into this direction to tension the web.
4. **Open the limitations for the tension controller**. That means set "LowLimitControl" and "HighLimitControl" at least to a value twenty times as high as the tension command value (N).
5. Synchronous run of the machine via specification of a velocity command value for the master axis (MoveVelocity for the master axis with 20 rpm for example). The web has to remain tensioned.

Increase the Kp-gain "PControl" incrementally and oscillograph the actual tension value and the torque limit "TorqueLimitBipolar" until these signals are located in the desired accuracy range.

Determine the critical Kp-gain "PControl" alternatively (increase Kp-gain step by step until the actual tension value oscillates. Subsequently, decrease the Kp-gain until the oscillation decays and halves the Kp-gain.

Enter the integral action time "IControl". A value within the range of seconds (e.g. two seconds) is recommended (a significantly lower value can be entered for "IControl" at standstill). Increase the integral action time "IControl" step by step and oscillograph the actual tension value and the torque limit "TorqueLimitBipolar" until these signals are located in the desired accuracy range.

6. Enter the values again for the **limitations of the tension controller**.
7. Check the values determined at higher machine velocities or master axis velocities. If necessary, travel along the velocity profile of the master axis and correct controller values if required.

Specifics features for the winder with closed-loop tension control and speed correction

Setting of the tension controller:

The Kp-gain value for the tension controller ("PControl") depends on the material of the web. The following generally applies: The stiffer the material to be wound, the lower the Kp-gain of the tension controller. If different materials are wound, adjust the Kp-gain to the material.

Basic sequence of a "flying splice"

A so-called "flying splice" is a change from a roll to a new roll when the material web is still moving which can be performed according to the following basic diagram:

(two winding axes and two winding function blocks are required).

1. Currently unwinding roll reaches critical diameter for chopping.
2. Switch on the respective winding function block for the new roll and preset the diameter with the diameter of the new roll. Subsequently, set the "Pause" input.
3. Command the winding axis of the new roll and accelerate to the current web velocity.
4. Perform the material chopping (separating the unwinding roll from the web) and stick the new roll.
5. Disable the "Pause" input of the winding function block for the new roll.

   The function block can be switched off for the old roll.

4.5.4 Diagnostics for the winder with closed-loop tension control and speed correction

The following error codes can occur for the winder with closed-loop tension control:

ErrorID	Additional1	Additional2	Text
STATE_MACHINE_ERROR	16#1100	16#0020	Error in state machine
INPUT_RANGE_ERROR	16#1101	16#0001	HighLimitDiameter < LowLimitDiameter
		16#0002	FormatLength < 0.0
		16#0003	WebWidth < 0.0
		16#0004	Density < 0.0
		16#0005	Core diameter < 0.0
		16#0006	DiamCalcRange < 0.0
		16#0007	Preset diameter < 0.0
		16#0008	Minimum diameter < 0.0
		16#0009	Maximum diameter < 0.0
		16#000A	HighLimitDiameter < 0.0
		16#000B	LowLimitDiameter < 0.0
		16#000C	DiamCalcMode invalid
		16#000D	Number of slave axis incorrect
		16#000E	Number of master axis incorrect
DEVICE_ERROR	16#1102	16#0001	No operating mode (no sercos phase 4)
RESSOURCE_ERROR	16#0004	16#0000	Incorrect drive firmware
RESSOURCE_ERROR	16#000F	16#0003	Drive function package "MA" not enabled

Tab. 4-15: Error codes of the MB_DiameterCalculatorType03 function block

ErrorID	Additional1	Additional2	Text
STATE_MACHINE_ERROR	16#1180	16#0020	Error in state machine
INPUT_RANGE_ERROR	16#1181	16#0001	HighLimit < LowLimit
INPUT_RANGE_ERROR	16#1181	16#0002	FormatLength < 0.0
INPUT_RANGE_ERROR	16#1181	16#0003	WebWidth < 0.0
INPUT_RANGE_ERROR	16#1181	16#0004	Density < 0.0
INPUT_RANGE_ERROR	16#1181	16#0005	CoreDiameter < 0.0
INPUT_RANGE_ERROR	16#1181	16#0008	MinDiameter < 0.0
INPUT_RANGE_ERROR	16#1181	16#0009	MaxDiameter < 0.0
INPUT_RANGE_ERROR	16#1181	16#000A	HighLimit < 0.0
INPUT_RANGE_ERROR	16#1181	16#000B	Lowlimit < 0.0
INPUT_RANGE_ERROR	16#1181	16#000C	Incorrect slave axis number
DEVICE_ERROR	16#1182	16#0001	No operating mode (sercos phase 4)
RESSOURCE_ERROR	16#0004	16#0000	Incorrect drive firmware
RESSOURCE_ERROR	16#000F	16#0003	Drive function package "MA" not enabled

Tab. 4-16: Error codes of the MB_DiameterMeasurementType01 function block

Functional description

ErrorID	Additional1	Additional2	Description
STATE_MACHINE_ERROR	16#11B0	16#0020	Error in the state machine
INPUT_RANGE_ERROR	16#11B1	16#0001	Diameter.MechanicInertia < 0.0
INPUT_RANGE_ERROR	16#11B1	16#0002	TensionCtrl.PreControlWeighting < 0.0
INPUT_RANGE_ERROR	16#11B1	16#0003	MaxTension < 0.0
INPUT_RANGE_ERROR	16#11B1	16#0004	TensionHighLimit < TensionLowLimit
INPUT_RANGE_ERROR	16#11B1	16#0005	Friction.StandstillTorque < 0.0
INPUT_RANGE_ERROR	16#11B1	16#0006	Friction.MaxTorque < 0.0
INPUT_RANGE_ERROR	16#11B1	16#0007	Friction.MinTorque < 0.0
INPUT_RANGE_ERROR	16#11B1	16#0008	Friction.MinVelocity < 0.0
INPUT_RANGE_ERROR	16#11B1	16#0009	WinderTension < 0.0
INPUT_RANGE_ERROR	16#11B1	16#000A	MinTension < 0.0
INPUT_RANGE_ERROR	16#11B1	16#000B	MaxTension < 0.0
INPUT_RANGE_ERROR	16#11B1	16#000C	Incorrect torque scaling (A-0-0050 or S-0-0086), scaling for motor torque has to be on the motor side
INPUT_RANGE_ERROR	16#11B1	16#000E	Axis number of the slave axis incorrect
INPUT_RANGE_ERROR	16#11B1	16#000F	Axis number of the master axis incorrect
INPUT_RANGE_ERROR	16#11B1	16#0010	SetpointStandstill < 0.0
INPUT_RANGE_ERROR	16#11B1	16#0011	SetpointOpMode < 0.0
INPUT_RANGE_ERROR	16#11B1	16#0012	DefaultTorqueLimit < 0.0
INPUT_RANGE_ERROR	16#11B1	16#0013	MinTorqueLimit < 0.0
INPUT_RANGE_ERROR	16#11B1	16#0014	TorqueLimitFactor < 0.0
INPUT_RANGE_ERROR	16#11B2	16#0001	Winding axis not in "BB"
RESOURCE_ERROR	16#0004	16#0000	Incorrect drive firmware
RESOURCE_ERROR	16#000F	16#0003	Drive function package "MA" not enabled
RESOURCE_ERROR	16#0012	16#00xx	AxisRef.CntrlNo incorrect
RESOURCE_ERROR	16#001C	16#00xx	Incorrect axis type for axis xx

Tab. 4-17: Error codes of the MB_WinderTensionCtrlSpeedType01 function block

5 Visualization dialogs

5.1 Introduction

Visualization dialogs are available for the MLC control for the following tasks in IndraWorks:

1. Winder with closed-loop dancer position control and dancer roll
2. Winder with open-loop tension control (without sensor)
3. Winder with closed-loop tension control and torque limitation

These are located in the project tree below the technology node.

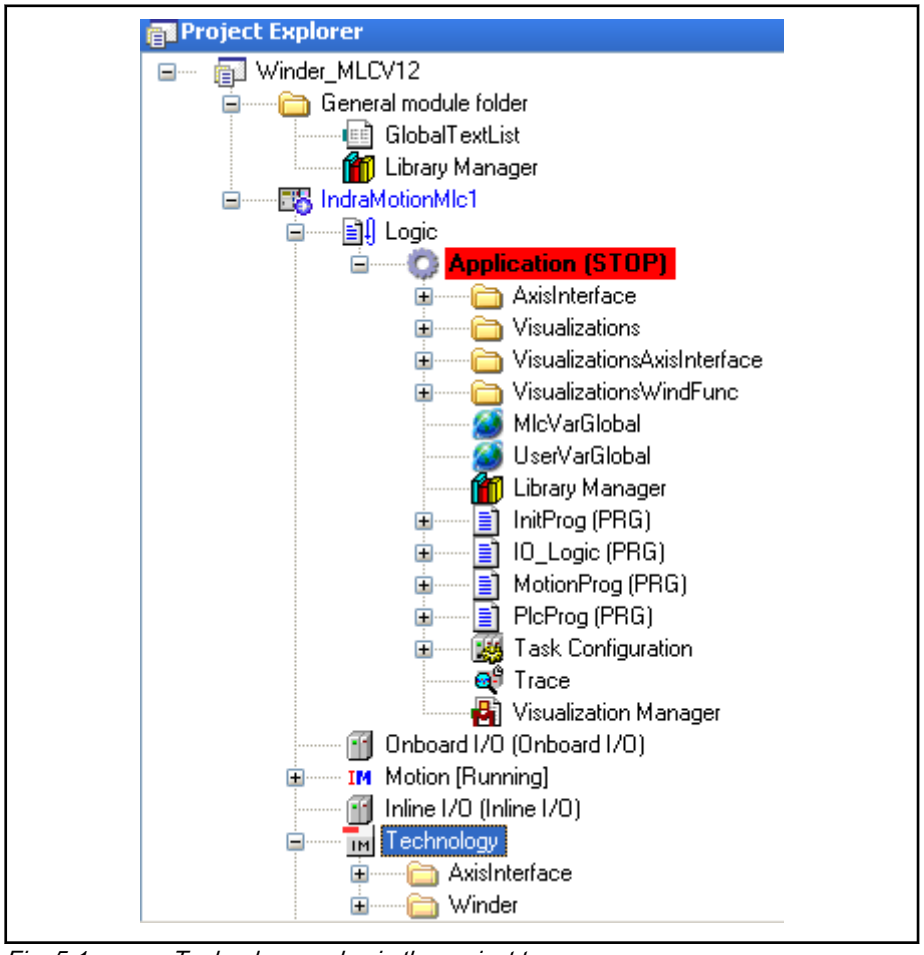

Fig. 5-1: Technology nodes in the project tree

These dialogs are provided in the project tree after the following conditions have been fulfilled:

- Usage of the respective function blocks in the PLC program
- Compiling the PLC project
- "Online switching" with the control

Visualization dialogs

5.2 Dialogs for winders with closed-loop dancer position control

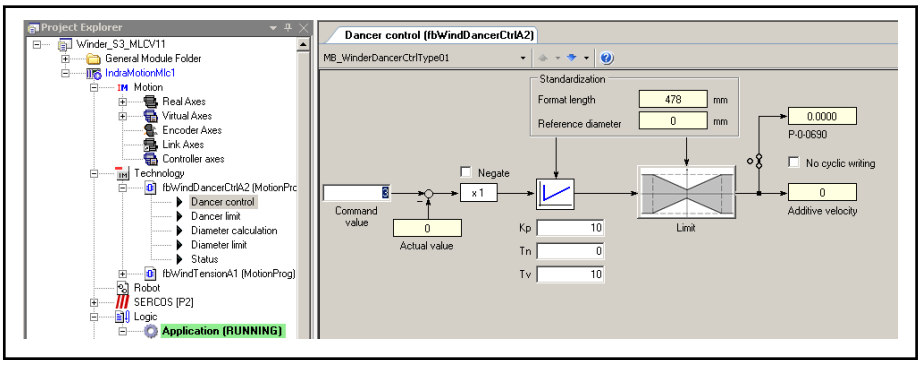

Fig. 5-2: Closed-loop dancer position control

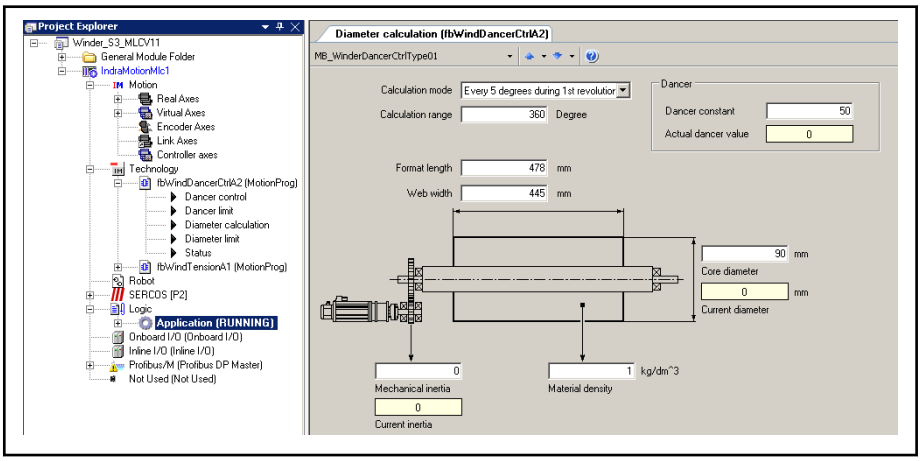

Fig. 5-3: Diameter calculation

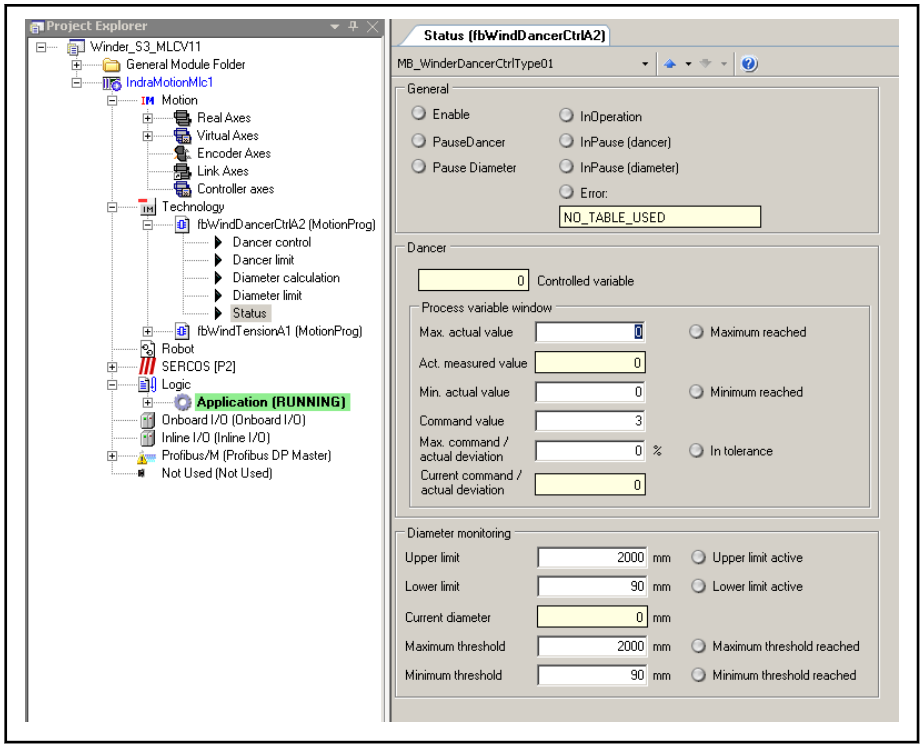

Fig. 5-4: Winder with dancer, status

5.3 Dialogs for winders with open-loop tension control (without sensor)

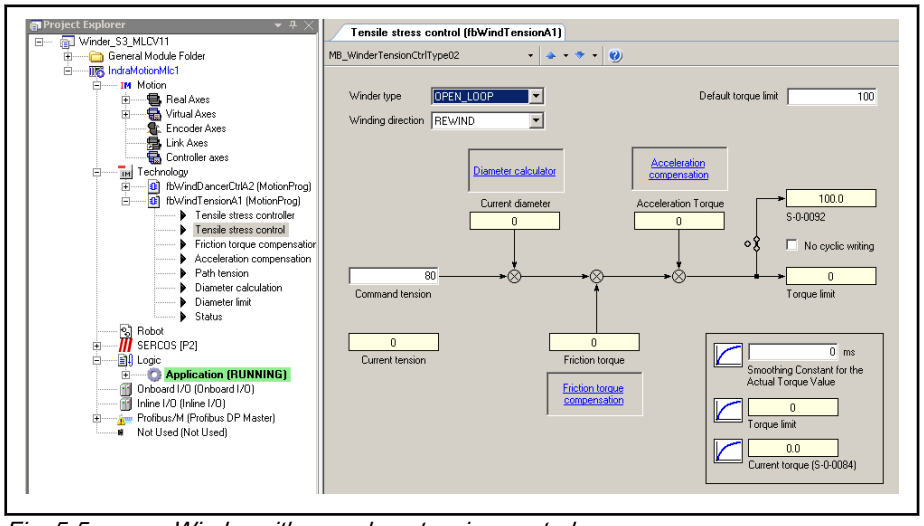

Fig. 5-5: Winder with open-loop tension control

Visualization dialogs

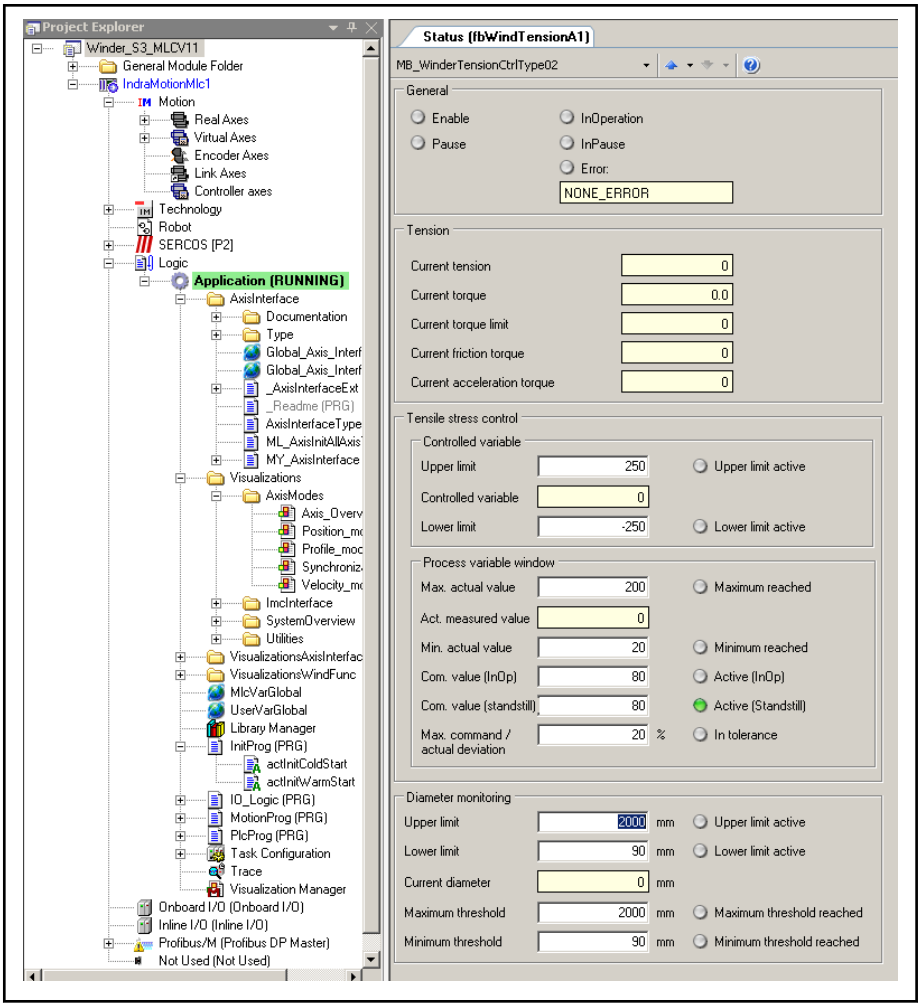

Fig. 5-6: Winder with open-loop tension control, status

5.4 Dialogs for winders with closed-loop tension control

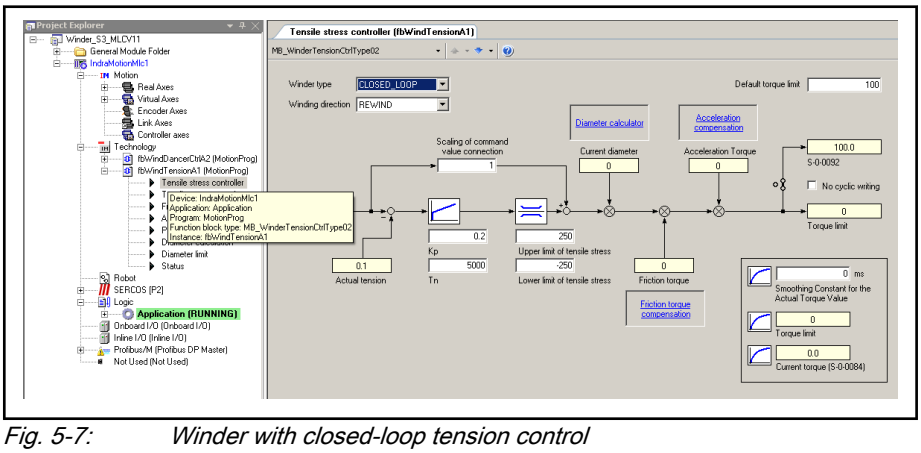

Fig. 5-7: Winder with closed-loop tension control

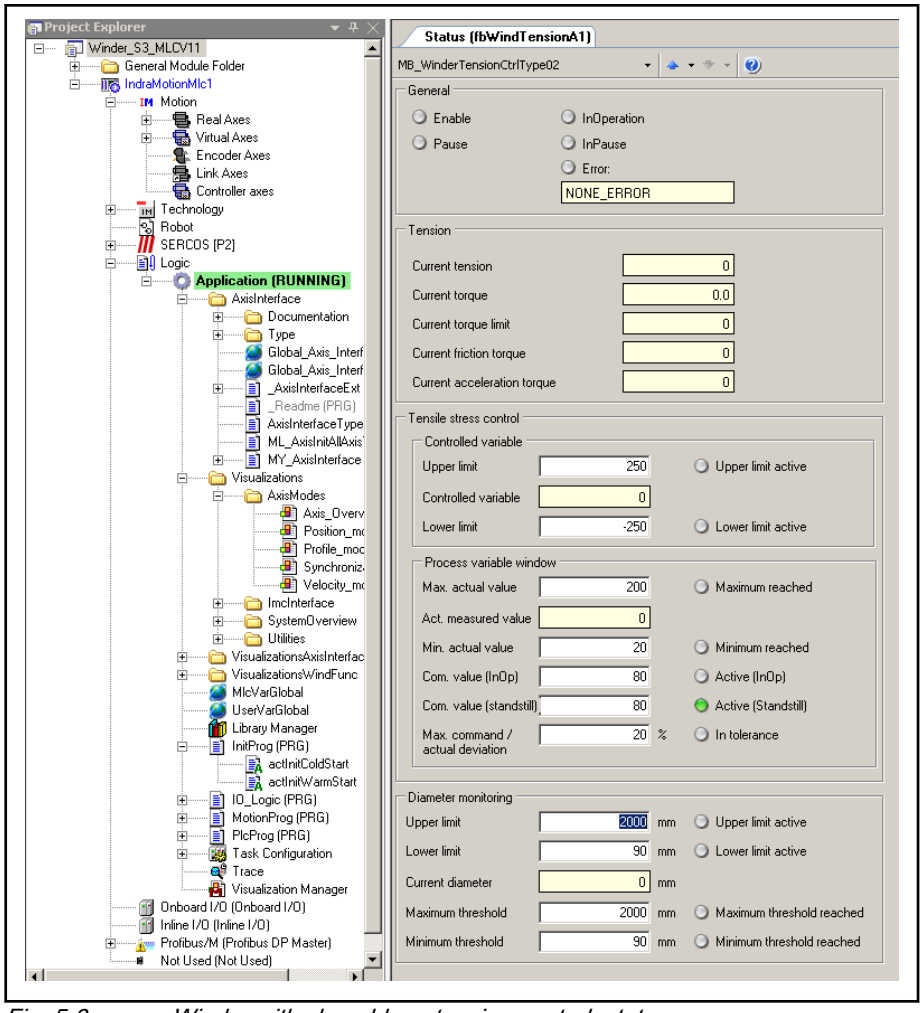

Fig. 5-8: Winder with closed-loop tension control, status

6 Service and support

Our worldwide service network provides an optimized and efficient support. Our experts offer you advice and assistance should you have any queries. You can contact us **24/7**.

Service Germany

Our technology-oriented Competence Center in Lohr, Germany, is responsible for all your service-related queries for electric drive and controls.

Contact the **Service Hotline** and **Service Helpdesk** under:

Phone:	**+49 9352 40 5060**
Fax:	**+49 9352 18 4941**
E-mail:	service.svc@boschrexroth.de
Internet:	http://www.boschrexroth.com/

Additional information on service, repair (e.g. delivery addresses) and training can be found on our internet sites.

Service worldwide

Outside Germany, please contact your local service office first. For hotline numbers, refer to the sales office addresses on the internet.

Preparing information

To be able to help you more quickly and efficiently, please have the following information ready:

- Detailed description of malfunction and circumstances
- Type plate specifications of the affected products, in particular type codes and serial numbers
- Your contact data (phone and fax number as well as your e-mail address)

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