



Instruction Manual

VLT[®] Frequency Converters - Safe Torque Off



Contents

1 Introduction	2
1.1 Purpose of the Manual	2
1.2 Additional Resources	2
1.3 Functional Overview	2
1.4 Approvals and Certifications	3
1.5 Symbols, Abbreviations and Conventions	4
2 Safety	5
2.1 Safety Symbols	5
2.2 Qualified Personnel	5
2.3 Safety Precautions	5
3 Installation	7
3.1 Safety Instructions	7
3.2 Safe Torque Off Installation	7
3.3 Installation in Combination with Thermistor Module MCB 112	8
4 Commissioning	9
4.1 Safety Instructions	9
4.2 Activation and Termination of Safe Torque Off	9
4.3 Parameter Settings for STO in Combination with Thermistor Module MCB 112	9
4.4 Automatic/Manual Restart Behavior	9
4.5 Safe Torque Off Commissioning Test	10
4.5.1 Restart Prevention for STO Application	10
4.5.2 Automatic Restart of Safe Torque Off Application	10
4.6 System Configuration Security	10
4.7 Service and Maintenance	10
5 Safe Torque Off Technical Data	11
Index	12

1 Introduction

1.1 Purpose of the Manual

This manual provides information for the use of Danfoss VLT® adjustable frequency drives in functional safety applications. The manual includes information about functional safety standards, Danfoss VLT® adjustable frequency drive Safe Torque Off (STO) function, and the related installation and commissioning as well as service and maintenance for STO.

1.2 Additional Resources

This manual is targeted at users already familiar with the VLT® adjustable frequency drives and is intended as a supplement to the manuals and instructions available for download at www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations/VLT+Technical+Documentation.htm. Read the instructions shipped with the adjustable frequency drive and/or adjustable frequency drive option before installation of the unit and observe the instructions for safe installation.

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1.3 Functional Overview

1.3.1 Introduction

The Safe Torque Off (STO) function is a component in a safety control system. Components in the system must be selected and applied appropriately to achieve the desired level of operational safety. STO disables the control voltage of the power semiconductors of the adjustable frequency drive output stage, which in turn prevents generating the voltage required to rotate the motor.

The adjustable frequency drive can integrate the safety function Safe Torque Off (STO, as defined by EN IEC 61800-5-2) and Stop Category 0 (as defined in EN 60204-1). The adjustable frequency drive is available with STO functionality via control terminal 37.

Before integrating and using STO in an installation, a thorough risk analysis on the installation must be carried out to determine whether the STO functionality and safety levels are appropriate and sufficient. The adjustable frequency drive with STO functionality is designed and approved, suitable for the requirements of:

- Category 3 in EN ISO 13849-1
- Performance Level "d" in EN ISO 13849-1
- SIL 2 in IEC 61508 and EN 61800-5-2
- SILCL 2 in EN 62061

1.3.2 Products Covered and Identification

The STO function is available for the following types of adjustable frequency drives:

- VLT® HVAC Drive FC 102
- VLT® Refrigeration Drive FC 103
- VLT® AQUA Drive FC 202
- VLT® AutomationDrive FC 301 enclosure type A1
- VLT® AutomationDrive FC 302

Identification

- Confirm that the adjustable frequency drive is configured with STO function by checking the unit type code on the nameplate (see *Table 1.1*).

Product	Type Code
VLT® HVAC Drive FC 102	T or U at digit 17 of the type code
VLT® Refrigeration Drive FC 103	T at digit 17 of the type code
VLT® AQUA Drive FC 202	T or U at digit 17 of the type code
VLT® AutomationDrive FC 301 enclosure type A1	T at digit 17 of the type code
VLT® AutomationDrive FC 302	X, B or R at digit 17 of the type code

Table 1.1 Type Code Identification

1.4 Approvals and Certifications



Table 1.2 Approvals and Certifications

More approvals and certifications are available. Contact local Danfoss partner.

Applied standards and compliance

Use of Safe Torque Off on terminal 37 requires that the user satisfies all provisions for safety including relevant laws, regulations and guidelines. The integrated STO function complies with the following standards:

- IEC 60204-1: 2005 Stop category 0 – uncontrolled stop
- EN 60204-1: 2006 Stop category 0 – uncontrolled stop
- IEC/EN 61508: 2010 SIL2
- IEC/EN 61800-5-2:2007
- IEC/EN 62061: 2005 SIL CL2
- ISO 13849-1: 2006 Category 3 PL d
- EN ISO 13849-1:2008 Category 3 PL d

1.5 Symbols, Abbreviations and Conventions

Abbreviation	Reference	Description
Cat.	EN ISO 13849-1	Category, level "B, 1-4"
DC		Diagnostic Coverage
FIT		Failure In Time: 1E-9/hour
HFT	EN IEC 61508	Hardware Fault Tolerance: HFT = n means that n+1 faults could cause a loss of the safety function
MTTFd	EN ISO 13849-1	Mean Time To Failure - dangerous. Unit: years
PFH	EN IEC 61508	Probability of Dangerous Failures per Hour. This value shall be considered if the safety device is operated in high demand or continuous mode of operation, where the frequency of demands for operation made on a safety-related system is greater than one per year
PFD	EN IEC 61508	Average probability of failure on demand, value used for low demand operation
PL	EN ISO 13849-1	Discrete level used to specify the ability of safety related parts of control systems to perform a safety function under foreseeable conditions. Levels a-e
SFF	EN IEC 61508	Safe Failure Fraction [%]; percentage of safe failures and dangerous detected failures of a safety function or a subsystem related to all failures
SIL	EN IEC 61508 EN IEC 62061	Safety Integrity Level
STO	EN IEC 61800-5-2	Safe Torque Off
SS1	EN IEC 61800 -5-2	Safe Stop 1
SRECS	EN IEC 62061	Safety Related Electrical Control System
SRP/CS	EN ISO 13849-1	Safety Related Parts of Control Systems
PDS/SR	EN IEC 61508	Power Drive System (Safety-related)

Table 1.3 Abbreviations Related to Functional Safety

Conventions

Numbered lists indicate procedures.

Bullet lists indicate other information and description of figures.

Italicized text indicates

- cross reference
- link
- parameter name

2 Safety

2.1 Safety Symbols

The following symbols are used in this document:

⚠ WARNING

Indicates a potentially hazardous situation which could result in death or serious injury.

⚠ CAUTION

Indicates a potentially hazardous situation which could result in minor or moderate injury. It may also be used to alert against unsafe practices.

NOTICE!

Indicates important information, including situations that may result in damage to equipment or property.

2.2 Qualified Personnel

The products may only be assembled, installed, programmed, commissioned, maintained, and decommissioned by persons with proven skills. Persons with proven skills

- are qualified electrical engineers, or persons who have received training from qualified electrical engineers and are suitably experienced to operate devices, systems, plant and machinery in accordance with the general standards and guidelines for safety technology.
- are familiar with the basic regulations concerning health and safety/accident prevention.
- have read and understood the safety guidelines given in this manual and also the instructions given in the *Instruction Manual* of the adjustable frequency drive.
- have a good knowledge of the generic and specialist standards applicable to the specific application.

Users of PDS(SR)s are responsible for

- hazard and risk analysis of the application
- identifying safety functions required and allocating SIL or PLr to each of the functions
- other subsystems and the validity of signals and commands from them

- designing appropriate safety-related control systems (hardware, software, parameterization, etc.)

Protective Measures

- Safety engineering systems may only be installed and commissioned by qualified and skilled personnel
- Install the adjustable frequency drive in an IP54 cabinet as per IEC 60529 or in an equivalent environment. In special applications, a higher IP degree may be necessary
- Ensure short-circuit protection of the cable between terminal 37 and the external safety device according to ISO 13849-2 table D.4
- When external forces influence the motor axis (e.g., suspended loads), additional measures (e.g., a safety holding brake) are required to eliminate hazards

2.3 Safety Precautions

See the *Safety Chapter* in the relevant *Instruction Manual* for general safety precautions.

⚠ CAUTION

After installation of STO, a commissioning test as specified in *chapter 4.5 Safe Torque Off Commissioning Test* must be performed. A passed commissioning test is mandatory after first installation and after each change to the safety installation.

⚠ WARNING

If external forces act on the motor, e.g., in the case of vertical axis (suspended loads) - and an unwanted movement, e.g., caused by gravity, could cause a hazard, the motor must be equipped with additional measures for fall protection. For example, mechanical brakes must be installed additionally. Risk of death and serious injury.

⚠ WARNING

Safe Torque Off (i.e., removal of 24 V DC voltage supply to terminal 37) does not provide electrical safety. The Safe Torque Off function itself is not sufficient to implement the Emergency-Off function as defined by EN 60204-1. Emergency-Off requires measures of electrical isolation, e.g. by switching off line power via an additional contactor. Risk of death and serious injury.

⚠ WARNING**SAFE TORQUE OFF FUNCTION**

The Safe Torque Off function does NOT isolate AC line voltage to the adjustable frequency drive or auxiliary circuits. Perform work on electrical parts of the adjustable frequency drive or the motor only after isolating the AC line voltage supply and waiting the length of time specified in the *Safety* chapter in the relevant *Instruction Manual*. Failure to isolate the AC line voltage supply from the unit and waiting the time specified could result in death or serious injury.

- Do not stop the adjustable frequency drive by using the Safe Torque Off function. If a running adjustable frequency drive is stopped by using the function, the unit trips and stops by coasting. If this is not acceptable, i.e., causes danger, stop the adjustable frequency drive and machinery by using the appropriate stopping mode before using this function. Depending on the application, a mechanical brake may be required.
- Safe Torque Off is suitable for performing mechanical work on the adjustable frequency drive system or affected area of a machine only. It does not provide electrical safety. Safe Torque Off should not be used as a control for starting and/or stopping the adjustable frequency drive.

⚠ CAUTION

Automatic restart behavior is only allowed in one of the two situations:

1. The unintended restart prevention is implemented by other parts of the Safe Torque Off installation.
2. A presence in the dangerous zone can be physically excluded when Safe Torque Off is not activated. In particular, paragraph 5.3.2.5 of ISO 12100-2 2003 must be observed.

⚠ WARNING

The Safe Torque Off function can be used for asynchronous, synchronous and permanent magnet motors. Two faults can occur in the power semiconductor of the adjustable frequency drive. When using synchronous or permanent magnet motors, a residual rotation can result from the faults. The rotation can be calculated to angle = $360/(\text{number of poles})$. The application using synchronous or permanent magnet motors must take this residual rotation into consideration and ensure that it does not pose a safety risk. This situation is not relevant for asynchronous motors. Risk of death and serious injury.

NOTICE!

The selection of a stop category in accordance with EN 60204-1 for each stop function must be determined by a risk assessment:

- Stop Category 0 is achieved with immediate removal of power to the servo, resulting in an uncontrolled coast to stop. Safe Torque Off (STO) according to EN 61800-5-2 accomplishes a Stop Category 0 stop.
- Stop Category 1 is achieved with power available to the machine servos to achieve the stop. Power is removed from the servos when the stop is achieved according to EN 61800-5-2 Safe Stop 1 (SS1).
- Stop Category 2 is a controlled stop with power available to the machine servos. The stop is followed by a holding position under power.

NOTICE!

When designing the machine application, timing and distance should be considered for a coast to stop (Stop Category 0 or Safe Torque Off). For more information regarding stop categories, refer to EN 60204-1.

3 Installation

3.1 Safety Instructions

See *chapter 2 Safety* for general safety instructions.

3.2 Safe Torque Off Installation

For motor connection, AC line power connection, and control wiring, follow the instructions for safe installation in the *Instruction Manual* of the adjustable frequency drive.

For installation with the Ex-certified Thermistor Module MCB 112, see *chapter 3.3 Installation in Combination with Thermistor Module MCB 112*.

Enable the integrated Safe Torque Off as follows:

1. Remove the jumper wire between control terminals 37 and 12 or 13. Cutting or breaking the jumper is not sufficient to avoid short-circuiting. (See jumper on *Figure 3.1*).

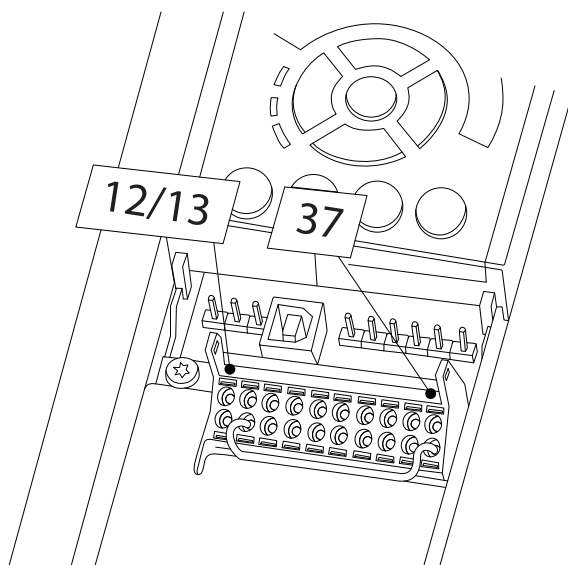
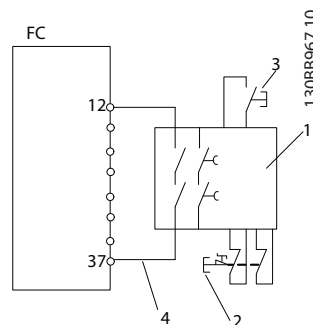


Figure 3.1 Jumper between Terminal 12/13 (24 V) and 37

2. Connect an external safety monitoring relay via a NO safety function to terminal 37 (Safe Torque Off) and either terminal 12 or 13 (24 V DC). Follow the installation instructions for the safety monitoring relay, and ensure that the safety monitoring relay comply with Category 3 /PL "d" (ISO 13849-1) or SIL 2 (EN 62061 and IEC 61508).



1	Safety relay (cat. 3, PL d or SIL2)
2	Emergency stop button
3	Reset button
4	Short-circuit protected cable (if not inside installation IP54 cabinet). See ISO 13849-2 Table D.4 for further information

Figure 3.2 Installation to Achieve a Stop Category 0 (EN 60204-1) with Safety Cat. 3/PL "d" (ISO 13849-1) or SIL 2 (EN 62061 and IEC 61508).

3. Complete wiring according to the instructions given in the *Instruction Manual* of the adjustable frequency drive.

3.3 Installation in Combination with Thermistor Module MCB 112

NOTICE!

Combination of Thermistor Module MCB 112 and Safe Torque Off function is only available for VLT® HVAC Drive FC 102, VLT® AutomationDrive FC 302, and VLT® AutomationDrive FC 301 enclosure type A1.

Thermistor Module MCB 112 uses terminal 37 as its safety-related switch-off channel.

- Ensure that the output X44/12 of MCB 112 is AND-ed with the safety-related sensor (such as emergency stop button, safety guard switch, etc.) that activates Safe Torque Off. This means that the output to Safe Torque Off terminal 37 is HIGH (24 V) only if both the signal from MCB 112 output X44/12 and the signal from the safety-related sensor are HIGH. If at least one of the two signals is LOW, then the output to terminal 37 must be LOW, too.
- Ensure that the safety device with AND-logic complies with the needed safety level.

- Short-circuit protect the connection from the output of the safety device with safe AND-logic to the Safe Torque Off terminal 37, see Figure 3.3.

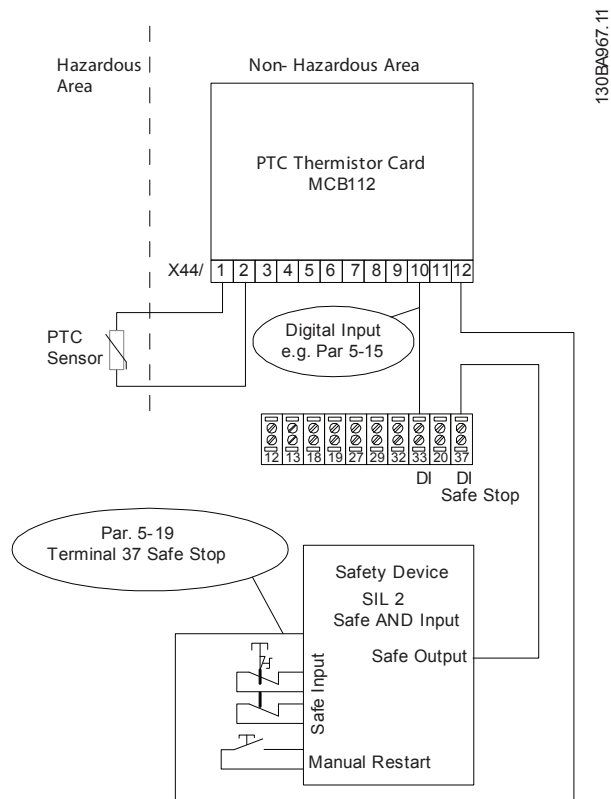


Figure 3.3 Combination of a Safe Torque Off Application and an MCB 112 Application

Figure 3.3 shows a Restart input for the external safety device. This means that in this installation 5-19 Terminal 37 Safe Stop can be set to value [7] PTC 1 & Relay W or [8] PTC 1 & Relay A/W. Refer to MCB 112 Instruction Manual for further details.

4 Commissioning

4.1 Safety Instructions

See *chapter 2 Safety* for general safety instructions.

4.2 Activation and Termination of Safe Torque Off

The STO function is activated by removing the voltage at terminal 37 of the adjustable frequency drive. By connecting the adjustable frequency drive to external safety devices providing a safe delay, an installation for a Safe Stop 1 can be obtained. External safety devices need to fulfill Cat./PL or SIL when connected to terminal 37. The STO function can be used for asynchronous, synchronous, and permanent magnet motors.

When the STO function (T37) is activated, the adjustable frequency drive issues an alarm, trips the unit, and coasts the motor to a stop. Manual restart is required. Use the STO function to stop the adjustable frequency drive in emergency stop situations. In normal operating mode when STO is not required, use the standard stop function instead. Ensure that requirements according to ISO 12100-2 paragraph 5.3.2.5 are fulfilled before using the automatic restart function.

4.3 Parameter Settings for STO in Combination with Thermistor Module MCB 112

When MCB 112 is connected, additional selections are available for *5-19 Terminal 37 Safe Stop* ([4] PTC 1 Alarm to [9] PTC 1 & Relay W/A).

- Selections [1]* *Safe Stop Alarm* and [3] *Safe Stop Warning* are still available, but are for installations without MCB 112 or any external safety devices. If [1]* *Safe Stop Alarm* or [3] *Safe Stop Warning* are selected and MCB 112 is triggered, the adjustable frequency drive reacts with an alarm "Dangerous Failure [A72]" and coasts the adjustable frequency drive safely, without automatic restart.

- Selections [4] *PTC 1 Alarm* and [5] *PTC 1 Warning* are not to be selected when an external safety device is used. Those selections are for when only MCB 112 uses the Safe Torque Off. If selection [4] *PTC 1 Alarm* or [5] *PTC 1 Warning* is selected and the external safety device triggers Safe Torque Off, the adjustable frequency drive issues an alarm "Dangerous Failure [A72]" and coasts the adjustable frequency drive safely, without automatic restart.
- Select [6] *PTC 1 & Relay A* to [9] *PTC 1 & Relay W/A* for the combination of external safety device and MCB 112.

CAUTION

Selections allow for automatic restart when the external safety device is de-activated.

Before selecting [7] PTC 1 & Relay W or [8] PTC 1 & Relay A/W, ensure that:

- The unintended restart prevention is implemented by other parts of the Safe Torque Off installation, or
- A presence in the dangerous zone can be physically excluded when Safe Torque Off is not activated. In particular, paragraph 5.3.2.5 of ISO 12100-2 2003 must be observed.

See *Instruction Manual for Thermistor Module MCB 112* for further information.

4.4 Automatic/Manual Restart Behavior

By default the STO function is set to unintended restart prevention behavior. To terminate STO and resume normal operation:

1. Reapply 24 V DC supply to Terminal 37.
2. Give a reset signal (via Bus, Digital I/O, or [Reset] key).

Set the STO function to automatic restart by setting the value of *5-19 Terminal 37 Safe Stop* from default value [1]* *Safe Stop Alarm* to value [3] *Safe Stop Warning*. Automatic restart means that STO is terminated, and normal operation is resumed, as soon as the 24 V DC is applied to terminal 37. No reset signal is required.

4.5 Safe Torque Off Commissioning Test

After installation and before first operation, perform a commissioning test of the installation, using Safe Torque Off.

Perform the test again after each modification of the installation or application involving the STO.

NOTICE!

A successful commissioning test of the STO function is required after the initial installation, and after each subsequent change to the installation.

4.5.1 Restart Prevention for STO Application

Application where 5-19 Terminal 37 Safe Stop is set to default value [1]* Safe Stop Alarm, or combined Safe Torque Off and MCB 112 where 5-19 Terminal 37 Safe Stop is set to [6] PTC 1 & Relay A or [9] PTC 1 & Relay W/A):

1. Remove the 24 V DC voltage supply to terminal 37 using the interrupt device while the adjustable frequency drive drives the motor (that is line power supply is not interrupted).
2. Check that:
 - the motor reacts with a coast,
 - the mechanical brake is activated (if connected), and
 - the alarm *Safe Stop [A68]* is displayed in the local control panel (LCP), if mounted.
3. Reapply 24 V DC to terminal 37.
4. Ensure that the motor remains in the coasted state, and the mechanical brake (if connected) remains activated.
5. Send reset signal (via Bus, Digital I/O, or [Reset] key).
6. Ensure that the motor becomes operational again.

The commissioning test is successfully completed when all the above steps are passed.

4.5.2 Automatic Restart of Safe Torque Off Application

Application where 5-19 Terminal 37 Safe Stop is set to [3] Safe Stop Warning, or combined Safe Torque Off and MCB 112 where 5-19 Terminal 37 Safe Stop is set to [7] PTC 1 & Relay W or [8] PTC 1 & Relay A/W):

1. Remove the 24 V DC voltage supply to terminal 37 by the interrupt device while the adjustable frequency drive drives the motor (that is line power supply is not interrupted).
2. Check that:
 - the motor reacts with a coast,
 - the mechanical brake is activated (if connected), and
 - the alarm *Safe Stop [A68]* is displayed in the local control panel (LCP), if mounted.
3. Reapply 24 V DC to terminal 37.
4. Ensure that the motor becomes operational again.

The commissioning test is successfully completed when all the above steps are passed.

NOTICE!

See the warning on the restart behavior in *chapter 2.3 Safety Precautions*.

4.6 System Configuration Security

- Security measures are the responsibility of the user
- The adjustable frequency drive parameters can be password-protected

4.7 Service and Maintenance

No maintenance of the Safe Torque Off (STO) functionality is needed.

5 Safe Torque Off Technical Data

NOTICE!

For technical specifications and operating conditions for the adjustable frequency drive, refer to the relevant *Instruction Manual* of the adjustable frequency drive.

NOTICE!

The STO signal must be SELV or PELV supplied.

The following values are associated with each safety level:

Reaction time for T37

- Maximum reaction time: 20 ms

Reaction time = delay between de-energizing the STO input and switching off the output bridge.

Data for EN ISO 13849-1

- Performance Level "d"
- MTTF_d: 14,000 years
- DC: 90%
- Category 3
- Lifetime 20 years

Data for EN IEC 62061, EN IEC 61508, EN IEC 61800-5-2

- SIL 2, SILCL 2
- PFH < 1E-10/h
- Component type: Type A
- HFT (Hardware Fault Tolerance) = 1 (1oo2 architecture)
- Lifetime 20 years

Data for EN IEC 61508 low demand

- PFD_{avg} for 1 year proof test: 1E-10
- PFD_{avg} for 3 year proof test: 1E-10
- PFD_{avg} for 5 year proof test: 1E-10

SISTEMA Data

Functional safety data are available from a data library for use with the SISTEMA calculation tool from the IFA (Institute for Occupational Safety and Health of the German Social Accident Insurance), and data for manual calculation. SISTEMA is available for download at www.danfoss.com/BusinessAreas/DrivesSolutions/SISTEMA/.

Index

A

Abbreviations..... 4
 Activation..... 9
 Alarm..... 9
 Approvals..... 3
 Automatic Restart..... 9, 10

C

Certifications..... 3
 Command..... 5
 Commissioning test..... 10
 Component type..... 11
 Control system..... 5
 Conventions..... 4

E

EN 60204-1..... 2
 EN 61800-5-2..... 2
 EN 62061..... 2
 EN ISO 13849-1..... 2
 External safety devices..... 9

H

Hardware Fault Tolerance..... 11

I

Identification..... 2
 IEC 61508..... 2
 Installation..... 8

M

Maintenance..... 10
 Mechanical brake..... 10

O

Output..... 8

P

Parameter Settings..... 9
 Performance Level "d"..... 11
 Products Covered..... 2

Q

Qualified Personnel..... 5

R

Reaction time..... 11
 Restart Behavior..... 9
 Restart Prevention..... 9, 10

S

Safe Torque Off..... 2
 Safety device..... 8
 Safety guard switch..... 8
 Safety-related sensor..... 8
 Selections..... 9
 Signal..... 5, 8
 SIL CL2..... 3
 SIL2..... 3
 SISTEMA Data..... 11
 Standards and Compliance..... 3
 Stop Category 0..... 2
 Switch-off channel..... 8
 Symbols..... 4

T

Technical Data..... 11
 Terminal 37..... 2
 Termination..... 9
 Thermistor module..... 8
 Thermistor Module MCB 112..... 8

U

Uncontrolled stop..... 3
 Unintended restart prevention..... 9



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