

FLEXI PRO Servo Drive Functional Safety Reference Manual

Revision 2.2



SEE IT BEFORE IT HAPPENS

***MOTOR
POWER***
COMPANY

Revision History

Doc. Rev.	Date	Remarks
2.2	Oct. 2015	Models and product ordering updates. Updated for SIL 3/PL e Cat.4
2.1	Jan.2015	minor fixes, cover graphic
2.0	7 Oct. 2014	Revised and added to FLEXI PRO documentation set.
1.0	27 July 2014	Formal version. Size 4A has STO_A. Final reliability values for STO_A. Updated current drain.
0.7	29 May 2014	Update of Reliability data, after calculation on final circuit (STO_A circuit version 3.2). Added maximum frequency of OSSD test pulses.
0.6	19 May 2014	STO cable length is limited to less than 30m. The product must be mounted inside an IP54 or better enclosure. Added description of unlikely failure in Exceptional Circumstance.
0.5	6 Apr 2014	Changed Altitude rating. Removed Trademarks.
0.4	13 Mar 2014	Added a section for Installation – identifies the STO connector and describes the pinout.
0.3	27 Feb 2014	Added note about possible motor movement of 120 electrical degrees.
0.2	18 Feb 2014	Added typical system configuration. Added block diagram showing the circuit principle. Added STO state diagnostics for EtherCAT. Updated requirements for STO cable to be spatially separated from environmental stress.
0.1	Feb 2014	Preliminary version.

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1 Introduction

1.1 About This Manual

Functional safety in the FLEXI PRO servo drive is implemented by means of the safe torque off (STO) function, which prevents unexpected startup and uncontrolled stops. STO ensures that the drive will not provide a rotational field within the motor, thereby preventing the motor from generating a torque on the shaft.

This manual describes the characteristics and use of the STO function in the FLEXI PRO series of servo drives.

Not all drives in the FLEXI PRO product line are certified for functional safety.

The information in this manual is applicable only to drives that are certified for functional safety, and whose part numbers include the suffix **-ST**.

This manual includes critical operational information, including expected behavior of motion systems when using the STO function, limitations in its use, and requirements for periodic testing by the user.

Note: The term **STO function engaged** means that power to the STO circuit has been removed, and power to the motor is inhibited.

1.2 STO Function Definition

The STO function is defined in standard EN/IEC 61800-5-2, and relates to an uncontrolled stop as per stop category 0 of IEC 60204-1.

Standard EN/IEC 61800-5-2, defines the functional safety requirements for adjustable speed electrical power drive systems. According to this standard, when the STO function is engaged, power that can cause motion is not applied to the motor.

The STO function may be used where power removal is required to prevent an unexpected startup.



Warning:

Drives with a suspended load must have an additional mechanical safety block (such as a motor-holding brake) since the drive cannot hold the load when STO is engaged. Serious injury could result if the load is not properly safeguarded.

The STO function in the FLEXI PRO removes power from the gate drivers of the power module, effectively inhibiting PWM pulses from driving the IGBTs, as shown in Figure 1.

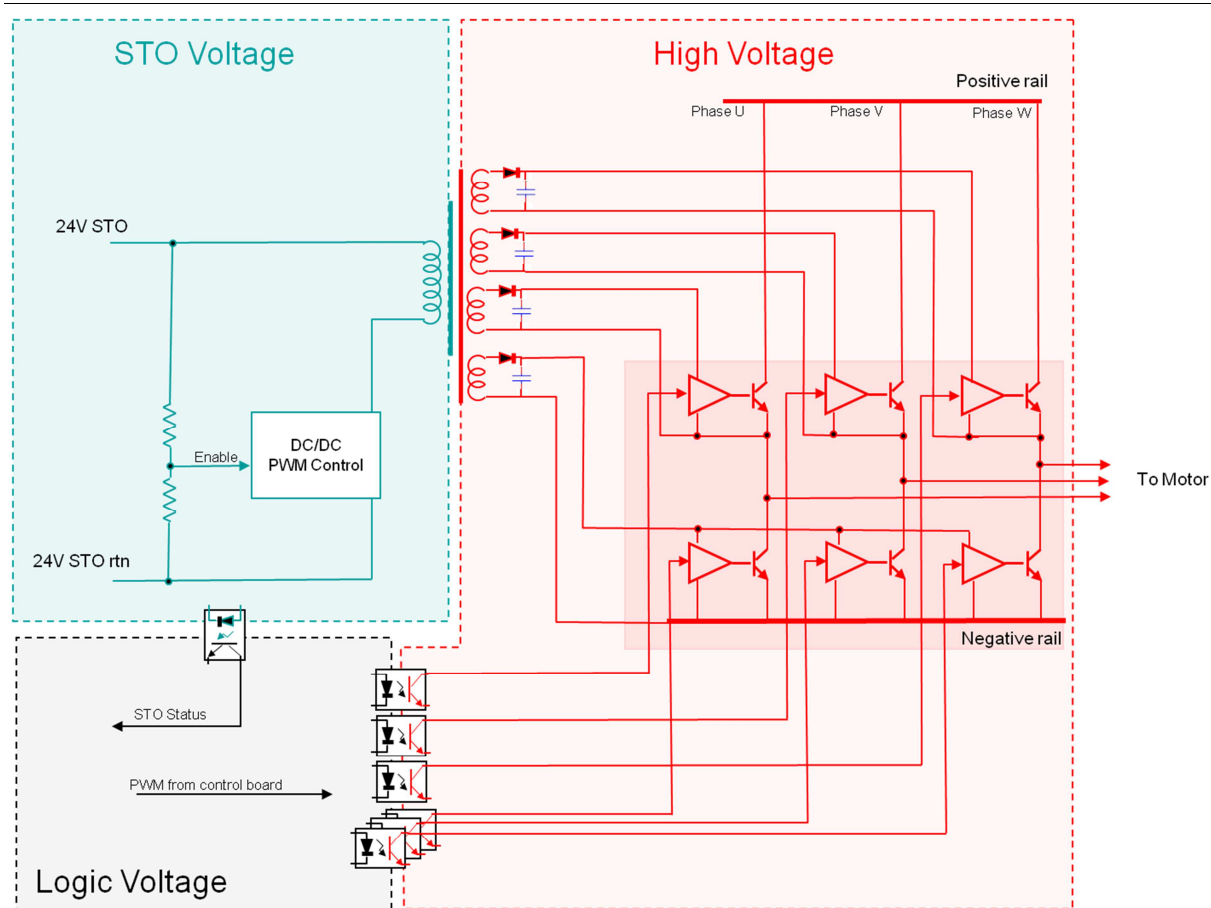


Figure 1

1.3 STO Modules in FLEXI PRO Servo Drives

Two different STO modules are currently in use in the various FLEXI PRO servo drives:

- **STO_A** generates only positive supply voltages to the gate drivers.
- **STO_B** generates both positive and negative supply voltages to the gate drivers.

The following table provides a cross-reference of STO modules and devices.

Product Family	Size	Input Voltage	Nominal Output Current	STO Circuit
FLEXI PRO	2A	120/240 VAC	1.5A, 3A	STO_A
FLEXI PRO	2B	120/240 VAC	4.5A, 6A	STO_A
FLEXI PRO	2C	120/240 VAC	8A, 10A, 13A	STO_A
FLEXI PRO	2D	120/240 VAC	20A, 24A	STO_B
FLEXI PRO	4A	400/480 VAC	3A, 6A	STO_A
FLEXI PRO	4B	400/480 VAC	12A	STO_B
FLEXI PRO	4C	400/480 VAC	30A	STO_B

2 Certified Products

2.1 Product Ordering Options

The ordering options that comprise the various model numbers of the drives in the FLEXI PRO product line are shown in Figure 2.

Note: To inquire about latest product availability, contact Motor Power Company.

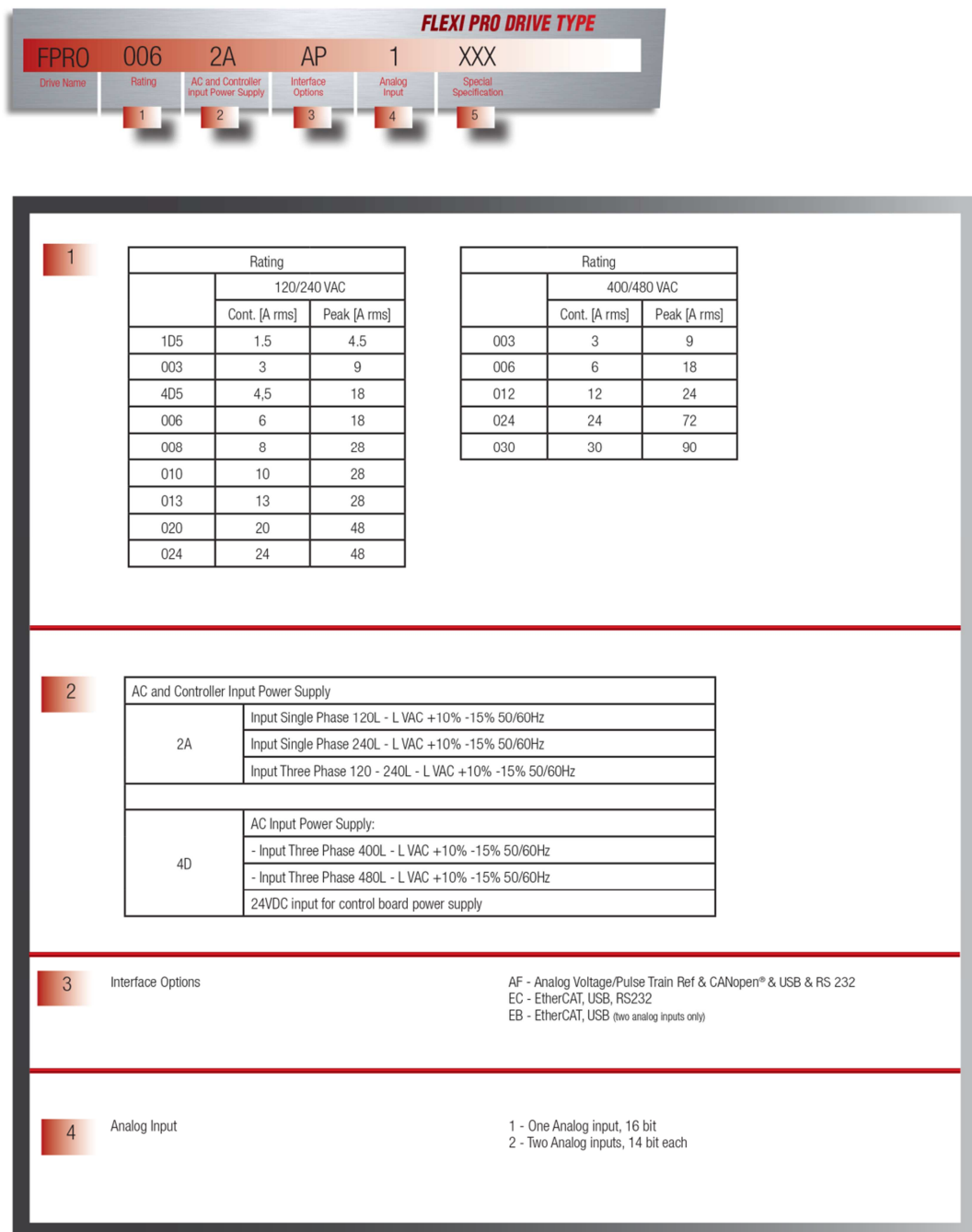


Figure 2

2.2 Products Approved for Functional Safety

The following FLEXI PRO models are certified for STO functional safety:

120/240 VAC 1.5A to 13A

FLEXI PRO-aaa2Adde-ST

where:

- *aaa* = 1D5, 003, 4D5, 006, 008, 010, 012 and 013 [continuous current]
- *dd* = AP, AF, EC, PB [interfaces]
- *e* = 1, 2 or 0 [number of analog inputs]

2.3 STO Certification and Reliability Data

STO implementation on the FLEXI PRO has been certified by TuV Rheinland.

The safety circuit implementation for the STO function in the FLEXI PRO conforms to SIL 3 according to IEC 61508-2, and PL e, Cat. 4 according to ISO 13849-1.

The following table shows the functional safety data for the FLEXI PRO drives:

STO Circuit	SFF	MTTFd	PFH*	PFD _{AVG} **	PL	Cat.
STO_A	98.9%	66757.5	1.71E-9	1.5E-4	e	4
STO_B	Pending	Pending	Pending	Pending	Pending	Pending

* Probability of failure per hour

** Probability of failure on demand, calculated as one demand per year

Refer to the section *Exceptional Circumstance*.

3 STO Specifications

3.1 Functional Safety

Feature	Specification
Performance Level	Performance level (PL) e, category 4 (ISO 13849-1)
Safety Integrity Level	SIL 3 (IEC 61508 / IEC 62061 / 61800-5-2)

3.2 Electrical Specification

Feature	Details	Specification
STO supply voltage	Nominal voltage	24 VDC
	Voltage levels in accordance with Type 2 EN 61131-2, with exception (operation from 15 VDC and not 11 VDC)	15–30 VDC: STO function not engaged (motion allowed) 0–5 VDC: STO function engaged (motion inhibited) 5–15 VDC: functionality is neither defined nor guaranteed
	Power supply characteristics	Must be a SELV/PELV power supply
Current drain	At 15 VDC	Less than 300 mA
	At 24 VDC	Less than 200 mA
	At 30 VDC	Less than 150 mA
Maximum reaction time	Time within which the motion is inhibited	40 ms
Maximum duration of OSSD test pulse	OSSD test pulse is ignored by the drive	1 ms
Maximum frequency of OSSD test pulses	Absolute maximum frequency of 1 ms test pulses that will be successfully filtered by the drive	475 Hz
Connector specification	Housing and crimp Pollution degree 3	Housing: Molex P/N 436450400 or equivalent Crimp: Molex P/N 0430300001 or equivalent
	Wire gauge	Ideal cable wire gauge is 22 AWG (0.34 mm ²). Current drain by the STO circuit is less than 0.25A, thus 24 AWG (0.25 mm ²) wire is also suitable.

3.3 Environmental Specifications

Feature	Specification
Operation ambient temperature	0–45°C
Storage ambient temperature	0–70°C
Humidity	10–90%
Altitude	According to the used clearances, based on IEC 61800-5-1, the FLEXI PRO is rated for use up to an altitude of 2000 m
Vibration	Per table 27 in IEC 61800-5-1: 10–57 Hz; amplitude 0.075 mm 57–150 Hz; acceleration 1.0g
Connector pollution level	Level 3
Protection class/Pollution degree	Protection class: IP20, pollution degree: 2 as per IEC 60664-1 The product is defined IP20, but the product must be mounted within an IP54 or better enclosure Do not use in the following locations: corrosive or flammable gasses, water oil or chemical, dust including iron dust and salts

3.4 Environmental Standards Compliance

Feature	Specification
EMC	EMC Directive 2004/108/EC, standard IEC61800-3 Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) – General industrial applications, standard IEC 61326-3-1
Safety	Low Voltage Directive 73/23/EEC IEC61800-5-1

4 STO System Requirements

4.1 Power Supply

To avoid a high voltage level at the STO input, a low voltage must be used for safety related parts.

A voltage supply unit of 24 volts must be used. This voltage supply unit must comply with PELV/SELV, as per EN 60204-1 (*Safety of Machinery - Electrical Equipment of Machines - Part 1: General Requirements*).

Note: The FLEXI PRO internal 24 VDC supply is not approved for use in safety applications, and is thus prohibited for use as the STO power supply.

4.2 STO Cable

The STO cable must be less than 30 meters in length to conform to EN 61326-3-1.

Shielded and double insulated cables must be used. Double insulation refers to the need for a cable jacket on the wire that supplies the power.

The cable shield must be connected to the ground of the power supply.

The ideal gauge for the cable wire is 22 AWG (0.34 mm²). Since current drain by the STO circuit is less than 0.25A, 24 AWG (0.25 mm²) is also suitable.

The STO cable must be spatially separated from any sources of environmental stress, be it mechanical, electrical, thermal or chemical.

5 Installation

5.1 STO Connector

STO uses interface **P1** on all FLEXI PRO models.



Figure 3

5.2 Pinout

The following table shows the pinout of the STO connector.

Pin	Pin Label	Function
1	24V	STO Enable
2	GND	STO Return
3		24V Return from the internal supply. Can be used to bypass the STO function, for use in non-safety applications only. The internal 24 VDC supply is not approved for use in safety applications.
4		24 VDC Supply from within the FLEXI PRO. Can be used to bypass the STO function, for use in non-safety applications only. The internal 24 VDC supply is not approved for use in safety applications.

5.3 Mating Connector

The following table shows the specifications for the mating connector:

Item	All Models
Manufacturer	Molex*
Housing PN and 4-pin crimp PN	436450400* and 0430300001*
Wire gauge	26–28 AWG

* Or equivalent.

5.4 Typical System Configuration

A typical STO system configuration, shown in Figure 4, includes the following components:

- FLEXI PRO with STO input
- SELV/PELV power supply
- Emergency stop or other switch to cut the power to the STO

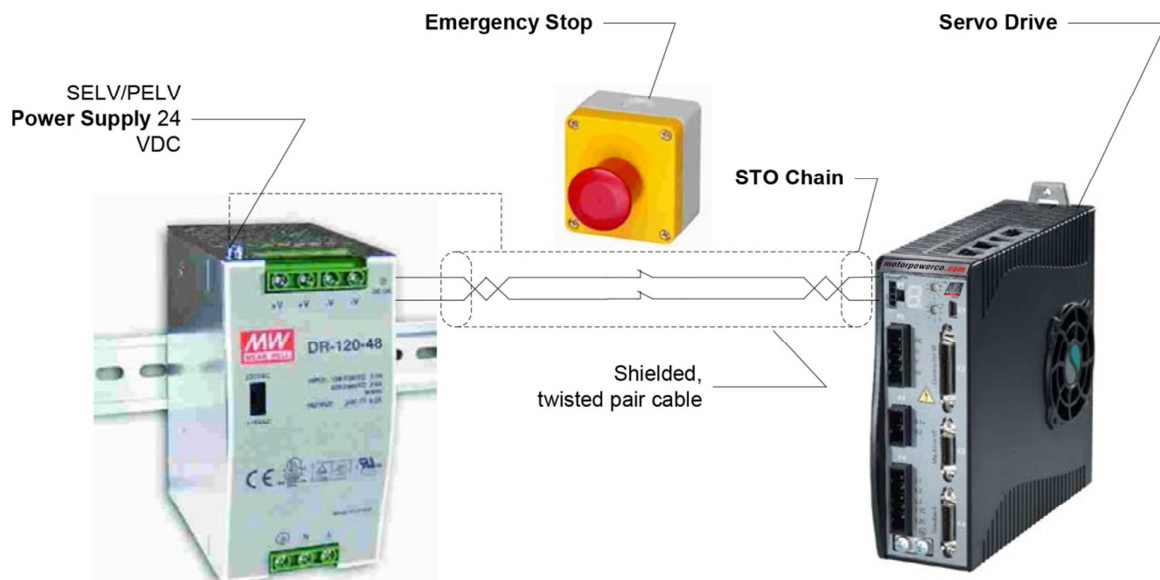


Figure 4

6 Using STO

6.1 STO Benefits

The advantage of the integrated STO safety function over standard safety technology using electromechanical switchgear is the elimination of separate components and the effort required to wire and service them.

In addition, the function has a shorter switching time than the electromechanical components in conventional safety solutions.

6.2 STO in Use

The STO function serves exclusively to provide a safe stop of the motion system according to the STO specification in IEC 61800-5-2. Triggering the STO function results in power being removed from the motor control circuits, and, as a result the motor is without control. When STO is triggered while the motor is in motion, the motor shaft and its linked mechanical elements coast until brought to a stop by their own friction.

The immediate effect of STO is that the drive cannot supply any torque-generating energy. STO can be used in applications where the motor is expected to reach a standstill within a sufficiently short time based on the load and friction, and when coasting down of the motor will not have any impact on safety.

Figure 5 illustrates what happens to the motor when the STO function is engaged. The graph depicts a motor being driven in constant velocity mode, and the coasting of the motor to a stop when the power to the STO circuit is removed.

The graph shows motor speed as a function of time. It compares the behavior of the motor when brought to a controlled stop (STO function not engaged – **VCMD** and **V** traces) and when coasting to a stop (STO function engaged – **Ref** traces).

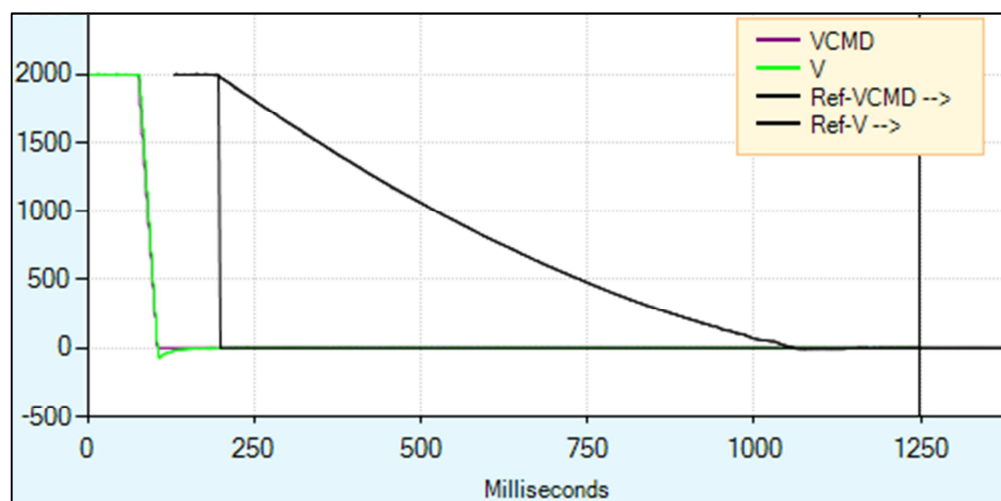


Figure 5

6.3 STO Diagnostics

STO status and diagnostic information is available in the following ways.

6.3.1 7-Segment Display on Drive Panel

- The drive's 7-segment display shows a *steady n* if the STO is engaged (STO power is removed) while the drive is disabled. This indicates a **Warning** condition.
- The drive's 7-segment display shows a *flashing n* if the STO is engaged (STO power is removed) while the drive is enabled. This indicates a **Fault** condition.

6.3.2 Serial Communication

Using serial communications (terminal), the query **ST** returns a list of status reports. The status varies slightly when the STO is engaged (STO power is removed), depending on whether the drive is enabled or disabled at time STO power was removed.

If the drive is disabled and the STO is engaged (STO power is removed), a Warning condition occurs, and the status report shows the warning:

```
Drive Inactive
Drive not ready:
  No SW enable
Warnings Exist:
  WRN 1  STO Signal Not Connected
```

If the drive is enabled and the STO power is removed, this is a fault condition, and the status report indicates a fault. Drive Inactive

```
Drive not ready:
  No SW enable
  Fault exists
Fault exists:
  FLT 4  STO Fault
```

Since the drive was enabled and a fault occurred, the Fault Recovery procedure must be performed.

6.3.3 CANopen and EtherCAT

If the drive is enabled and the STO power is removed, a fault condition occurs.

Object **603Fh** sub-index 0 provides the error code for the current errors.

The STO fault code is 12673 (decimal).

6.4 Recovery from an STO Event

If the drive is disabled while the STO function is engaged, no recovery procedure is required. Once the STO power is restored, the drive is functional as usual.

If the drive is enabled while the STO function is engaged, the drive enters a Fault state. A fault recovery procedure is required since the drive fault status is latched, and the drive cannot be enabled until the fault status is explicitly cleared.

After the STO power is restored, a Fault Clear command must be executed. After a successful Fault Clear, the drive is again functional.

Fault Clear can be performed in any of the following ways:

- Toggling Drive Enable. This is done either by executing a drive disable command (K) followed by the enabled (EN) command, or by toggling the Remote Enable line (REMOTE).
- In some systems a specific drive input is defined as Alarm Clear. In such a system, toggling the input clears the fault.
- Executing the clear faults command (CLEARFAULTS)

If the STO fault condition no longer exists, the drive is reenabled.

6.5 Prohibited Use of STO

The STO function must not be used in conditions where external influences will create a hazard when the function is engaged, as for example, the dropping of a suspended load.

The STO function is specifically prohibited for use in elevator applications. In these cases, additional measures (such as mechanical brakes) are required to prevent any hazard.

6.6 Exceptional Circumstance

A short circuit of two non-adjacent IGBTs within a brief time can produce a movement of up to a 120 electrical degrees, even if the STO function is engaged. Such an event is highly unlikely but possible. However, the probability of such a failure is 1.5×10^{-15} per hour (without common cause failure), and is thus considered negligible.

7 Maintenance

Users must perform a manual test of the STO function at least once a year.

The diagnostic test entails removing the STO supply voltage and verifying that the drive is indeed in the STO Fault state, and that motion is inhibited.

The maintenance procedure is performed as follows:

- 1.** Set up the system such that nominal STO voltage is supplied to the drive, and the drive is enabled.
- 2.** Remove (or switch off) the STO power supply. Verify that:
 - The drive is in a Fault state, and the STO Fault is indicated.
 - The drive cannot be enabled.
- 3.** Restore the STO voltage, and clear the fault. Verify that the drive can be enabled.

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