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Safety Integrated for entry level personnel

Technical overview

Edition

09/2013

Answers for industry.

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SINAMICS G converters Safety Integrated for entry level personnel

Brochure

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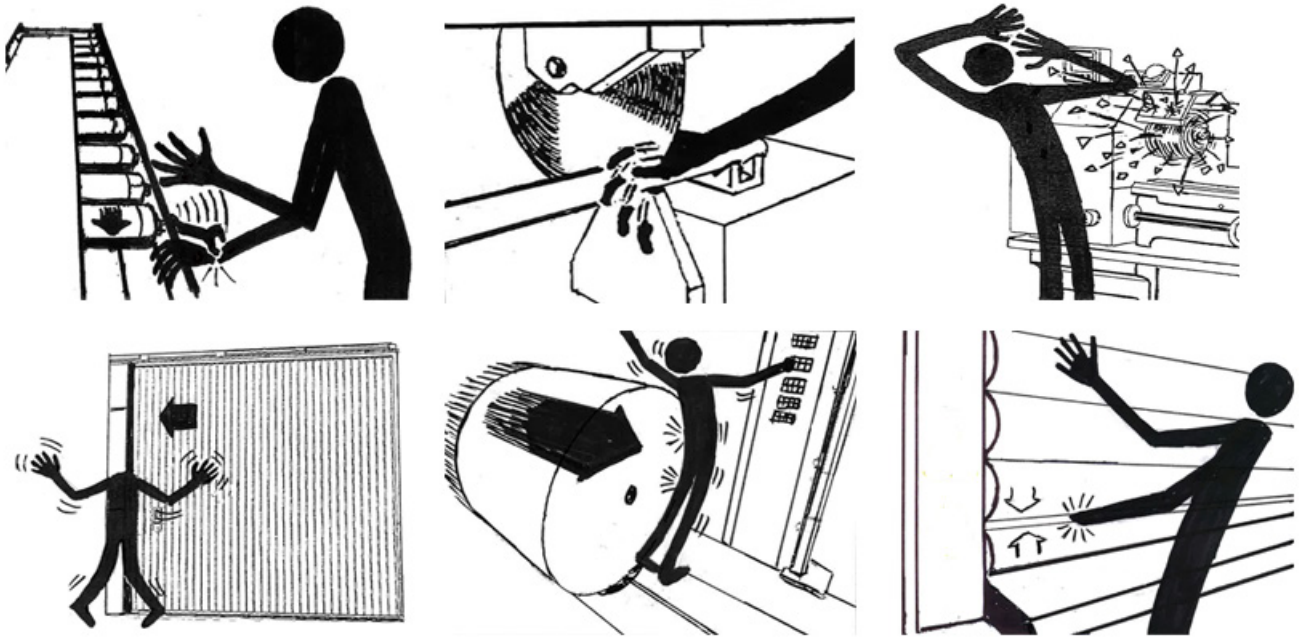
Disclaimer of Liability

We have reviewed the contents of this publication to ensure consistency with the hardware and software described. Since variance cannot be precluded entirely, we cannot guarantee full consistency. However, the information in this publication is reviewed regularly and any necessary corrections are included in subsequent editions.

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Hazards in plants and machines



If part of your job involves the construction of plants or machines, you are perhaps already aware of these or similar hazards and risks for people who operate or maintain/service machines.

What does "Safety Integrated" have to do with these hazards?

"Safety Integrated" means that the sensors, controls, switching devices and drives installed in the machine already have integrated functions that address typical hazards in a machine.

Generally, the movement of machine parts is the root cause of hazards. For this reason, special emphasis has been placed on electric drives in this description.

The risks in machines are as varied as the machines themselves. This is the reason that this description describes the use of drives equipped with "Safety Integrated" by means of examples:

- What does a typical application in a plant or machine look like?
- What is the hazard in this particular application?
- How is the machine made safer?
- What does a classic solution with converter and external wiring look like?
- In a direct comparison, what does a solution based on a drive and "Safety Integrated" look like?
- How difficult is it to commission "Safety Integrated"?

The focus is on relatively simple machines or simple applications in complicated machines – applications, which frequently do not require a programmable controller.

Further, we will restrict ourselves to applications with standard induction motors without encoder for speed sensing.

After some application examples for "Safety Integrated", we will explain the general approach to perform a risk analysis in plants/systems and machines.

And finally, we will show you how to obtain other brochures and more detailed information on the topic of "Safety Integrated".

After having read this description, we hope that you have a better understanding of what drives equipped with "Safety Integrated" can do and how to use them. Perhaps as machine builder the examples inspire you to discover new applications for drives with "Safety Integrated".

Drives with "Safety Integrated" in the application

Some typical hazards in production machines are described below. The measures applied to reduce these hazards are classified in the following four typical categories:

- Preventing starting (Page 10)
- Safely stopping (Page 13)
- Safely limiting velocity or speed (Page 18)
- Rotating safely in a certain direction (Page 26)

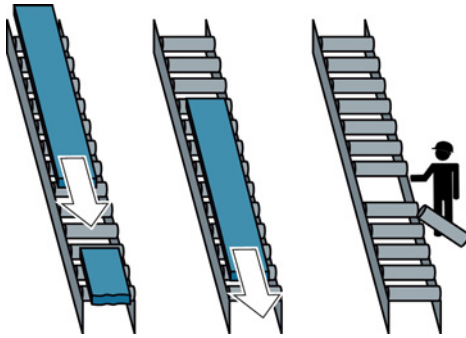
The examples do not go down to the finest technical detail. In order to keep the description concise and readable, for example, the solutions only show the most important signals to control the converter and the principle applied when commissioning. You always require the technical documentation for the product before completely selecting/dimensioning, installing and commissioning a drive.

2.1 Preventing starting

2.1 Preventing starting

Preventing a drive from starting means that the energy feed to the drive must be immediately and safely shut down.

Repair work carried out on a roller conveyor



In a plant or system, roller conveyors transport material from one processing station to another.

Within the context of carrying out maintenance or repair work, mechanical components of a roller conveyor must be replaced.

<p>⚠ DANGER</p> <p>Risk of injury if the roller conveyor drive starts while repair work is being carried out.</p>	<p>Risk minimization:</p> <p>While carrying out repair work, it is not permissible that the roller conveyor starts.</p>

Classic solution with external wiring

A safety relay evaluates the signal from an Emergency Stop button and de-energizes the two line contactors K1 and K2. The drive is electrically disconnected from the line supply and can no longer start.

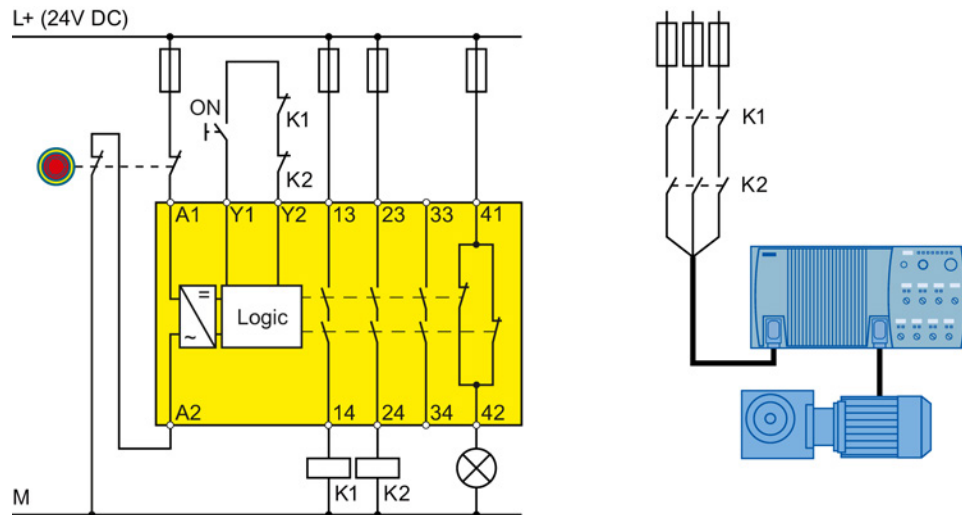
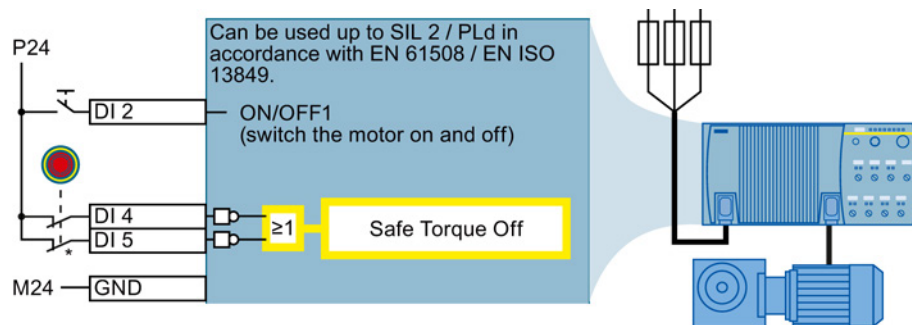


Figure 2-1 Preventing starting using external wiring

Solution with "Safety Integrated"

For this application, the converter has the certified "Safety Integrated" function "Safe Torque Off". The converter directly evaluates the Emergency Stop button signal. When the Emergency Stop button is pressed, the "Safe Torque Off" function prevents the conveyor from starting.



* Short-circuit free cabling in accordance with EN ISO 13849-2 is required.

Figure 2-2 Preventing starting using "Safety Integrated"

The "Safe Torque Off" function prevents the motor from starting, just as safely and reliably as the classic electrical disconnection. With the "Safety Integrated" solution however, the converter remains connected to the line supply during the Emergency Stop, and is immediately ready for use again after the Emergency Stop pushbutton has been released.

Commissioning the "Safe Torque Off" function using STARTER

STARTER is a Windows-based application for SIEMENS drives, which is used to commission the converter. STARTER helps you to adapt the converter function to your particular application using graphic screen forms.

The "Safe Torque Off" (STO) function is commissioned with just a few mouse clicks.

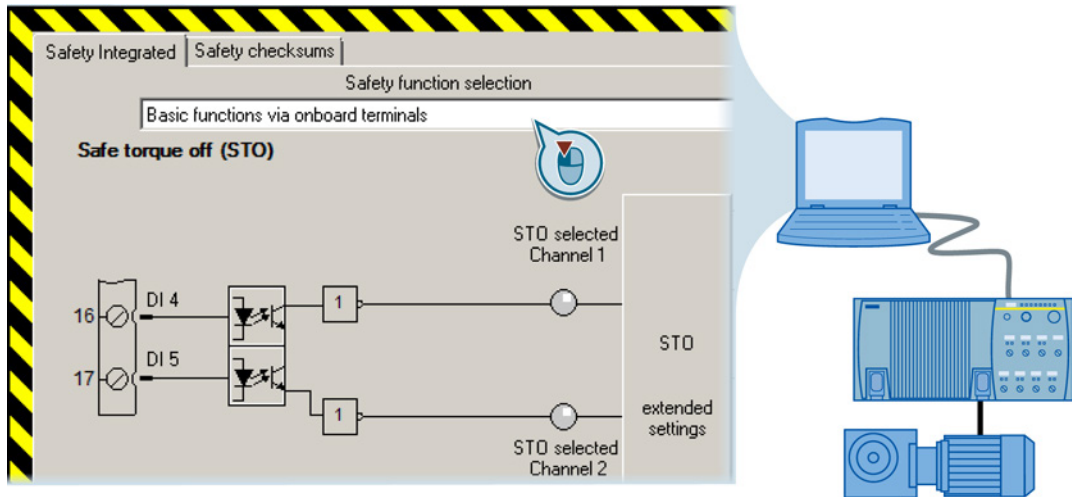
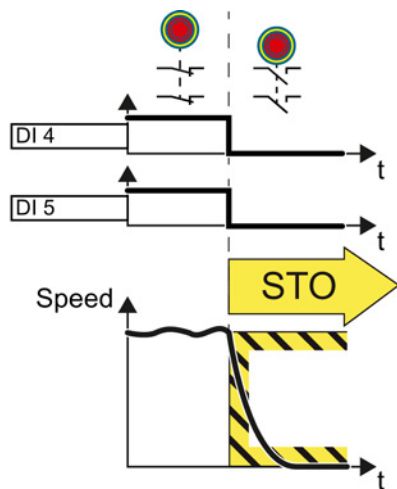


Figure 2-3 Commissioning the "Safe Torque Off" (STO) function using STARTER



In STARTER, if you select the setting "Basis functions via onboard terminals", you enable the STO function in the converter. The converter automatically assigns both digital inputs DI 4 and DI 5 to the STO function.

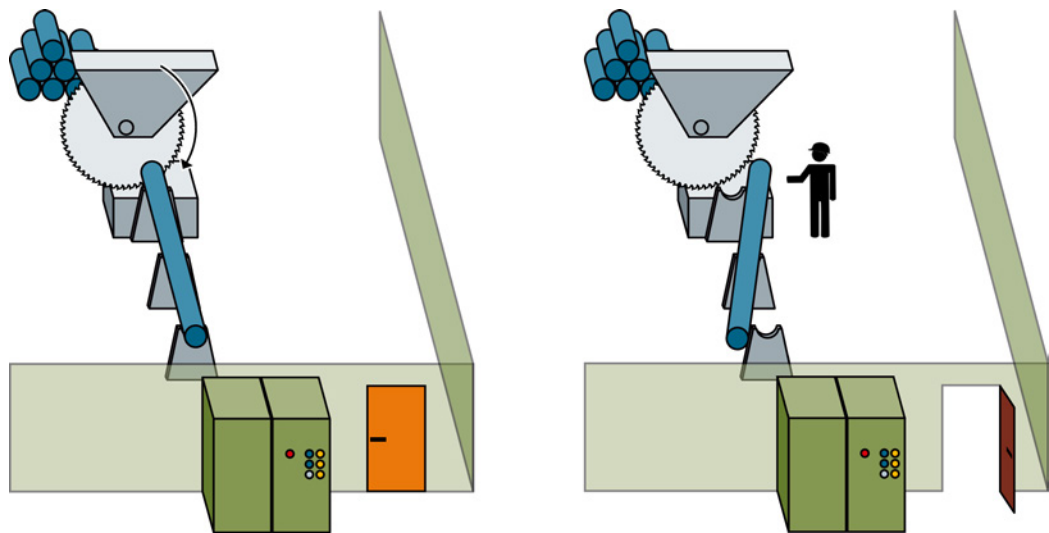
The "Low" signal state at both inputs activates the STO function.

2.2 Safely stopping

Safely stopping means that the motor is initially braked down to standstill. What happens at standstill depends on the particular application. For reasons of simplicity, here we are only considering applications which allow the energy feed to the motor to be switched off at standstill; this means preventing the motor from restarting.

Troubleshooting a saw

In the following example, a saw cuts material to the appropriate lengths. The sawing system is secured using a fence. However, if faults develop, it may be necessary for somebody to enter the sawing system.



<p>⚠ DANGER Risk of injury by the saw blade, which continues to run after the motor has been switched off.</p>	<p>Risk minimization: The saw must come to a standstill before anybody enters the hazardous area.</p>

Classic solution with external wiring

A safety relay evaluates the Emergency Stop command. After pressing the Emergency Stop button, the drive receives the command to stop the motor as quickly as possible (OFF3). The safety relay disconnects the converter from the line supply with a delay..

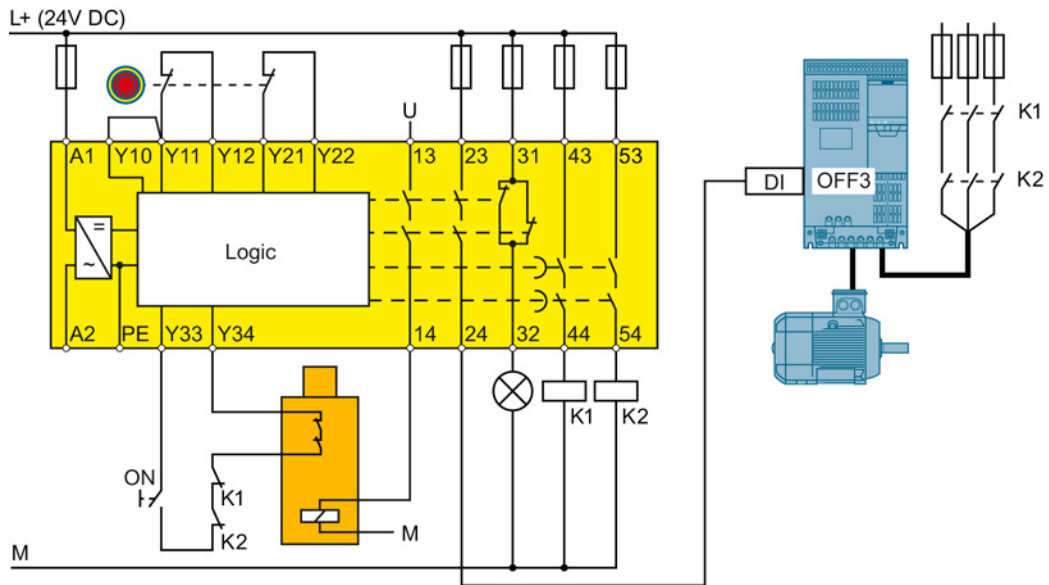
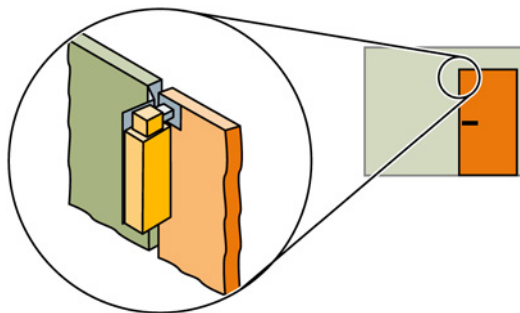


Figure 2-4 Safely stopping - a classic solution with external wiring



During normal operation, the protective door in the fence must be locked. It is only permissible to release the door if there is no risk of injury in the sawing system.

Position switches with electromagnetic tumbler mechanisms have established themselves for safety-relevant protective door applications such as these.

The safety relay not only switches the drive on and off, but it must also evaluate the position switch of the protective door. The drive can only be switched on when the protective door is closed. The protective door is locked when the drive is switched on.

Solution with "Safety Integrated"

The same functionality with significantly lower installation costs can also be implemented using a converter and a certified "Safety Integrated" function. The signal from the Emergency Stop button is directly wired to the converter terminals. The Emergency Stop command initiates the "Safe Stop 1" function in the converter. The converter brakes the saw blade down to a non-hazardous speed, and then enables the protective door via its output.

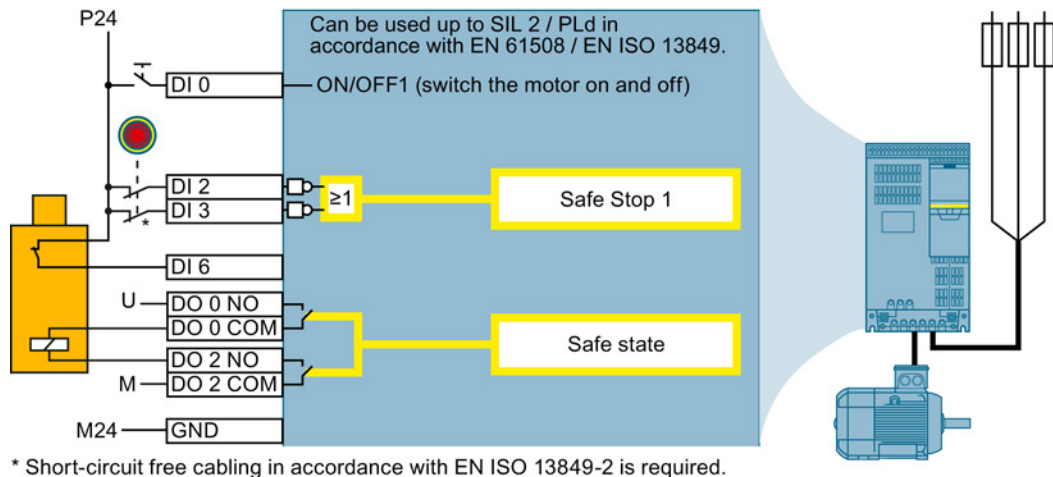


Figure 2-5 Safely stopping - the solution with "Safety Integrated"

Contrary to a classic solution with external wiring, the converter always remains connected to the power supply, and is immediately ready for operation after the Emergency Button has been released. Further, the converter permanently monitors the motor speed – also while stopping. If, in the case of a fault, the motor does not brake at the appropriate time, the converter signals this and the protective door remains locked.

Commissioning the "Safe Stop 1" function using STARTER

Using STARTER, enable the "Safety Integrated" function "Safe Stop 1", and allocate this function to a safe input of your choice.

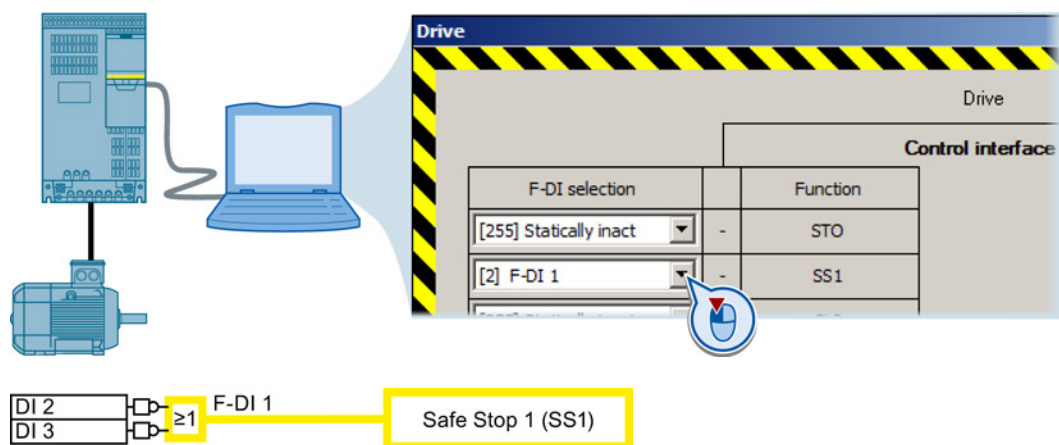


Figure 2-6 Assigning the safe input to the "Safe Stop 1" (SS1) function

2.2 Safely stopping

The converter monitors the braking of the motor. You must set this monitoring function, by adapting the "Safe braking ramp monitoring" to the braking ramp of the particular drive.

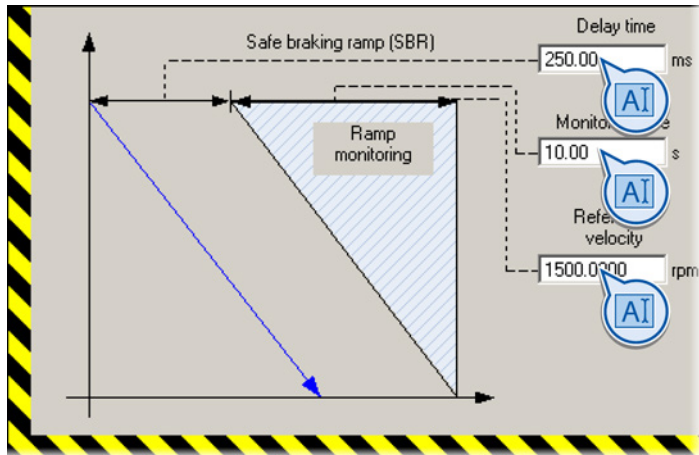
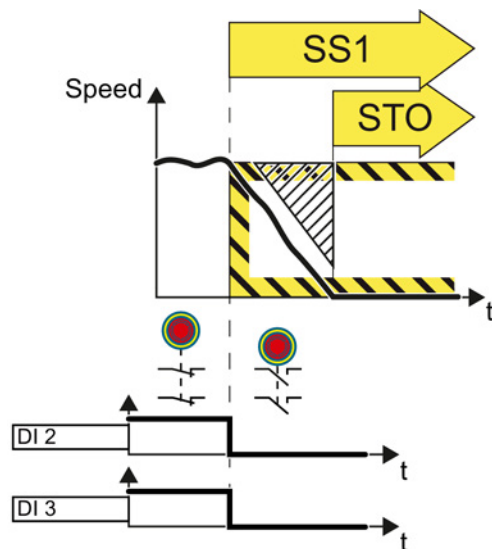


Figure 2-7 Adapting the monitoring of function SS1 to the braking ramp



The "Low" signal state at the two assigned terminals activates the SS1 function.

The converter brakes the motor and monitors whether the speed decreases as expected.

As soon as the speed is low enough, the converter switches off the motor and safety prevents the motor from restarting using the "STO" function.

Now you also require a signal that releases the protective door.

A converter with safe output directly supplies this signal to the position switch of the protective door.

The protective door may only open if all of the following conditions are met:

- Function SS1 is selected → "SS1 active" = 1
- The motor has been braked → "STO is active" = 1
- When braking, the speed monitoring function in the converter did not identify any error → "internal event" = 1

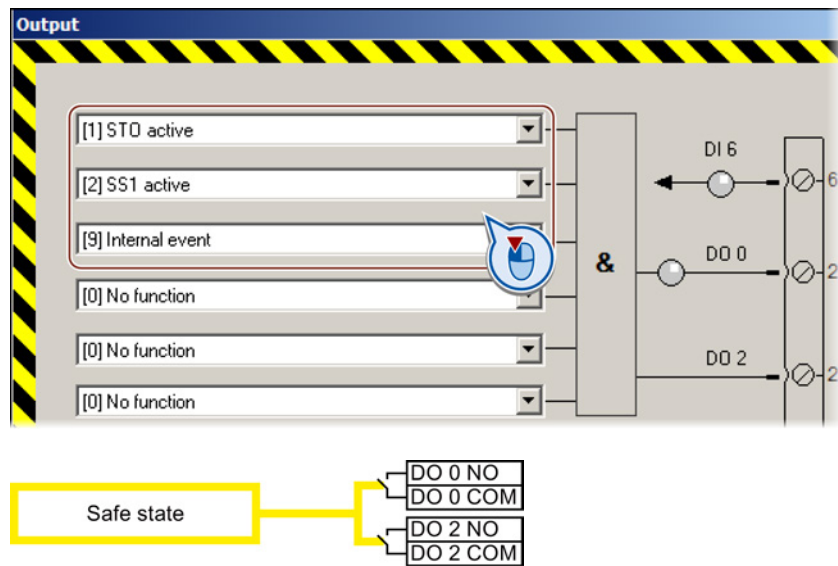


Figure 2-8 Generating the signal to release the protective door

If you are using a converter that does not have a safe output, you must generate the signal to release the protective door in the higher-level control system. In this case, you require a safety-relevant control system and a PROFIsafe connection to the converter.

2.3 Safely limiting velocity or speed



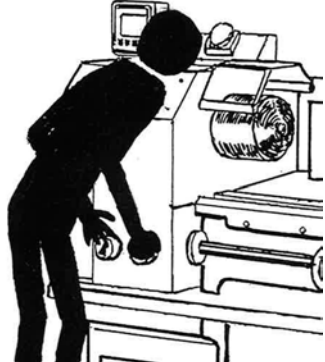
Whether it involves introducing material while setting up a machine or maintaining machine parts – personnel may have to intervene in plants and machines that are operational. In cases such as these, the risk of injury can only be appropriately handled if the speed of the machine components involved is reduced.

2.3.1 Chuck protection on a lathe

Lathes used to machine metal, which are equipped with a converter to drive a spindle with chuck, allow the speed to be continually adjusted; this also facilitates maintenance-free operation. Contrary to induction motors that are directly connected to the line supply, converters can extend the speed range up to a multiple of the line frequency.

However, an incorrect setting, caused by manipulating the converter, can result in dangerously high machine speeds, for example.

The task of the machine manufacturer is to utilize the advantages of converter drives without tolerating any increased risks.

<p> DANGER</p> <p>Risk of injury as the centrifugal forces could force open the chuck at high speeds, therefore releasing the workpiece.</p>	<p>Risk minimization:</p> <p>The machine limits and independently monitors the speed of the chuck drive.</p>
	

Classic solution with external wiring

A safety-relevant speed monitor evaluates the signals from the encoder and shaft breakage detection function of the motor. The output signals of the speed monitor are wired to a safety relay.

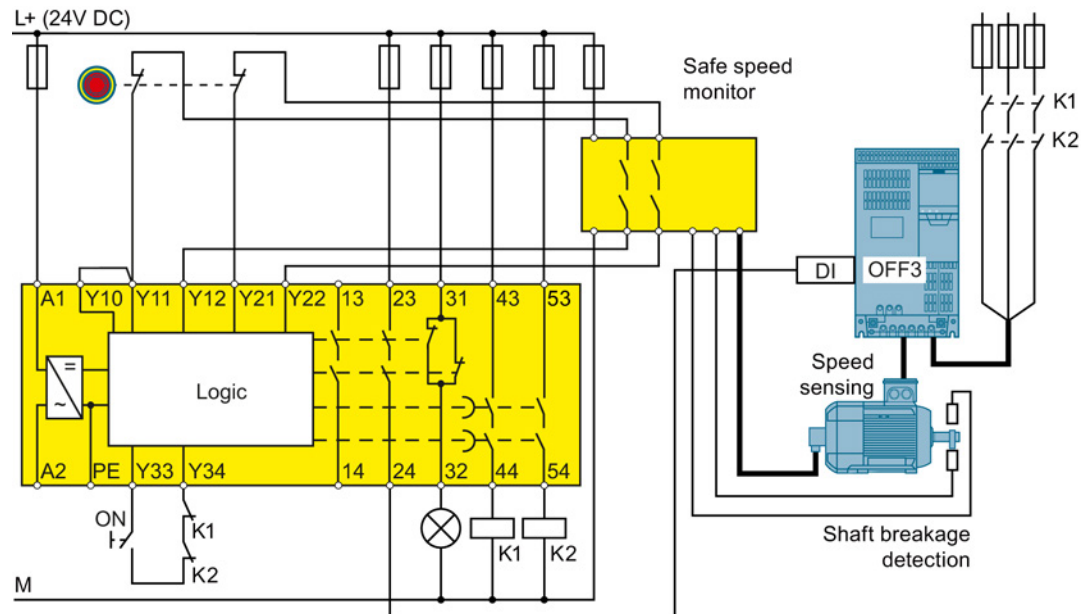
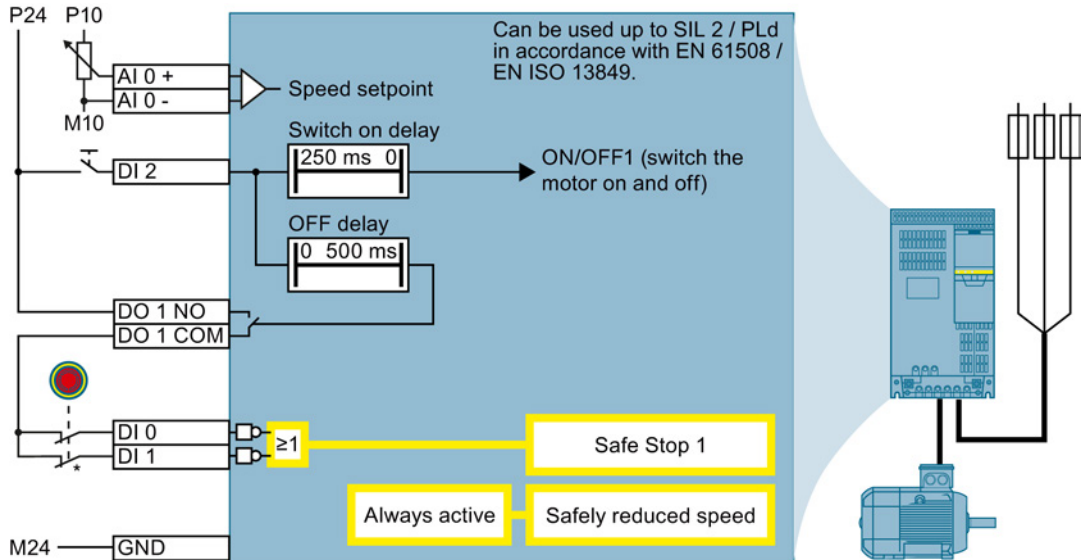


Figure 2-9 Safely monitoring the speed – a classic solution with external wiring

When the motor speed is excessively high (and when the Emergency Stop button is pressed), the converter receives an OFF3 command and stops the motor as quickly as possible. The safety relay disconnects the converter from the line supply with a delay..

Solution with "Safety Integrated"

If you implement the same functionality with a converter and a certified "Safety Integrated" function, you can eliminate both encoders.

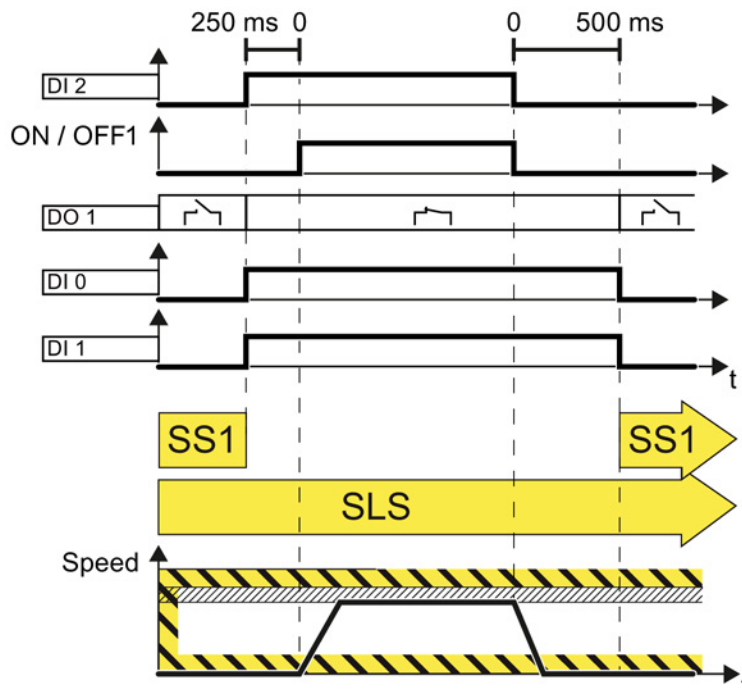


* Short-circuit free cabling in accordance with EN ISO 13849-2 is required.

Figure 2-10 Safely monitoring the speed - the solution with "Safety Integrated"

The "Safely Limited Speed" function is always active in the converter. Using this function, the converter permanently monitors the motor speed. The converter stops the motor if it has an excessively high speed.

As already indicated above, the special architecture of the converter also allows the induction motor speed to be monitored without requiring an encoder. Speed monitoring without an encoder functions as long as the motor is switched-on – that is to say, as long as the converter is sensing the motor currents and voltages. When the motor is switched off, the converter can no longer directly monitor the motor speed.



As a consequence, after the motor has been switched off, the drive goes into a "safe state": The converter automatically initiates the "Safe Torque Off" function in order to safely prevent the motor from actively accelerating.

The converter only exits this safe state if it receives the "Select STO" or "Select SS1" command from "outside" (i.e. externally).

If, as shown above, you enter the command to switch on the motor via two internal delay blocks in the converter, the motor without encoder can be switched on and switched off with seamless and safe monitoring.

2.3.2 Supplying paper to a printing machine

The "Safely Limited Speed" function can be used for an extremely wide range of applications. The machine manufacturer must also solve the problem of safely limiting the speed in the following example involving supplying paper to a printing machine:

The printing machine itself is secured using a fence and a light barrier, and is not investigated any further here. However, we want to focus on the relatively basic application, which supplies the printing machine with paper.

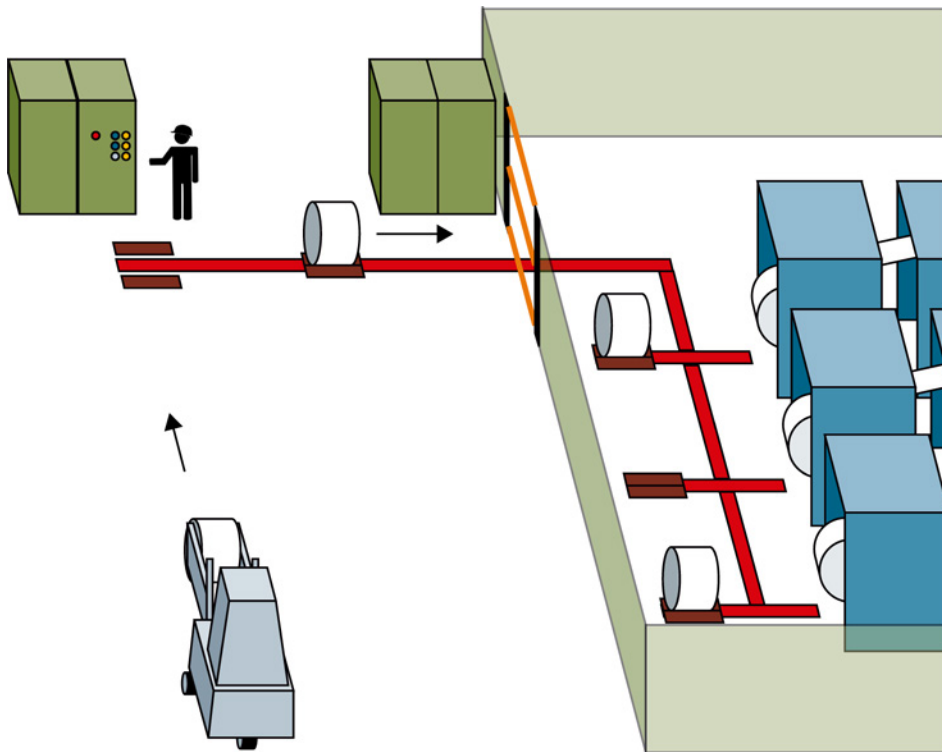
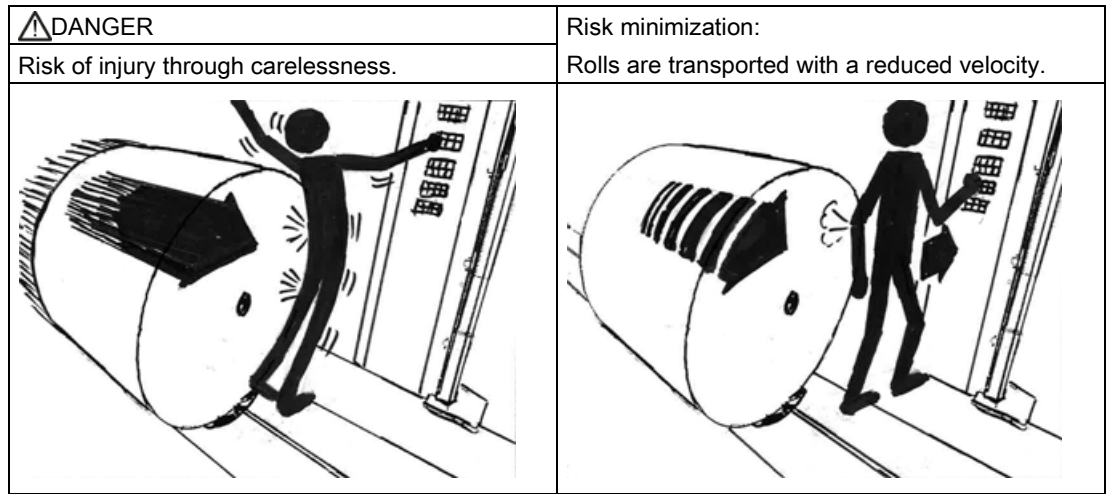


Figure 2-11 Supplying paper to a printing machine

Stackers supply new paper rolls from the warehouse at the interface to the automated printing machine. The machine operator removes the packaging materials, weighs and adjusts the supplied rolls. A transport conveyor then automatically transports the paper rolls to the roll storage in the printing machine.

This automated roll transport represents a hazard for the machine operator.



Solution with "Safety Integrated"

As in the previous example ("lathe"), the "Safety Integrated" function "Safety limited speed" is always active in the converter here as well. However, the command to switch on and switch off the motor is now received from the higher-level control system via the PROFIBUS interface.

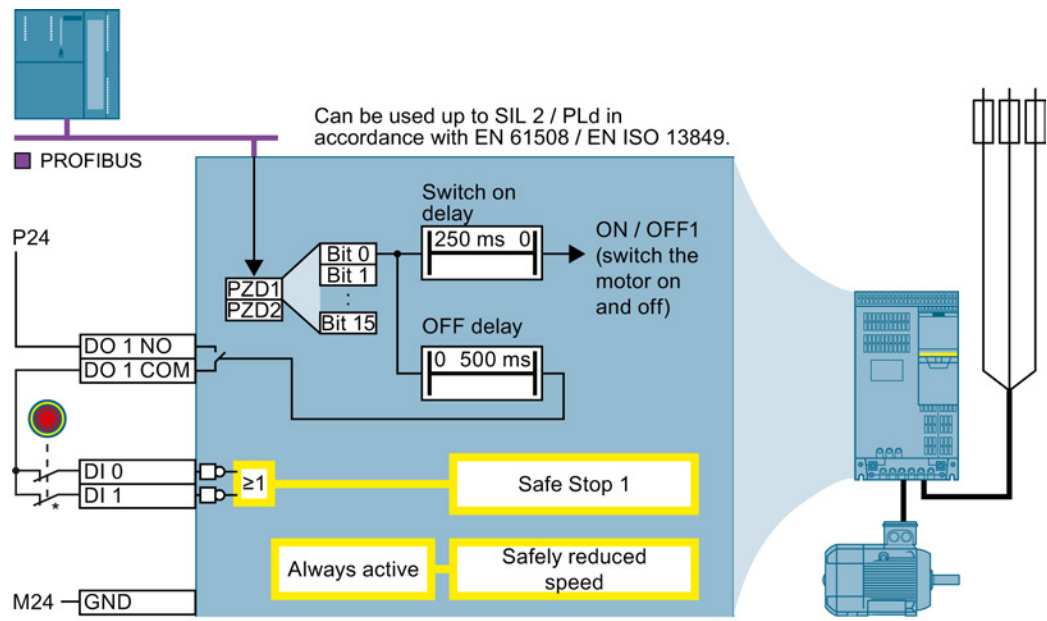


Figure 2-12 Safely monitoring the speed - the solution with "Safety Integrated"

2.3.3 Commissioning the "Safely reduced speed" function using STARTER

You enable the "Safety Integrated" function "Safely Limited Speed" using STARTER. The drive allows safety functions to be assigned to a specific safe input; however, it is also possible to permanently activate these safety functions in the drive. This means that input terminals do not have to be used.

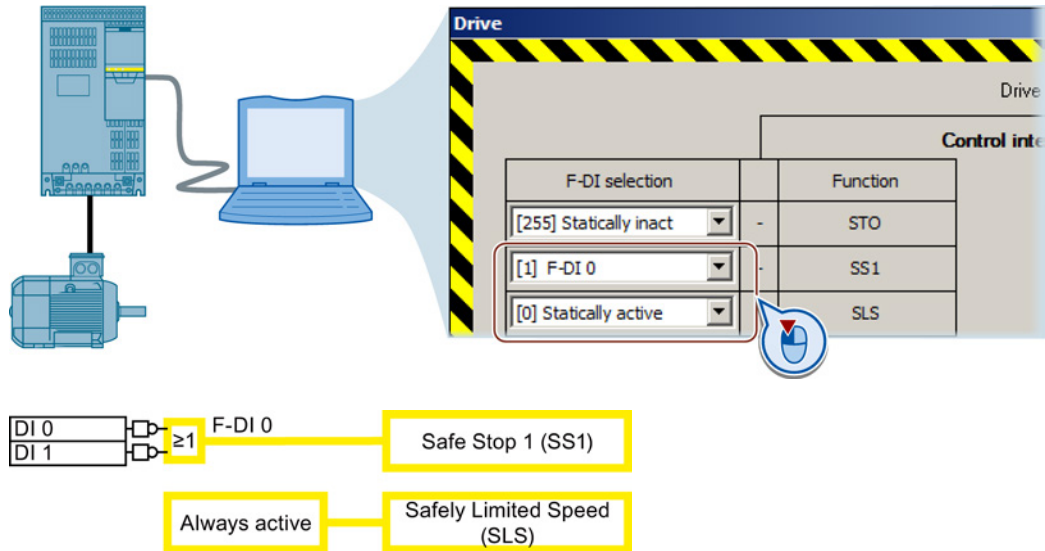


Figure 2-13 Assigning the safe input to the SS1 function – and selecting that the SLS function is always active

You must set the following in order to set the "Safely reduced speed" function:

- The speed, which the drive monitors.
- The value, to which the drive limits the speed
- The drive response, if the motor becomes too fast:
 - STOP A: the motor coasts down to standstill.
 - STOP B: The converter brakes the motor to a standstill.

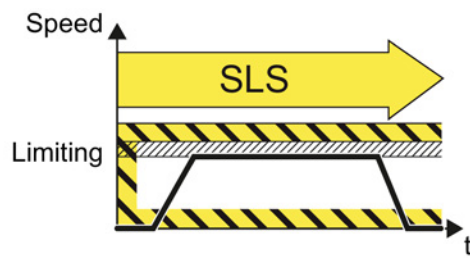
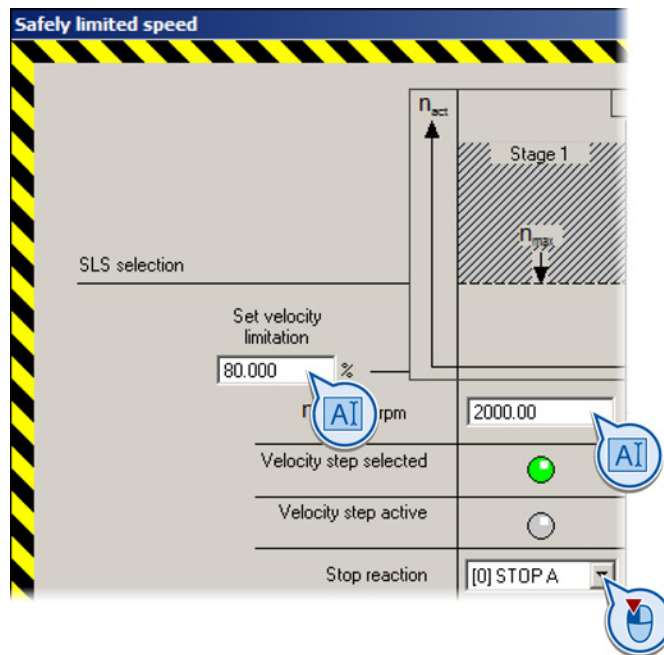
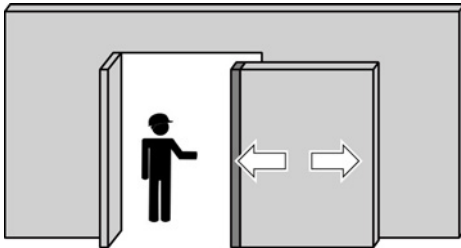


Figure 2-14 Setting the monitoring, limiting and stop response of the SLS function

2.4 Rotating safely in a certain direction

Just the same as in the last section, this also involves monitoring speeds. However, the hazard does not involve the absolute value of the speed, but instead the direction of rotation.

2.4.1 Gate/door drive



In a plant or system, a door/gate opens when requested and then automatically closes after a specific time.

<p>⚠ DANGER</p> <p>The door closes and an inattentive person gets stuck and is injured.</p>	<p>Risk minimization:</p> <p>The drive stops when there is contact.</p>
	<p>Stopping the door drive can be implemented with relatively simple resources. However, it is possible that the person involved cannot free himself without external help. When an attempt is made to free somebody that is stuck, the door/gate must safely open – and under no circumstances may it reclose.</p>

Is there a classic solution with external wiring?

There is no classic solution with external wiring that monitors a direction of rotation.

Without using a converter equipped with "Safety Integrated", you must engineer, program and commission a solution comprising the following parts:

- A motor with encoder to sense the speed.
- A higher-level, fail-safe control system.
- A converter with PROFIsafe interface.
- A PROFIsafe connection between the converter and control system.
- A safety program in the control system, which evaluates the speed signal of the converter as well as the encoder, and from this generates a direction of rotation monitoring function.

Solution with "Safety Integrated"

The "Safe direction of rotation" function in the converter is a certified function. This independently monitors the direction of rotation of the connected motor, also without requiring an encoder. The converter only requires the sensor signal, which inhibits or releases the hazardous direction of rotation, and a connection to the higher-level control system.

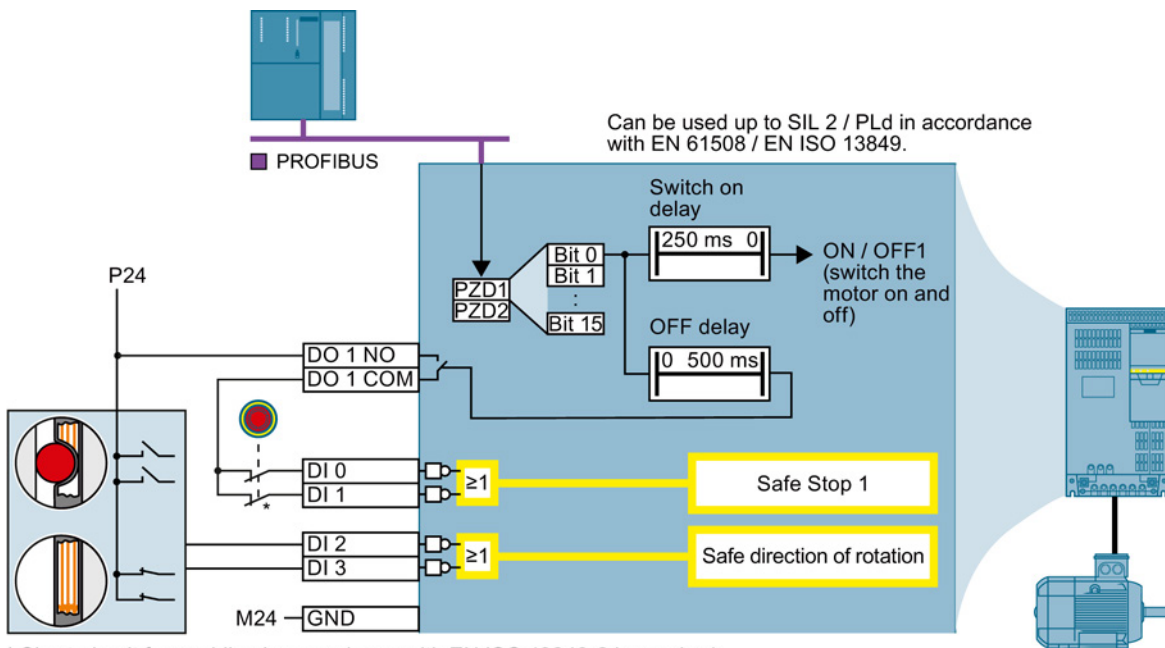


Figure 2-15 Safely rotating in a certain direction – the solution with "Safety Integrated"

2.4 Rotating safely in a certain direction

For example, an elastic sensor mounted at the front of the door/gate is suitable to detect whether somebody is stuck in the door or gate. A light beam enters the sensor, which is interrupted as a result of mechanical pressure.

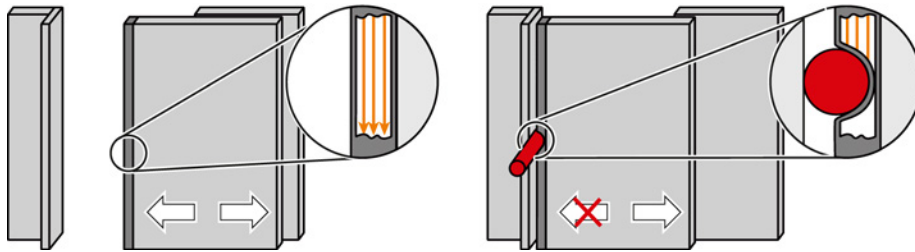


Figure 2-16 Sensor for protection against jamming

In case of danger, the drive stops the door, and inhibits the direction of rotation to close it. After switching on again, the drive can only open the door.

2.4.2 Cleaning printing rolls

Maintenance personnel must enter the machine to clean the rolls. Maintenance personnel must rotate the rolls in order that they can be thoroughly and completely cleaned.

<p>⚠ DANGER Risk of injury due to body parts being drawn in (between the rolls).</p>	<p>Risk minimization: The printing rolls may only rotate in one direction.</p>

Solution with "Safety Integrated"

The converter with "Safety Integrated" evaluates a maintenance switch, which controls the "Safe direction of rotation" function and inhibits the hazardous direction of rotation.

2.4.3 Commissioning the "Safe direction of rotation" function using STARTER

You assign a safe input to "Safety Integrated" functions using STARTER. The "Safe direction of rotation" function can be separately selected for each direction of rotation.

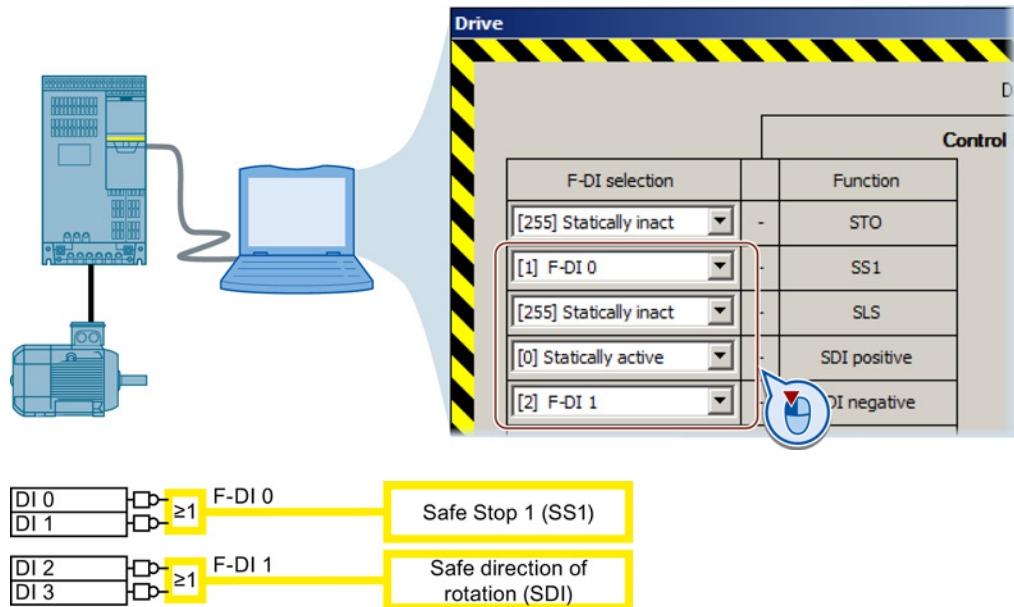


Figure 2-17 Assigning safe inputs to the SS1 and SDI functions

After selecting the function, the converter waits for a specific time before it monitors the direction of rotation. When making the appropriate settings in the converter, you must adapt this delay time to the motor braking time.

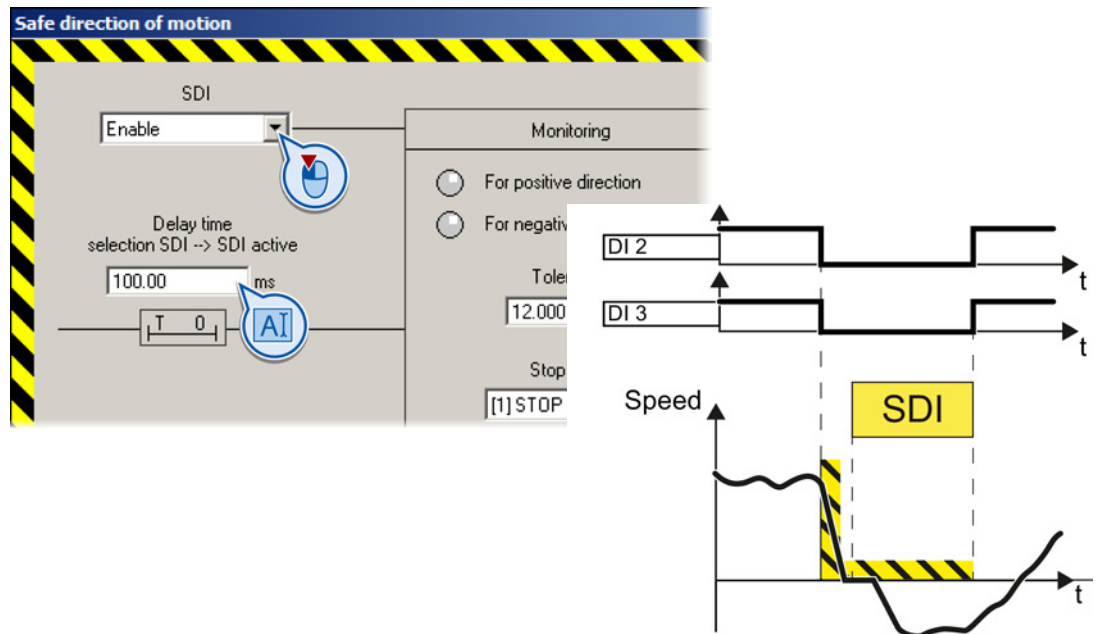
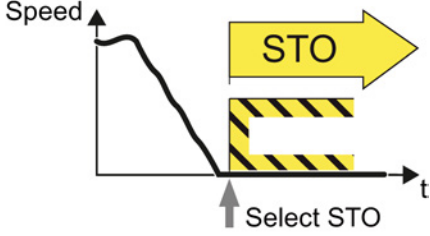
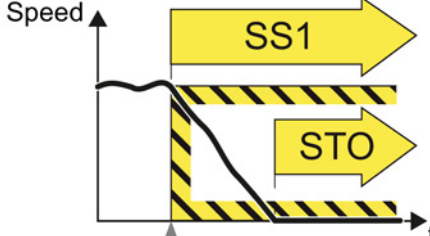

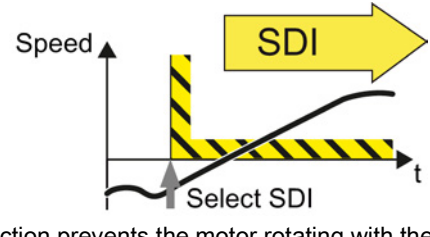


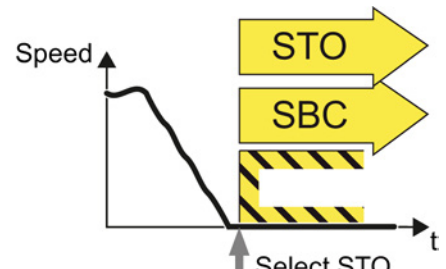
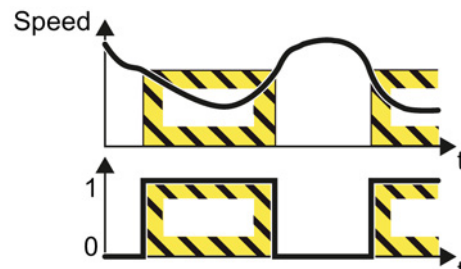
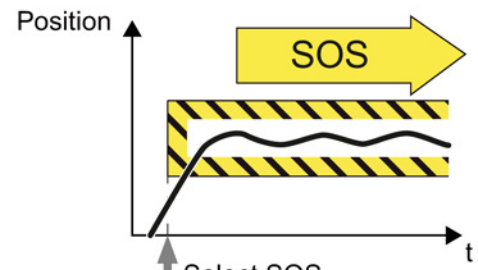
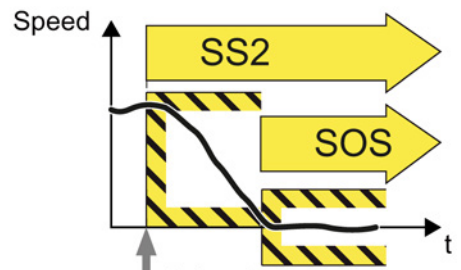
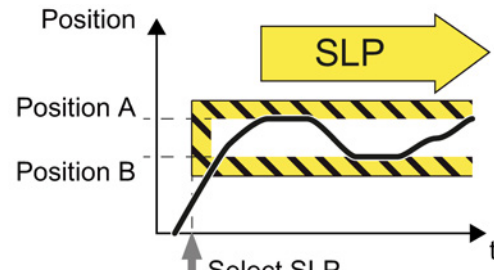
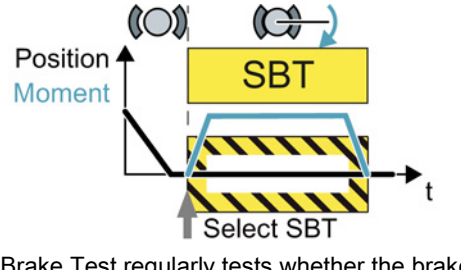
Figure 2-18 Enabling the SDI function and setting the monitoring delay time

Drives with "Safety Integrated" in the application

2.4 Rotating safely in a certain direction

An overview of the "Safety Integrated" functions

<p style="text-align: center;">Safe Torque Off (STO)</p>  <p>The STO function inhibits the supply of energy to the motor which can generate a torque.</p> <p>You do not require an encoder for this function.</p> <p>It is used, for example, in conveyor technology.</p>	<p style="text-align: center;">Safe Stop 1 (SS1)</p>  <p>The SS1 function safely brakes the motor. After it comes to a standstill, the drive switches off the motor torque.</p> <p>This function is possible with and without encoder.</p> <p>It is used, for example, in saws, winders, grinding machines, centrifuges and hoisting gear (cranes).</p>
<p style="text-align: center;">Safely Limited Speed (SLS)</p>  <p>The SLS function prevents the drive from exceeding the parameterized maximum speed.</p> <p>This function is possible with and without encoder.</p> <p>It is used, for example, in conveyor belts, grinding machines, winders, presses and punches.</p>	<p style="text-align: center;">Safe direction of rotation (SDI)</p>  <p>The SDI function prevents the motor rotating with the incorrect direction of rotation. This function is possible with and without encoder.</p> <p>It is used, for example, in stacker cranes, cranes and presses.</p>

<p style="text-align: center;">Safe Brake Control (SBC)</p>  <p>The converter activates the SBC function together with STO. The SBC function supplies a safe output signal to control an external brake. This function does not require an encoder. It is used, for example, in vertical conveyors, winders and elevators.</p>	<p style="text-align: center;">Safe Speed Monitor (SSM)</p>  <p>The SSM function supplies a safe output signal to indicate whether the motor speed is below a specified limit value. This function is possible with and without encoder. It is used, for example, in centrifuges, saws, conveyor belts and packaging machines.</p>
<p style="text-align: center;">Safe Operating Stop (SOS)</p>  <p>The function prevents the motor from deviating from the stop position by more than a defined amount. While the function is active, the drive remains in closed-loop position control or closed-loop speed control. You require an encoder for this function. It is used, for example, in winders, packaging machines and robot applications.</p>	<p style="text-align: center;">Safe Stop 2 (SS2)</p>  <p>The function comprises two steps: 1. The drive stops and monitors the speed while braking. 2. The drive goes into "Safe Operating Stop". You require an encoder for this function. It is used, for example, in processing machines and machine tools.</p>
<p style="text-align: center;">Safely Limited Position (SLP)</p>  <p>The SLP function prevents that the motor moves beyond a defined absolute position. You require an encoder for this function. It is used, for example, in gantry cranes, stacker cranes and machining centers.</p>	<p style="text-align: center;">Safe Brake Test (SBT)</p>  <p>The Safe Brake Test regularly tests whether the brake can maintain the expected torque. The drive applies a test torque to the closed brake and checks whether the motor rotates. You require an encoder for this function. It is used, for example, in gantry cranes and presses.</p>

Minimizing risks in plants and machines

"Safety Integrated" functions play an essential role in achieving functional safety of plants and machines. Functional safety means that all parts of machines function correctly and have sufficient equipment to minimize risks.

In addition to functional risks, plants and machines have a whole series of other potential hazards.

Using risk analysis, risk assessment and the appropriate measures to minimize risk – if necessary, involving several iterations – you can achieve a safe plant or machine.

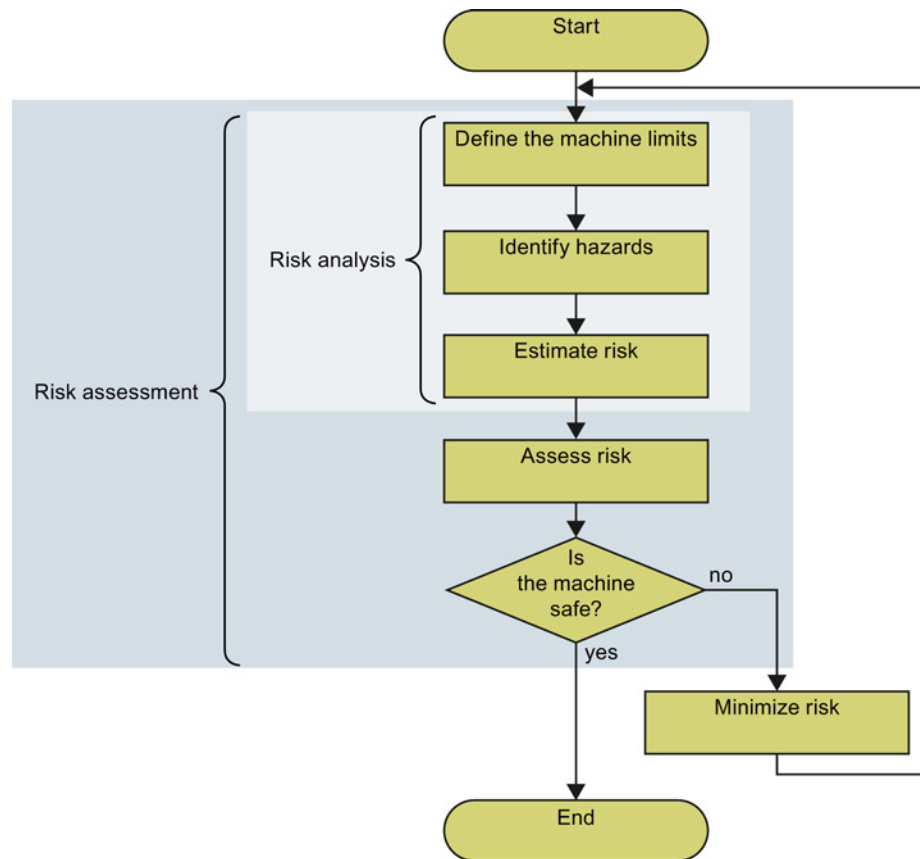


Figure 4-1 Risk analysis and risk assessment of a plant or machine

Define the machine limits	Determine the area where a machine represents hazards for people or material assets.
Identify hazards	<p>Identify systematic hazards, hazard situations and hazard events:</p> <ul style="list-style-type: none"> • Mechanical hazards • Electrical hazards • Thermal hazards • Noise hazards • Hazards from materials/substances, chemical hazards • Ergonomic hazards • Hazards in conjunction with the environment in which the machine is used • Combinations of hazards <p>Analyze these hazards for each phase in the machine lifecycle:</p> <ul style="list-style-type: none"> • Transport, mounting, installation • Commissioning • In all operating modes: Normal operation and faulted operation • Cleaning, service and maintenance • Decommissioning, disassembly and disposal
Estimate and assess the risk	Starting from the hazards that have been identified, you must then estimate the risks according to the extent of damage and the probability of occurrence and assign priorities.

For the risk analysis and risk assessment, Siemens can provide you with free-of-charge support in the form of its Safety Evaluation tool. The tool navigates you in a detailed and structured fashion through the complete process and documents your analysis and assessment. See also: Additional information on "Safety Integrated" (Page 35).

If the risk assessment indicates that measures are required to remove or at least minimize risks, apply measures to reduce risks in the following sequence:

1. Minimize risk by improving the safety through the design and construction of the plant or machine.
2. You must implement additional technical protective measures for risks that cannot be resolved through the design and construction of the machine.

The technical protective measures include the installation of electronic safety equipment, for example sensors and drives featuring "Safety Integrated".
3. You must inform the user about residual risks in the user information, for example using warning labels, documentation or training.

As a machine manufacturer, you must of course satisfy the statutory regulations on introducing machines onto the market. These are, for example,

- You have to prove that the machine satisfies the requirements of the Machinery Directive.
- You have to monitor all the risk minimization measures during manufacture of the machine.

Additional information on "Safety Integrated"

You can find additional information on Safety Integrated on the home page: Safety Integrated (www.siemens.com/safety-integrated).

You can find the Safety Evaluation Tool at: Safety Evaluation Tool (www.siemens.com/safety-evaluation-tool).

For additional information on the topics discussed in this technical overview, we recommend the following brochures on the topic of Safety Integrated that can be found at this address: Info center (www.automation.siemens.com/mcms/infocenter).



The Safety Integrated Function Manuals provide a detailed description of the safety functions.

For drives with SINAMICS G120, G120C or G120D: Sinamics G Function Manual (<http://support.automation.siemens.com/WW/view/en/63035886/0/en>).

For drives with SINAMICS S120: Sinamics S Function Manual (<http://support.automation.siemens.com/WW/view/en/68047679>).

Additional information

SINAMICS converters:

www.siemens.com/sinamics

Safety Evaluation Tool:

www.siemens.com/safety-evaluation-tool

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