Safe vertical axes – Pilz Motion Control

Safe motion monitoring on vertical axes with
Safe Motion – PMCprotego DS or safety relay PNOZ s50
Pilz drive technology – safe, energy efficient, open, productive

Pilz motion control provides overall and energy-efficient solutions for your machine automation. The portfolio comprises both individual components and complete solutions: from motion control systems through servo amplifiers to servo motors, including all safety aspects. Pilz drive technology is embedded into the relevant system environment – whether a new structure or a retrofit – and open for a variety of interfaces and functionalities.

**Your benefits at a glance**
- Safe: up to PL e of EN ISO 13849-1 for each piece of feedback
- Energy efficient: high energy savings thanks to efficient servo technology
- Open: high flexibility, as it can be used with a variety of fieldbus/feedback systems and functionalities
- Productive: short cycle times enable high performance
- Simple parameter setting and diagnostics thanks to intuitive commissioning tools

**Expert advice on all issues relating to your drive**
From planning to implementation, Pilz is the expert you can rely on. The range of services extends from risk assessment to drive configuration, hardware and software design through to commissioning. Regular safety checks and a comprehensive range of training measures complete our range.

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Pilz drive technology: products, services, systems – the one stop shop.
There is an enormous amount of danger in automated production, particularly from gravitational forces in the case of vertical movements, if a power failure occurs or a braking device fails. A risk assessment must consider the risks of unintended descent and define measures to minimise the risk.

Pilz offers a variety of solutions to ensure safe motion monitoring on vertical axes:

- **Safe Motion** – drive-integrated safety functions for safeguarding holding brakes with cyclical testing
- **Safety relay PNOZ s50** – safe brake control and monitoring of holding brakes or safety brakes
Risk assessment

Risk assessments are the key to machinery safety. They pave the way for risk reduction that is both effective and economical. Many activities carried out by operators and maintenance staff represent a high risk. Pilz supports you in issues of risk assessment and machine safety based on applicable standards and directives.

1. Risk estimation

<table>
<thead>
<tr>
<th>Determination of the required performance level (PL)</th>
</tr>
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<tbody>
<tr>
<td>Low contribution to risk reduction</td>
</tr>
<tr>
<td>Starting point for evaluation of safety function's contribution to risk reduction</td>
</tr>
<tr>
<td>High contribution to risk reduction</td>
</tr>
</tbody>
</table>

- **S** – Severity of injury
  - S1 = Slight (normally reversible injury)
  - S2 = Serious (normally irreversible injury or death)

- **F** – Frequency and/or duration of exposure to a hazard
  - F1 = Seldom to quite often and/or the exposure time is short
  - F2 = Frequent to continuous and/or exposure time is long

- **P** – Possibility of avoiding the hazard or limiting the harm
  - P1 = Possible under specific conditions
  - P2 = Scarcely possible

**Product standards**
- EN 61496 Safety on electrosensitive protective equipment
- EN 61800-5-2 Safety functions for drives

**Design specifications**
- EN ISO 13855 Safety of machinery
  - Positioning of safeguards
- EN ISO 12100 Safety of machinery
  - Principles for design and risk analysis
  - General principles for design – Risk assessment and risk reduction

**Application standards**
- EN 60204-1 Safety of electrical equipment
- EN 61326-3 EMC and functional safety
- EN 62061 Functional safety for machinery (electrical incl. EMC)
- EN 61508 Functional safety, generic standard
- EN ISO 13849 Safety-related parts of machinery (electrical and non-electrical)
- EN 61511 Safety systems for the process industry
2. Selection of the measures required to minimise risk

According to the Machinery Directive, every machine manufacturer has a duty to produce a risk assessment. DIN EN ISO 12100 provides general information about how to do this and determine the risks.

Various requirements from the Machinery Directive concern operating modes that necessitate human intervention on the machine. This intervention can also take place while safeguards are partially disconnected. Various solutions are allowed, depending on the design or the duration of exposure. While in many applications switching off a motor is usually a safe solution, in the case of vertical axes switching off could present a danger.

People are exposed to a variety of dangers when setting up lifting equipment, for instance. High speeds and forces and the uncontrolled descent of gravity-loaded axes can lead to injuries such as crushing, drawing in, entanglement or collision. The risk can be reduced by various safety functions.

- **Safe Torque Off (STO)**
  With the “Safe Torque Off” function, the power to the motor is safely removed directly within the servo amplifier. The drive cannot generate any hazardous movements. If the STO is activated when the drive is moving, the motor will run down in an uncontrolled manner.

- **Safe Stop 1 (SS1)**
  With a “Safe Stop 1” function, the drive is brought to a controlled stop and then the power to the motor is safely removed. Once at a standstill, the drive cannot generate any hazardous movements. On gravity-loaded axes, the drive must also be secured by a mechanically-based braking concept.

- **Safe Stop 2 (SS2)**
  With a “Safe Stop 2” function, the drive is brought to a controlled stop and then a “Safe Operating Stop” is initiated. In a “Safe Operating Stop”, the drive’s control functions are maintained in full.

- **Safe Operating Stop (SOS)**
  The “Safe Operating Stop” function monitors the stop position reached by the axis and prevents any deviation from the position window. The drive’s control functions are maintained in full. If the position strays outside of the monitored window, the drive is shut down safely. On gravity-loaded axes, the drive must also be secured by a mechanically-based braking concept.

- **Safely Limited Position (SLP)**
  The “Safely Limited Position” function monitors the end positions of previously defined ranges. If a limit value is violated, the drive is shut down safely.

- **Safe Brake Test (SBT)**
  The “Safe Brake Test” function checks the function of the brake. This test can be used to identify any faults in the brake’s control and mechanics. The brake test may be carried out in each production cycle or only every 8 hours, depending on the specific application and the requirement from the risk analysis.

- **Safe Brake Control (SBC)**
  The “Safe Brake Control” function enables brakes to be controlled safely, thereby preventing suspended loads from falling.
Risk assessment

3. Evaluation of the safety functions

There are different types of device, as each manufacturer applies different parameters due to technological differences. The safety performance data are defined by the application.

- Device type 1: safety-related devices with evaluation of the integrated diagnostics. The classification is specified by the device manufacturer.
- Device type 2: devices with a failure mode that is time-dependent. Additional application data is required in order for the user to evaluate a safety function.
- Device type 3: devices with a failure mode that depends on the switching frequency. Additional application data is required in order for the user to evaluate a safety function.
- Device type 4: special form of device type 1, but without random, hazardous failures (PFH_D = 0).

The calculation is performed in accordance with EN ISO 13849-1 (e.g. with the calculation tool PAScal).
4. Verification of safety functions

To be able to produce a safety concept, the life phases, operating modes, user tasks and actions and the associated hazards and risks must be considered. In addition to the emergency stop and automatic mode, the machine should also be considered more closely in setup mode and during maintenance work. The following consideration is given as an example for lifting equipment.

**Emergency operation: Active in all operating modes**

If the emergency stop button is pressed, a “Safe Stop 1” (SS1) must be initiated and then the brakes activated.

**Setup operating mode**

If the mode selector switch is turned to Setup, the safety functions of this mode are active, so movements even while the safeguard is open are possible under reduced risk with a guard locking device and active enabling function. The speed is safely monitored and, if the limit is breached, a “Safe Stop 1” (SS1) is triggered with activation of the holding brake and shutdown of the axis.

**Automatic operating mode**

As long as the mode selector switch is turned to Automatic, all movements are only possible if the guard is closed and locked with a guard locking device. If the locked guard (safety gate) is opened, a “Safe Stop 2” (SS2) is triggered. In addition, the minimum and maximum speed of the vertical axis is monitored thanks to “Safe Speed Range” (SSR). If the limit is exceeded, the “Safe Stop 1” (SS1) is triggered with activation of the brakes in a shutdown.

A prolonged stay under the gravity-loaded axis is essential in the case of maintenance, repair and cleaning. This means that the axis must be supported from underneath or locked mechanically.
Complete solutions on vertical axes

### Application example

The operator stays outside the access-protected area.

### Hazardous situation 1:
The operator puts his upper limbs briefly under the vertical axis.

### Operating modes

<table>
<thead>
<tr>
<th>Automatic mode</th>
<th>Set-up mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guard with guard locking device:</td>
<td></td>
</tr>
<tr>
<td>Mechanical safety switch PSENmech</td>
<td>Safety bolt PSENbolt</td>
</tr>
<tr>
<td>Safety gate system PSENsgate</td>
<td></td>
</tr>
</tbody>
</table>

**With guard door closed**:
Before the guard locking device is deactivated, a cyclical test of the braking equipment is performed by the machine control in accordance with Cat. 2, EN ISO 13849-1:

- Servo amplifier PMCprotego DS – Safe Motion

**With guard door open**:
If access to the protected area is possible, the protection regulations of hazardous situations 1 and 2 apply:

- Servo amplifier PMCprotego DS – Safe Motion

+ Measures for set-up mode in accordance with standard, e.g. EN ISO 10218-1, DIN EN 12417:

- Manually operated control device PITjog
- Enabling switch PITenable

### Safe solution

- Configurable control systems PNOZmulti
- Control system PSSuniversal PLC
Application example

Hazardous situation 2: The operator puts his whole body under the vertical axis.

Operating modes

Automatic mode

Redundant fall protection equipment in accordance with Cat. 3, EN ISO 13849-1. The use of a second brake may be necessary. As only one holding brake is normally integrated in the motor, an additional external brake is required.

Servo amplifier

PMCprotego DS – Safe Motion

Safety relay PNOZ s50 with feedback loop for monitoring the air of external brakes

Set-up mode

Before the guard locking device is deactivated, a cyclical test of the braking equipment is performed by the machine control in accordance with Cat. 2, EN ISO 13849-1:

Servo amplifier

PMCprotego DS – Safe Motion

+ Measures for set-up mode in accordance with standard, e.g. EN ISO 10218-1, DIN EN 12417:

Manually operated control device PITjog

Enabling switch PITenable

Prolonged stay:

Redundant fall protection equipment in accordance with Cat. 3, EN ISO 13849-1. The use of a second brake may be necessary. As only one holding brake is normally integrated in the motor, an additional external brake is required.

Safety relay PNOZ s50

Legend

1) The servo amplifier PMCprotego D prevents an unexpected start-up. The safety card PMCprotego S is used to perform the cyclical brake test:
   - If a guard is present, a brake test before every entry (immediately before the guard locking device is enabled) is sufficient.
   - The brake test is carried out at 1.3 times the load torque (if one brake is used).
   - The safety card also permits the “Safe Operating Stop” (SOS), which safely monitors the stop position reached by the axis and prevents the axis leaving the position window.
   - In many cases the brake test allows the use of expensive mechanical or hydraulic weight compensation to be dispensed with.

2) The unexpected start-up of the vertical axis must be reliably prevented.
Cyclical testing of holding brakes with Safe Motion

The holding brake that exists for process reasons does not normally offer sufficient protection against the descent of suspended loads. That is because mechanical wear or oil fouling can mean that the rated braking torque of the brake is not reached. This can result in the axis collapsing.

Depending on the risk assessment, a holding brake with cyclical testing may suffice as protection. This presupposes that the probability of descent is rated lower, as either a protective structure prevents access below the vertical axis or the length of stay for particular activities is low.

Safe working on vertical axes

PMCprotego DS verifies the function of the brake with the “Safe Brake Test” (SBT). The brake test may be carried out in each production cycle or only every 8 hours, depending on the specific application and the requirement from the risk analysis. The brake is loaded with an additional torque. If the position changes during testing, this is identified as an inadmissible state and results in a message that prevents further operation. The plant is shut down safely to allow the brake to be repaired.

As well as the “Safe Brake Test” (SBT), safe motion also enables other safety functions to be realised. Motion functions such as “Safely Limited Speed” (SLS) and stop functions such as “Safe Torque Off” (STO) allow reduced setup times and enhance availability for the process.

All safety functions with PMCprotego DS meet the requirements of the Machinery Directive based on IEC 61800-5-2 and are designed up to PL e of EN ISO 13849-1 and SIL CL 3 of EN/IEC 62061.
Benefits at a glance  Safe Motion – PMCprotego DS

Flexible connection
The safe motion solution can be easily integrated into any existing system environment. That’s because PMCprotego DS is not only suitable for the connection and integration of the motion control systems PMCprimo directly in the servo amplifier, but also open for connection to commercial PLC and motion controls through interfaces such as analogue/digital, CANopen, S7 – PROFIBUS-DP, EtherCAT, Sercos II and DeviceNet.

Your benefits at a glance
- Very short reaction times of up to 2 ms at maximum performance due to the integrated stop functions
- Simple integration within an existing system environment thanks to open interfaces
- High flexibility thanks to safe digital inputs and outputs that are compatible with all programmable safety systems on the market
- Safe, dual-pole, digital output for activating a brake
- Mechanical fault exclusion is not required because breaks are monitored through an additional external encoder
- Reduction in total costs because the highest safety category – PL e – is achieved with one encoder

Easy parameterisation with PASconfig SDrive
Configuration of the safety card is simple and user-friendly with PASconfig SDrive. Thanks to its informative graphics, this software tool is a part of the Pilz safety concept because user information helps to prevent invalid entries. The inputs and outputs of the safety card S1-2 can be flexibly assigned to one or more safety functions in the configurator. Functions such as “Safely Limited Speed” (SLS) and “Safe Direction” (SDI) can be started via a common input and can be connected to a digital output on the safety card separately or together. This reduces the work involved in programming and wiring.
Technical details – PMCprotego DS

Safety card PMCprotego S1-2

Technical features
- 9 inputs (1-pole)
- 1 output (1-pole, 2 A)
- Control of external brake < 2 A: via safety card
- Control of external brake > 2 A: via external brake module
- Encoder type: SSI and incremental
- 1 external encoder
- Category: SIL CL 3, PL e

Servo amplifier PMCprotego D

Technical features
- Position controller with max. 200 motion tasks
- Electronic gearing
- Master-Slave mode
- Encoder emulation
- Universal voltage range
- Intermediate circuits can be connected in parallel
- 2 encoder inputs
- 1 encoder output
- 2 digital inputs, STO Enable
- 2 digital inputs, 5 µs
- 2 digital inputs, 250 µs
- 2 digital inputs or outputs, 250 µs
- 2 analogue inputs ±10 V, 16 Bit
- CANopen
- DS301 communication profile
- DS402 drive profile
- Ethernet-based bus communication
- EtherCAT
- Serial interface RS 232
- SD card

Type code

<table>
<thead>
<tr>
<th>Type/Order number</th>
<th>Mains voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMCprotego D_ _ / _ _ / 0 / _ /</td>
<td>208 … 480 VAC</td>
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</tbody>
</table>

Hardware option

<table>
<thead>
<tr>
<th>Slot 1</th>
<th>0 None</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 I/O expansion</td>
<td></td>
</tr>
<tr>
<td>2 PROFIBUS</td>
<td></td>
</tr>
<tr>
<td>3 Sercos III</td>
<td></td>
</tr>
<tr>
<td>4 DeviceNet</td>
<td></td>
</tr>
<tr>
<td>Slot 2</td>
<td>0 None</td>
</tr>
<tr>
<td>1 PosI/O</td>
<td></td>
</tr>
<tr>
<td>2 PosI-O-AIO</td>
<td></td>
</tr>
<tr>
<td>Slot 3</td>
<td>0 None</td>
</tr>
<tr>
<td>1 PosI/O</td>
<td></td>
</tr>
<tr>
<td>2 PosI-O-AIO</td>
<td></td>
</tr>
</tbody>
</table>

Standard bus systems: CANopen

We reserve the right to change technical details.
Safety functions

- Safe Torque Off (STO)
- Safe Stop 1 (SS1)
- Safe Stop 2 (SS2)
- Safe Operating Stop (SOS)
- Safety Limited Speed (SLS)
- Safe Speed Range (SSR)

Order number: 680004

Options

- Slot 1 optionally configurable with:
  - D1 I/O expansion card with 14 inputs and 8 outputs
  - Fieldbuses: PROFIBUS-DP-S, Sercos, DeviceNet

- Slot 2 optionally configurable with:
  - PosI/O with rapid bidirectional 5-V-I/O for position encoder emulation (ROD or SSI) or RS 485 signals for encoder guide or master/slave
  - PosI/O monitor for functions of the PosI/O-AIO; 2 analogue inputs ±10 V, 16 Bit

- Slot 3 optionally configurable with safety card:
  - PMCprotego S1
  - PosI/O with rapid bidirectional 5-V-I/O for position encoder emulation (ROD or SSI) or RS 485 signals for encoder guide or master/slave
  - PosI/O monitor for functions of the PosI/O; analogue input ±10 V, 16 Bit analogue output ±10 V, 16 Bit

Options

- Firmware option
  - SafetyNET p
  - EtherCAT

- Options
  - 0 P

Firmware option

- Default
  - $I_{peak} = 3 \times I_{peak}$

Further technical details in the installation manual

The Pilz solution is already safe with the feedback system of the servo motor. If the risk analysis of the mechanical transmission means that a second encoder is required, a second external encoder can be connected.
Safety relay PNOZ s50 for safe brake control

The stand-alone safety relay PNOZ s50 offers a cost-effective solution to the control of two brakes up to category PL e of EN ISO 13849-1. The contactless technology allows very short reaction times to be achieved, enhancing personal protection. You can take advantage of the full flexibility and the individual shutdown options for your application of this manufacturer-independent solution.

Safe, contactless braking – so it’s non-wearing

PNOZ s50 helps to make your plant energy efficient: application cycle times are shortened because temporary excitation is followed by selectable voltage reduction (pulse width modulation PWM). The safety relay allows rapid switching in emergency situations and slow, low-wearing switching in normal operation, thereby helping to reduce maintenance costs.

As an addition to the PNOZsigma product range, PNOZ s50 has a rotary knob for menu navigation and a display for showing setup parameters and diagnostic messages.

Both motor brakes and safety brakes can be safely controlled and monitored with the safety relay PNOZ s50. Safety is significantly improved due to “wear monitoring”, particularly on motor-integrated holding brakes.

Safety relay PNOZ s50

Technical features

- Stand-alone device
- 2 brakes up to PL e of EN ISO 13849-1 / SIL CL 3 of EN/IEC 62061
- 1 brake up to PL d of EN ISO 13849-1 / SIL CL 3 of EN/IEC 62061
- 2 x 2-pin safe electronic digital outputs for 24 VDC, each 4.5 A
- Temporary overexcitation with subsequent voltage reduction
- Ambient temperature: 0 ... 45 °C
- Number of inputs:
  - Failsafe: 4
  - Standard: 4
- Number of failsafe semiconductor outputs:
  - 1-pole: 3
  - 2-pole: 2
Benefits at a glance Safety relay PNOZ s50

Your benefits at a glance

- Highest level of safety up to PL e when controlling 2 brakes (holding brakes or safety brakes)
- Contactless technology up to 4.5 A per brake allows short reaction times and a long-lasting solution
- Reduced cycle times through temporary overexcitation with subsequent voltage reduction
- High safety and low wear on the brake thanks to fast and slow shutdown of the power circuits
- Rapid diagnostics by means of display
- Manufacturer-independent brake control thanks to safe, digital inputs

In many applications a second brake needs to be protected in addition to the holding brake. In stage technology, for instance, hoists are operated with dual brakes.

Supply voltage:
- 1-pole: 24 VDC
- 2-pole: 24 VDC, 48 VDC
Voltage tolerance:
- 1-pole: -15 % … +20 %
- 2-pole: -10 % … +10 %
Output current of semiconductor outputs (1-pole): 0.1 A
Test pulse outputs of semiconductor outputs (1-pole): 2

Reduced voltage of semiconductor outputs (2-pole):
- 6 V, 8 V, 12 V, 16 V, 24 V
Output current of semiconductor outputs (2-pole):
- 24 VDC supply voltage:
  Continuous duty (1 output/2 outputs): 1 x 6.5 A/2 x 4.5 A
  Overexcitation (1 output/2 outputs): 1 x 6.5 A/ ∑ = 10
- 48 VDC supply voltage:
  Continuous duty (1 output/2 outputs): 1 x 3.25 A/2 x 2.25 A
  Overexcitation (1 output/2 outputs): 1 x 3.25 A/2 x 3.25 A

Order number
751 500
(with spring-loaded terminals)

Technical documentation on safety relays PNOZ s50:
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Pilz develops environmentally-friendly products using ecological materials and energy-saving technologies. Offices and production facilities are ecologically designed, environmentally-aware and energy-saving. So Pilz offers sustainability, plus the security of using energy-efficient products and environmentally-friendly solutions.