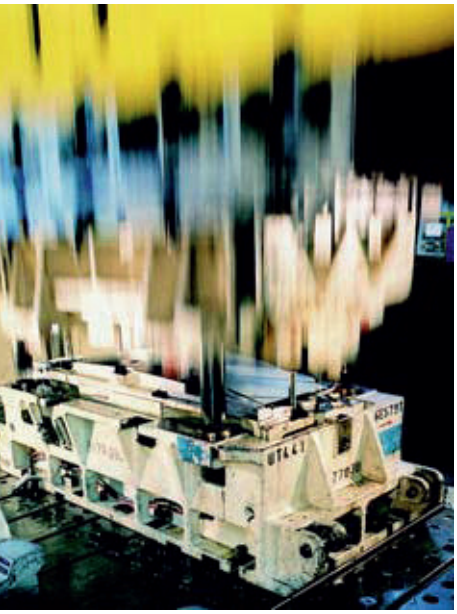
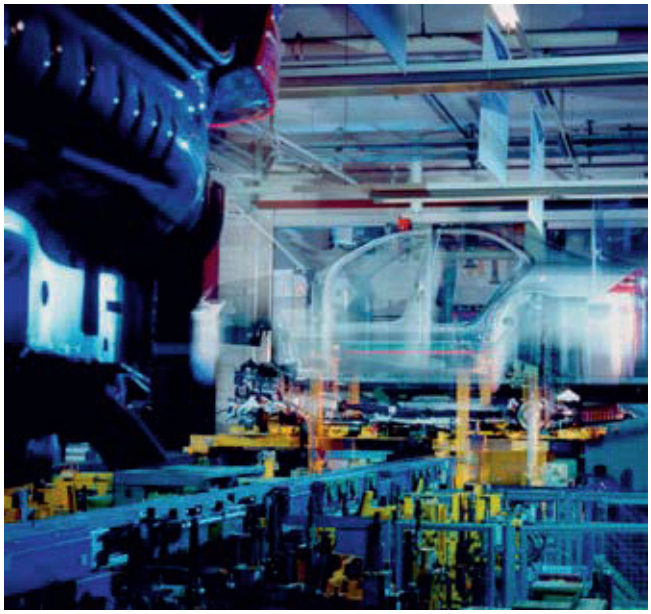
Innovations



Safety Integrated

Overview



The integrated safety functions of SINAMICS G120 and SINAMICS G120D provide highly effective application-oriented protection for personnel and machinery.

SINAMICS G120 and SINAMICS G120D offer the following Safety Integrated functions (terms as defined in IEC 61800-5-2):

- Safe Torque Off (STO)
- Safe Stop 1 (SS1)
- Safely Limited Speed (SLS)
- Safe Brake Control (SBC) (SINAMICS G120 only)

The Safety Integrated functions are completely integrated into the drive system. They can be activated as follows:

- via safe digital inputs on the Control Unit (SINAMICS G120 only) without the need for an additional safety switching device
- via PROFIBUS with PROFIsafe
- via PROFINET with PROFIsafe

The Safety Integrated functions are implemented electronically and therefore offer short response times in comparison to solutions with externally implemented monitoring functions. This system is absolutely unique in that it does not require speed feedback through sensors or encoders.

The STO and SBC functions can be used without restriction for all applications.

The SS1 and SLS functions may be used for any application in which the load never accelerates when the frequency inverter is switched off. They are therefore not suitable for applications involving pull-through loads such as lifting gear and winders.

Legal framework

Machine manufacturers and plant constructors must ensure that their machines or plants cannot cause danger due to malfunctions apart from the general risks of electric shock, heat or radiation.

In Europe, for example, compliance with the machinery directive is required in law by the EU industrial safety directive. In order to ensure compliance with this directive, it is recommended that the corresponding harmonized European standards are applied. This triggers the “assumption of conformity” and gives manufacturers and operators the legal security in terms of compliance with both national regulations and EU directives. The machine manufacturer uses the CE marking to document the compliance with all relevant directives and regulations in the free movement of goods.

Safety-related standards

Functional safety is specified in various standards.
EN ISO 12100 and EN 1050, for example, are concerned with the construction and risk assessment of machines. EN 62061 (only applicable for electrical and electronic control systems) and EN ISO 13849-1, which will replace the previously used EN 954-1 as from 2009, define the functional and safety-related requirements of control systems with relevance to safety.

The above-mentioned standards define different safety requirements that the machine has to satisfy in accordance with the risk, frequency of a dangerous situation, probability of occurrence and the opportunities for recognizing impending danger.

- EN 954-1: Categories B, 1 … 4
- EN ISO 13849-1: Performance Level PL a … e
- EN 62061: Safety Integrity Level SIL 1 … 3

Trend toward integrated safety systems

The trend toward greater complexity and increasing modularity of machines has seen a shift in safety functions away from the classical central safety functions (for example, shutdown of all drives by a line contactor) and into the machine control system and the drives. One advantage of this development is that some safety-related circuitry involving complex hardware is now no longer necessary.

Integrated safety functions act much faster than those of a conventional design. The safety of a machine is increased further with Safety Integrated. Furthermore, safety measures controlled by integrated safety systems are perceived as less interfering by the operator of the machine due to the faster action, so the motivation to consciously bypass safety functions is significantly reduced.

Function

Safety functions integral to the SINAMICS G120 and SINAMICS G120D drive systems

SINAMICS G120 and SINAMICS G120D are characterized by a large number of integrated safety functions.

They satisfy the requirements of

- Category 3 according to EN 954-1
- Safety Integrity Level (SIL) 2 according to EN 61508

The Safety Integrated functions provided by SINAMICS G120 and SINAMICS G120D have been certified by independent institutes. You can obtain the corresponding external test certificates and manufacturer's declarations from your Siemens contact partner;

and at the following address for SINAMICS G120:

http://support.automation.siemens.com/WW/view/en/22339653/134200

and at the following address for SINAMICS G120D:

http://support.automation.siemens.com/WW/view/en/25021636/134200

The Safety Integrated functions currently available in SINAMICS G120 and SINAMICS G120D are listed below (terms as defined in IEC 61800-5-2):

Safe Torque Off (STO)

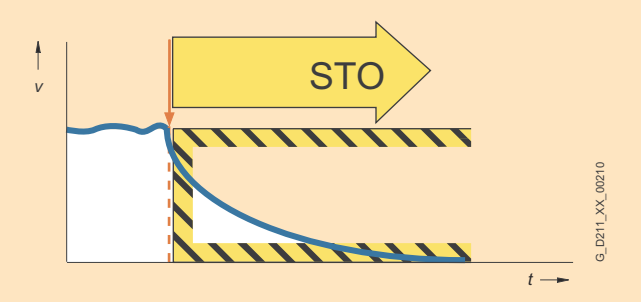
Description of functions

This function is a mechanism that prevents the drive from restarting unexpectedly, in accordance with EN 60204-1, Section 5.4. Safe Torque Off disables the drive pulses and disconnects the power supply to the motor (corresponds to Stop Category 0 of EN 60204-1). The drive is reliably torque-free. This state is monitored internally in the drive.

Application, customer benefits

STO has the immediate effect that the drive cannot supply any torque-generating energy.

STO can be used wherever the drive will reach a standstill autonomously due to the load torque or friction in a sufficiently short time or when coasting down of the drive will not have any relevance for safety.



Safe Stop 1 (SS1)

Description of functions

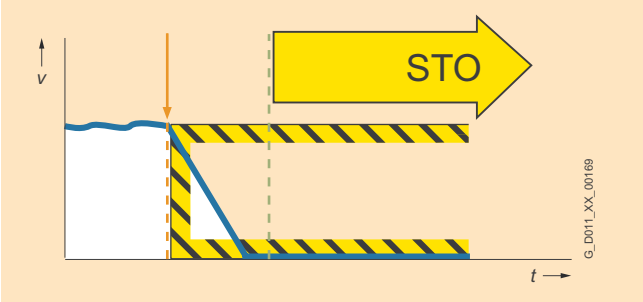
The Safe Stop 1 function can safely stop the drive in accordance with EN 60204-1, Stop Category 1. When the SS1 function is selected, the drive brakes autonomously along an adjustable, monitored ramp and automatically activates the Safe Torque Off and Safe Brake Control functions (if used) when 2 Hz is reached.

If the drive does not brake along the parameterized ramp when the stop function is activated, Safe Torque Off and Safe Brake Control (if used) are activated instantaneously.

Application, customer benefits

This integrated fast-brake function eliminates the need for complex external monitoring equipment. Furthermore, it is often possible to eliminate mechanical brakes which wear, or to lessen the load on them, so that maintenance costs and the stresses on the machine can be reduced.

Safe Stop 1 is employed for applications which require monitored braking, e.g. on centrifuges, conveyor vehicles, etc.



Function (continued)

Safely Limited Speed (SLS)

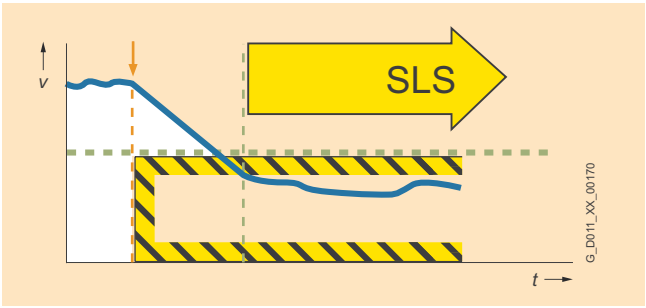
Description of functions

The Safely Limited Speed function monitors the drive and, depending on the mode selected, either limits the motor speed to a safe value or monitors the system directly for a parameterized maximum speed.

If the drive does not follow the parameterized ramp or exceeds the maximum speed when the function is activated, it is either braked along the Safe Stop 1 ramp or Safe Torque Off and Safe Brake Control (if used) are activated (depending on which mode is selected).

Application, customer benefits

When many machines are being set up, the operating personnel must work on the moving machine. This either occurs in stages because the operator must exit the danger area repeatedly when the machine is started up, or the operator works on the moving machine and is therefore exposed to increased risk. The SLS function can save a considerable amount of time here and still increase the safety of operating personnel.



Safe Brake Control (SBC)

Description of functions

Safe Brake Control SBC is used to control motor brakes which are operative at zero current, e.g. motor holding brakes. The brake control circuit is a fail-safe, two-channel design.

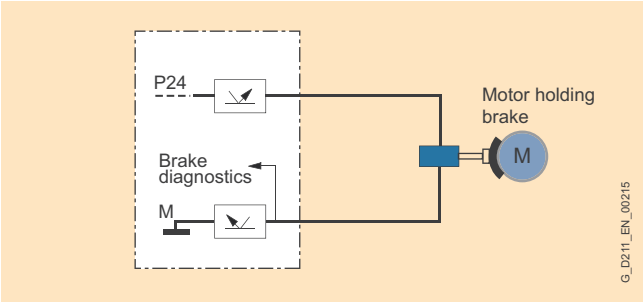
The Safe Brake Control is activated when the Safe Torque Off function is selected and when safety monitors with safe pulse disable are tripped.

- This function is available only for the SINAMICS G120 system. It requires an additional Safe Brake Relay.
- The Safe Brake Control does not detect mechanical faults in the brake itself, such as worn brake linings.
- The Safe Brake Relay is only capable of controlling 24 V motor brakes.

Application, customer benefits

SBC can also be activated in combination with STO and SS1. SBC provides the option of safely controlling a motor brake on the motor when the torque-generating energy has been disconnected.

As the Safe Brake Control module does not contain any mechanical components, there are no restrictions on switching frequency.



5

Function (continued)

PROFIsafe

PROFIsafe is an open communications standard that supports standard and safety-related communication over the same communications cable (wired or wireless). A second, separate bus system is therefore not necessary. To ensure safe communication, the transmitted message frames are continuously monitored. Possible errors, such as lost or repeated messages or those received in the wrong order are avoided in that safety-related messages are numbered consecutively, their arrival is monitored within a defined period, and an identifier for the sender and receiver of a message is transferred. A CRC (cyclic redundancy check) data security mechanism is also used.

PROFIsafe can be implemented on PROFIBUS and PROFINET on the SINAMICS G120 and SINAMICS G120D systems.

Licensing

The Safety Integrated functions for SINAMICS G120 and SINAMICS G120D do not require a license.

The availability of Safety Integrated functions depends on the type of Control Unit, i.e. whether it is a Standard Control Unit or a Fail-safe Control Unit.

An overview of the Safety Integrated functions of SINAMICS G120 and SINAMICS G120D plus their boundary conditions is given in the following table:

Function	Activation	Underlying function	Reaction to limit overshoot	External setpoint input effective	Encoder required
STO	• PROFIsafe over PROFIBUS or PROFINET • Fail-safe digital inputs (with SINAMICS G120 only)	SBC (if parameterized)	–	no	no
SS1	• PROFIsafe over PROFIBUS or PROFINET • Fail-safe digital inputs (with SINAMICS G120 only)	STO when 2 Hz is reached, followed by SBC (if parameterized)	Activation of STO Activation of SBC (if parameterized)	no	no
SLS	• PROFIsafe over PROFIBUS or PROFINET • Fail-safe digital inputs (with SINAMICS G120 only)	–	Activation of STO or SS1 Activation of SBC (if parameterized)	yes (depending on mode)	no
SBC (with SINAMICS G120 only)	• With STO • With SS1 when 2Hz is reached	–	–	–	no

The operating principle of Safety Integrated

Two independent switch-off signal paths

Two independent switch-off signal paths are available. All switch-off signal paths are low active, thereby ensuring that the system is always switched to a safe state if a component fails or in the event of an open circuit. If an error is discovered in the switch-off signal paths, the “Safe Torque Off” function is activated and a system restart inhibited.

Two-channel monitoring structure

All the main hardware and software functions for Safety Integrated are implemented in two independent monitoring channels (e.g. switch-off signal paths, data management and data comparison). A cyclic crosswise comparison of the safety-relevant data in the two monitoring channels is carried out.

The monitoring functions in each monitoring channel work on the principle that a defined status must prevail before each action is carried out and a specific acknowledgement must be made after each action. If these expectations of a monitoring channel are not fulfilled, the drive coasts to a two-channel standstill and an appropriate message is output.

Forced dormant error detection using test stop

The functions and switch-off signal paths must be tested at least once within a defined time in order to meet requirements as per EN 954-1 and IEC 61508 in terms of timely fault detection. This functionality must be implemented by means of test stop triggering either in cyclic manual mode or by the automated process. The test stop cycle is monitored and a warning is output following a timeout.

A test stop does not require Power On. The acknowledgment is set by canceling the test stop request.

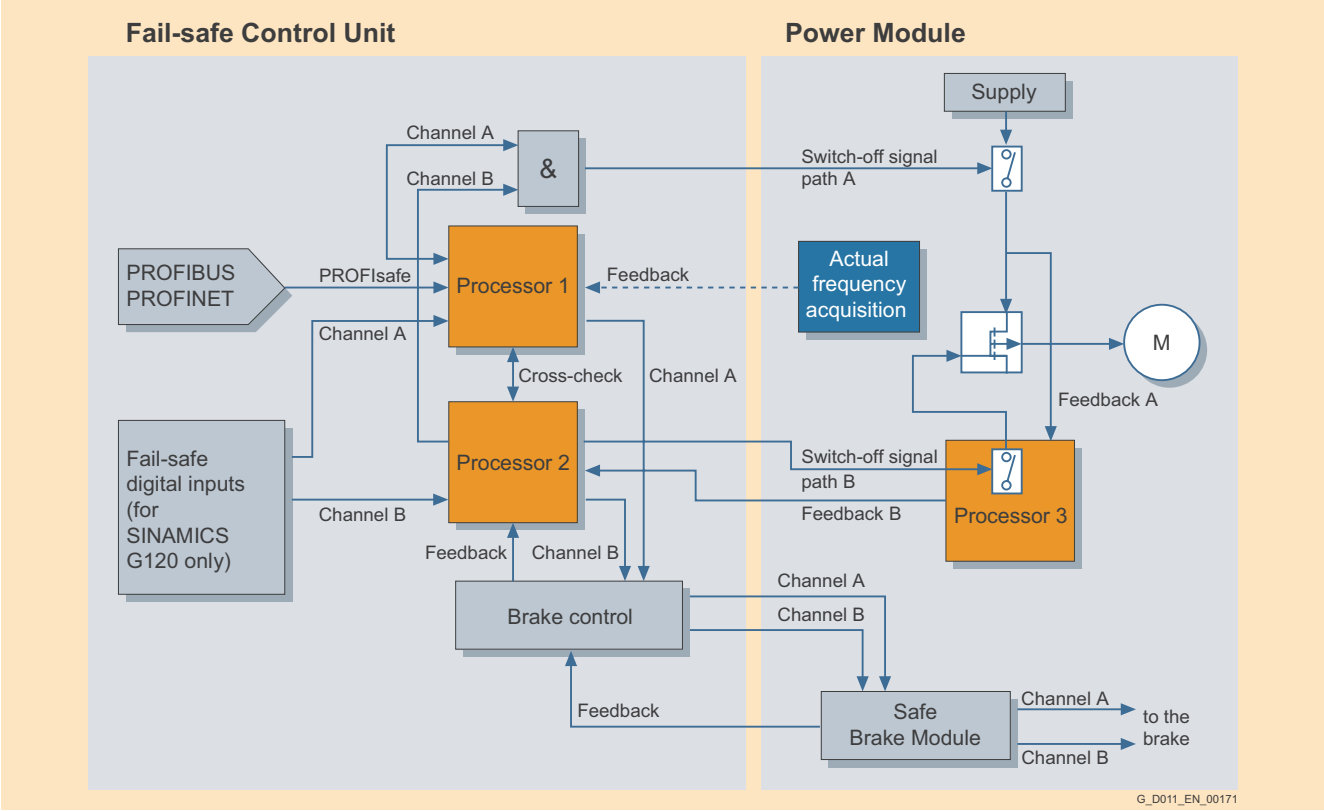
When the appropriate safety devices are implemented (e.g. protective doors), it can be assumed that running machinery will not pose any risk to personnel. For this reason, only an alarm is output to inform the user that a forced dormant error detection run is due, thereby requesting that this be carried out at the next available opportunity.

Examples of when forced dormant error detection runs are required:

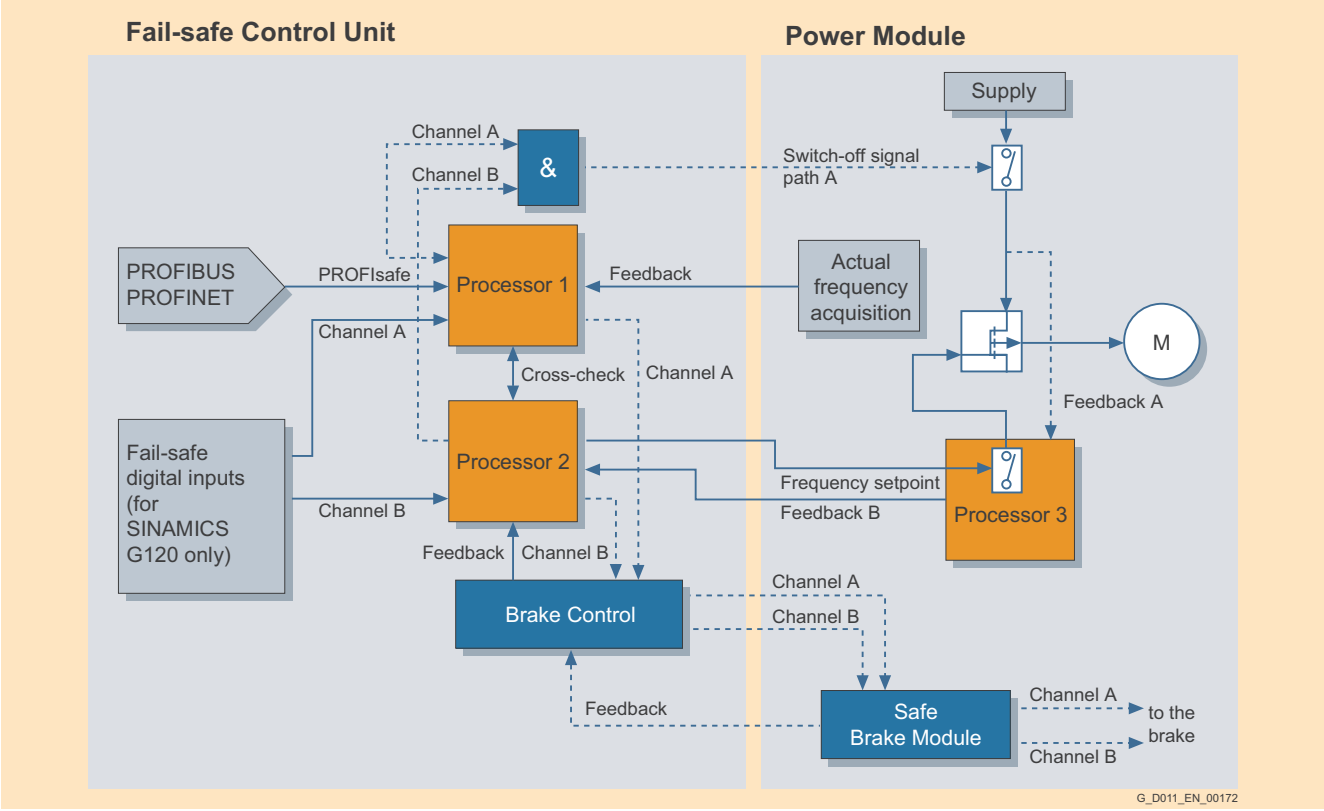
- When the drives are at a standstill after the system has been switched on
- Before the protective door is opened
- At defined intervals (e.g. every 8 hours)
- In automatic mode, time- and event-driven

Function (continued)

STO function structure on the SINAMICS G120 and SINAMICS G120D drive systems



SS1 and SLS function structure on the SINAMICS G120 and SINAMICS G120D drive systems



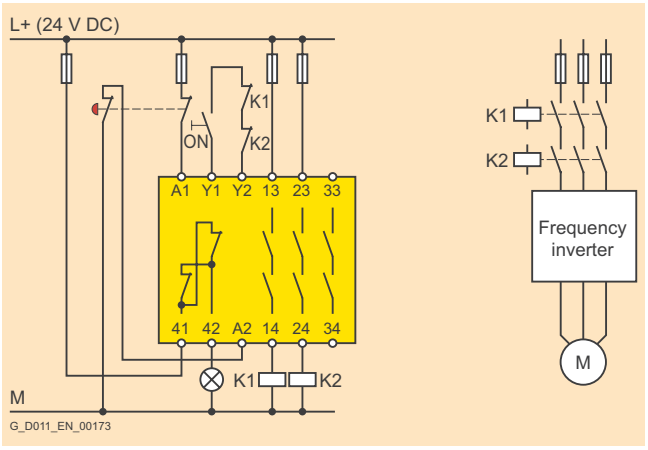
Function (continued)

Comparison between conventional and integrated safety systems

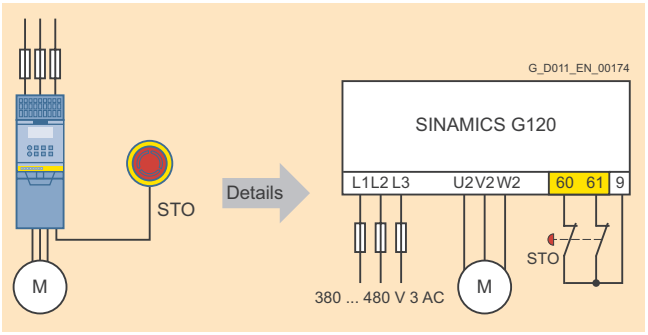
The implementation of safety functions on drives demands solutions which can be complex and costly.

The safety functions integrated in the SINAMICS G120 and SINAMICS G120D systems are significantly simpler and cheaper than conventional solutions.

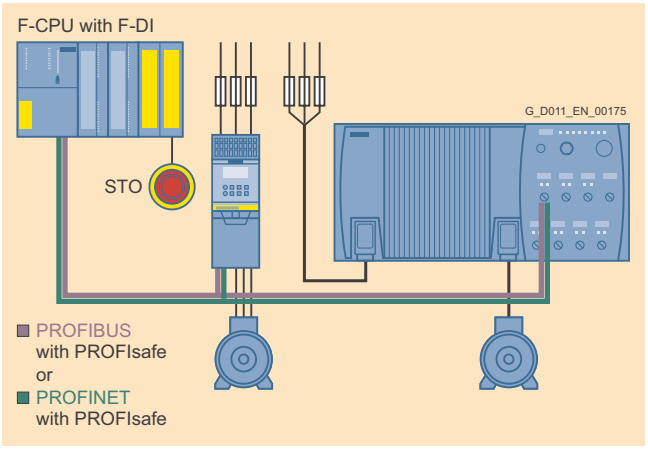
Safe Torque Off (STO)



Conventional wiring

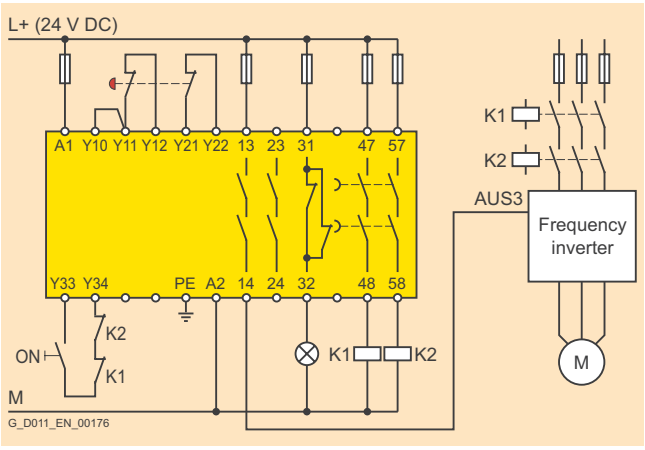


Integrated safety via fail-safe inputs

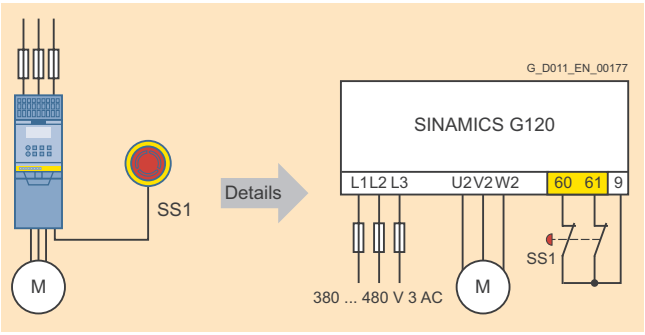


Integrated safety via PROFIsafe

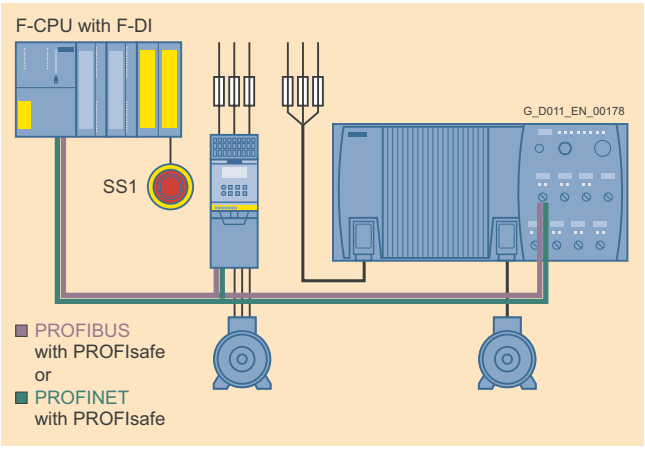
Safe Stop 1 (SS1)



Conventional wiring



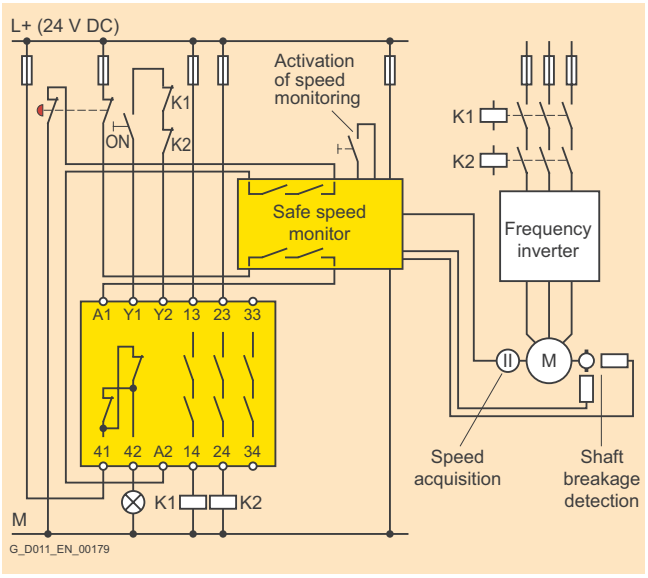
Integrated safety via fail-safe inputs



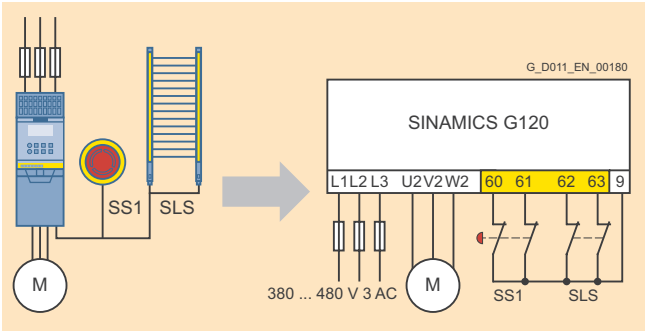
Integrated safety via PROFIsafe

Function (continued)

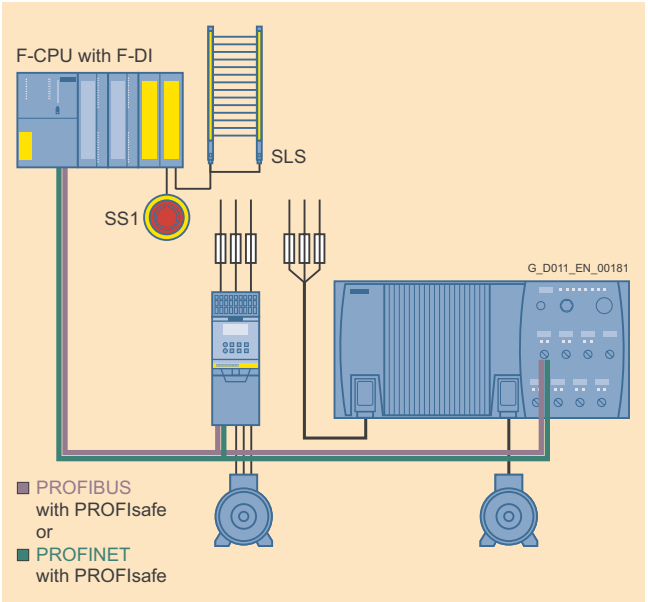
Safely Limited Speed (SLS)



Conventional wiring



Integrated safety via fail-safe inputs



Integrated safety via PROFIsafe

Overview

Siemens AG is setting a completely unique new standard in the field of compact inverters: The technology applied is a world first and provides regenerative feedback capability in smaller, lighter and much lower-cost inverter units.

Available inverters with Efficient Infeed Technology

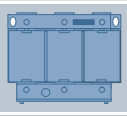
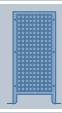
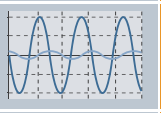
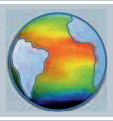
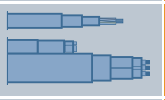
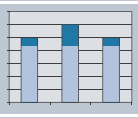
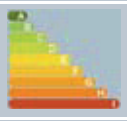
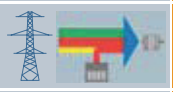
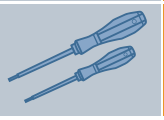
The following inverters are equipped with Efficient Infeed Technology:

- SINAMICS G120 (integrated in PM250 and PM260 Power Modules)
- SINAMICS G120D
- SIMATIC ET 200S FC
- SIMATIC ET 200pro FC

You will find SINAMICS G120 and SINAMICS G120D in this catalog (sections 3 and 4).
For information about the two SIMATIC ET 200 inverters, please refer to section 8 and Catalog IK PI.

Potential savings thanks to Efficient Infeed Technology

The table below shows the advantages of the technology as compared to conventional 2-quadrant inverters.

	Standard Technology	Efficient Infeed Technology
Line reactor 	Required	**Not required**
Braking resistor 	Required	**Not required**
Configuration overhead 	Standard	**Low**
Generated harmonics 	Standard	**Minimal**
Heat generated when braking 	Yes	**No**
Power infeed 	Standard	**Approx. 22% less**
Power consumption 	Standard	**Approx. 22% less**
Energy efficiency 	Standard	**Good**
Reactive power compensation 	No	**Yes**
Installation outlay 	Standard	**Low**

G_D011_EN_00182

Three technical criteria are of particular significance:

- Regenerative feedback
  - 100 % braking power is fed back, allowing continuous braking. This is not possible in practice using braking resistors
  - A braking resistor does not need to be configured
  - No need for installation, heat dissipation monitoring, etc. for external components
- Minimal reactive power distortion
  - Power consumption is not “spiky”, but almost like a block, so a minimal transformer throughput rating is required and reduced reactive power distortion
  - To achieve these low harmonics using an inverter with standard DC link, a line reactor with u_K = 6 % is required.
  - Results in approx. 22 % lower power consumption which corresponds to approximately 40 % lower losses in the supply system
  - Burden on the power supply system is thus lessened
- Reactive power compensation, improvement cos φ
  - Slightly capacitive at input ~ 0.94
  - Compensates the reactive power of motors and other inductive loads on the same supply
  - The power draw of the entire system is reduced. In a system comprising one inverter with motor and another motor on the same supply, the total power draw is reduced by up to 12 %.

Line supply conditions

Inverters with Efficient Infeed Technology have a much lower harmonic content (and therefore lower reactive current component) than a standard inverter. The harmonics up to and including the 11th are significantly lower than specified in the relevant standard. These relevant harmonics are less than half the magnitude stipulated by the relevant standard (EN 61000-3-12).

The requirements of the supply system are no more stringent than for comparable standard frequency inverters. Experience has proven that this technology can be applied worldwide. Sole exception: In “island networks” with a separate generator (without mains connection), an external capacitor must be used to reduce resonance. This must be dimensioned according to the individual installation.

Permissible ratio between network short-circuit power $S_{K\_network}$ and inverter apparent power $S_{inverter}$:

$S_{K\_network} \geq 100 \times S_{inverter}$ according to $u_K \leq 1$ %

Benefits

- Continuous braking with 100 % braking power
- Energy savings through regenerative feedback with motor operating in generator mode
- Omission of braking resistor, line reactor and brake chopper
- No costly configuration of the braking resistors and no time-consuming cabling
- Requires considerably less space than a conventional compact inverter
- Up to 22 % less power infeed
- No additional heat generated during braking
- Cost savings
- Space savings

Efficient Infeed Technology

Application

Whenever an application involves movements with frequent changes in speed or rotational direction or requires large masses to be electrically braked, inverters with regenerative feedback capability are an attractive drive solution for both operators and machine manufacturers.

Below are listed some of the relevant applications:

- Applications with vertical movements in general
- Drives for conveyor vehicles
- Machines with a high moment of inertia
- Centrifuges
- Renewable energies (water power, wind power)
- Applications with high braking power over long periods

Example of an application with a hoist drive of a stacker crane

The following example shows the total cost calculation for a hoist drive of a stacker crane. A generally available compact inverter without regenerative feedback is compared to an inverter with Efficient Infeed Technology (e.g. SINAMICS G120 with PM250 and regenerative feedback). The configuration overhead and installation costs must still be considered separately. This results in additional savings in time and costs through Efficient Infeed Technology.

	Price example	Space requirement (equipment only)
	Euro	cm^3
Standard technology		
Standard inverter without PROFIBUS or encoder without regenerative feedback, 22 kW high overload	2830	35035
Braking resistor (2 in series, 2 in parallel)	1480	80100
Line reactor	240	12155
Energy costs [1]	8850	–
Total	**13400**	**127290**
Efficient Infeed Technology		
SINAMICS G120 with PM250 and CU240E with regenerative feedback, 22 kW high overload	3780	29610
Energy costs [1]	4220	–
Total	**8000**	**29610**
	40 % cost saving	**77 % space saving**

This application example is based on the following data:

Hoist drive (technical specifications)

m_{total} = 1900 kg

m_{load} = 1000 kg

m_{own} = 900 kg

v_{hoist} = 60 m/min = 1 m/s

$a_{starting/braking}$ = ±0.5 m/s^2 ($t_{starting/braking}$ = 2 s)

η_{total} = 0.85

Total height = 24 m

Hoisting height = 18 m

Motor (technical specifications)

P_{rated} = 11.0 kW

$n_{50\ Hz}$ = 1460 rev/min

n_{max} = 2980 rev/min (102 Hz)

M_{rated} = 71.9 Nm

η = 0.89

I_{rated} = 37.2 A (at 230 V)

87 Hz characteristic

Gearing (technical specifications):

Bevel helical gear unit with i = 40.5

η = 0.96

More information

SINAMICS Infeed concepts

The Efficient Infeed concept is one of four different designs of SINAMICS inverter infeed circuit currently available on the market. An overview of the different concepts is shown below:

Concept	Characteristic features
Basic Infeed	• No regenerative feedback capability • Braking resistor required for braking operation • High harmonic content (reactor available as option) • …
Smart Infeed	• Regenerative feedback capability • Line reactor essential • Efficiency approx. 96 % to 97 % • …
Efficient Infeed	• Regenerative feedback capability • Line reactor not required/not permitted • Efficiency approx. 98 % • High energy efficiency and active current component • Low harmonic component • …
Active Infeed	• Regenerative feedback capability • Sine-wave current in motor and generator modes • High DC link voltage, compensation of line fluctuations • …

[1] For a total service life of 12500 h, FEM 9.512 basis for calculation for stacker cranes.