



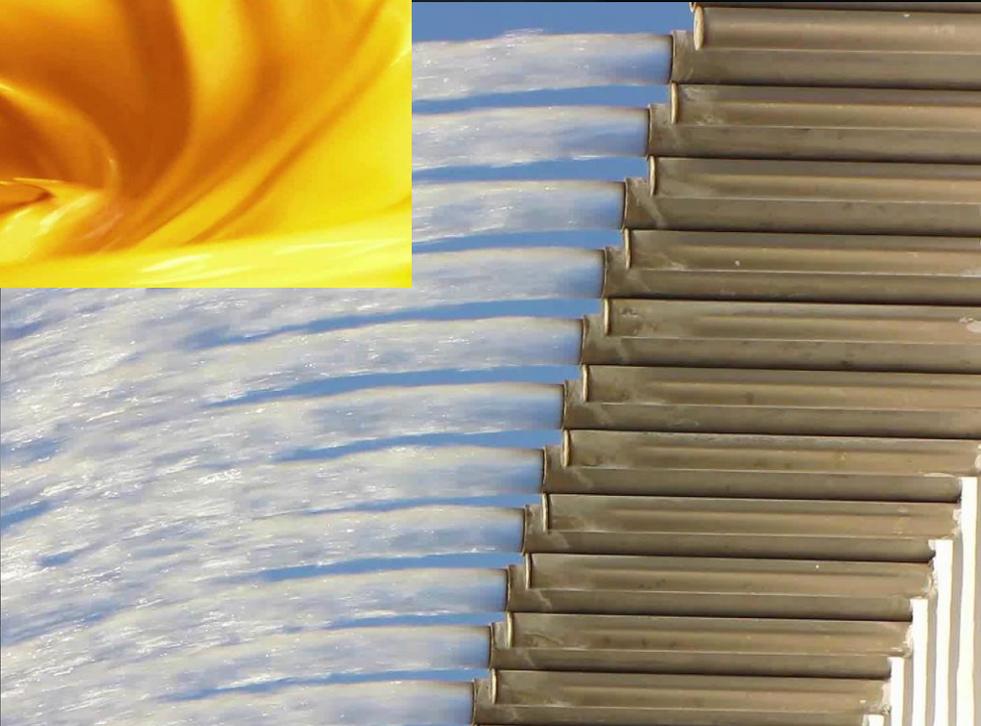
# Motion Control – Siemens Nederland

## Basiskennis frequentieregelaars

[www.siemens.com/nl/aandrijftechniek](http://www.siemens.com/nl/aandrijftechniek)

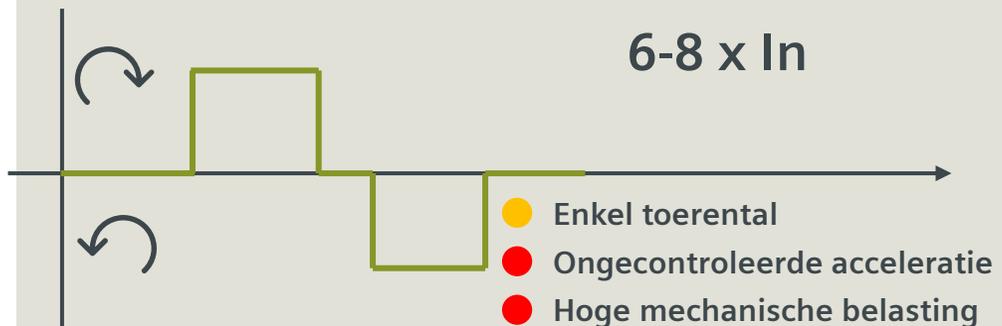
# Inhoud

- Start technieken
- Verschil softstarter en frequentieregelaar
- Principewerking frequentieregelaar
- Ster / Driehoek
- EMC gradaties
- 4 kwadranten
- Variabel koppel / constant koppel
- Voorbeveiliging
- Harmonischen
- Machineveiligheid



# Algemene start technieken

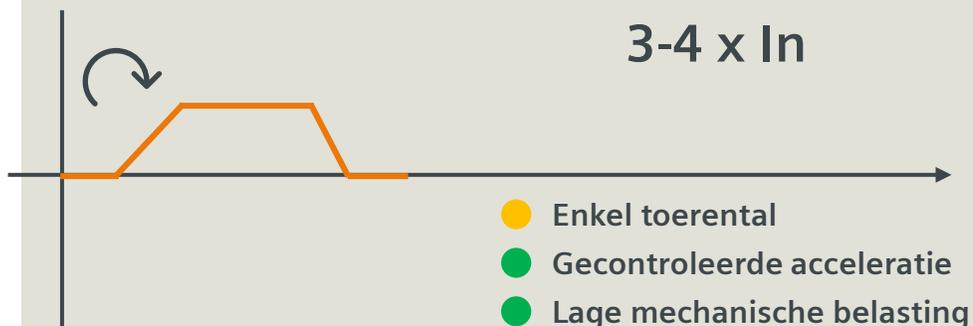
## DOL / omkeerstarter



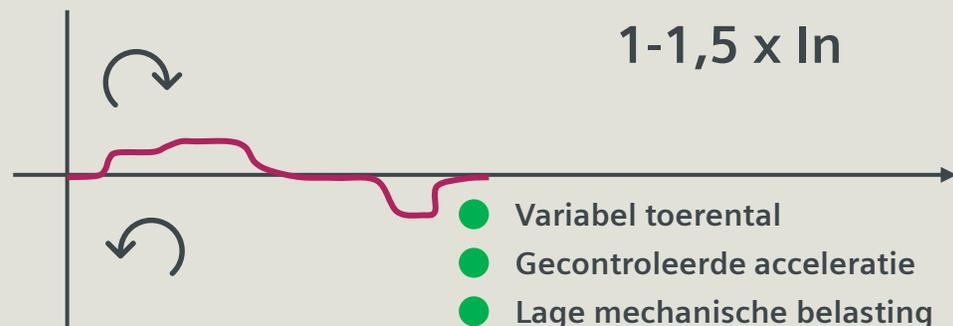
## Y- $\Delta$ -Start



## Softstarter



## Frequentie-regelaar



# Algemene start technieken

## DOL / omkeerstarter

Direct geschakeld via 3 polige magneetschakelaar

- Motorbeveiligingsschakelaar
- Magneetschakelaar (1 of meer)



0 - 5,5kW

## Y- $\Delta$ -Start

In twee stappen geschakeld eerst in STER, daarna in DRIEHOEK

- Motorbeveiligingsschakelaar
- 3 magneetschakelaars
- Tijdrelais
- Hulpcontacten
- Extra motorkabels



7,5 - 500kW

## Softstarter

Soft start en stop door middel van fase aansnijding (spanningsopbouw)

- Kortsluitbeveiliging
- Softstarter



1,5 - 1200kW

## Frequentie-regelaar

Volledige controle door AC-DC-AC regelaar (frequentie regeling)

- Kortsluitbeveiliging
- Regelaar
- Encoder

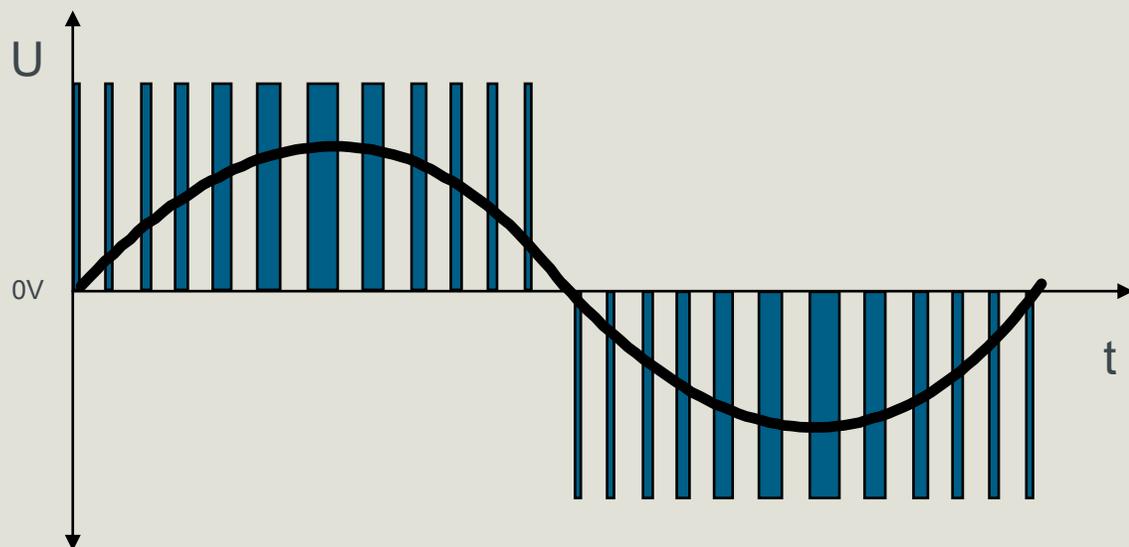


0 - ....kW

# Werkingprincipe frequentieregelaar en softstarter

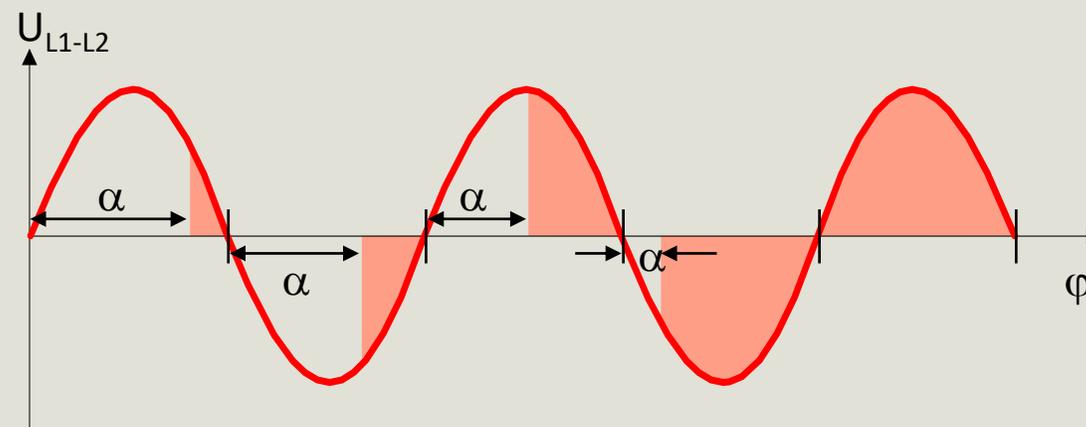
## Frequentieregelaar

1. Gelijkspanning (DC) creëren
2. Frequentie-opbouw met pulsbreedte modulatie

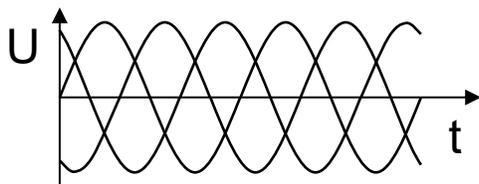
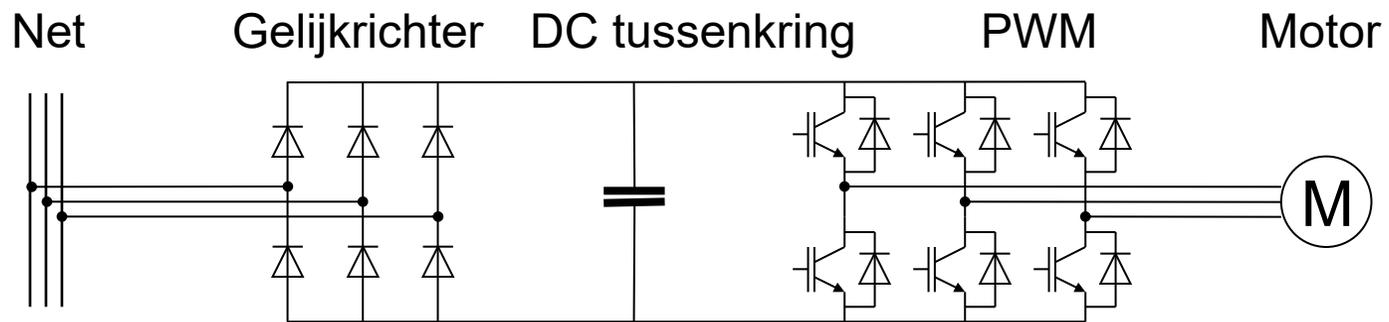


## Softstarter

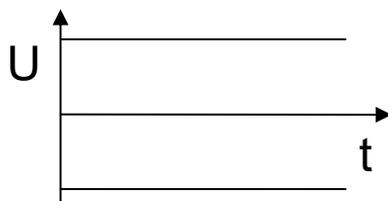
1. Spanningsopbouw via fase aansnijding
2. Bypass contact bij bereiken eindsnelheid



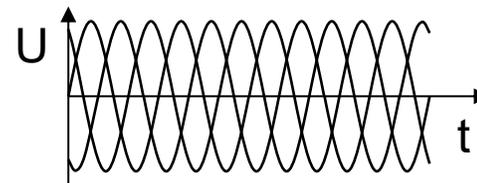
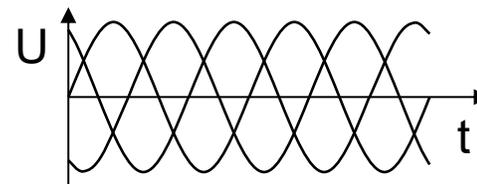
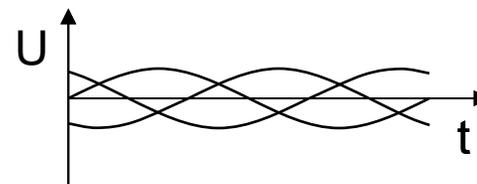
# Principe frequentieregelaar



$U = \text{const.}$   
 $f = \text{const.}$



Gelijkspanning

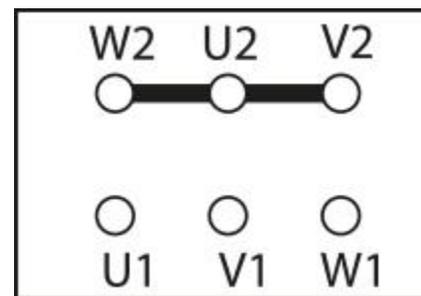
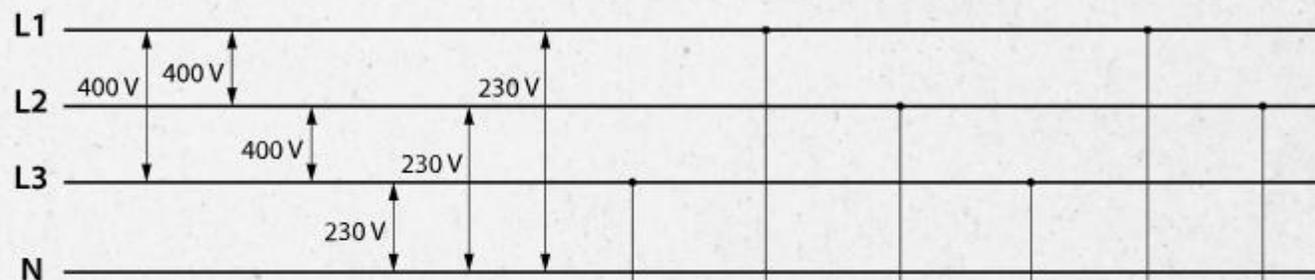


$U = \text{variabel}$      $f = \text{variabel}$

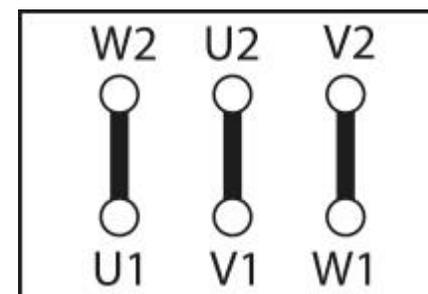
## 230 / 400V motor

Het 3 fase voedingsnet van 400V, krachtstroom, ziet er als volgt uit:

Tussen elk van de fasen (L1, L2, L3) en de nul (N) staat 230 V, dit is de fasespanning. Tussen twee fasen onderling staat 400 V, de lijnspanning (fig.1).



Sterschakeling 400V

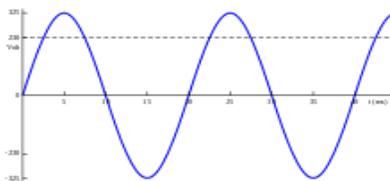


Driehoekschakeling 230V

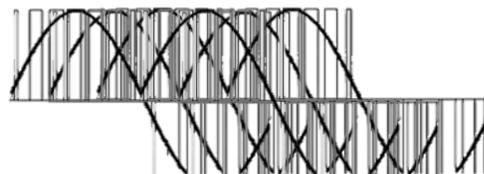
In een driehoek schakeling gaat de volledige lijnspanning van 400 V over de spoel en bij een ster schakeling is dit 230 V.

# Enkelfasig 200 - 240 Vac

1 fase 230V in

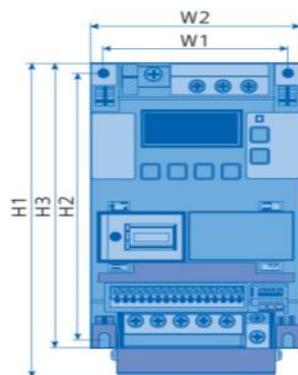
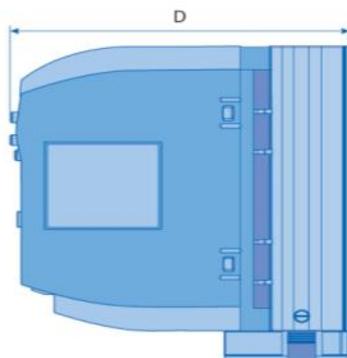


3 fase 230V uit



EMC : C1                      C1                      C1                      C1  
 KW HO : 0,37                0,75                    1,5                    3,0

**FSAA      FSAB      FSAC      FSAD**

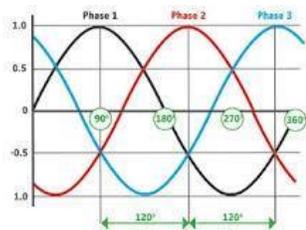


Frame size	Width [mm]		Height [mm]			Depth [mm]	Weight** [kg]
	W1	W2	H1	H2	H3		
FSAA	58	68	–	132	142	107,8	0,7
FSAB	58	68	–	132	142	127,8	0,9
FSAC	80	90	-	150	160	147	
FSC	170	184	182	140	–	169	2,6

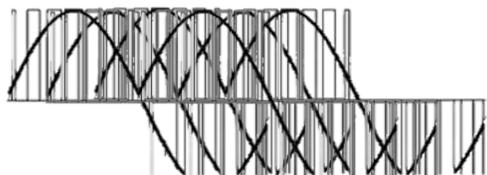
\*\* with integrated line filter

# Driefasig 380 - 480 Vac

3 fasen 400V in



3 fasen 400V uit



EMC : C3  
KW HO : 2,2

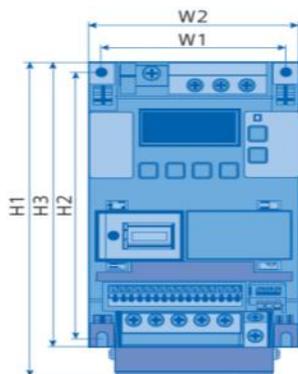
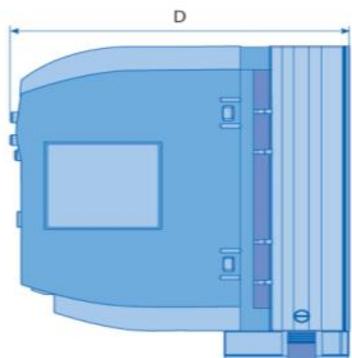
C3  
4,0

C3  
5,5

C3  
15

C3  
22 (30 LO)

FSA	FSB	FSC	FSD	FSE
-----	-----	-----	-----	-----



Frame size	Width [mm]		Height [mm]			Depth [mm]	Weight** [kg]
	W1	W2	H1	H2	H3		
FSA	79	90	166	140	150	145,5	1,05
FSB	127	140	160	135	–	164,5	1,8
FSC	170	184	182	140	–	169	2,6
FSD	223	240	206,5	166	–	172,5	4,3
FSE	228	245	264,5	206	–	209	6,6

\*\* with integrated line filter

## Toepassingsgebieden

C1 : 1<sup>e</sup> omgeving, huishoudelijk en kantoortoepassingen, hoogste EMC beschermingsgraad

C2 : 2<sup>e</sup> omgeving, licht industriëel, iets lagere EMC bescherming

C3 : 3<sup>e</sup> omgeving, industriëel, lage EMC bescherming

C4 : 4<sup>e</sup> omgeving, geen EMC bescherming (alleen nog Aziatische markt)

### Maximum motor cable lengths

Converter variant	Maximum cable length					
	EMC compliant		Without output reactor		With output reactor	
400 V	With integrated EMC filter <sup>1)</sup>	With external line filter <sup>2)</sup>	Unshielded	Shielded	Unshielded	Shielded
FSA	10 m	25 m	50 m	25 m	150 m	150 m
FSB to FSD	25 m	25 m	50 m	25 m	150 m	150 m
FSE	50 m	25 m	100 m	50 m	300 m	200 m
230 V	With integrated EMC filter	With external line filter	Unshielded	Shielded	Unshielded	Shielded
FSAA/FSAB	5 m <sup>3)</sup>	5 m <sup>3)</sup>	50 m	25 m	200 m	200 m
FSAC	10 m <sup>3)</sup>	10 m <sup>2)</sup>	50 m	25 m	200 m	200 m
FSAD	5 m <sup>3)</sup> , 25 m <sup>2)</sup>	5 m <sup>3)</sup>	50 m	25 m	200 m	200 m

<sup>1)</sup> EMC (RE/CE C3) compliant, second environment (industrial area). RE/CE C3 refers to EMC compliance to EN61800-3 Category C3 (level equivalent to EN55011, Class A2) for Radiated and Conducted Emissions.

<sup>2)</sup> EMC (RE/CE C2) compliant, first environment (residential area). RE/CE C2 refers to EMC compliance to EN61800-3 Category C2 (level equivalent to EN55011, Class A1) for Radiated and Conducted Emissions. See Section B.1.7 for the specifications of external line filters.

<sup>3)</sup> EMC (RE/CE C1) compliant, first environment (residential area). RE/CE C1 refers to EMC compliance to EN61800-3 Category C1 (level equivalent to EN55011, Class B) for Radiated and Conducted Emissions.

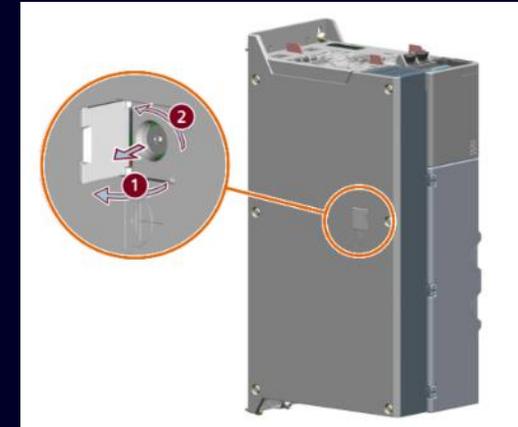
# SINAMICS G220

## EMC category and maximum motor cable length

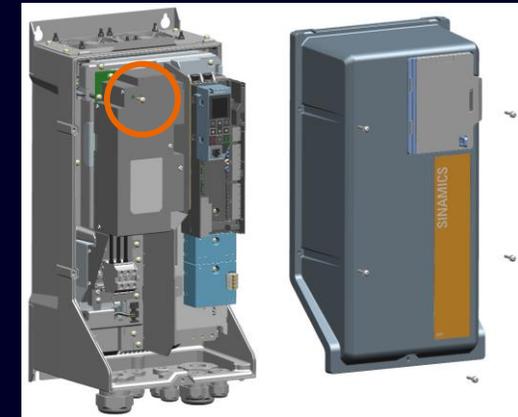
Application environment		Achievable EMC category	
		C2	C4 <sup>4)</sup>
		Converter with integrated line filter <sup>3)</sup>	Converter without integrated line filter
Cable length	Motor	≤ 150 m shielded CY cable	≤ 200 m shielded ≤ 300 m unshielded
	Braking resistor	≤ 10 m shielded CY cable	≤ 10 m shielded
Installation location	Residential environment	No	No
	Light industry and commerce	Yes	No
	Heavy industry	Yes	Yes <sup>2)</sup>
Line supply	Public	Yes <sup>1)</sup>	No
	Non-public	Yes	Yes <sup>2)</sup>
Permissible line system configuration		TN or TT system with grounded neutral point	Any

- 1) Corresponds to IEC 61000-3-12, Table 4, for RSC ≥ 120. The compatibility level for harmonic voltage distortions at the line connection point must be taken into consideration.
- 2) Complex, large-scale industrial applications and/or IT supply networks. An EMC plan must be drawn up.
- 3) Operation with the default pulse frequency or with reduced pulse frequency
- 4) An external line filter is required to comply with the requirements relating to CE certification.

Removing the screw to open the ground connection of the integrated line filter

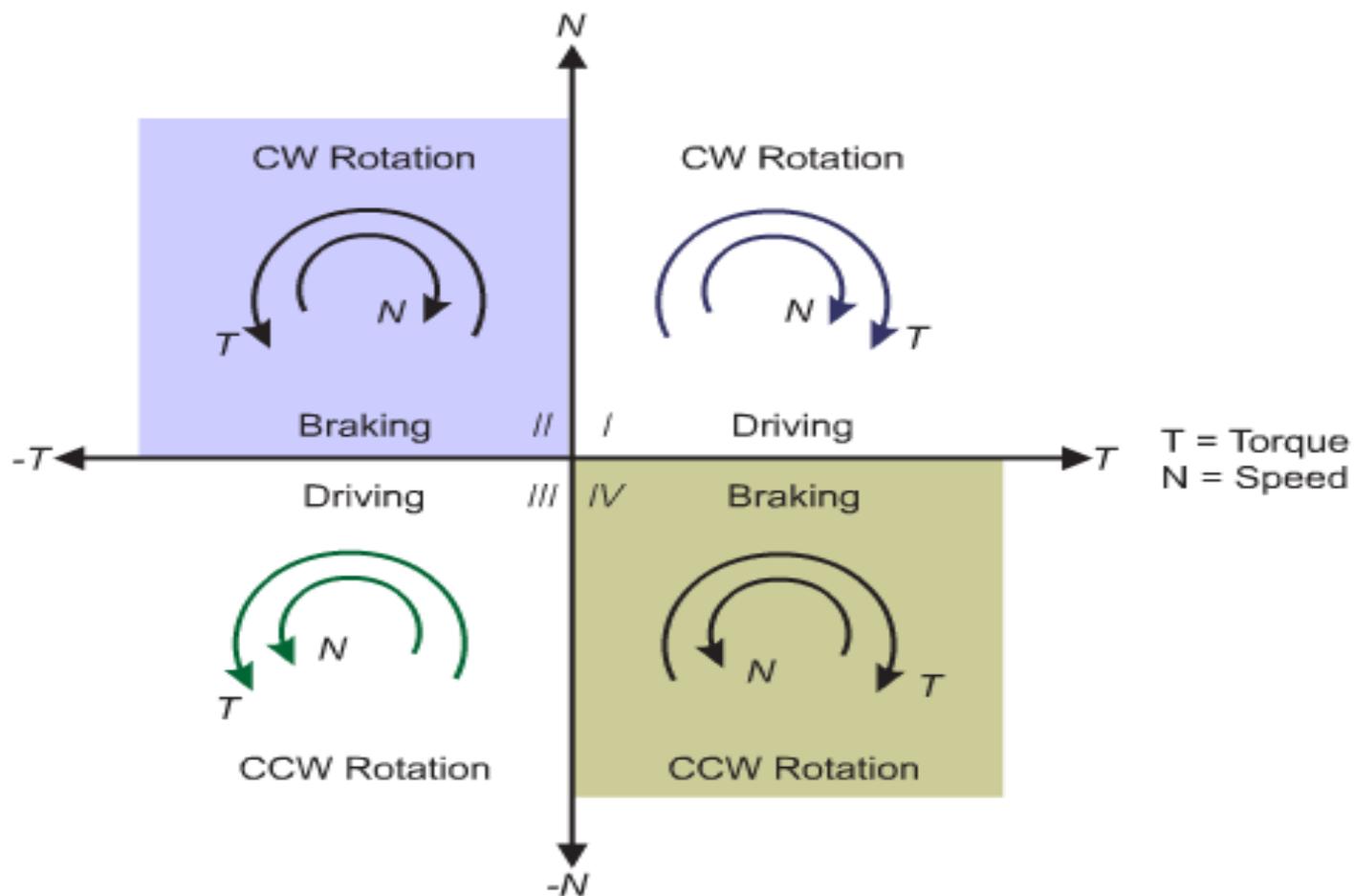


Converter IP20



Converter IP55/UL Type 12

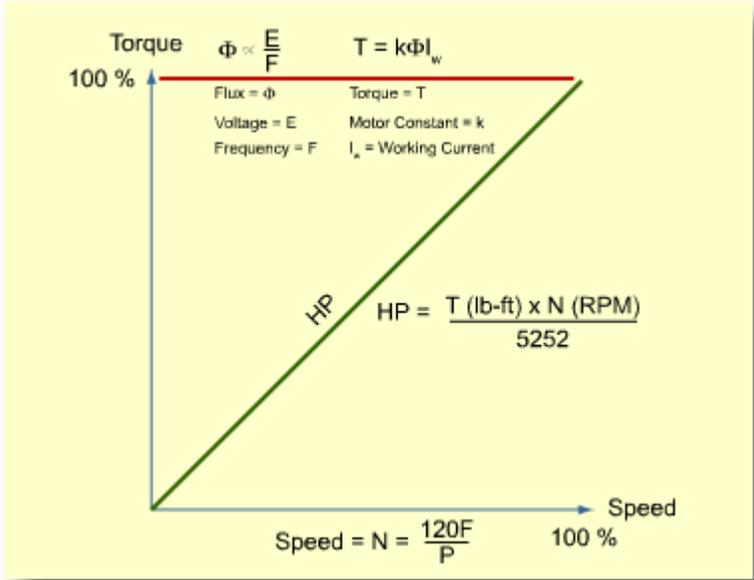
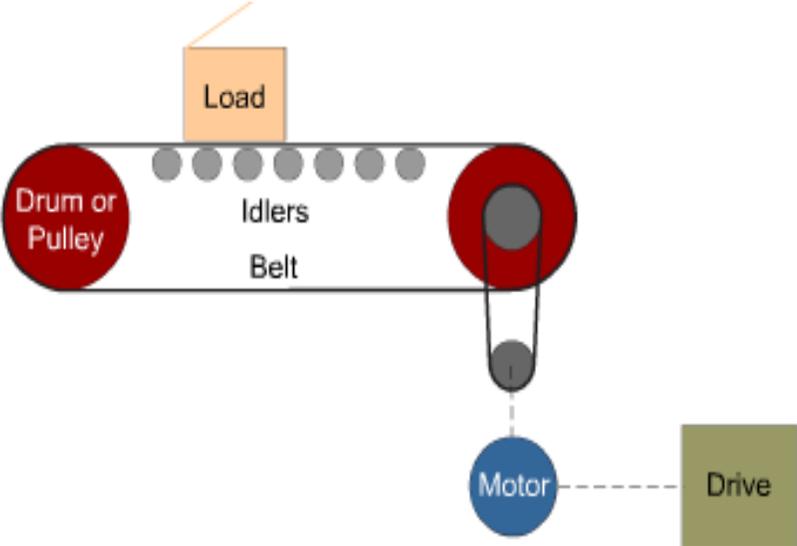
## 4 kwadranten



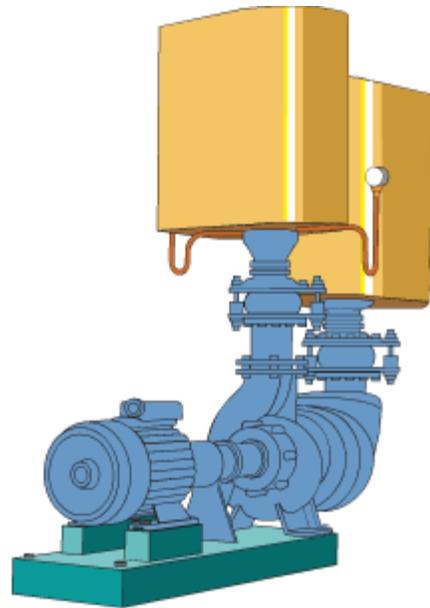
### Werking van vierkwadrantenbedrijf

- **Kwadrant I (positief koppel, positieve snelheid):** De motor drijft de applicatie aan. Energie gaat van de stroombron naar de motor.
- **Kwadrant II (negatief koppel, positieve snelheid):** De motor wordt geremd door de applicatie. De regelaar kan dan de energie van de motor terugvoeren naar het net of een remweerstand.
- **Kwadrant III (negatief koppel, negatieve snelheid):** De motor wordt achteruit aangedreven en werkt als aandrijving.
- **Kwadrant IV (positief koppel, negatieve snelheid):** De motor remt af in de achterwaartse draairichting en kan energie terugleveren.

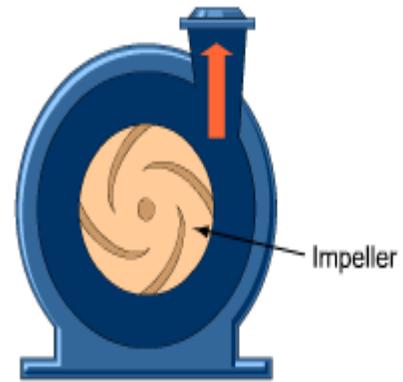
# Constant koppel toepassing (CT / HO)



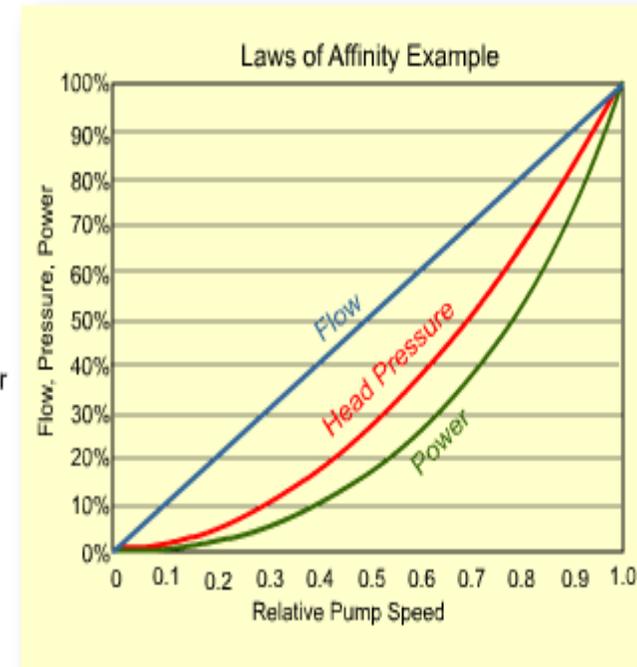
# Kwadratisch koppel (VT/LO)



Pump

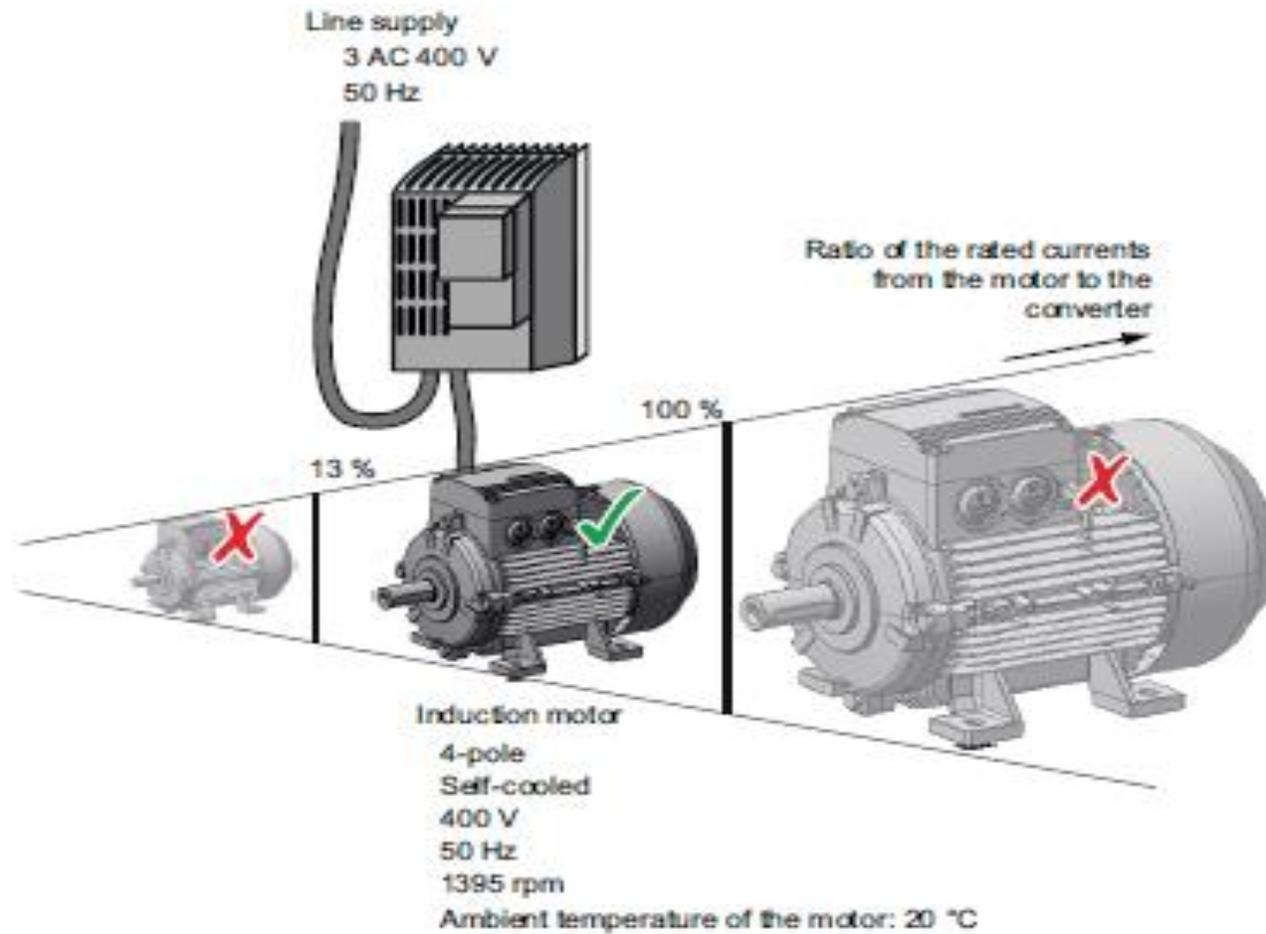


Centrifugal Pump



Vraag : hoe verloopt het vermogen ?

## Welk motorampèrage mag worden aangesloten ?



# Features and functions

## Application

- PID controller
- BICO function
- Hammer start
- Super torque mode
- Blockage clearing mode
- Motor staging
- Flexible boost control
- Wobble function
- Slip compensation
- Dual ramp
- Adjustable PWM modulation

## Energy saving

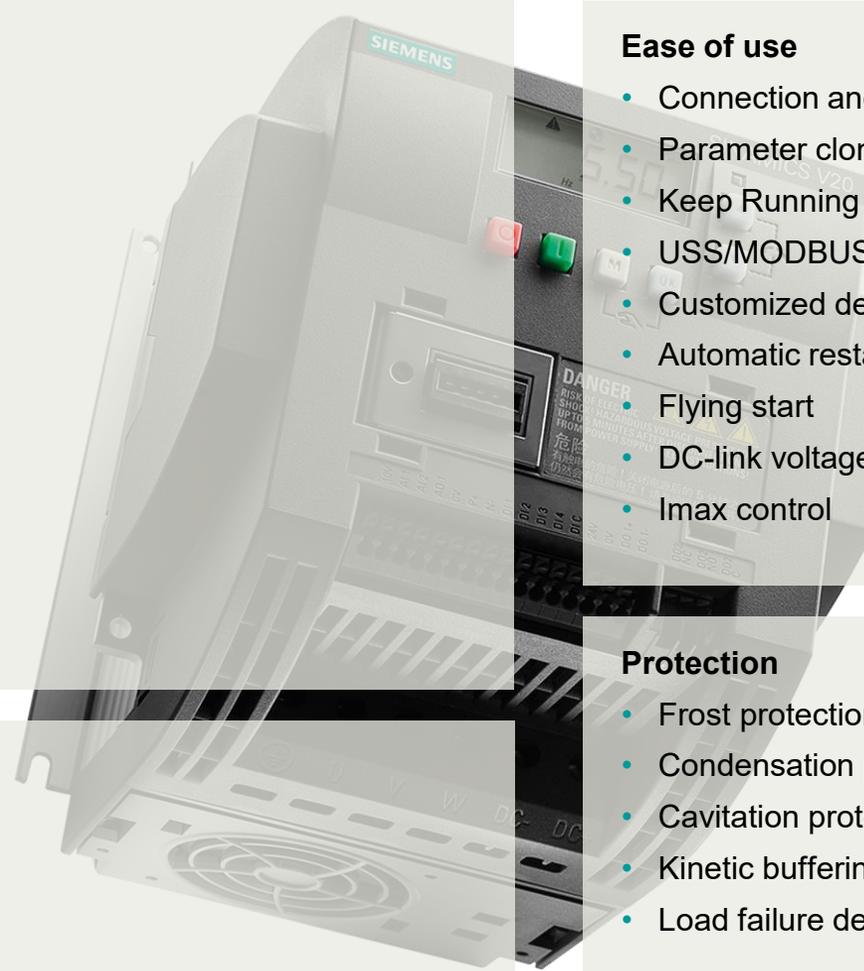
- ECO mode
- Hibernation mode
- Energy consumption monitoring

## Ease of use

- Connection and application macro
- Parameter cloning
- Keep Running Mode
- USS/MODBUS RTU communication
- Customized default value
- Automatic restart
- Flying start
- DC-link voltage control
- Imax control

## Protection

- Frost protection
- Condensation protection
- Cavitation protection
- Kinetic buffering
- Load failure detection



# Opties

## Remweerstand

- Dissipeert regeneratieve energie (als warmte)
- 5% duty cycle als default setting



## EMC lijn filter

- Hogere EMC ontstoringsgraad conform EN61800-3 categorie C2



## Output reactor / motorsmoorspoel

- Langere motor kabellengten

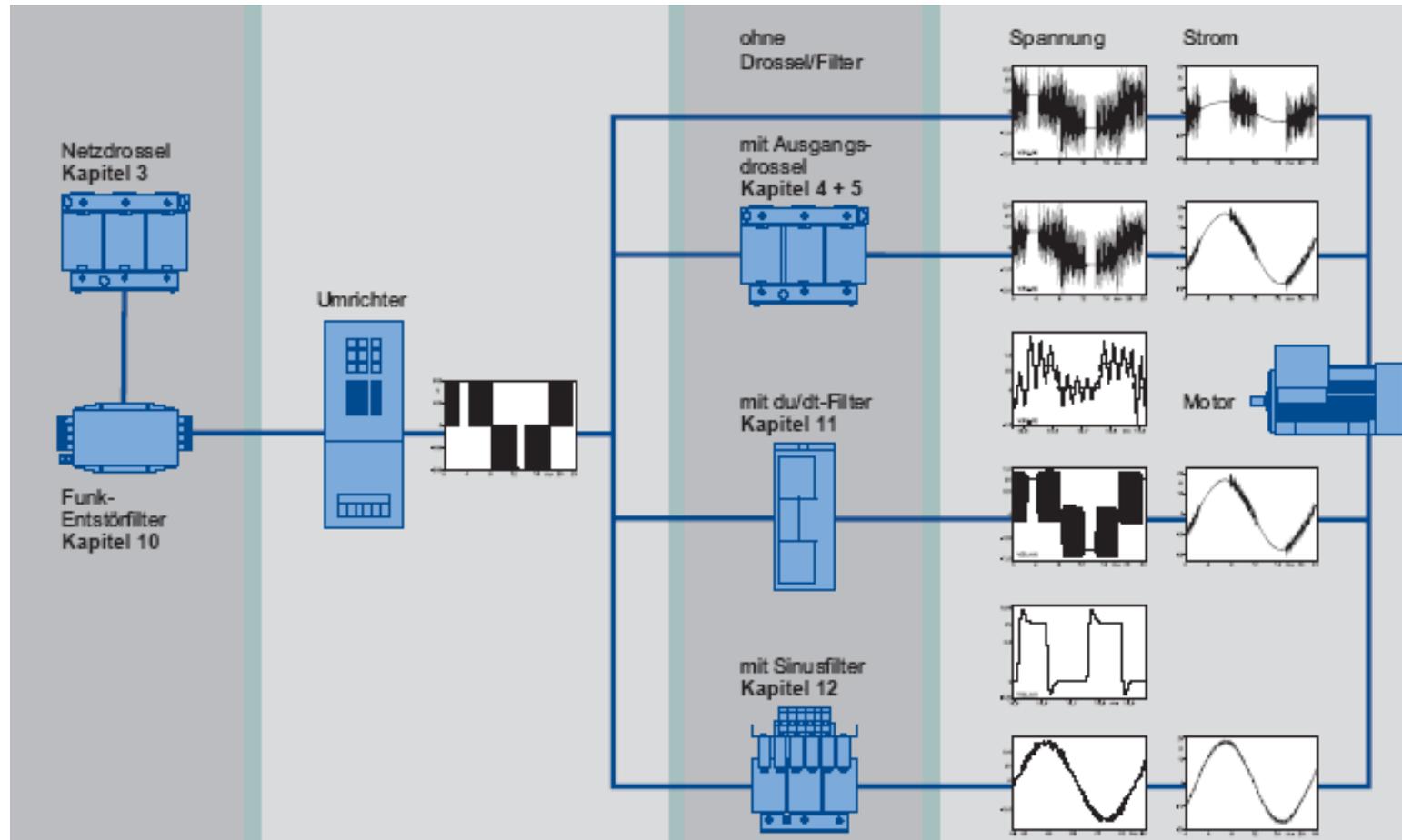


## Line reactor / netsmoorspoel

- Vermindert aandeel Laagfrequent netvervuiling (hogere harmonische stromen)



# Basis training frequentie regelaars



# Beveiliging

**Gebruik van automaten**, let op thermisch extra verwarming.

Omdat de ingangstroom niet sinus-vormig is krijg je extra opwarming en hierdoor onterechte afschakelingen.

De omvormer niet thermisch bewaken, de thermische bewaking van de motor zit in de regelaar.

**Gebruik van zekeringen**, geen thermisch deel dus beter.

Je kan normale (3NA) of snelle zekeringen (SITOR) nemen.

**Aardlek stromen.**

De aardlekstromen zijn in de meeste gevallen oorzaak in het ingang EMC-filter en capacatieve stromen van de motor kabel.

Gebruik altijd de in de catalogus voorgestelde componenten hierdoor kan je geen problemen verwachten en kan je de maximale performance van de regelaar benutten.

## 1.2.1 IEC standard fuses 3AC 380...480V

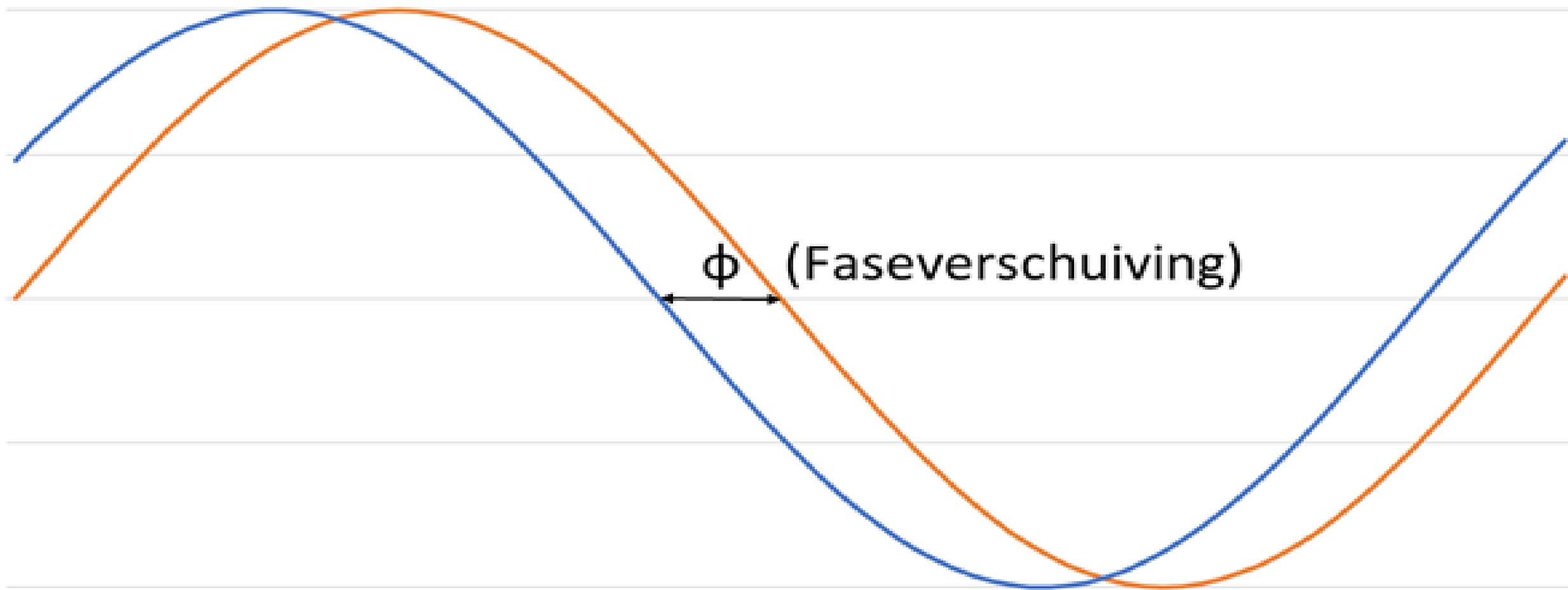
Converter			Protective Device				Min. enclosure volume	
Frame size	P <sub>rated</sub> (LO)	Article no.	I <sub>rated</sub> A	Article no. 1)	I <sub>sp,ref</sub> kA	I <sub>cc</sub> / kA @ 400 V	Metric	Imperial
A	3 kW	6SL3210-1KE17-5..1	16	3NA3805	0.4	100 2)	0.06 m <sup>3</sup>	2.12 ft <sup>3</sup>
	4 kW	6SL3210-1KE18-8..1	16	3NA3805	0.4	100 2)		
	0.55 kW	6SL3210-1KE11-8..2	10	3NA3803	0.25	100		

## 1.3.1 IEC motor starter protectors 3AC 380...480V

Converter			Protective Device				Min. enclosure volume	
Frame size	P <sub>rated</sub> (LO)	Article no.	I <sub>rated</sub> A	Article no.	I <sub>sp,ref</sub> kA	I <sub>cc</sub> / kA @ 400 V 1)	Metric	Imperial
A	3 kW	6SL3210-1KE17-5..1	16	3RV2011-4AA..	0.25	55	0.03 m <sup>3</sup>	1.06 ft <sup>3</sup>
			16	3RV2021-4AA..	0.25	55		
	4 kW	6SL3210-1KE18-8..1	16	3RV2011-4AA..	0.25	55		
			16	3RV2021-4AA..	0.25	55		

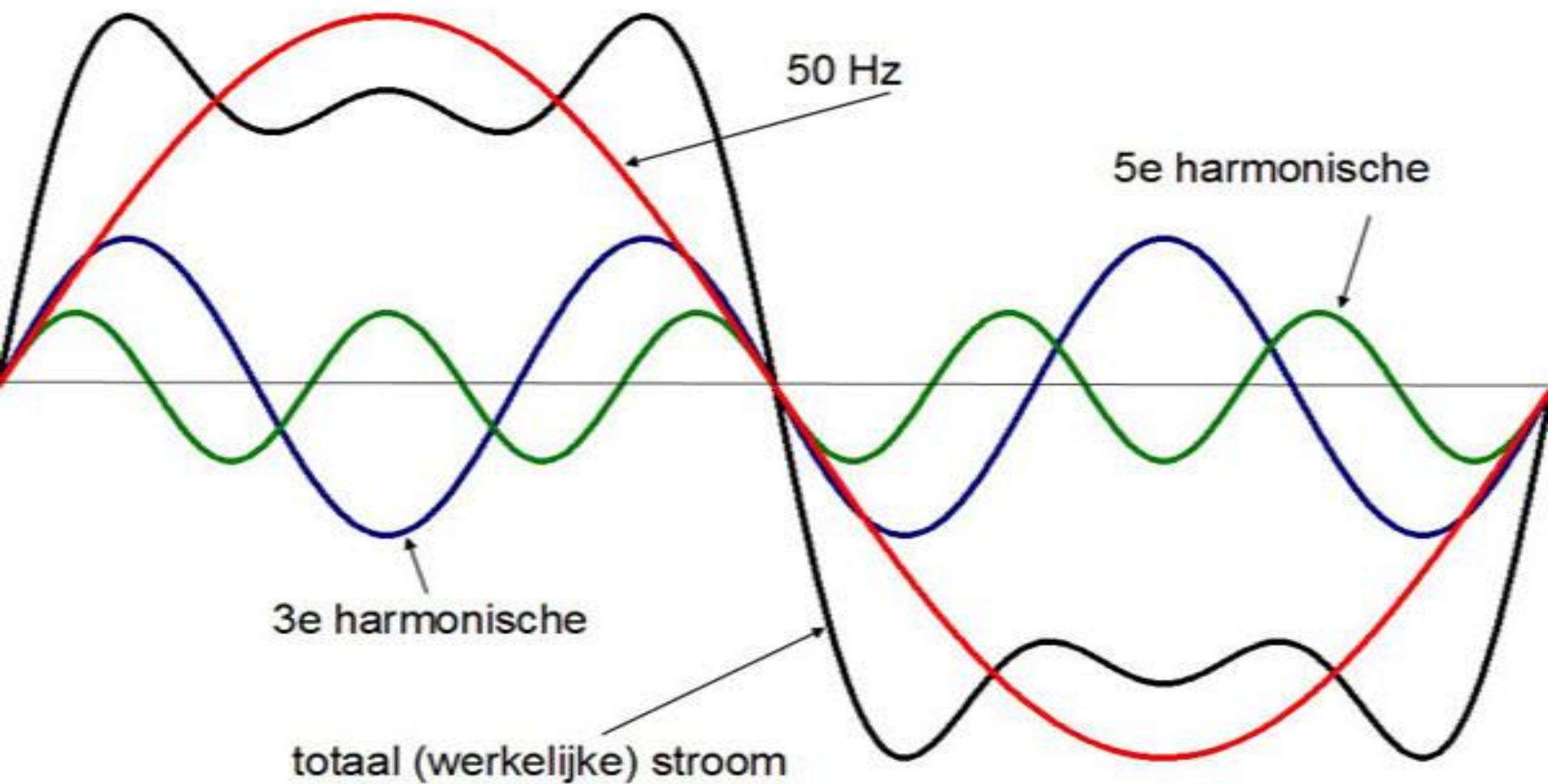
# Wat zijn Harmonischen?

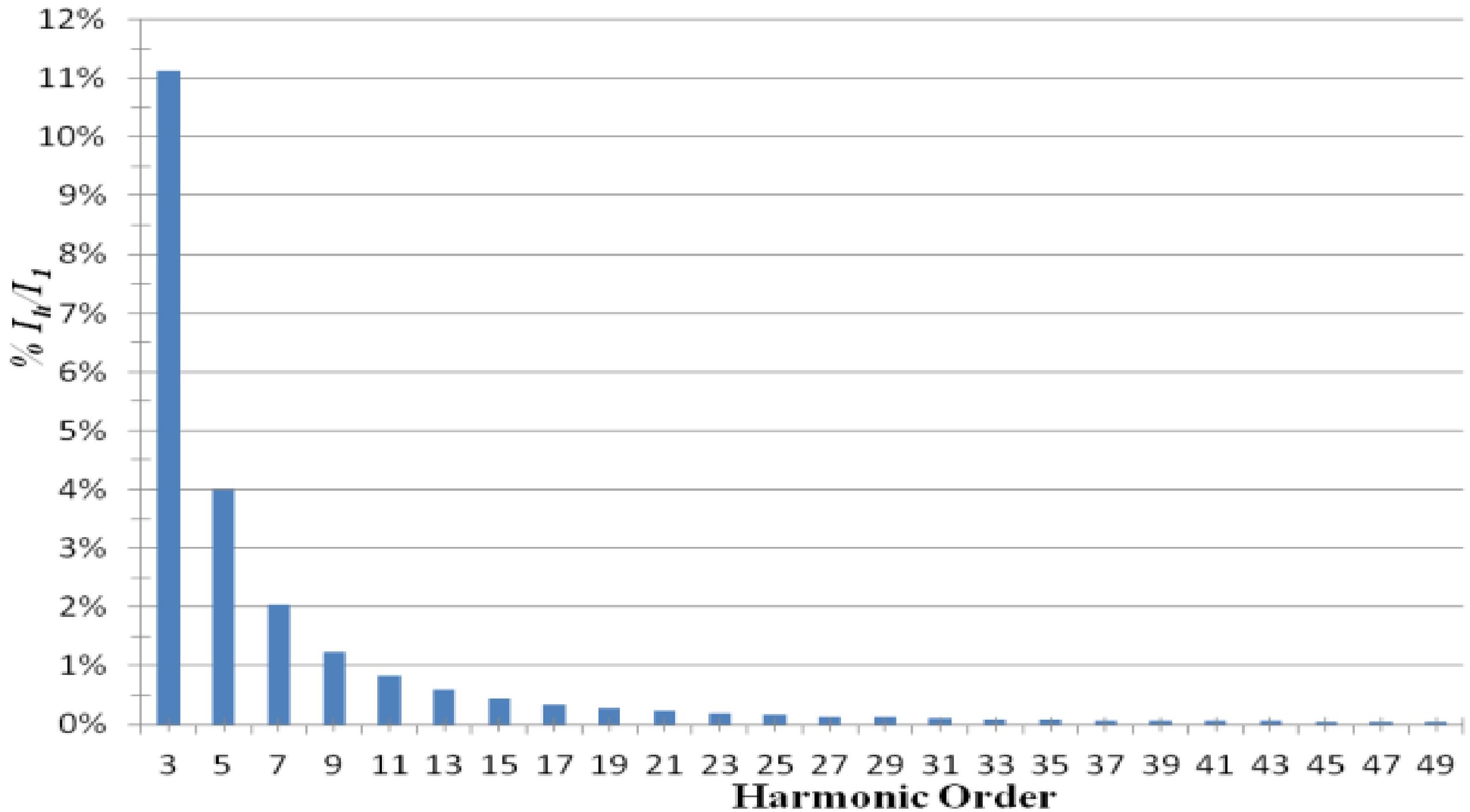
V (Spanning)



$\phi$  (Faseverschuiving)

I (Stroom)





- **Systeemverliezen in kabels en transformatoren**
- **Verstoring van andere gebruikers**
- **Hogere temperatuur van motoren**
- **Hoger geluidsniveau**
- **Verlaagd koppel**
- **Lagere arbeidsfactor**

# Unlocking the Secrets of Harmonics in Power Systems

Are you curious about harmonics in power systems? This white paper is here to provide you with general awareness of power system harmonics: what are their causes, effects, and control methods, particularly in relation to variable frequency drives?

[Download the white paper](#)



- **IEC/EN 61000-3-2:**

Beperkt de emissie van harmonische stromen voor apparaten die  $\leq 16$  A per fase verbruiken.

- **IEC/EN 61000-3-12:**

Beperkt harmonische stromen voor apparaten die  $> 16$  A en  $\leq 75$  A verbruiken.

- **IEEE 519:**

Beperkt de emissie van harmonische stromen voor apparaten in USA.

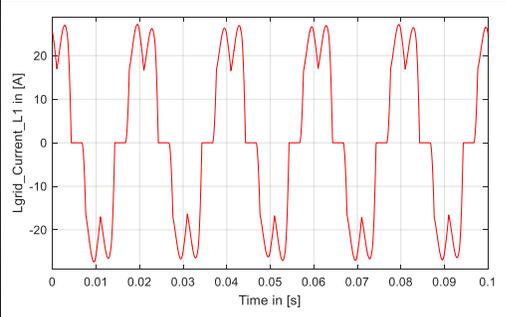
- Smoor spoelen in de DC tussenkring
- AC smoor spoelen aan de netzijde
- Passieve filters aan netzijde
- Multipulsfilters
- Active frontend
- Vienna rectifier

# SINAMICS G220 Clean Power

## SINAMICS G220 (7,5 kW / 10 hp)



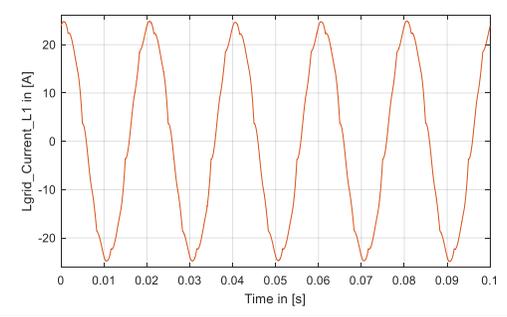
**THDi = 33 %\***



## SINAMICS G220 (7,5 kW / 10 hp) with passive harmonic filter



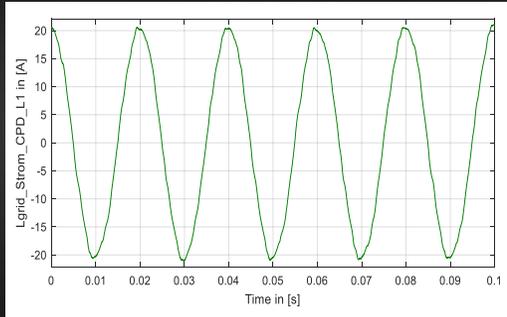
**THDi = 3.9 %\***



## SINAMICS G220 Clean Power (7,5 kW / 10 hp)



**THDi = 1.9 %\***



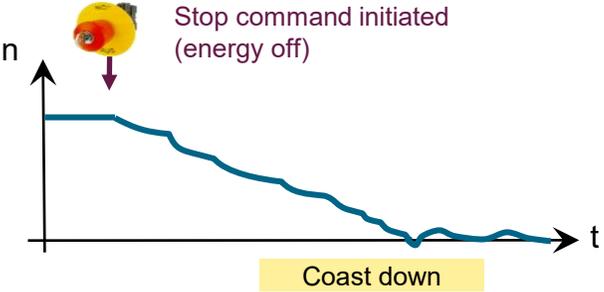
THDi – Total Harmonic Distortion in current  
\* Relative Short-Circuit power (RSC) = 33 in undistorted networks.

# Machineveiligheid

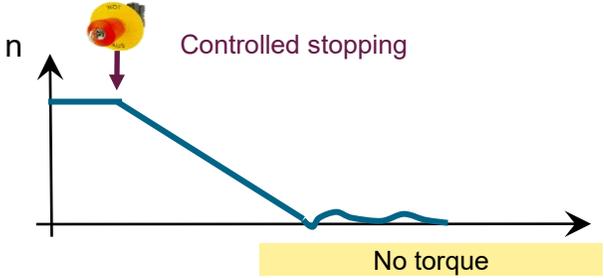
# Implementatie van stop functies conform IEC 60204 met gebruikmaking van geïntegreerde safety functies in de drive

## IEC 60204

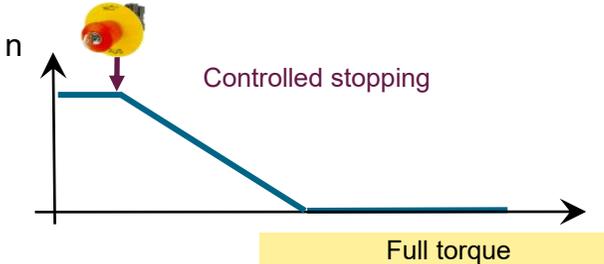
Stop - Categorie 0



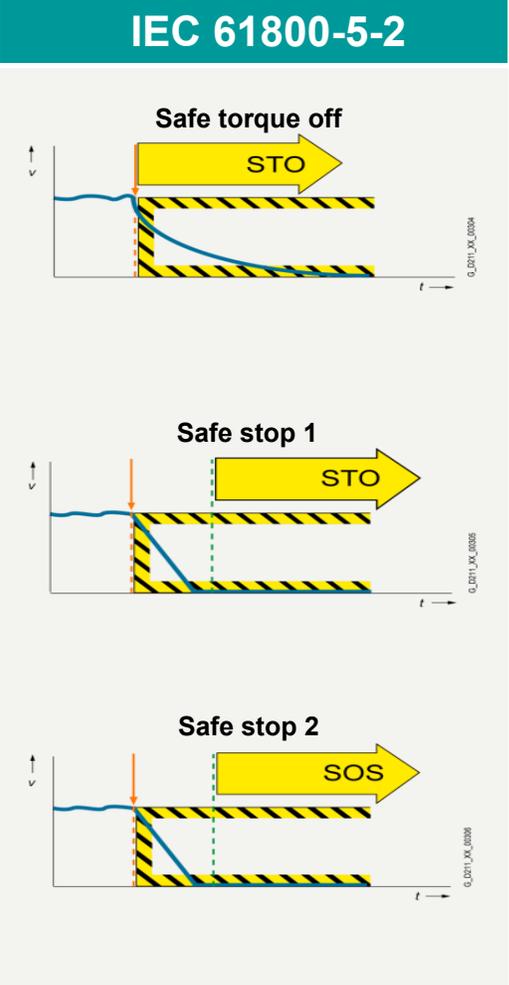
Stop - Categorie 1



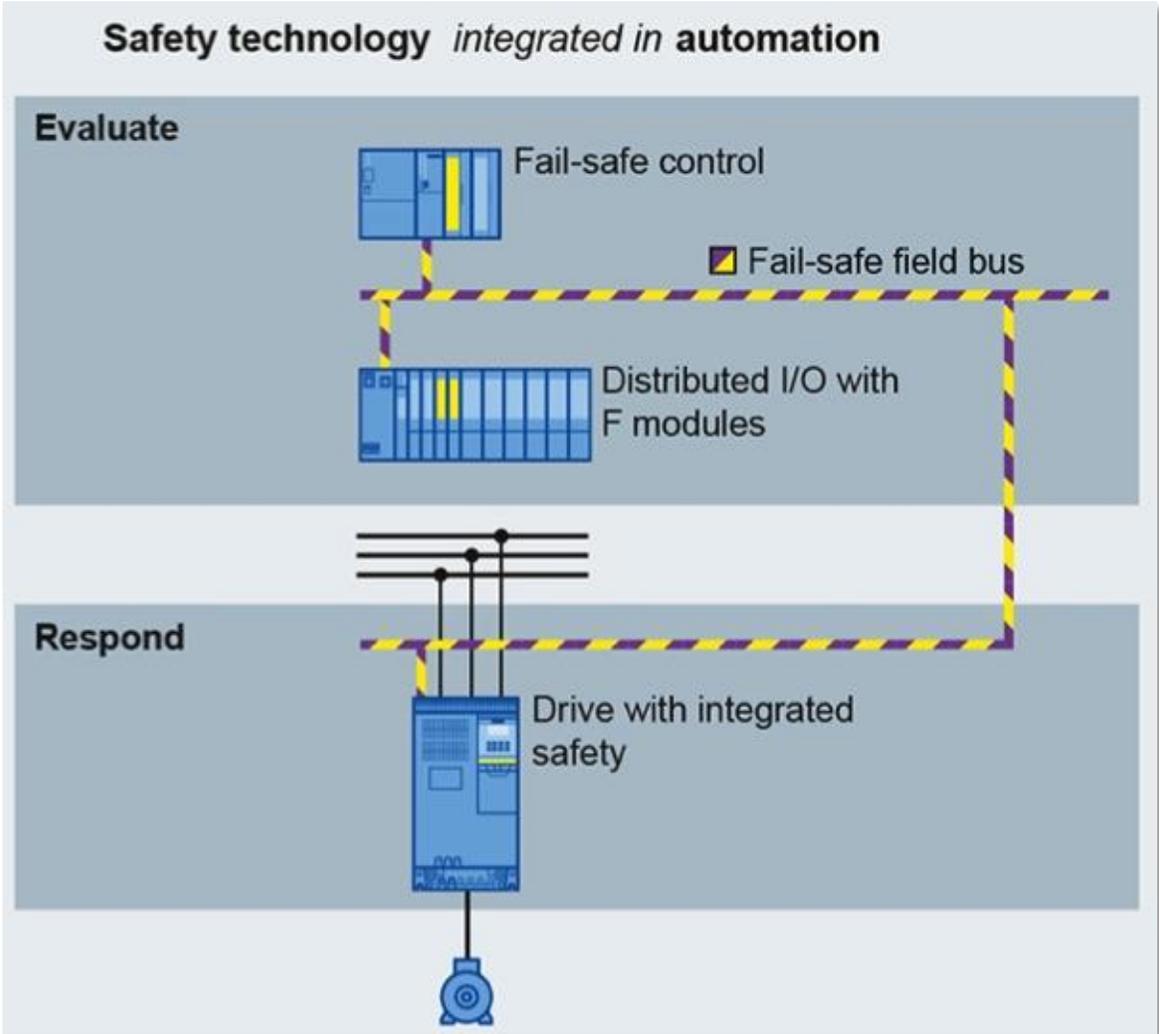
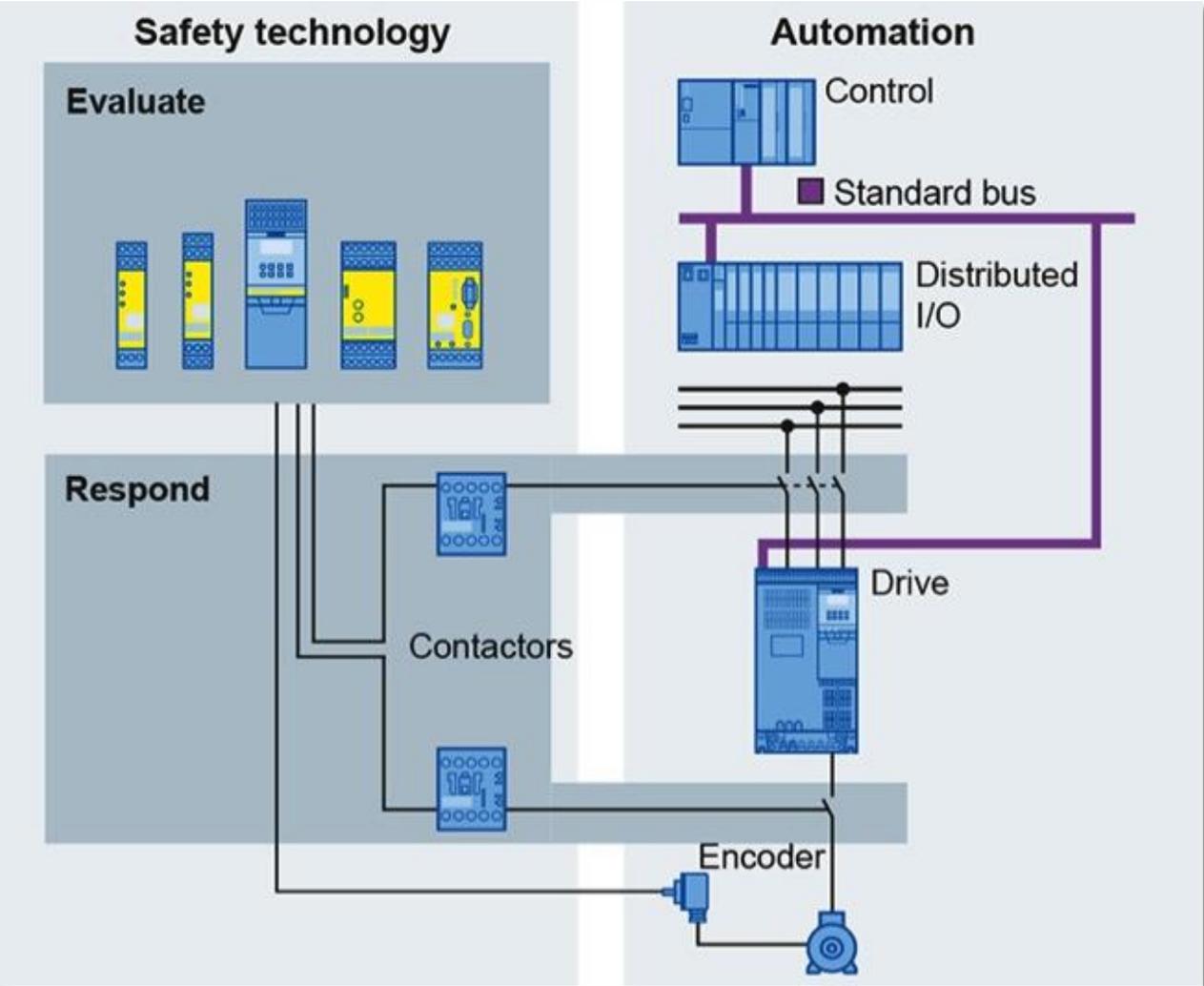
Stop - Categorie 2



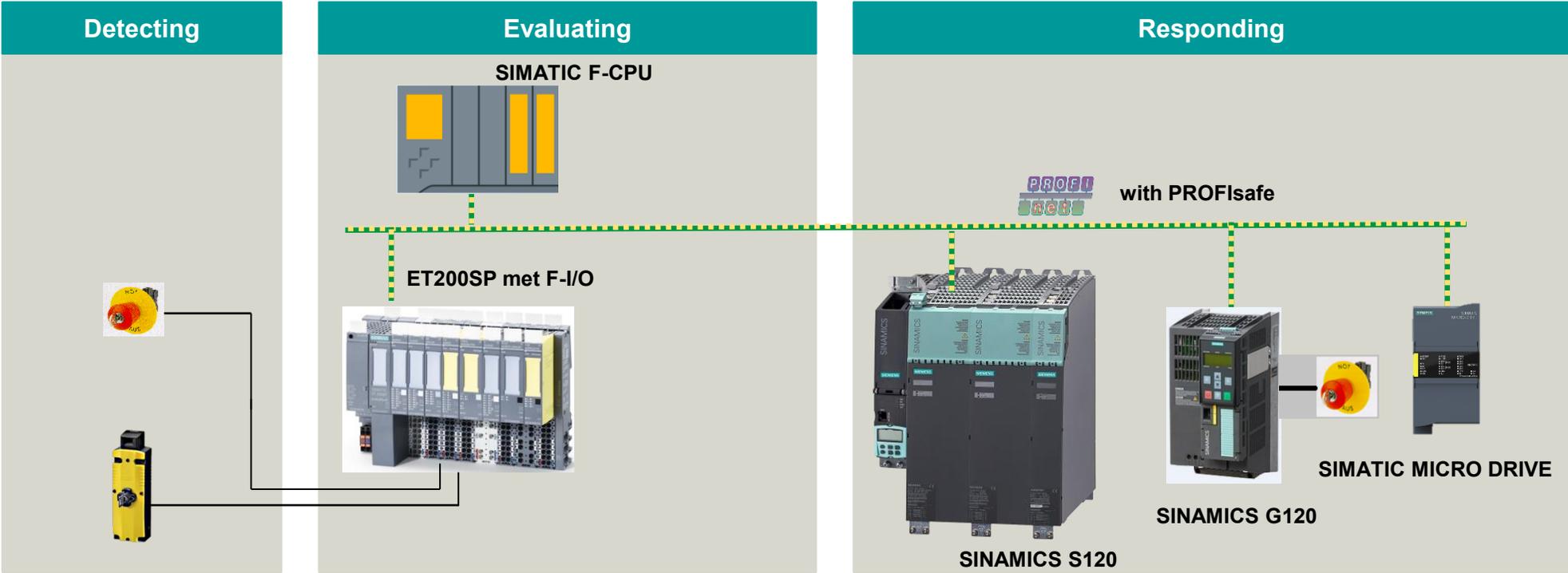
## IEC 61800-5-2



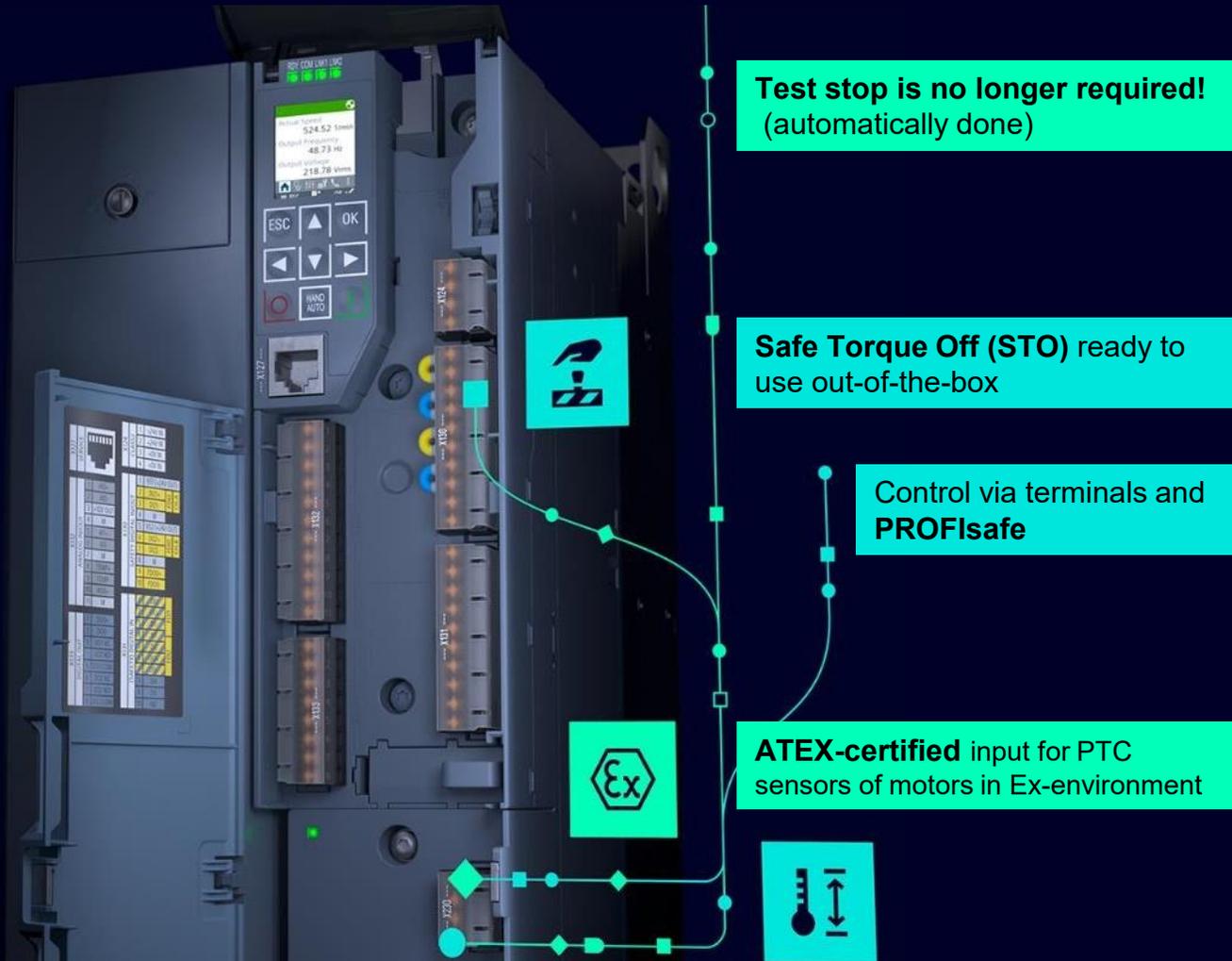
# Sinamics Safety Integrated



# PROFIsafe



# Guarantee maximum machine and operator safety with SINAMICS Safety Integrated



## Challenge

 **Protect personnel, machines and systems**

## Solution

- ✓ Always on the safe side with SIL 3 / PL e Cat. 4 for all Safety Integrated functions<sup>1</sup> including an online self-test
- ✓ Suitable for the connection to motors in Ex-environments thanks to the new safety function SMT – Safe Motor Temperature
- ✓ Reduced effort in commissioning due to the improved usability concept
- ✓ Set up safety functions in advance with the digital twin DriveSim Engineer<sup>2</sup>

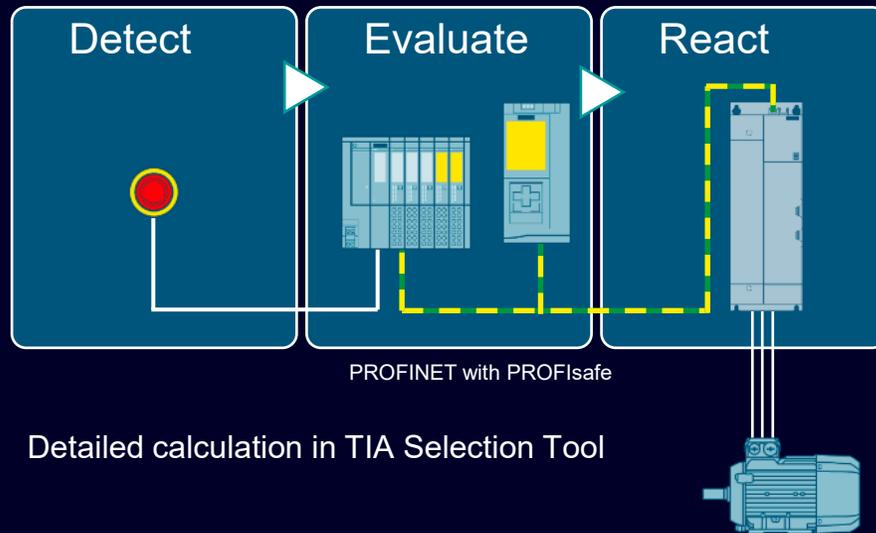
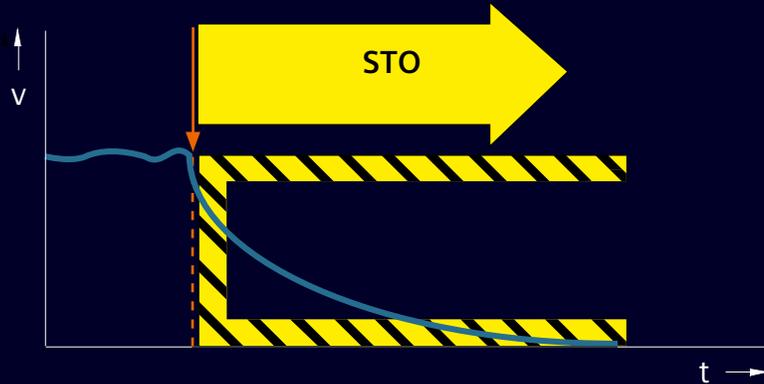
# Safety Integrated Functions for every control type

Function	Control	SIL	PL	Category	Encoder required	License required
<b>Basic functions</b> (no additional license is required)						
STO (Safe Torque Off)	F-DI PROFIsafe	SIL 3	PL e	Category 3 or 4 <sup>1)</sup>	No	No
SS1-t (Safe Stop 1 time-controlled)	F-DI PROFIsafe	SIL 3	PL e	Category 3 or 4 <sup>1)</sup>	No	No
SMT (Safe Motor Temperature)	Option Module SMT required	SIL 2	PL d	Category 3	No	No
<b>Extended functions</b>  (license is required)						
SS1-a (acceleration monitoring) SS1-r (braking ramp monitoring)	F-DI PROFIsafe	SIL 3	PL e	Category 3 or 4 <sup>1)</sup>	Yes	Yes
SLS (Safely-Limited Speed)	F-DI PROFIsafe	SIL 3	PL e	Category 3	Yes	Yes
SDI (Safe Direction)	F-DI PROFIsafe	SIL 3	PL e	Category 3	Yes	Yes
SSM (Safe Speed Monitor)	F-DI PROFIsafe	SIL 3	PL e	Category 3	Yes	Yes

1) Depending on the parameterized self-test of the fail-safe digital inputs

# Safe Torque Off (STO) SIL 3, PL e, Cat. 4 Overview

## Basic



The STO is used in many applications including all machines and systems with moving axes (for example, conveyor technology, handling).

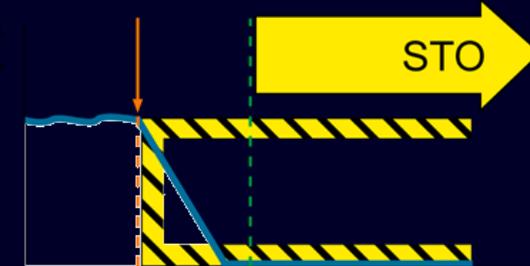
The Safe Torque Off (STO) function is activated and prevents the torque-generating supply of energy to the motor and avoids the motor from unexpectedly starting.

With STO, maintenance work on the machine with an open protective door is possible, for example. An EMERGENCY STOP with electromechanical disconnection is not required.

# Safe Stop 1 (SS1) Overview

Safe Stop 1 (SS1) stops a dangerous movement of a machine component.

- Controlled stopping of large masses and moments of inertia
- Three different versions, depending on the requirement
  - SS1-t **Basic**
  - SS1-a **Extended** 
  - SS1-r **Extended** 

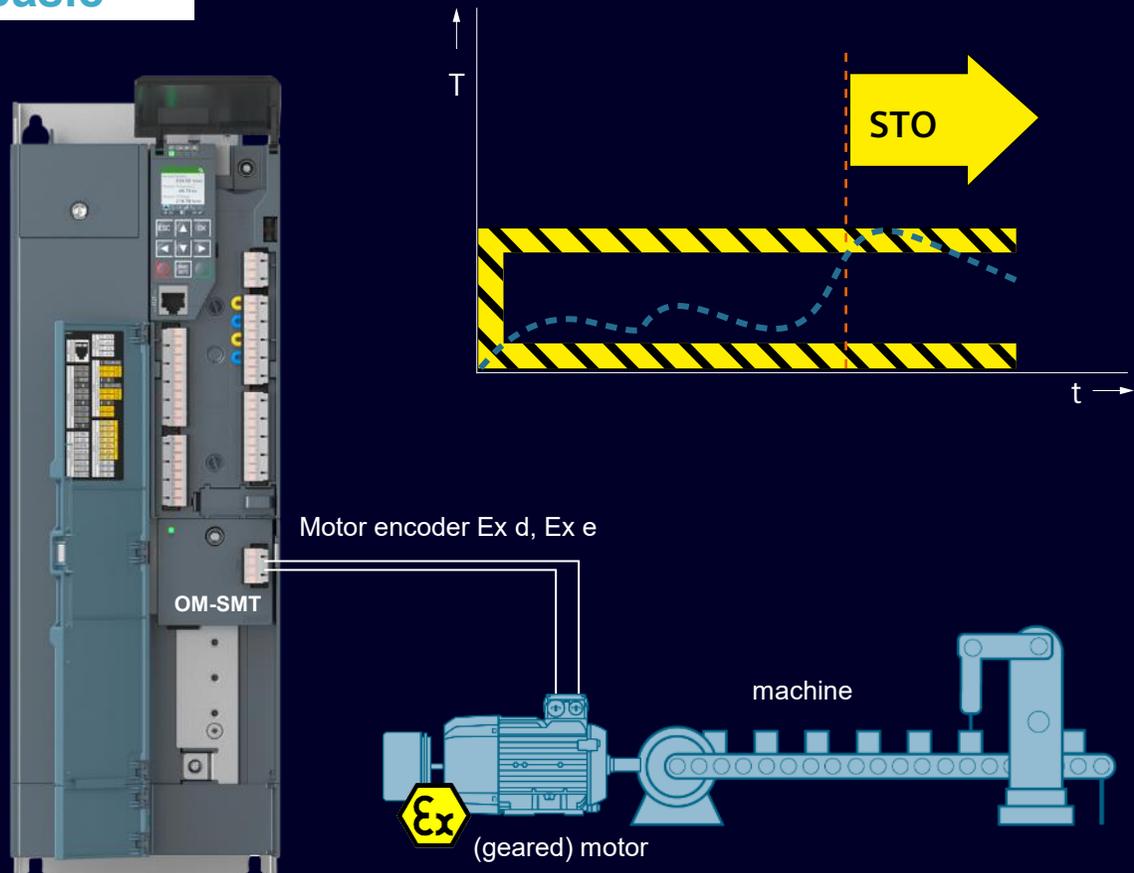


## Example

Using an Emergency Stop, the storage and retrieval machine is braked before the pulses are canceled, the mechanical brakes and buffer at the end of the aisle are not used – therefore reducing wear.

# Safe Motor Temperature (SMT)

## Basic



SMT is used to protect against overtemperature of a motor in hazardous environments, e.g. in the chemical industry, in paper mills, or in paint shops.

Safe Motor Temperature (SMT) prevents the motor temperature from exceeding a specified limit. SMT is used to protect against overtemperature of a motor that is used in a potentially explosive atmosphere.

SMT is a safety function in accordance with IEC 61800-5-2.

# Safely-Limited Speed (SLS)

Extended



SLS is suitable for machines where hazards due to excessive speeds are possible. In the following work steps, the use of SLS is particularly useful for direct contact between man and machine:

- During commissioning
- During setup
- For maintenance work

The speed is monitored in the positive and negative directions of rotation.

The system can switch between four speed limit values during the runtime.

One speed limit value that can be changed during the runtime via PROFIsafe.



## Example

Setup mode: The machine operator must enter the dangerous area of a machine and manually introduce material into a machine part.

# Safe Speed Monitor (SSM)

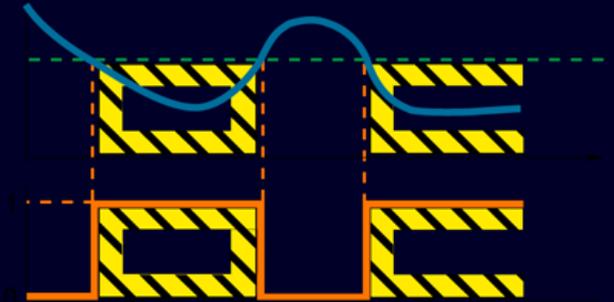
Extended



Safe Speed Monitor (SSM) safely detects when the speed falls below a speed limit in both directions of motion.

SSM is a pure signaling function. The converter provides a safety related signal for further processing.

If the speed of the motor exceeds the SSM limit value, no stop response is initiated, contrary to other Safety Integrated Functions.



## Example

SSM is suitable for enabling access to the machine by way of safe SSM feedback. For example, it is possible to unlock safety doors only when the speed falls below critical levels.

# Safe Direction (SDI)

Extended



With Safe Direction (SDI), the converter monitors the direction of motion of the motor.

If the motor moves in the inhibited direction, then the converter stops the motor with an SDI-specific stop response.

The following SDI variants are available, depending on the direction of motion:

- SDI positive (SDI+)
- SDI negative (SDI-)



## Example

SDI prevents the machine from being mechanically damaged if moved in an impermissible direction.

# Tools Support

## Safety Acceptance Test and Safety Activation Test

### Safety Acceptance Test (since Startdrive V15)

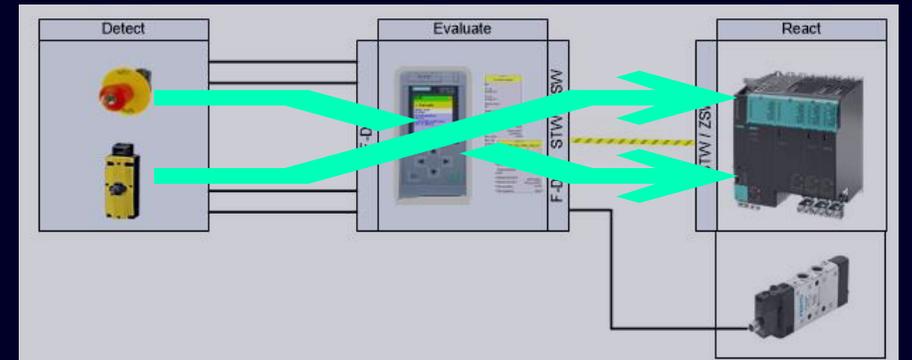
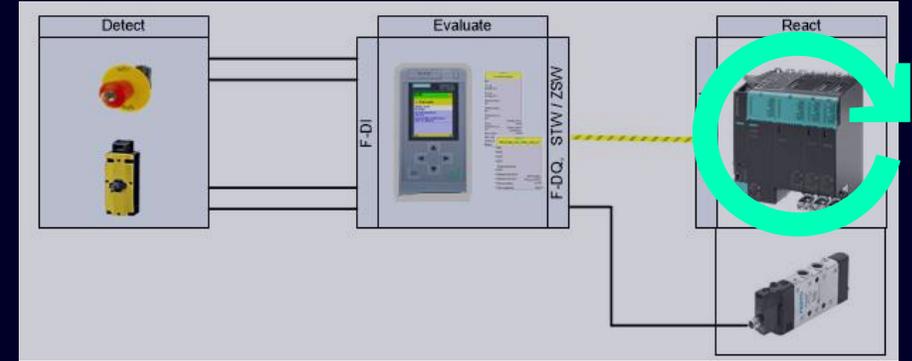
Validation of correct **safety parameterization for the integrated drive safety** functions. The configuration test according to IEC 61800-5-2 is used to detect potential parameterization errors and to document the correct operation. Clearance about questions such as:

- Are the safely monitored braking ramps set correctly?
- Are the safely monitored limitations and fault reactions set correctly?
- ...

### Safety Activation Test (since Startdrive V17)

Validation of the **safety control chain from sensor to actuator**. The functional tests of the system interfaces (automation & drive components) can be taken into account for the validation. Clearance about questions such as:

- Does every drive select the correct safety function when a safety sensor is activated?
- Are all safety functions realized according to the risk minimization?
- ...



# Vragen ?