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Application description • 07/2016

Serial hoisting equipment with SINAMICS G120

Dimensioning and commissioning

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WARNING

Danger for personnel as a result of unintentional lowering

If the holding brake does not provide adequate protection, for vertical axes there is danger for personnel as a result of unintentional lowering of the load. Plant or machine builders must take this danger into account during the risk assessment and must take the appropriate measures to minimize the risk of danger.

A description of the technical and organizational protective measures for different operating modes is provided in \10\ Technical information sheet for axes subject to gravity of the German Social Accident Insurance (DGUV).

This application document does not describe a machine safety concept that is intended to minimize any danger corresponding to the information sheet of vertical axes. The document only demonstrates how the control-related safety functions of the products presented can be utilized.

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1 Serial hoisting equipment

Serial hoisting equipment is machinery with a vertical moving direction. They are generally distinguished between its energy source (muscle, electronic, pressure), the load transmission (rope, chain, gear rack) as well as the directional impact (hoist, push) and the stroke size (long or short). Typical examples are wire rope hoists or chain or cable winches, hoisting platforms, etc.

Main focus of this application document

This application document is for hoisting drives in electrically operated serial hoisting equipment. It is intended to provide support when engineering and commissioning basic hoisting drives – and provides basic information on moving vertical loads.

As basic hoisting drive, SINAMICS G120 is discussed in combinations of power units and control modules. The operating instructions and function charts should be reviewed as supplement to the functions and components that are described.

1.1 Mechanical system

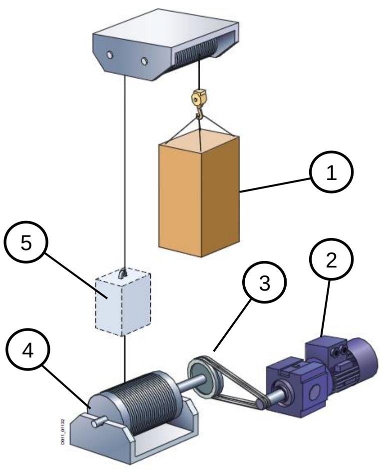
An overview of the various mechanical configurations of serial hoisting equipment is provided in the following.[1]

1.1.1 Cable-based serial hoisting equipment

Serial hoisting equipment with winch

Fig. 1-1 schematically shows a hoisting gear with winch, where the load (1) is moved using a helical geared motor (2). In the application shown, the cable winch or drum winch (4) is connected to the motor through a second belt-driven gearbox. The counterweight (5) is located on the other side of the load.

Fig. 1-1: Schematic representation of a serial hoisting equipment



Cable winches can be wound with single or multiple layers. Depending on the winch speed, the cable is wound mechanically or electrically using a traversing drive. For single-layer cable drums, grooves are used to guide the cable; a pressure roll keeps the cable in the groove.

[1] A detailed description can be taken from /2/ [Kiel 2007].

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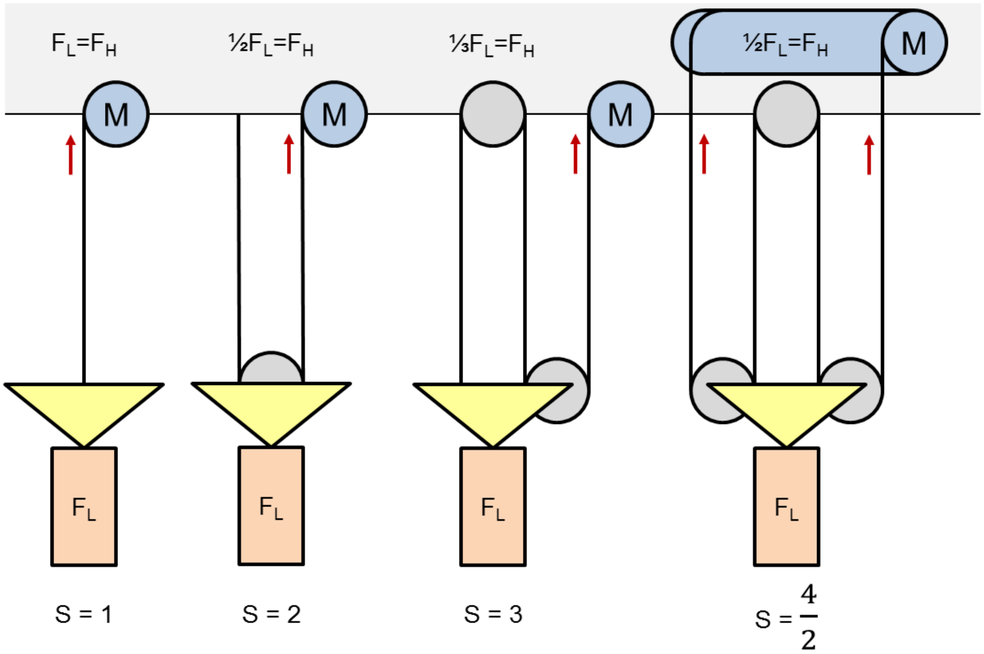
Winches are winder drives with changing peripheral (circumferential) velocity. For a constant motor speed, the winch speed either decreases or increases. The output torque at the winch changes to the same extent.

Serial hoisting equipment with reeving

Reeving can be used to reduce the torque required. Reeving works just like a block and tackle; the principle of operation is shown in Fig. 1-2. In addition to reducing the required torque by the reeving factor, the drum torque required increases by the reeving factor, while the hoisting velocity remains the same. The reeving factor is calculated from the ratio of all of the cables to the cables that are pulled.

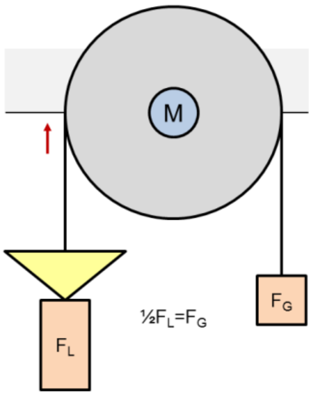
Fig. 1-2: Principle of operation of reeving



Serial hoisting equipment with traction sheave

Serial hoisting equipment with traction sheaves exist as an alternative to winches; generally, these require a counterweight. The cables run across the traction sheave, whereby the force is transmitted to the cable through friction. Fig. 1-3 shows a serial hoisting equipment with traction sheave and counterweight. Contrary to winches, the speed is always proportional to the hoisting velocity. Further, the cable length is not limited by the drum, but only by the weight of the cable.

Fig. 1-3: Principle of a serial hoisting equipment with traction sheave



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Generally, the counterweights of serial hoisting equipment are designed for half of the payload, plus the weight of the lift platform. As a consequence, depending on the operation and load of the serial hoisting equipment, all four motor quadrants are used, see Table 1-1.

Table 1-1: Operating ranges of serial hoisting equipment with counterweight

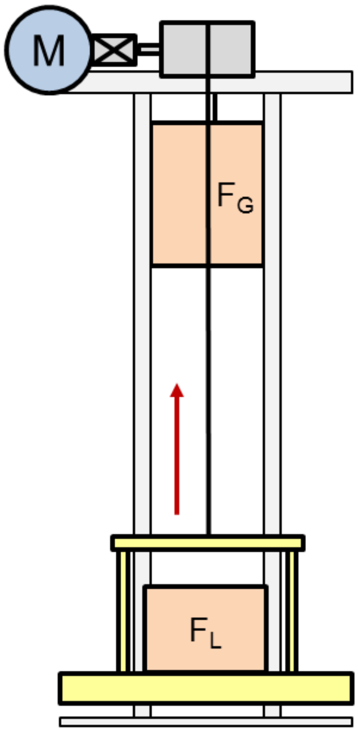
	Descending	**Ascending**
With payload	Generating, counterclockwise rotation, braking	Motoring, clockwise rotation, driving
Without load	Motoring, counterclockwise rotation, driving	Generating, clockwise rotation, braking

1.1.2 Additional mechanical assemblies

Lifter with continuous, circulating belt

Lifting equipment used in conveyor systems with continuous, circulating belts function in a similar way to serial hoisting equipment with traction sheaves. However, the drum diameter is far lower than the sheave diameter. Fig. 1-4 shows a belt lifter for conveyor technology.

Fig. 1-4: Lifter in conveyor technology



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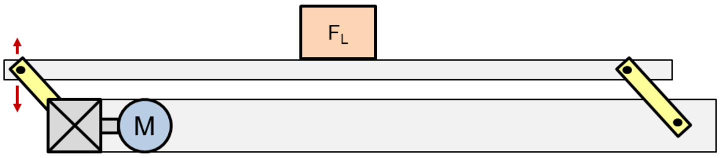
Excentric lifting table

For excentric lifting tables, lift is implemented using a lever arm. The arm can be implemented as bar (lever-based mechanical system) or as disk with excentric, rotating axle. Fig. 1-5 schematically shows an excentric lifting table. When stationary at the end positions, this type of serial hoisting equipment has the advantage that the weight is held by the mechanical system, and not by the drive. However, it has the disadvantage that the lifting height is low.

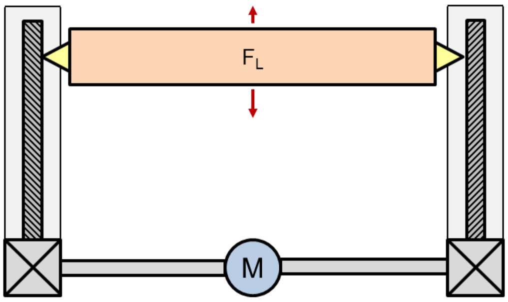
Fig. 1-5: Excentric lifting table



Elevating platform with spindle drive

Generally, for elevating platforms with spindle drive, two spindles must be synchronously coupled. For low spindle pitches, the mechanical system is self locking. This means that the motor does not accelerate uncontrollably under load.

Fig. 1-6: Elevating platform with spindle drive



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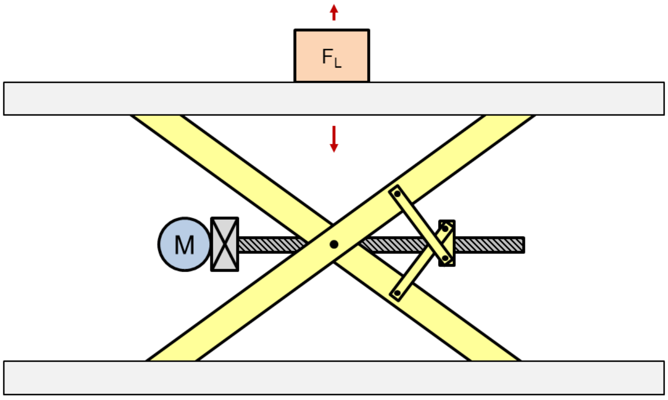
Shears-type elevating platform

Shears-type elevating platforms are available with a spindle drive or belt. Fig. 1-6 shows a shears-type elevating platform with spindle drive. With a low spindle pitch, this can also be implemented to be self locking.

Fig. 1-7: Shears-type platform with spindle drive



1.2 Open-loop and closed-loop control components

Generally, lifting equipment are manually operated using the appropriate operator controls. On the other hand, sensors are becoming increasingly important for automated lifting equipment.

1.2.1 Operator control devices

These are mobile operator terminals that allow lifting gear to be operated from the ground. There are suspended mobile control terminals, which are either fixed to the gantry or can be moved – as well as those that are attached to the trolley. Remote control systems are also available.

Suspended operator control stations/terminals are generally equipped with two-stage switches for direction and drive as well as an emergency off switch. A pushbutton can be used to select crawl or rated velocity in the selected direction. When using inverters, by selecting the second stage, the velocity can be continuously increased up to the rated velocity. Once the required velocity has been reached, the switch is moved from the second to the first stage. The velocity is reduced by releasing the first stage until the required velocity is reached.

Remote control systems are available with pushbuttons and master switches.

Diagram 1-8 Suspended operator control station

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1.2.2 Position switches

Position limiter

After a risk assessment, position limiters or also emergency limit switches must be installed at locations where the hoisting equipment is not allowed to operate. The actual definition should be taken from the appropriate standards, e.g. the /3/ UVV BGV D6 Krane [German regulations relating to serial hoisting equipment operation].

Retracting from the position limit switch in the opposite direction is always manually undertaken at the minimum velocity.

Limit switches

Limit switches define traversing range limits that can be operationally approached. These prevent the relevant axis hitting mechanical end stops or emergency limit switches. Limit switches can be implemented using proximity switches (hardware) or can be software-based in the drives.

Rapid traverse and crawl mode switchover

Rapid traverse crawl mode switchover represents the simplest form of automated positioning. Here, a proximity switch is used to switch over from rapid traverse into crawl mode. The axis then positions at the limit switch in the crawl velocity. This allows fixed positions to be relatively reliably approached on a continuous basis. The proximity switches can be directly evaluated in the drive via digital inputs. An example is given in \3\.

1.2.3 Position sensing systems

Positioning can be made more dynamic using position sensing systems (position feedback). Using a motor encoder, the speed (incremental encoder) can be determined – or using a machine encoder, the position of the load (absolute encoder). Linear measuring systems such as barcodes, cable length encoders or laser measuring systems are used as machine encoders. These can supply an absolute position actual value. Faster HTL or TTL signals of the incremental encoder can be used for closed-loop speed control. Absolute encoders with SSI, Drive CLiQ or EnDat interface are used for the closed-loop position control.

1.3 Hoisting drives

Inverter-based hoisting drives are now discussed in the following.

1.3.1 Inverter

Inverters allow variable-speed operation and starting and stopping along defined ramps. This significantly reduces the wear on the mechanical components. The jerk limiting protects the cable or belt, and the motor holding brake can always be closed when the motor shaft is stationary. Further, the inverter can generate output frequencies that are higher than the line frequency; this means that the motor can be operated in the field weakening range.

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Closed-loop control modes

For serial hoisting equipment with induction motors, motors can be operated in the V/f control mode, encoderless vector control or vector control with encoder. Table 1-2 compares these three control modes, listing the associated advantages and disadvantages. [2]

Table 1-2: Comparison of the various control modes

	U/f control	Vector control without encoder	Vector control with encoder
Advantages	• Good price-performance ratio • Simple commissioning	• Can follow the setpoint speed independent of the load • Shorter correction times when the setpoint changes • Shorter correction times when the load changes • Maximum adjustable torque possible • Torque independent of the speed • More motor protection functions	Supplement to vector control without encoder: • Closed-loop speed control down to 0 Hz • Constant torque in the rated speed range (no step when switching over) • Even shorter response times when the setpoint changes • Even shorter response times when the load changes • Higher speed accuracy
Disadvantages	• Actual speed is not known • Fewer motor protection functions • Overdimensioning of the drive might be necessary	• U/f control down to 10% rated speed • No defined torque down to 10% of rated speed • Restricted speed control range • Speed n=0 cannot be maintained • No torque control	• Possible inaccuracies without KTY temperature sensor

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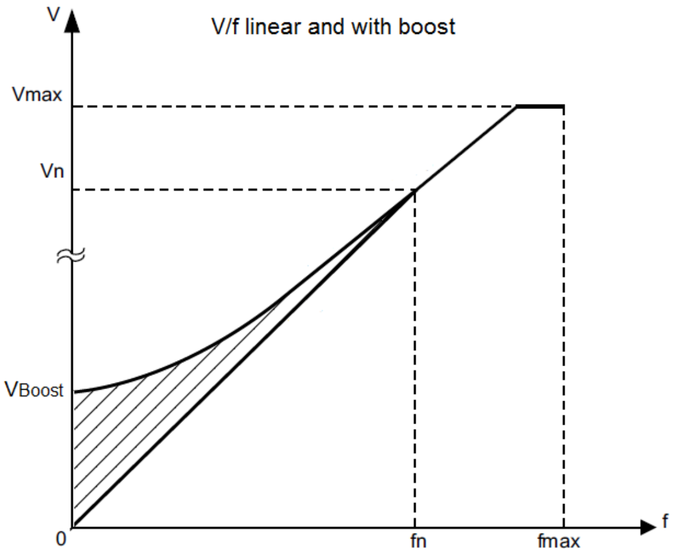
[2] A detailed description of the control modes can be taken from \9\. From FW 4.5, the principle of operation for SINAMICS S120 and G120 is identical.

U/f control

When using V/f control, the stator voltage of an induction motor is controlled proportionately to the stator frequency. This procedure is used for many standard applications where the dynamic performance requirements are low. As the output frequency and output voltage change proportionally, the flux Φ and therefore the available torque remain constant. Without additional sensors, it is not possible to determine the actual motor speed and to monitor zero speed with V/f control mode. Fig. 1-9 shows the V/f characteristic with linear voltage characteristic and with permanent voltage boost.

Fig. 1-9: Linear V/f characteristic and with voltage boost



A linear characteristic means that at zero speed, the voltage is also almost close to zero. In this case, at low speeds, the current would not be sufficient to maintain the load. As a consequence, we recommend that the output voltage is permanently boosted. The voltage should be increased to the value that is required to hold the maximum load that occurs, as long as the motor is not overloaded.

Vector control without encoder (closed-loop speed control)

When operating the motor with vector control without encoder, the actual speed must be determined based on the electric motor model. The closed-loop control uses the measured voltage and the measured current. As a consequence, the motor can follow the setpoint speed, independent of the load.

At low frequencies (below 10% of the rated speed) – and the associated low output voltages – the motor model cannot determine the speed with sufficient accuracy. The V/f characteristic is used in this range. In this particular case, for serial hoisting equipment, a permanent (static) torque must be adjusted, which should lie 10% above the maximum load that occurs.

NOTICE	Hoisting drives without encoder must always be started in the open-loop speed controlled mode. Closed-loop speed controlled operation with vector control but without encoder starting at 0 Hz is not permissible.

In the following applications, a motor encoder should be used – and not encoderless vector operation:

- If, for speeds less than 10% of the rated motor speed, a defined motor torque is to be generated.

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- If the speed control range is > 1:10 of the rated motor speed.
- If the drive is to be continuously operated in the range 0 … 10% of the motor rated speed.
- When the speed is to be held at n=0.
- When the drive should be operated in torque control.

Vector control (closed-loop speed control) with encoder

Vector control with encoder controls the speed based on the actual speed provided from a rotary pulse encoder or incremental encoder, and not based on a calculated speed. The advantages of speed control with an encoder include:

- Speed can be controlled down to 0 Hz (i.e. at standstill)
- Constant torque in the rated speed range
- Compared with speed control without an encoder, the dynamic response of drives with an encoder is significantly better because the speed is measured directly and integrated in the model created for the current components.
- Higher speed accuracy

Protection functions

The inverter protects itself and the motor against overtemperature and overcurrent. The inverter temperature is monitored in three different ways:

- The I2t monitoring measures the actual utilization based on a current reference value.
- The inverter monitors the temperature difference between the power chip (IGBT) and the heat sink.
- The inverter monitors the heatsink temperature of the Power Module.

For serial hoisting equipment drive applications, if the inverter develops an overtemperature condition, then the inverter should be shut down without first reducing the output current. The motor temperature calculation function is only possible in vector control as the calculation is based on a thermal motor module.

In vector control, the motor current limits can be defined. In V/f control, the maximum current controller (I-max controller) protects the inverter against overloading by limiting the output current. The I-max controller changes the drive speed, and flattens the acceleration or braking ramp. In hoisting applications the torque is not dependent on the speed, and therefore the I-max controller does not reduce the inverter load.

When lowering (or for very steep braking ramps), the motor goes into the generator mode and feeds energy back into the inverter. The inverter DC link voltage increases. If the energy cannot be dissipated using a braking resistor – or fed back into the line supply – the inverter inhibits itself with a DC link overvoltage fault message and the motor coasts down. If the motor holding brake is integrated in the sequence control, the brake is applied when a fault occurs.

1.3.2 Motors

For hoisting applications with high power ratings, DC drives are still being used. Hoisting applications demanding an extremely high dynamic performance occasionally demand the use of synchronous motors. Standard induction motors with gearboxes are the most widely established approach.

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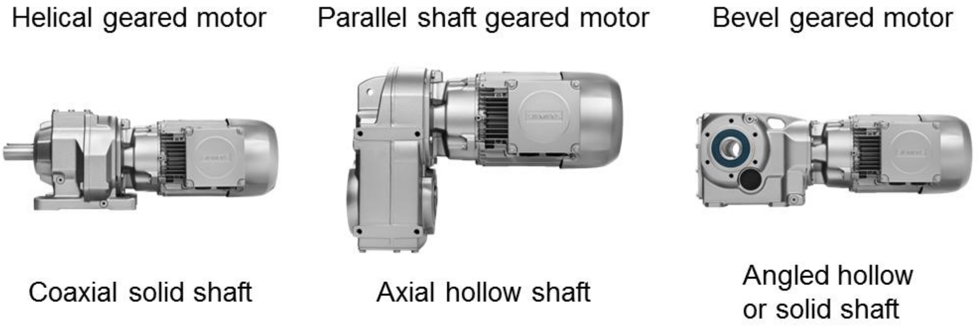
Geared motor

Fig. 1-10 shows various induction geared motors belonging to the SIMOGEAR series. Frequently, helical geared motors are axially coupled with a cable drum. In order to axially couple two cable drums, angled bevel geared motors with hollow shafts can be used.

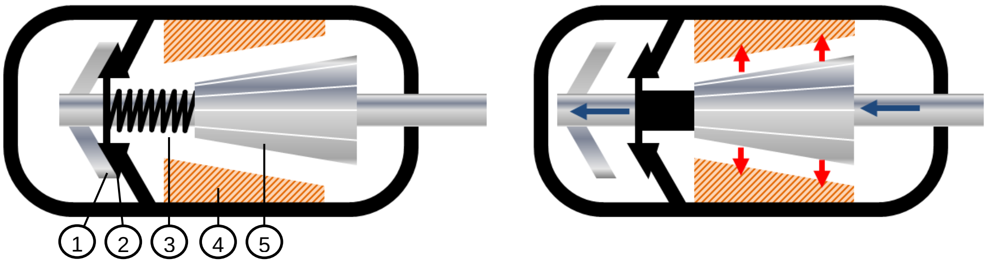
Fig. 1-10: SIMOGEAR geared motors



Sliding rotor motor

Sliding rotor motors represent a special form of induction motor, where as a result of the intrinsic design; the brake is automatically applied when current is not flowing through the motor. These motors have a conically shaped laminated rotor core. When a magnetic field is generated in the stator, the rotor shifts axially to minimize the air gap. If the magnetic field is reduced, a spring pushes the rotor out of the stator field and back into the brake mechanism. This is especially advantageous for serial hoisting equipment, because the load is held by the brake as long as the motor cannot generate any torque. On the other hand, they are very maintenance intensive.

Fig. 1-11: Diagram showing the principle of operation of a sliding rotor motor (1 Brake disk, 2 Brake blocks, 3 Brake spring, 4 Stator bores, 5 Laminated rotor core)



As a result of the larger air gap, sliding rotor motors draw a higher current.

NOTICE	**V/f control mode** When using a sliding rotor motor we recommend operation with a V/f control mode.

Slip ring motor

For slip ring motors, the rotor winding connections are brought outside via slip rings. By changing the rotor resistance, the motor can start with a high starting torque and relatively low starting current. They are used for hoisting systems with high power ratings. Increasingly, slip ring motors are being replaced by squirrel-cage induction motors fed from inverters.

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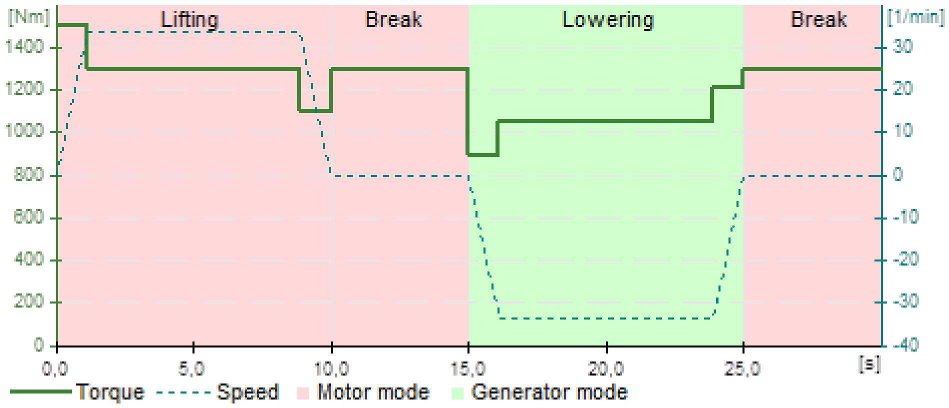
Regenerative energy

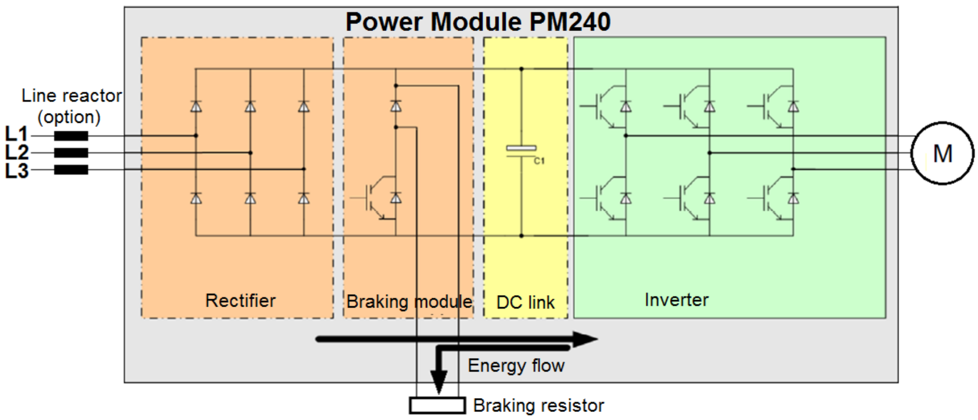
Fig. 1-12 shows the speed and torque characteristic at the drive output for a serial hoisting equipment with a payload of one ton when lifting and lowering, 0.5 t hoisting platform and 0.75 t counterweight. When lowering (or for very steep braking ramps), the motor goes into the generator mode and feeds energy back into the inverter.

Fig. 1-12: Torque and speed characteristic



When using dynamic braking (resistor-based brake), the energy when braking is fed to an external braking resistor by the braking chopper, where it is converted into heat. As a consequence, also in generator operation, the inverter can track the motor corresponding to the setpoint input.

Fig. 1-13: Inverter with PM240 power unit and braking resistor



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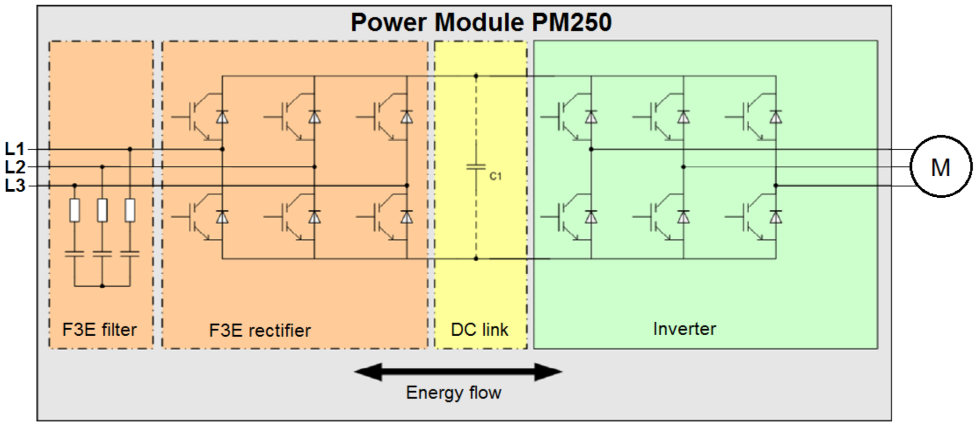
Alternatively, inverters capable of energy recovery can regenerate into the line supply, for example, the PM250 power unit in Fig. 1-14. This reduces the energy consumption and eliminates the braking resistor, therefore relieving space. The line conditions must be carefully checked when using the PM250, see Chapter 2.4.2.

Fig. 1-14: Inverter with PM250 power unit for energy recovery



Field weakening

Serial hoisting equipment are typically used under load with low velocity and without load, with high velocity. When using an inverter, the motor can be operated in the field weakening range. The stall torque in the field weakening range decreases proportionally to $1/n^2$ and the torque, proportionally to $1/n$. The peak torque in field weakening should have a safety margin of 30% to the stall torque.

Motor temperature monitoring

The following temperature sensors can be connected to the inverter to protect the motor against overtemperature:

- Temperature switch (e.g. bimetallic switch)
- PTC sensor
- KTY84 sensor

A temperature change in the motor rotor or stator directly impacts its resistance. Changes to these resistances can result in inaccuracy in the vector control. We recommend that a KTY84-130 is used to determine the rotor and stator temperature with adequate accuracy.

1.3.3 Braking

Generally, every hoisting gear is equipped with a brake. This brake is either a motor holding brake or an external brake, which acts directly on the cable drum or shaft. For inverter operation, a hoisting brake is only implemented as holding brake.

Brakes for operation and lowering

Operating brakes have the task of braking a motor from its rated speed down to standstill. In addition to absorbing the potential energy of the load, these brakes must also absorb the kinetic energy. For instance, sliding rotor motors have operating brakes. When compared to holding brakes, operating brakes are designed for wear as a result of braking operations.

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Brakes for lowering, e.g. for slip ring motor drives are used, such as Eldro control brakes. Using the rotor voltage, they control the velocity when lowering – and predominantly absorb the potential energy.

For inverter operation, the brake used for operation or when lowering becomes a holding brake and must be correspondingly controlled. In this case, the brake linings are subject to significantly less wear.

Motor holding brake, holding brake

State-of-the-art hoisting equipment is equipped with an external holding brake or a holding brake integrated in the motor. Here, the armature disk presses the brake disk against the braking shoe using spring pressure. When the solenoid behind the armature disk is energized, the spring pressure holding the brake disk against the brake shoe is released. The motor can rotate.

Ideally, this brake is controlled from the inverter. The brake control can be integrated in the inverter sequence control for this purpose. In this case, the brake is only released after the motor has been magnetized and a motor torque has been established. The drive (inverter) knows the brake closing time – and can delay enabling the torque by precisely this time. This functionality must be programmed in the control system if the brake control integrated in the drive is not used.

A motor holding brake is not suitable to frequently brake large loads from high speeds, i.e. to work as operating brake. However, some faults can mean that the motor coasts down. For serial hoisting equipment, it is especially important to ensure that the brake closes as quickly as possible. The distance dropped is a function of the square of the closing time, which means that the load can drop significantly within just a few milliseconds in the case of fault. As a consequence, for serial hoisting equipment, brake control systems that ensure the shortest possible brake closing time are crucial.

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2 Engineering

The SIZER for Siemens Drives engineering tool supports you when engineering variable speed drives. Various mechanical systems can be calculated; this also includes hoisting gears with various travel profiles. The software can be downloaded at no charge from the Internet at \4\. A belt lifter can be engineered step-by-step using SIZER in the application example in \5\ . Please touch base with your Siemens contact person for engineering serial hoisting equipment with SIZER.

The essential formulas for engineering hoisting equipment are described in detail in the following. An engineering example is then provided. Rough calculations have been consciously avoided. Always use SIZER when engineering serial hoisting equipment.

2.1 Engineering serial hoisting equipment

Serial hoisting equipment is engineered for operation with the maximum payload (rated hoisting load). However, they must be operationally moved with 10% overload (110 % of the rated load) until the overload trip is initiated. Repeat tests can be carried out once with 25% overload (125% of the rated load). The hoisting drive should be able to raise and lower this load once.

NOTE Before commencing engineering, carefully checked as to whether the maximum payload already takes into account these overload cycles.

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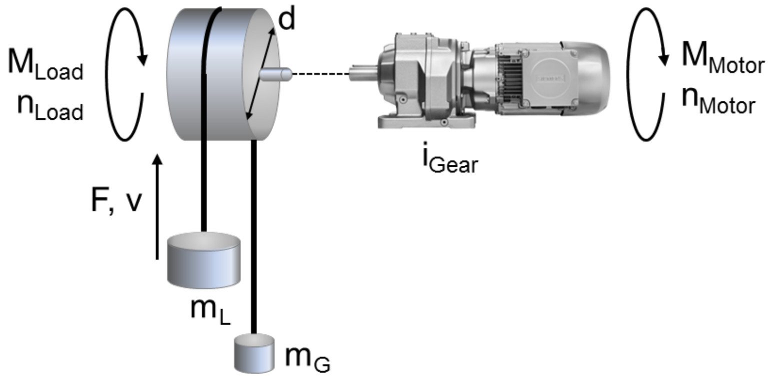
Fig. 2-1 shows the parameters when engineering a serial hoisting equipment with geared motor and a counterweight with load torque (M_{load}), load speed (n_{load}), hoisting force (F), hoisting velocity (v), payload (m_L), counterweight (m_G), drum diameter (d), gearbox ratio (i), motor torque (M_{motor}) and motor speed (n_{motor}).

Fig. 2-1: Parameters when engineering the drive



When lifting a payload and counterweight with constant velocity, the static hoisting power $P_{hoist,stat}$ must be made available with acceleration due to gravity g

$$P_{hoist,stat} = \frac{(m_L - m_G) \cdot g \cdot v}{\eta_{Mechanic}} \quad (2.1)$$

For hoisting velocity v, load speed $n_{load, hoist}$ is obtained as follows

$$n_{load,hoist} = \frac{s \cdot v}{\pi \cdot d} \quad (2.2)$$

where s corresponds to the number of reevings, see Fig. 1-2. From converting power into torque

$$P_{hoist,stat} = 2\pi \cdot M_{Hoist,stat} \cdot n_{Load,Hoist} \quad (2.3)$$

the static hoisting torque $M_{hoist,stat}$ is obtained as follows

$$M_{hoist,stat} = \frac{(m_L - m_G) \cdot g \cdot d}{\eta_{Mechanic} \cdot 2 \cdot s} \quad (2.4)$$

Taking into account the acceleration, the dynamic hoisting power $P_{hoist,dyn}$ is given by

$$P_{Hoist,dyn} = \frac{(m_L + m_G) \cdot a \cdot v}{\eta_{mechanic}} \quad (2.5)$$

and the dynamic hoisting torque $M_{hoist,dyn}$

$$M_{Hoist,dyn} = \frac{(m_L + m_G) \cdot a \cdot d}{\eta_{Mechanic} \cdot 2 \cdot s} \quad (2.6)$$

The hoisting power corresponds to the sum of the static and dynamic hoisting power, whereby this for a rated load that is equal to the rated hoisting power of the hoisting equipment:

$$P_{Hoist,n} = P_{Hoist,stat} + P_{Hoist,dyn} = v \frac{(m_L - m_G) \cdot g + (m_L + m_G) \cdot a}{\eta_{Mechanic}} \quad (2.7)$$

Analogously, the load torque is the sum of the static and the dynamic hoisting torques

$$M_{Hoist} = M_{Hoist,stat} + M_{Hoist,dyn} = d \cdot \frac{(m_L - m_G) \cdot g + (m_L + m_G) \cdot a}{\eta_{Mechanic} \cdot 2 \cdot s} \quad (2.8)$$

As can be seen from the calculations for the static and dynamic power, the counterweight reduces the static torque; however, it increases the required dynamic torque. This should be taken into account when dimensioning the counterweight. Generally, the counterweight is dimensioned as follows

$$m_G = m_H + \frac{m_L}{2} \quad (2.9)$$

where m_H corresponds to the intrinsic weight of the hoisting equipment.

The mass moment of inertia of the load is calculated the same as for a straight circular cylinder

$$J_{Load} = (m_L + m_G) \cdot \left(\frac{d}{2}\right)^2 \quad (2.10)$$

2.2 Selecting the geared motor

If the precise motor characteristic for S1 continuous duty or the load cycle of the serial hoisting equipment is not known, a motor is selected with a rated power greater than the static hoisting power.

$$P_{Motor,n} \geq \frac{P_{Hoist,stat}}{\eta_{Gear}} = \frac{(m_L - m_G) \cdot g \cdot v}{\eta_{Mechanic} \cdot \eta_{Gear}} \quad (2.11)$$

NOTICE	**Operation with U/f characteristic** When the motor is operated with U/f control, the motor should be selected corresponding to the rated hoisting power instead of the static hoisting power so that the rated motor torque is not exceeded.

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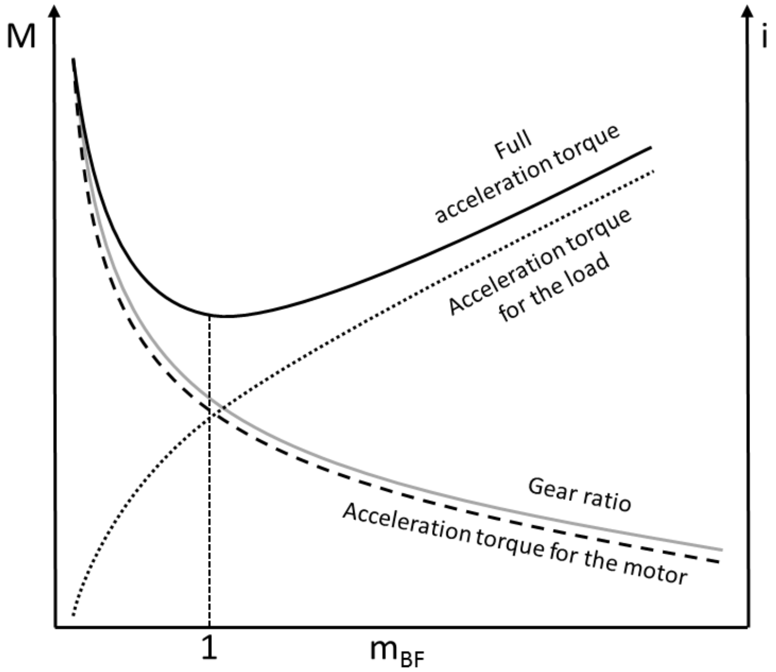
2.2.1 Selecting the gearbox

Geared motors connected directly to the line supply (DOL operation) are dimensioned according to the ratio between the rated motor speed and the load speed. When operating a geared motor with inverter, this is not necessary as a result of the variable frequency range. In fact, by utilizing field weakening, a gearbox is selected with a ratio that optimizes the overall accelerating torque. This allows the energy usage of the overall system to be reduced. Fig. 2-2 shows the characteristic of the accelerating torque and the gearbox ratio.

Fig. 2-2: Gearbox ratio to achieve optimum energy usage



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The mass acceleration factor m_{BF} is calculated from

$$m_{BF} = \frac{J_{Load,total}}{J_{Motor}} \quad (2.12)$$

In Fig. 2-2 it can be seen that the overall accelerating torque has a minimum for a mass acceleration factor of one, which means that the following relationship must be satisfied[3]

$$J_{Motor} = J_{Load,total} = \frac{J_{Load}}{i^2 \cdot s^2} + \frac{J_{Cylinder}}{i^2} \quad (2.13)$$

If the formula is changed according to the gearbox ratio, the following is obtained

$$i_{opt} = \sqrt{\frac{\frac{J_{Load}}{s^2} + J_{Cylinder}}{J_{Motor}}} \quad (2.14)$$

The load classification that the gearbox must be able to withstand is determined from the mass acceleration factor, using Table 2-1. For an m_{BF} of one, the load classification is always II (moderate torque surges).

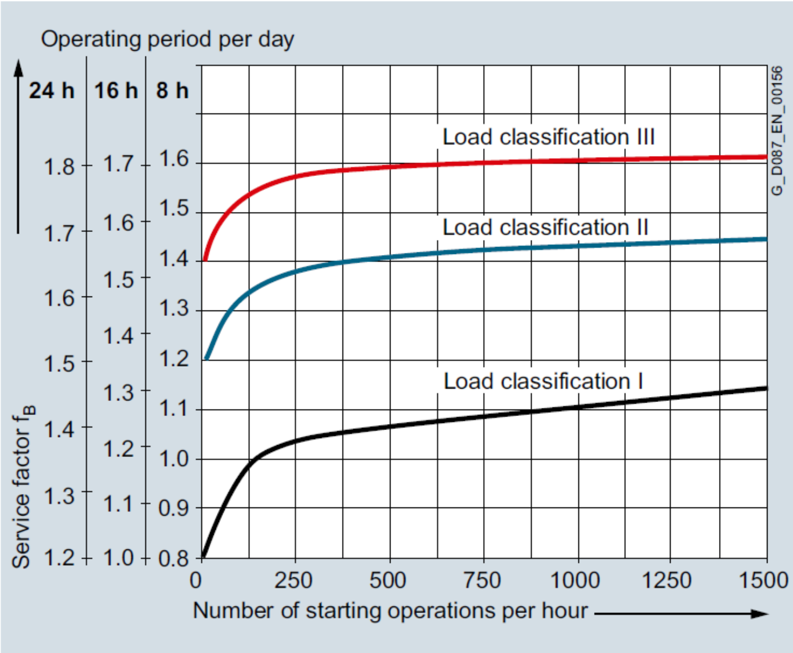
[3] Additional mass moments of inertia, for instance, a brake, are neglected.

Table 2-1: Load classification of driven machines

Load classification	I (almost free of torque surges)	II (moderate torque surges)	Heavy shocks
m_{BF}	≤ 0,3	≤ 3	≤ 10

Depending on the daily operating duration and the number of starting operations per hour, Fig. 2-3the required service factor f_{B1} of the gearbox is read off from.

Fig. 2-3: Required service factor f_{B1}



The following relationship applies to the service factor of a gearbox

$$f_B = \frac{M_{Gear,n}}{i \cdot M_{Motor,n}} \qquad (2.15)$$

NOTE The service factor is a safety factor to take into account the influence of the driven machine on the gearbox. It has an impact on the gearbox life span. The larger the service factor, the longer the life span. As a rough approximation, a service factor of two can also be specified to adequately overdimension the gearbox.

With the selected gearbox, the motor speed obtained at the hoisting velocity v with the actual gearbox ratio $i_{gearbox}$ can be calculated

$$n_{Motor,Hoist} = \frac{s \cdot v \cdot i_{Gear}}{\pi \cdot d} \qquad (2.16)$$

NOTE If the motor speed at the hoisting velocity is less than 20% of the rated speed of the motor $n_{motor,n}$ (<10 Hz), then different gearbox should be selected, or the inverter overdimensioned. Also refer to the FAQ on the alternating load capability in \10\.

Checking the selected motor

The motor stability criteria should then be checked with the selected gearbox. Taking into consideration the gearbox, the static motor torque is obtained as follows

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$$M_{Motor,stat} = \frac{(m_L - m_G) \cdot g \cdot d}{\eta_{Mechanic} \cdot \eta_{Gear} \cdot 2 \cdot s \cdot i} \tag{2.17}$$

and the dynamic motor torque is the sum of the acceleration of the load and the acceleration of the rotor

$$M_{Motor,dyn} = \frac{(m_L + m_G) \cdot a \cdot d}{\eta_{Mechanic} \cdot \eta_{Gear} \cdot 2 \cdot s \cdot i} + J_{Motor} \cdot \alpha \tag{2.18}$$

where α is the angular acceleration, with

$$\alpha = \frac{2 \cdot \pi \cdot n_{Motor,Hoist}}{t_{acceleration}} \tag{2.19}$$

The maximum torque on the motor side should have a safety margin of 30% to the motor stall torque:

$$M_{Motor,K} \geq 1{,}3 \cdot M_{Motor,max} = 1{,}3 \cdot \left(M_{Motor,stat} + M_{Motor,dyn}\right)$$

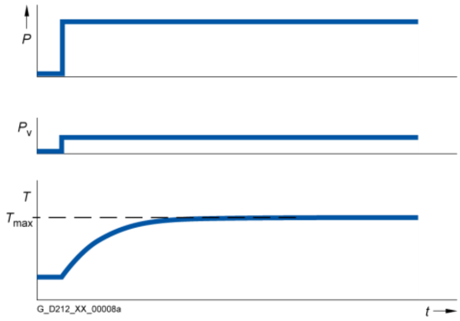
$$M_{Motor,K} \geq 1{,}3 \cdot \frac{d \cdot \left((m_L - m_G) \cdot g + (m_L + m_G) \cdot a\right)}{\eta_{Mechanic} \cdot \eta_{Gear} \cdot 2 \cdot s \cdot i_{Gear}} + J_{Motor} \cdot a \cdot 2 \cdot \pi \tag{2.20}$$

NOTICE	**Utilizing field weakening**
	When operating in the field weakening range, the motor stall torque decreases to the square of the speed, and the motor torque is proportional to the speed. In order to guarantee the safety margin of 30% to the stall torque, the load torque in the field weakening range must be appropriately low. The motor characteristic is required to precisely engineer the application.

2.2.2 Taking account load cycles

The motor was previously dimensioned for S1 continuous duty based on the static hoisting power.

Fig. 2-4: S1 continuous duty



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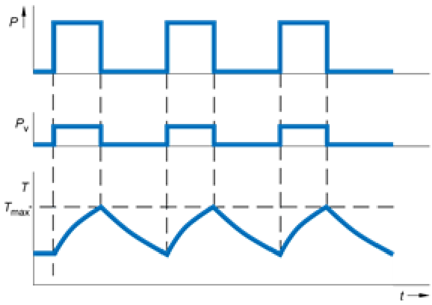
In most cases, the serial hoisting equipment is not operated in continuous duty, but is operated with a specific load cycle. In this particular case, the rated motor power must be greater than or equal to the rms hoisting power, see Fig. 2-5.

Fig. 2-5: S3 intermittent duty without the influence of starting



$$t_r = \frac{t_{Hoist}}{t_{Hoist} + t_{break}} \tag{2.21}$$

The rms motor torque is then always less than the static motor torque

$$M_{Motor,eff} = \sqrt{t_r \cdot M^2_{Motor,stat}} \tag{2.22}$$

The motor operating point

$$n_{Motor,avg} = \frac{1}{t_{cycle}} \left(\frac{t_{acceleration}}{2} + t_{Hoist} + \frac{t_{deceleration}}{2} \right) n_{Motor,Hoist} \tag{2.23}$$

can be determined based on the average speed. For a given load characteristic, it is possible that a smaller motor can be selected, as long as the operating point lies within the S1 motor characteristic.

2.2.3 Motor options

Generally, the motor must be selected and dimensioned taking into account the applicable motor options.

Motor encoder

Table 2-2 lists the advantages and disadvantages when operating serial hoisting equipment with encoder.

Table 2-2: Advantages and disadvantages when operating a motor with an encoder

Advantages	Disadvantages
• The rotation direction of the rotor and overspeed are immediately detected • Closed-loop speed control down to 0 Hz • Constant torque in the rated speed range (no step when switching over) • Higher dynamic drive performance • Higher speed accuracy	• Additional cost of the hoist drive • Additional wiring and mounting/installation costs • Encoders can be damaged when carrying out maintenance work on narrow trolleys

If an encoder is not used, then the SINAMICS G120 can be selected with a CU240E-2 Control Unit. When using an encoder, the CU250S-2 Control Unit must be used whis can evaluate incremental as well as absolute encoders.

Motor holding brake

For serial hoisting equipment with a suspended load, the torque of the motor holding brake should be dimensioned for twice the rated motor torque. This provides sufficient reserve, as the hoisting drive is never operated with two hundred percent overload.

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A function rectifier equipped with fast rectifier and shutdown on the DC side should be selected to control the brake. These release and close the motor holding brake the fastest, therefore minimizing load sag in the case of faults.

Note When using the G120D, the brake is always controlled using 180 V DC via the motor cable.

Temperature sensing

A KTY 84-130 temperature sensor provides the most accurate motor temperature monitoring. Further, a KTY sensor improves speed control with encoder in the lower speed range.

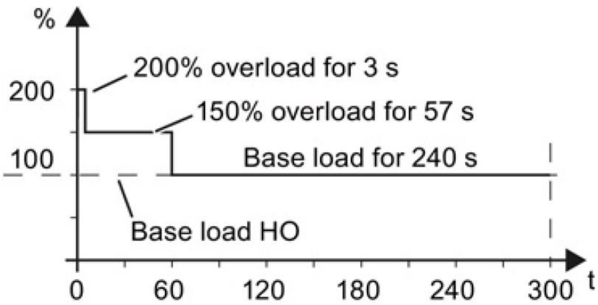
2.3 Inverter

The inverter can either be selected based on the rated motor data – or according to the actual current requirement. For serial hoisting equipment, a drive should always be selected based on a high overload (High Overload - HO). When dimensioned according to the rated motor data, the inverter must be able to continuously supply the rated motor current

$$I_{Inverter,HO} \geq I_{Motor,n} \quad (2.24)$$

In addition, the inverter must also be able to supply the maximum motor current for the load cycle. Induction motors should be operated with a maximum of 200% overload (generally, serial hoisting equipment is only dimensioned for 150% motor overload). SINAMICS G120 can provide the overload cycle for high overload shown in Fig. 2-6 (caution, this depends on the power unit frame size).

Fig. 2-6: Permissible overload for High Overload (HO)



As a consequence, depending on the hoisting load cycle, the following applies

$$I_{Motor,max} \leq 2 \cdot I_{Inverter,HO} \quad \text{for 3s every 5min} \quad (2.25)$$

$$I_{Motor,max} \leq 1{,}5 \cdot I_{Inverter,HO} \quad \text{for 57s every 5min} \quad (2.26)$$

If the rated output current $I_{inverter,HO}$ of the inverter satisfies the overload condition, then the inverter can be selected for the serial hoisting equipment. Otherwise, an inverter with a higher output current must be used.

Alternatively, the inverter can also be selected according to the actual current demanded by the motor. The current of induction motors comprises the reactive current and the active current. The reactive current is required to establish the magnetic field – and already flows under no load operation.

$$I_{Motor,Reactive} = I_{Motor,n} \cdot \sqrt{1 - \cos \varphi^2} \quad (2.27)$$

whereby, in the field weakening range, the reactive current decreases with the motor speed

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$$I_{Motor,Reactive} = I_{Motor,n} \cdot \sqrt{1-\cos\varphi^2} \cdot \frac{n_{Motor,n}}{n_{Hub,n}} \quad (2.28)$$

The active current to establish the torque is calculated from

$$I_{Motor,Active} = I_{Motor,n} \cdot \cos\varphi \cdot \frac{M_{Motor,Hoist}}{M_{Motor,n}} \quad (2.29)$$

whereby, in the field weakening range, the active current increases with the motor speed

$$I_{Motor,Active} = I_{Motor,n} \cdot \cos\varphi \cdot \frac{M_{Motor,Hoist}}{M_{Motor,n}} \cdot \frac{n_{Hub,n}}{n_{Motor,n}} \quad (2.30)$$

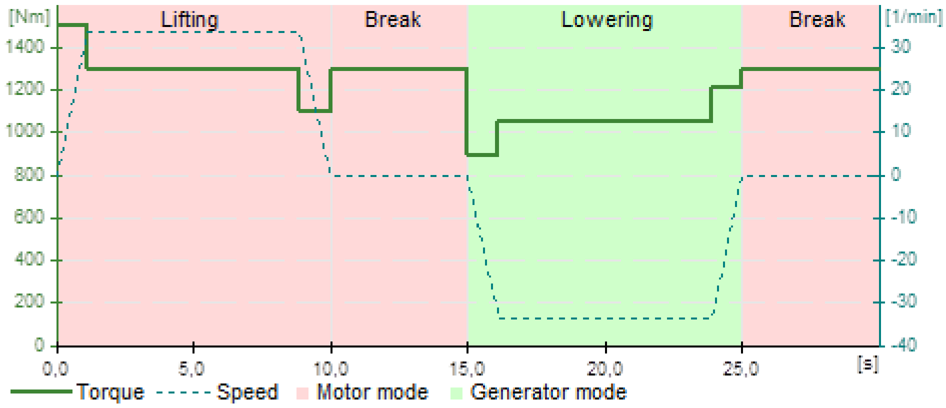
Neglecting losses in no load operation, the complete current consumption can be calculated as follows

$$I_{Motor,Hoist} = \sqrt{I_{Motor,Reactive}{}^2 + I_{Motor,Active}{}^2} \quad (2.31)$$

2.3.1 Dimensioning the braking resistor with PM240-2 power unit

Depending on the mechanical system of the serial hoisting equipment, the motor can also be operated in the generating mode. Self-locking spindle drives with low spindle pitch are always lowered in the motoring mode, for example. For hoisting equipment with a counterweight, the precise load cycle is required, as even without load lifting can result in the motor operating as generator. In the following it is assumed that lifting and lowering is with rated load, see Fig. 2-7. A braking resistor must be selected and dimensioned when using a power unit without energy recovery (PM240, PM240-2 and PM340).

Fig. 2-7: Load cycle when lifting and lowering with rated load



Static regenerative power

In the generator mode, energy flows from the motor through the gearbox and inverter into the braking resistor. These components have an intrinsic energy loss, so that the static, regenerative power is reduced according to the efficiency.

$$P_{Gen,stat} = (m_L - m_G) \cdot g \cdot v \cdot \eta_{Mechanic} \cdot \eta_{Motor} \cdot \eta_{Gear} \cdot \eta_{Inverter} \quad (2.32)$$

Peak power when generating

The maximum generator power is obtained when lowering with the rated load at the start of deceleration. The maximum power when generating is calculated as follows:

$$P_{Gen,max} = P_{Gen,stat} + \left(M_{Gen,dyn} \cdot 2 \cdot \pi \cdot n_{Motor,Hoist}\right) \cdot \eta_{Motor} \cdot \eta_{Inverter} \quad (2.33)$$

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$$M_{Gen,dyn} = \frac{(m_L + m_G) \cdot a \cdot d \cdot \eta_{Mechanic} \cdot \eta_{Gear}}{2 \cdot s \cdot i} + J_{Motor} \cdot \frac{2 \cdot \pi \cdot n_{Motor,Hoist}}{t_{Beschl}} \quad (2.34)$$

The peak braking power of the selected braking resistor can either be taken from the technical data of the braking resistor, or calculated. To do this, the peak voltage of the inverter DC link, which is switched to the resistor via the braking chopper, is used as basis. For the SINAMICS PM240-2 power units, this is 800V DC.

$$P_{Resistor,max} = \frac{(800V)^2}{R_{Widerstand}} \quad (2.35)$$

The maximum braking power must be less than equal to the peak power of the selected braking resistor

$$P_{Gen,max} \leq P_{Resistor,max} \quad (2.36)$$

Rms power when generating

From Fig. 2-7, it can be seen that with the same acceleration and deceleration, the average torque when lowering corresponds to the static torque when moving with a constant velocity. The speed while accelerating and decelerating is a maximum of $n_{motor,hoist}$. As a consequence, when approximately calculating the rms generator power, the static generator power can be used as basis. The relative duty ratio (switch-on duration) is then calculated as follows

$$t_r = \frac{t_{Lowering}}{t_{total}} \quad (2.37)$$

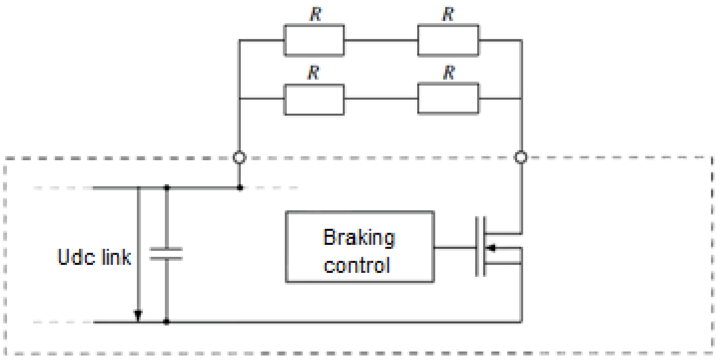
The rms braking power can then be calculated as follows

$$P_{Gen,eff} = \sqrt{t_r \cdot P_{Gen,stat}^2} \quad (2.38)$$

$$P_{Gen,eff} \leq P_{Resistor,eff} \quad (2.39)$$

If the selected braking resistor cannot dissipate the rms braking power, however, the peak power, then the same resistor as in Fig. 2-8 can be connected in series and parallel. The total resistance remains unchanged, and the rms braking power is quadrupled. This is because each individual resistor only has to absorb its percentage of the braking power.

Fig. 2-8 Increased power rating of the braking resistors



2.3.2 Dimensioning the PM250 power unit with energy recovery

When using the SINAMICS PM250 power unit with energy recovery, a braking resistor is not required. The regenerative feedback power of the PM250 is limited to the rated power, based on the rated current $I_{inverter,HO}$ for high overload. The regenerative feedback current cannot be exceeded. As a consequence, the inverter must also the dimensioned according to the maximum regenerative power

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and not just according to the motor current $I_{motor,hoist}$. The rated inverter power for high overload must be greater than the peak power of the generating mode

$$P_{Inverter,HO} \geq P_{Gen,max} \tag{2.40}$$

Further, the PM250 power unit places higher demands on the line supply. A stiff line supply with an $R_{SCE} > 100$ is required. The application conditions must be especially checked when powered from auxiliary power units[4].

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[4] For Siemens personnel, a description of the general conditions is available in the Internet at \6\. Further, the quiescent current should be taken into account, which is discussed in \7\.

2.4 Engineering example

A serial hoisting gear that can lift and lower with load is required. A helical geared motor is to be used. The machine data should be taken from Table 2-3.

Table 2-3: Machine data

Maximum payload (including 25% overload)	m_L	3,500 kg
Weight of load carrying equipment	m_H	1,500 kg
Counterweight	m_b	3,250 kg
Drum diameter	d	400 mm
Moment of inertia of the drum	J_T	10 kgm²
Reeving	s	2
Efficiency of the mechanical system	$\eta_{mechanical\ system}$	90%
Hoisting distance	h	5 m
Hoisting velocity	v	0.556 m/s
Total travel time	t_h	10 s
Ramp-up and ramp-down time	t_a	1 s
Acceleration/deceleration	a	0.55556 m/s²
Cycle time	t_{total}	50 s
Daily operating duration		16 h

2.4.1 Geared motor

The motor is selected based on the static hoisting power:

$$P_{stat} = \frac{(5000\ \text{kg} - 3250\ \text{kg}) \cdot 9{,}81\,\frac{\text{m}}{\text{s}^2} \cdot 0{,}556\,\frac{\text{m}}{\text{s}}}{0{,}9} = 10605\ \text{W} = 10{,}605\ \text{kW}$$

Corresponding to Fig. 2-9, the IE3 induction motor 1LE1003-1DB2 with an 11kW power rating and the motor data listed below is selected.

Fig. 2-9: Motor selected from the SIMOTICS low-voltage motor catalog

P_N, 50 Hz	P_N, 60 Hz 1)	Baugröße	Betriebswerte bei Bemessungsleistung: n_N, 50 Hz	M_N, 50 Hz	IE-Klasse	η_N, 50 Hz, 4/4	η_N, 50 Hz, 3/4	η_N, 50 Hz, 2/4	$\cos\varphi_N$, 50 Hz, 4/4	I_N, 50 Hz, 400 V	M_A/M_N, 50 Hz	I_A/I_N, 50 Hz	M_K/M_N, 50 Hz	L_{pfA}, 50 Hz	L_{WA}, 50 Hz	Aluminiumreihe 1LE1003 – IE3-Ausführung nach IEC 60034-30 Bestell-Nr.	$m_{IM\ B3}$	J	Momentenklasse
kW	kW	BG	min^{-1}	Nm		%	%	%		A				dB(A)	dB(A)	▲ Neuaufnahme	kg	kgm^2	KL
• Kühlung: eigengekühlt (IC 411) • Wirkungsgrad: Premium Efficiency IE3, Servicefaktor (SF) 1,15 • Isolierung: Thermische Klasse 155 (Wärmeklasse F), Schutzart IP55, Ausnutzung gemäß thermischer Klasse 130 (Wärmeklasse B)																			
2-polig: 3000 min^{-1} bei 50 Hz, 3600 min^{-1} bei 60 Hz 1)																			
0,75	**0,86**	**80 M**	2850	2,5	IE3	80,7	82,0	81,5	0,86	1,56	2,6	6,2	3,0	60	71	**1LE1003-0DA2■-■■■■**	11	0,0011	16
1,1	**1,3**	**80 M**	2885	3,6	IE3	82,7	82,7	81,7	0,85	2,25	2,8	7,4	3,8	60	71	**1LE1003-0DA3■-■■■■**	12	0,0013	16
1,5	**1,75**	**90 S**	2910	4,9	IE3	84,2	84,5	83,5	0,86	3,00	2,7	8,1	4,2	65	77	**1LE1003-0EA0■-■■■■**	15	0,0021	16
2,2	**2,55**	**90 L**	2920	7,2	IE3	85,9	86,8	86,1	0,88	4,2	2,6	8,3	4,0	65	77	**1LE1003-0EA4■-■■■■**	19	0,0031	16
3	**3,45**	**100 L**	2920	9,8	IE3	87,1	87,1	86,1	0,88	5,6	2,8	8,0	4,3	67	79	▲ **1LE1003-1AA4■-■■■■**	26	0,0054	16
4	**4,55**	**112 M**	2950	12,9	IE3	88,1	88,1	87,1	0,89	7,4	1,9	7,5	3,9	69	81	▲ **1LE1003-1BA2■-■■■■**	34	0,012	16
5,5	**6,3**	**132 S**	2950	17,8	IE3	89,2	89,2	88,2	0,90	9,9	1,8	7,4	3,6	68	80	▲ **1LE1003-1CA0■-■■■■**	43	0,024	16
7,5	**8,6**	**132 S**	2950	24,3	IE3	90,1	90,1	89,1	0,92	13,1	1,9	8,3	3,9	68	80	▲ **1LE1003-1CA1■-■■■■**	57	0,031	16
11	**12,6**	**160 M**	2955	35,5	IE3	91,2	91,2	90,2	0,89	19,6	2,4	7,9	3,8	70	82	▲ **1LE1003-1DA2■-■■■■**	75	0,053	16
15	**18**	**160 M**	2960	48,4	IE3	91,9	91,9	90,9	0,87	27,0	2,7	8,7	4,3	70	82	▲ **1LE1003-1DA3■-■■■■**	84	0,061	16
18,5	**22**	**160 L**	2955	60,0	IE3	92,4	92,4	91,4	0,90	32,0	2,8	9,0	4,2	70	82	▲ **1LE1003-1DA4■-■■■■**	94	0,068	16
4-polig: 1500 min^{-1} bei 50 Hz, 3600 min^{-1} bei 60 Hz 1)																			
0,55	**0,63**	**80 M**	1440	3,6	-	81,3	82,0	80,2	0,78	1,25	2,1	5,9	3,1	53	64	**1LE1003-0DB2■-■■■■**	11	0,0021	16
0,75	**0,86**	**80 M**	1450	4,9	IE3	82,5	82,3	80,0	0,75	1,75	2,7	7,1	3,9	53	64	**1LE1003-0DB3■-■■■■**	14	0,0029	16
1,1	**1,3**	**90 S**	1440	7,3	IE3	84,1	84,6	83,5	0,78	2,4	2,9	6,9	3,6	56	68	**1LE1003-0EB0■-■■■■**	16	0,0036	16
1,5	**1,75**	**90 L**	1445	9,9	IE3	85,3	85,9	84,9	0,80	3,15	2,6	7,2	2,7	56	68	**1LE1003-0EB4■-■■■■**	19	0,0049	16
2,2	**2,55**	**100 L**	1465	14,3	IE3	86,7	86,7	85,7	0,83	4,4	2,1	7,6	3,6	60	72	▲ **1LE1003-1AB4■-■■■■**	30	0,014	16
3	**3,45**	**100 L**	1460	19,6	IE3	87,7	87,7	86,7	0,83	5,9	2,3	7,3	3,7	60	72	▲ **1LE1003-1AB5■-■■■■**	30	0,014	16
4	**4,55**	**112 M**	1460	26,0	IE3	88,6	88,6	87,6	0,82	7,9	2,4	7,1	3,7	58	70	▲ **1LE1003-1BB2■-■■■■**	34	0,017	16
5,5	**6,3**	**132 S**	1470	35,7	IE3	89,6	89,6	88,6	0,84	10,5	2,1	7,2	3,4	64	76	▲ **1LE1003-1CB0■-■■■■**	64	0,046	16
7,5	**8,6**	**132 M**	1470	48,7	IE3	90,4	90,4	89,4	0,84	14,3	2,4	7,4	3,5	64	76	▲ **1LE1003-1CB2■-■■■■**	64	0,046	16
11	**12,6**	**160 M**	1475	71,0	IE3	91,4	91,4	90,4	0,84	20,5	2,2	6,9	3,2	65	77	▲ **1LE1003-1DB2■-■■■■**	83	0,083	16
15	**18**	**160 L**	1475	97,0	IE3	92,1	92,1	91,1	0,82	28,5	2,5	8,5	3,8	65	77	▲ **1LE1003-1DB4■-■■■■**	100	0,99	16

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The motor data from the catalog are summarized in Table 1-1.

Table 2-4: Data of the 1LE1003-1DB2 motor

Rated power	$P_{motor,n}$	11 kW
Rated speed	$N_{motor,n}$	1475 rpm
Rated torque	$M_{motor,n}$	71 Nm
Efficiency	η_{motor}	91,4 %
Cos φ	Cos φ	0,84
Rated current	In	28.5 A
Breakdown torque	$M_{motor,k}$	227,2
Moment of inertia	J	0.083 kgm²

The mass moment of inertia of the load is 330 kgm².

$$J_{Load} = (3500 + 1500 + 3250) \cdot \left(\frac{0,4}{2}\right)^2 = 330\ \text{kgm}^2$$

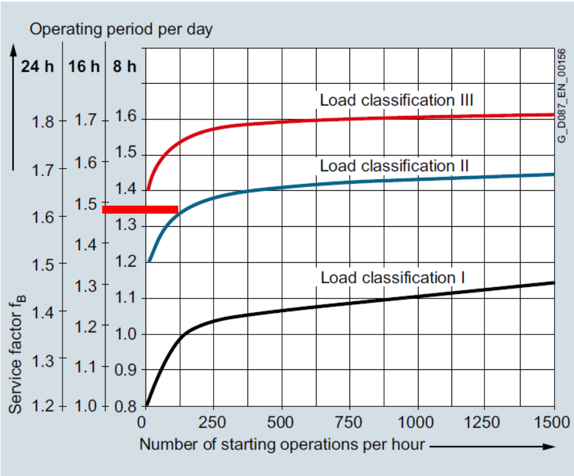
The optimum gearbox ratio from an energy perspective is 33.38 – and the mass acceleration factor for this ratio is equal to one, which represents a load classification of II.

$$i_{opt} = \sqrt{\frac{\frac{330\ \text{kgm}^2}{2^2} + 10\ \text{kgm}^2}{0,083\ \text{kgm}^2}} = 33,38$$

The gearbox is subject to 72 switching operations per hour.

$$\text{Schalthäufigkeit pro Stunde} = \frac{3600\ \frac{s}{h}}{50\ s} = 72\ h^{-1}$$

Fig. 2-10: Determining the service factor required



From Fig. 2-11, a service factor of f_B of at least 1.5 is required, so that the Z.129 gearbox can be selected corresponding to these two values.

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Fig. 2-11: Gearbox selected from the SIMOGEAR geared motor catalog

P_{rated} kW	n_2 rpm	T_2 Nm	i -	F_{R2} N	f_B -	m kg	Article No. (Article No. supplement → below)	Order code No. of poles
11	**Z.149-LE160MF4E**							
	28	3 770	52.84	55 500	2.0	283	**2KJ3112 - ■ JP22 - ■ ■ V1**	
	31	3 350	46.98	54 000	2.3	283	**2KJ3112 - ■ JP22 - ■ ■ U1**	
	35	3 010	42.18	52 600	2.5	283	**2KJ3112 - ■ JP22 - ■ ■ T1**	
	D.129-LE160MF4E							
	19	5 630	78.78	29 000	0.89	223	**2KJ3211 - ■ JP22 - ■ ■ C1**	
	Z.129-LE160MF4E							
	24	4 460	62.48	29 300	1.1	219	**2KJ3111 - ■ JP22 - ■ ■ X1**	
	27	3 820	53.47	29 300	1.3	219	**2KJ3111 - ■ JP22 - ■ ■ W1**	
	29	3 590	50.33	29 300	1.4	219	**2KJ3111 - ■ JP22 - ■ ■ V1**	
	31	3 370	47.18	29 300	1.5	219	**2KJ3111 - ■ JP22 - ■ ■ U1**	
	35	2 980	41.82	29 300	1.7	219	**2KJ3111 - ■ JP22 - ■ ■ T1**	
	40	2 650	37.15	29 300	1.9	219	**2KJ3111 - ■ JP22 - ■ ■ S1**	
	44	2 390	33.52	29 300	2.1	219	**2KJ3111 - ■ JP22 - ■ ■ R1**	
	49	2 120	29.70	28 600	2.4	219	**2KJ3111 - ■ JP22 - ■ ■ Q1**	
	56	1 870	26.30	27 900	2.7	219	**2KJ3111 - ■ JP22 - ■ ■ P1**	
	63	1 670	23.41	27 100	3.0	219	**2KJ3111 - ■ JP22 - ■ ■ N1**	

Table 2-5: Data of the Z.129-LE160MF4E gearbox

Output torque	$M_{gearbox,n}$	2390 Nm
Gear ratio	i	33,52
Service factor	f_B	2,1
Efficiency	$\eta_{gearbox}$	Approx. 96 %

For the hoisting velocity, a motor speed of 1780 revolutions per minutes is obtained.

$$n_{Motor,Hoist} = \frac{2 \cdot 0{,}556\ \frac{m}{s} \cdot 33{,}52}{3{,}14 \cdot 0{,}4\ m} = 29{,}68\ s^{-1} = 1780\ min^{-1}$$

The static torque is 59.28 Nm

$$M_{Motor,stat} = \frac{(5000\ kg - 3250\ kg) \cdot 9{,}81\ \frac{m}{s^2} \cdot 0{,}4\ m}{0{,}9 \cdot 0{,}96 \cdot 2 \cdot 2 \cdot 33{,}52} = 59{,}28\ Nm$$

and the dynamic torque is 31.29 Nm.

$$M_{Motor,dyn} = \frac{(5000\ kg + 3250\ kg) \cdot 0{,}55556\ \frac{m}{s^2} \cdot 0{,}4\ m}{0{,}9 \cdot 0{,}96 \cdot 2 \cdot 2 \cdot 33{,}52}$$

$$+0{,}083\ kgm^2 \cdot \frac{2 \cdot \pi \cdot 1780\ min^{-1}}{1\ s \cdot 60\ \frac{s}{min}} = 31{,}29\ Nm$$

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To evaluate the motor stability, it must be checked as to whether the peak load torque lies below the stall torque plus a reserve of 30%. The peak torque is at 1780 rpm and is 90.6 Nm. At a motor speed of 1780 rpm the motor stall torque must be greater than 117.8 Nm.

$$M_K \geq 1{,}3 \cdot (59{,}3\ \mathrm{Nm} + 31{,}3\ \mathrm{Nm}) = 117{,}8\ \mathrm{Nm}$$

As this operating point is located in the field weakening range, the S1 motor characteristic must be used to make a check. Fig. 2-12 shows the S1 characteristic of the selected motor as well as the characteristic of the motor stall torque minus the 30% safety margin. Further, the relative load torque at the rms current and the peak torque is shown. The first stability criterion is fulfilled, if the relative load torque – i.e. the continuous rms load – lies below the S1 characteristic. The second criterion is also fulfilled, as the peak torque lies below the stall torque characteristic minus the safety margin.

Fig. 2-12: Motor speed-torque characteristic from SIZER

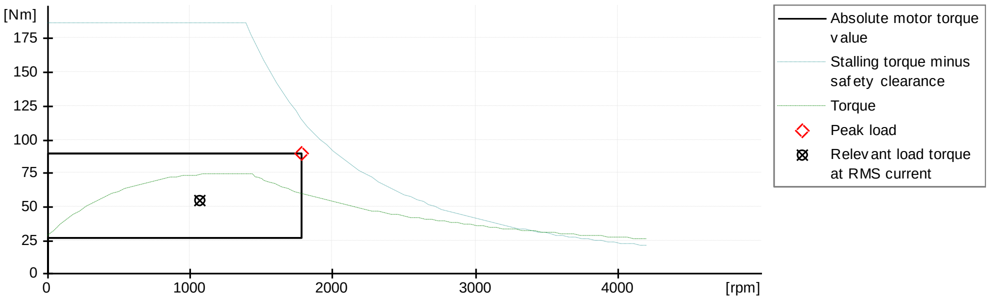
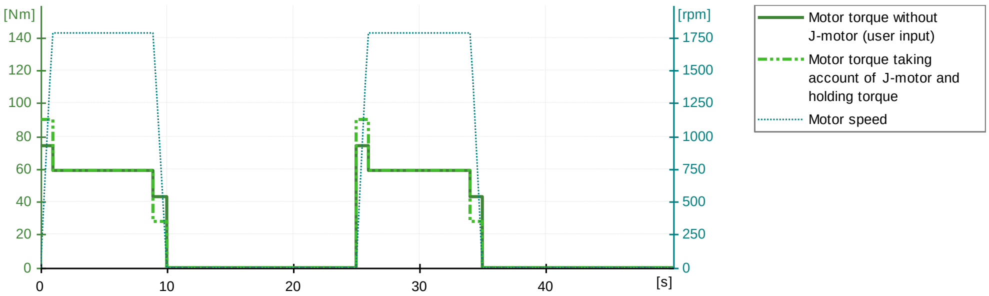


Fig. 2-13 shows the associated speed-torque characteristic with respect to time.

Fig. 2-13: Speed-torque characteristic of the load cycle from SIZER



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Options

The rated motor torque is 71 Nm. With the usual requirement for serial hoisting equipment that the rated braking torque is at least twice as high as the rated motor torque, the following is obtained:

$$M_{Motor,n} \cdot 2 \leq M_{Brems,n}$$

This is the reason that brake L150 is selected, see Fig. 2-14.

Fig. 2-14: Motor holding brake selected from the SIMOGEAR geared motor catalog

Brake type	Rated braking torque T_{br} at 100 rpm	Disconnection time t_2 Standard excitation	Disconnection time t_2 Overexcitation	Application time $t_1 = t_{11} + t_{12}$ (AC and DC switched or DC switched)	Response time t_{11} (AC and DC switched or DC switched)	Rise time t_{12} (AC and DC switched or DC switched)	Application time $t_1 = t_{11} + t_{12}$ (AC switched)	Response time t_{11} (AC switched)	Rise time t_{12} (AC switched)	Weight	Moment of inertia J_B	Moment of inertia J_B For wear-resistant lining
	Nm	ms	ms	ms	ms	ms	ms	ms	ms	kg	10^{-4} kgm^2	10^{-4} kgm^2
L4/1.4	1.4	20	13	31	13.0	18.0	250	110	140	0.85	0.11	0.15
L4/2	2.0	27	17	22	9.0	13.0	175	77	98			
L4/3	3.0	29	18	30	12.0	18.0	230	101	129			
L4	4.0	45	28	28	15.0	13.0	190	120	70			
L4/5	5.0	56	35	25	13.0	12.0	158	100	58			
L8/3	3.0	21	12	65	39.0	26.0	510	326	184	1.5	0.34	0.61
L8/4	4.0	30	17	50	30.0	20.0	390	250	140			
L8/5	5.0	35	20	40	24.0	16.0	310	200	110			
L8/6.3	6.3	45	30	38	18.0	20.0	315	174	141			
L8	8.0	57	38	31	15.0	16.0	245	135	110			
L8/10	10.0	71	47	26	12.5	13.5	205	113	92			
L16/8	8.0	55	41	36	22.0	14.0	350	183	167	2.6	2	2
L16/10	10.0	48	36	58	35.0	23.0	680	355	325			
L16/13	13.0	60	34	50	30.0	20.0	560	293	267			
L16	16.0	76	48	47	28.0	19.0	460	240	220			
L16/20	20.0	93	59	38	23.0	15.0	390	204	186			
L32/14	14.0	65	50	46	27.0	19.0	400	210	290	3.9	4.5	4.5
L32/18	18.0	65	44	70	45.0	25.0	600	325	275			
L32/23	23.0	82	56	75	40.0	35.0	680	300	380			
L32	32.0	115	78	53	28.0	25.0	490	215	275			
L32/40	40.0	140	95	45	24.0	21.0	440	194	246			
L60/25	25.0	130	66	47	25.0	22.0	540	220	320	5.8	6.3	6.3
L60/38	38.0	140	60	60	24.0	36.0	800	290	510			
L60/50	50.0	175	75	50	20.0	30.0	665	240	425			
L60	60.0	210	90	42	17.0	25.0	580	210	370			
L80/25	25.0	95	56	103	48.0	55.0	1 600	690	710	8.4	15	15
L80/35	35.0	128	75	73	34.0	39.0	1 200	520	680			
L80/50	50.0	160	94	90	42.0	48.0	1 920	830	1 090			
L80/63	63.0	170	100	72	34.0	38.0	1 550	670	880			
L80	80.0	220	130	57	27.0	30.0	1 200	520	680			
L80/100	100.0	280	165	49	24.0	25.0	990	430	560			
L150/60	60.0	135	81	55	27.5	27.5	920	470	450	12.5	29	29
L150/80	80.0	180	108	40	20.0	20.0	690	350	340			
L150/100	100.0	180	108	93	48.0	45.0	1 300	700	600			
L150/125	125.0	225	135	85	44.0	41.0	1 200	650	550			
L150	150.0	270	160	78	33.0	45.0	1 080	480	600			

A function rectifier equipped with fast rectifier and shutdown on the DC side must always be selected to control the brake.

Absolute encoder 1XP8024-21 with SSI position values and HTL incremental tracks is used as the motor encoder.

The option for the KTY 84 – 130 motor temperature sensor is selected by specifying code M16.

2.4.2 Inverter

The inverter is dimensioned based on the actual motor currents. The reactive current in field weakening at 1780 rpm is 12.8 A.

$$I_{Motor,Reactive} = 28{,}5\ A \cdot \sqrt{1 - 0{,}84^2} \cdot \frac{1475}{1780} = 12{,}8\ A$$

The active current in field weakening at 1780 rpm is 24.1 A.

$$I_{Motor,Wirk} = 28{,}5\ A \cdot 0{,}84 \cdot \frac{59{,}3\ Nm}{71\ Nm} \cdot \frac{1780}{1475} = 24{,}1\ A$$

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The motor current when lifting the load is then 26.9 A.

$$I_{Motor,Hoist} = \sqrt{12{,}8^2 + 24{,}1^2} = 26{,}9\ A$$

The rms motor current referred to the load cycle is 17 A.

$$I_{Motor,Eff} = \sqrt{\frac{1}{50s} \cdot (10s \cdot 26{,}9^2 A + 10s \cdot 26{,}9^2 A)} = 17\ A$$

The power unit of the G120 to be selected must provide a rated output current or at least 17 A based on high overload.

$$I_{Motor,Eff} \leq I_{Inverter,HO}$$

The PM240-2 power unit from a power rating of 7.5 kW fulfills this condition, see Fig. 2-15.

Fig. 2-15: PM240-2 selected from the SINAMICS single-axis drive catalog

Rated Power LO		Rated output current LO	Rated Power HO		Rated output current HO
kW	hp	A	kW	hp	A
3 AC 380 ... 480 V [4)]					
0,55	0,75	1,7	**0,37**	0,5	1,3
0,75	1	2,2	**0,55**	0,75	1,7
1,1	1,5	3,1	**0,75**	1	2,2
1,5	2	4,1	**1,1**	1,5	3,1
2,2	3	5,9	**1,5**	2	4,1
3	4	7,7	**2,2**	3	5,9
4	5	10,2	**3**	4	7,7
5,5	7,5	13,2	**4**	5	10,2
7,5	10	18	**5,5**	7,5	13,2
11	15	26	**7,5**	10	18
15	20	32	**11**	15	26

Table 2-6: Power unit data

Rated power	$P_{inverter,HO}$	7.5 kW
Rated output current	$I_{inverter,HO}$	18 A
Overload capability		2 * $I_{inverter,HO}$ for 3s every 5 min 1.5 * $I_{inverter,HO}$ for 57s every 5 min

The overload capability should now be checked.

$$I_{Motor,Active,max} = 28{,}5\ A \cdot 0{,}84 \cdot \frac{90{,}6\ Nm}{71\ Nm} \cdot \frac{1780}{1475} = 36{,}9\ A$$

$$I_{Motor,max} = \sqrt{12{,}8^2 + 36{,}9^2} = 39{,}1\ A$$

In five minutes, the serial hoisting equipment runs through six cycles, so that the maximum motor current of 39.1 A flows when lifting and at the same time accelerating for a period of six seconds. Further, within a period of five minutes, the motor draws the static motor current of 26.9 A for a total of 114 seconds. As a consequence, the 7.5kW power unit does not have the specified overload capability. This is the reason why the 11 kW power unit must be selected.

Depending on the setpoint input, a Control Unit (CU) must be selected. When using PROFINET and a motor encoder, the CU250S-2 PN is selected without extended safety functions.

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Braking resistor for the PM240-2 power unit

The braking resistor is selected to match the power unit, and the technical data can be taken from Table 2-7.

Table 2-7: Braking resistor data

Resistance	R	30 Ω
Rated power	$P_{resistor,rms}$	0.925 kW
Peak power	$P_{resistor,max}$	18.5 kW

The peak regenerative power when lowering is calculated. The static regenerative power is 7.3 kW.

$$P_{Gen,stat} = (5000\ kg - 3250\ kg) \cdot 9{,}81\ \frac{m}{s^2} \cdot 0{,}556\ \frac{m}{s} \cdot 0{,}9 \cdot 0{,}914 \cdot 0{,}96 \cdot 0{,}97$$
$$= 7311\ W = 7{,}31\ kW$$

$$M_{Gen,dyn} = \frac{(5000\ kg + 3250\ kg) \cdot 0{,}55556\ \frac{m}{s^2} \cdot 0{,}4 \cdot 0{,}9 \cdot 0{,}96}{2 \cdot 2 \cdot 33{,}52}$$
$$+0{,}083\ kgm^2 \cdot \frac{2 \cdot \pi \cdot 1780\ min^{-1}}{1\ s \cdot 60\ \frac{s}{min}} = 27{,}3\ Nm$$

The peak regenerative power is 11.8 kW.

$$P_{Gen,max} = 7311 + \left(27{,}3 \cdot 2 \cdot 3{,}14 \cdot 1780 \cdot \frac{1}{60\ s}\right) \cdot 0{,}914 \cdot 0{,}97 = 7311\ W + 4509\ W$$
$$= 11820\ W = 11{,}8\ kW$$

The maximum regenerative power of 11.8 kW can be dissipated using a resistor with peak power of 18.5 kW.

$$P_{Resistor,max} = 18{,}5\ kW$$

$$P_{Gen,max} = 11{,}8\ kW \leq P_{Resistor,max} = 18{,}5\ kW$$

In addition to the peak power, the braking resistor must also be able to absorb the rms regenerative power in continuous operation. The rms regenerative power of the load cycle is first calculated. Lowering represents 20% of the overall load cycle.

$$t_r = \frac{t_{Lowering}}{t_{total}} = \frac{10\ s}{50\ s} = 0{,}2$$

The rms regenerative power is 3.3 kW.

$$P_{Gen,eff} = \sqrt{0{,}2 \cdot 7{,}31^2} = 3{,}269\ kW$$

The regenerative power must be less than the rated power of the resistor.

$$P_{Gen,eff} \leq P_{Resistor,eff} = 0{,}925\ kW$$

The rated power of the resistor is too low, so that in this case four resistors must be used connected in a series and parallel configuration, see Fig. 2-8.

Selecting the PM250 power unit with energy recovery

As has already been calculated, the maximum regenerative power that occurs is 11.8 kW. As a maximum, the PM250 can feed back its rated power, respectively its rated current. As a consequence, instead of the 11 kW power unit, in this case, the next larger power unit must be selected with a rated power of 15 kW for high overload.

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Fig. 2-16: PM250 power unit from the SINAMICS single-axis drive catalog

Rated power [1]		Rated output current I_{rated} [2]	Power based on the base-load current [3]		Base-load current I_H [3]	Frame size	PM250 Power Module without integrated line filter	PM250 Power Module with integrated line filter class A
kW	hp	A	kW	hp	A		Order No.	Order No.
380 ... 480 V 3 AC								
7.5	10	18	**5.5**	7.5	13.2	FSC	–	**6SL3225-0BE25-5AA1**
11.0	15	25	**7.5**	10	19	FSC	–	**6SL3225-0BE27-5AA1**
15.0	20	32	**11.0**	15	26	FSC	–	**6SL3225-0BE31-1AA1**
18.5	25	38	**15.0**	20	32	FSD	**6SL3225-0BE31-5UA0**	**6SL3225-0BE31-5AA0**
22	30	45	**18.5**	25	38	FSD	**6SL3225-0BE31-8UA0**	**6SL3225-0BE31-8AA0**

Further, there is a supply transformer with 250 kVA and a U_k of 6%. This results in a transformer short-circuit power of

$$P_{Transformer,short-circuit} = \frac{250\ KVA}{0{,}06} = 4{,}166\ MVA$$

The apparent inverter power at rated power is

$$P_{Inverter,Apparent} = \frac{P_{Inverter,HO}}{\lambda \cdot \eta_{Inverter}} = \frac{15\ kW}{0{,}9 \cdot 0{,}97} = 17{,}2\ kVA$$

The total power of all PM250 power units must have an R_{SCE} greater than 100:

$$R_{SCE} = \frac{P_{Transformer,short-circuit}}{\sum P_{Inverter,Apparent}} = \frac{4166\ kVA}{17{,}2\ kVA} = 242 \gg 100$$

The power unit can be selected for this transformer, as the line supply is appropriately stiff (has the appropriate fault level).

Conclusion

It is possible to manually engineer serial hoisting equipment. However, the motor characteristic must be precisely known for high dynamic requirements, utilization of the overload capability and field weakening. Therefore, we always recommend that SIZER is used for engineering.

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3 Basic commissioning

This chapter describes commissioning the drive functions essential for a hoisting drive.

Preconditions:

- Basic knowledge about SINAMICS inverters
- SINAMICS STARTER commissioning software from version 4.4
- SINAMICS G120 firmware from V4.6 with CU240E-2 or CU250S-2

Commissioning serial hoisting equipment for three different types of applications is described in the following:

- U/f control with CU240E-2
- Encoderless speed control with CU240E-2
- Speed control with encoder with CU250S-2

Note

Using the CU250S-2 Control Unit, in addition to speed control with encoder, positioning can also be implemented in the drive. A detailed application example to commission the position control with the basic positioner (EPos) is provided here in \5\.

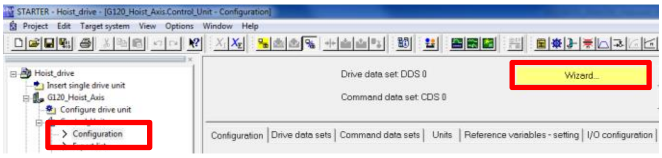
WARNING

The Emergency Off functions must be fully operational during commissioning. To protect the machines and personnel, the relevant safety regulations must be observed.

3.1 Commissioning Wizard

You are connected online with the drive. The drive is in the factory setting. Start the Wizards under "Control_Unit > Configuration".

Table 3-1 Preconfigured the drive using the wizard

Procedure	Remark
Open the Wizard	
Control structure ➔ Press»Next«.	Select one of the following • [0]U/f control with linear characteristic • [20] speed control (without encoder) • [21] speed control (with encoder)
Default settings for setpoints/command sources ➔ Press»Next«.	Depending on the local situation, at the system, select. The I/O configuration can be subsequently modified using the expert list or the Wizard – and adapted to what is actually required for the application.
Drive setting ➔ Press»Next«.	Standard: select, corresponding to the particular application Power unit application: "[0] Load cycle with high overload for vector drives"

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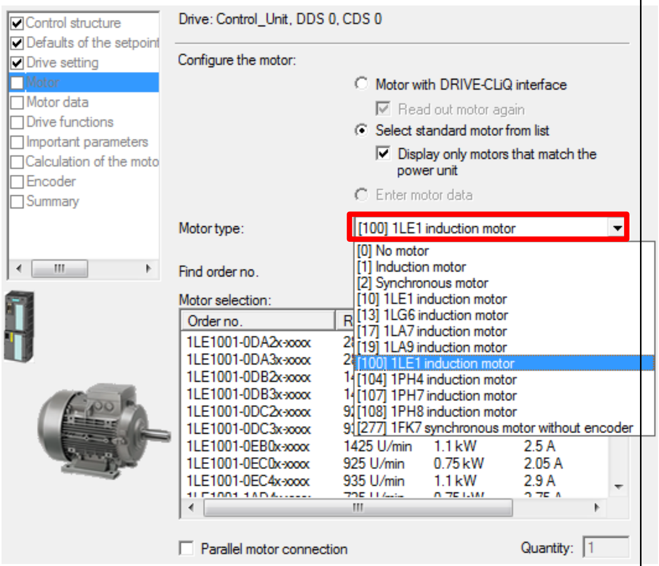
<table>
<tr><th>Procedure</th><th>Remark</th></tr>
<tr><td>Motor

➔ Press»Next«.</td><td>Motor type:

"[1] Select an induction motor" or a Siemens motor type.
The actual SIMOTICS GP motors can be selected using a selection list.



For third-party motors, and motors that are not included in the list, use "Enter motor data"
Do not set a checkmark for "Parallel motor connection"!
</td></tr>
<tr><td>Motor data

➔ Press»Next«.</td><td>
At first select "Star or delta" motor connection type
For third-party motors, or motors not in the selection lists, enter the rating plate data »Enter motor data«.
If necessary, "87Hz calculation"
</td></tr>
<tr><td>Drive functions
➔ Press»Next«.</td><td>
Motor identification: [2] Identify motor data (at standstill)
</td></tr>
</table>

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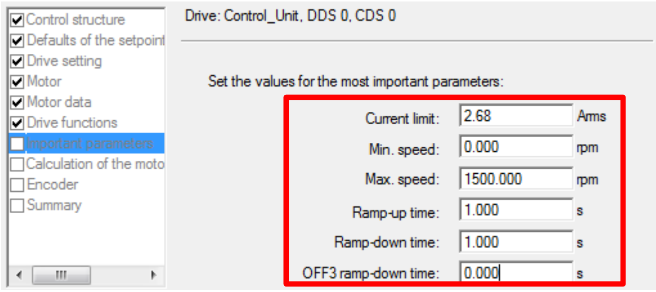
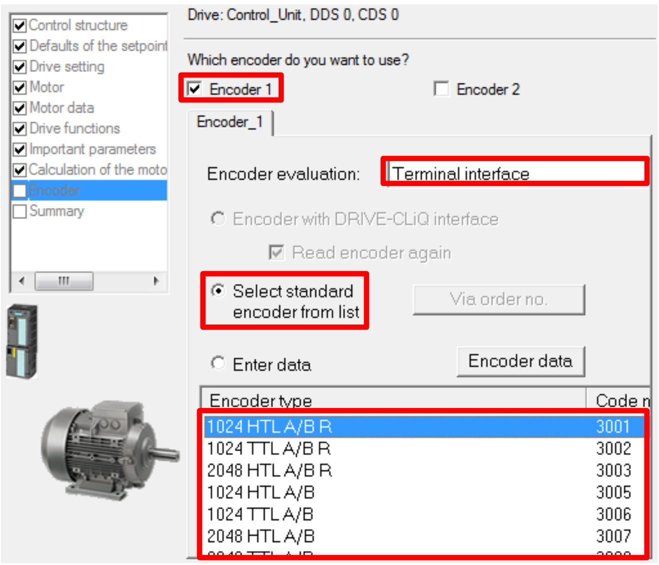
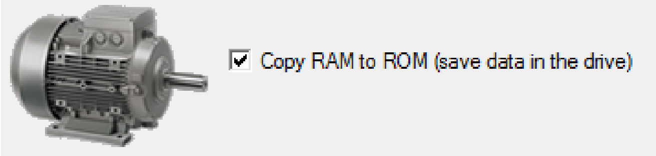
Procedure	Remark
Important parameters ➔ Press»Next«.	 • Keep the minimum speed at zero rpm • Max. speed, the rated line speed is set corresponding to the number of pole pairs. This is automatically interpolated for a 87Hz characteristic. Set the limit higher if you wish to allow operation in the field weakening range. • Set the ramp-up and ramp-down time corresponding to the acceleration required. The value refers to the time from zero up to the maximum speed. • Select an OFF3 ramp-down time of zero seconds so that the brake is immediately applied in the case of a fault!
Calculating the motor data ➔ Press»Next«.	Select "Complete calculation" of the motor parameters
	A progress bar is displayed: "Completing commissioning"
Encoder: ➔ Press»Next«.	Activate encoder_1 when using speed control with encoder. (it is defined that encoder_2 is on the load side, and encoder_1 is on the motor side.) - select the corresponding encoder interface, terminal, D-SUB or DRIVE-CLiQ - Select a standard encoder from the list, or enter the appropriate data  For U/f characteristic p1300<20 you are not prompted to enter/select an encoder.

Procedure	Remark
Summary ➔ Press»Finish«.	Activate"RAM to ROM (backup data in the drive)" 

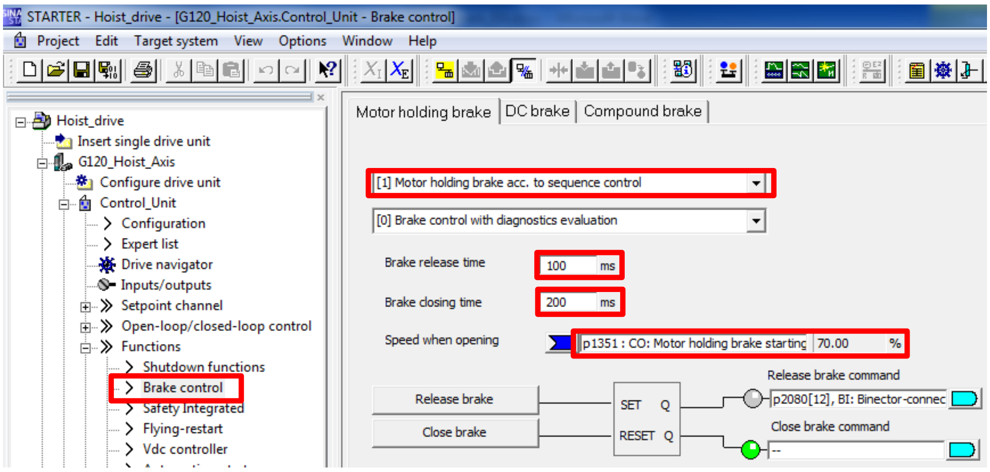
Data is transferred into the non-volatile memory by transferring from RAM to ROM. After running through the various wizards, load the configuration to the PG, or to the PC, and then save the project.

3.2 Drive functions

3.2.1 Brake Control

If the drive controls the brake, the brake control must be set under "Control_Unit > Functions > Brake control".

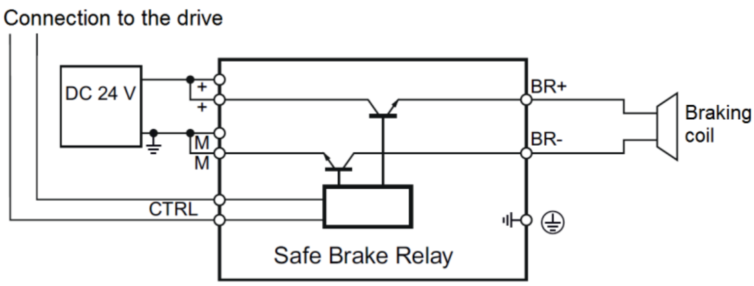
Fig. 3-1 Brake control with U/f



The brake control must be included in the sequence control, i.e. for ON1 it is released, and for OFF1, OFF2 or OFF3 it is applied. There are two possibilities of configuring the motor holding brake in the parameter P1215:

[1] Motor holding brake acc. to sequence control
The brake is controlled via the interface of the power unit and the brake relay, see Fig. 3-2.

Fig. 3-2: Brake control using the brake relay



[3] Motor holding brake acc. to sequence control, connection via BICO
A digital output of the control module is used to control an external relay. For this

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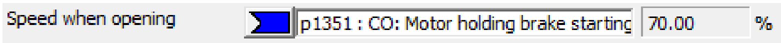
purpose, for example digital output DO 0 in P730 can be logically interlocked with the command to open the brake in the sequence control (P899.12).

Further, set the brake opening (P1216) and closing time (P1217). Slightly round off the closing time, so that the drive only switches off once the brake has reliably closed.

Behavior when opening the brake in U/f

A load step occurs after the brake opens. A starting frequency can be entered as percentage for the slip compensation using parameter P1351. Using a starting frequency in P1351 greater than zero, the slip compensation scaling (P1335) is automatically set to 100%. A starting frequency of 100% corresponds to the rated motor slip.

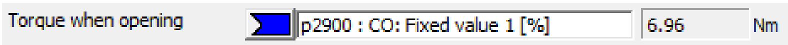
Fig. 3-3: Speed when opening the brake



Behavior when opening the brake in closed-loop speed control

Using parameter P1475, when opening the brake, a torque can be entered as a percentage, e.g. by linking with a fixed value P2900. A torque setting value of 50% corresponds to the rated motor torque.

Fig. 3-4: Torque when opening the brake



3.2.2 Dynamic braking

The following issues should be observed when using dynamic braking to dissipate energy in the regenerative mode without having energy recovery:

- Inhibit the Vdc controller:
  - Vdc controller configuration (vector control) p1240 to "[0] Inhibit Vdc controller" for speed control
  - Vdc controller configuration (U/f) p1280 to "[0] Inhibit Vdc controller" for U/f control
- Keep the DC braking configuration p1231 deactivated with "[0] No function"
- Keep the compound braking function inhibited

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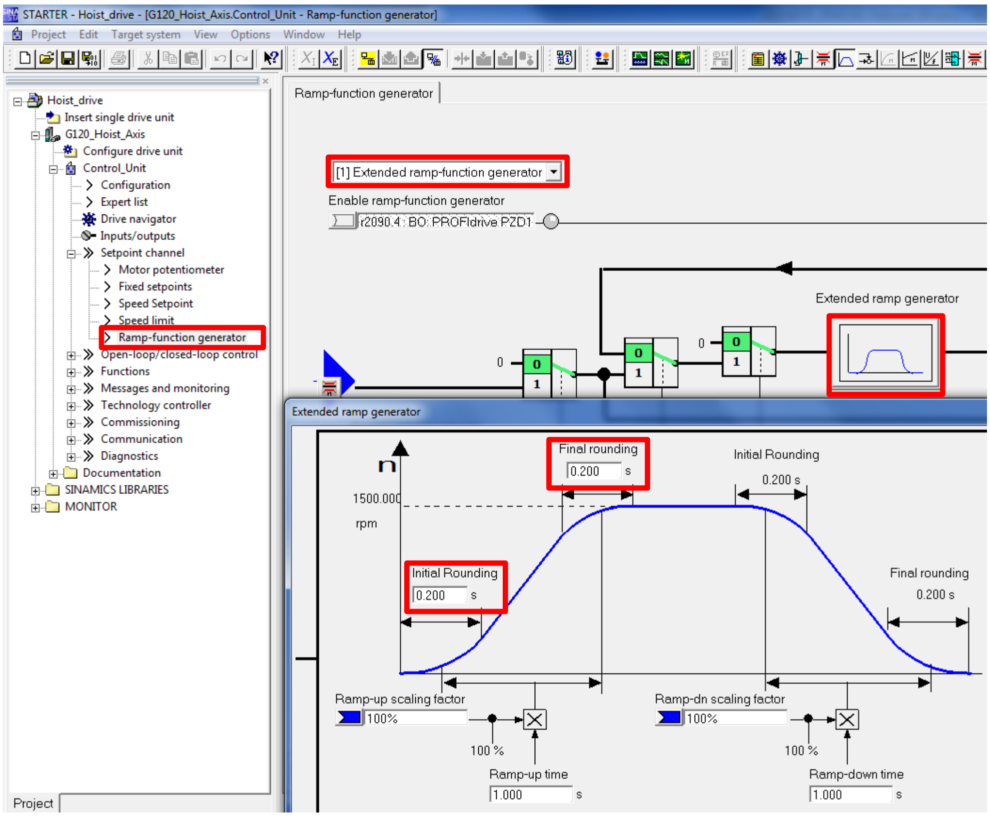
3.2.3 Jerk limiting

Rounding functions can be set under "Control_Unit > Setpoint channel > Ramp-function generator“ for jerk limiting. With the ramp-function generator selection p1115 = [1] extended ramp-function generator, initial rounding (p1130) and final rounding (p1131) can be parameterized. These rounding functions ensure a soft transition into and out of the steady-state condition, therefore reducing associated oscillations.

Fig. 3-5: Extended ramp-function generator



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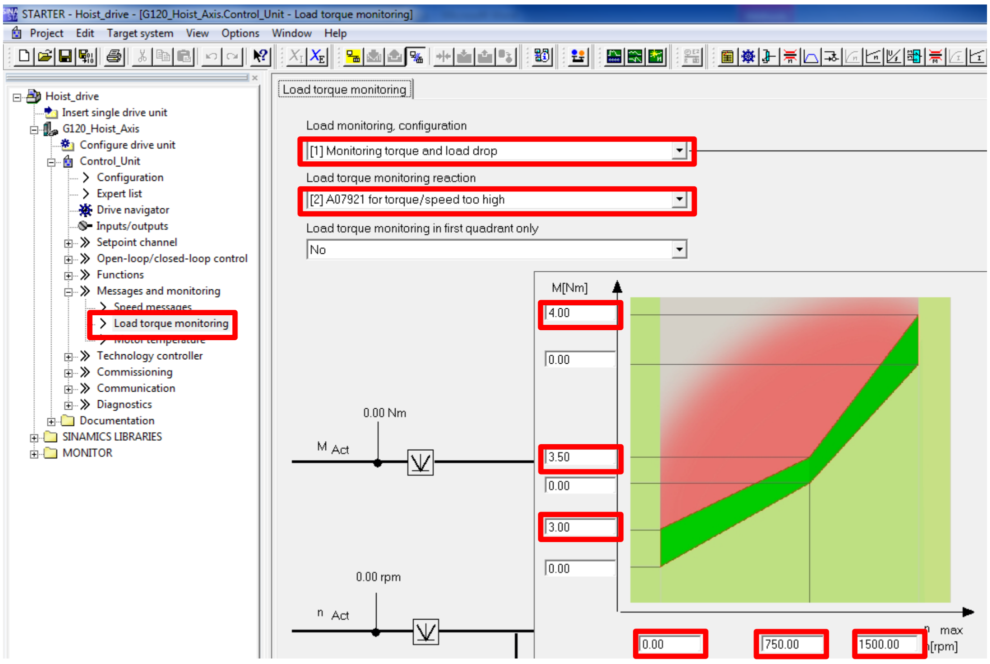
3.3 Monitoring functions

3.3.1 Load torque monitoring

Using the load torque monitoring function, under "Control_Unit > Messages and monitoring > Load torque monitoring“ you can monitor the hoisting drive for overload, cable or belt breakage as well as blockage. To do this, the load monitoring in p2193 should be configured with "[1] Monitoring torque and load drop". In p2181, fault "[2] A07921 for torque/speed too high" can be set as response.

Fig. 3-6: Setting the load monitoring to torque too high



In U/f control, current and torque limiting are not effective. As a consequence, load torque monitoring, especially in U/f control, provides the possibility of monitoring the drive for an overload condition.

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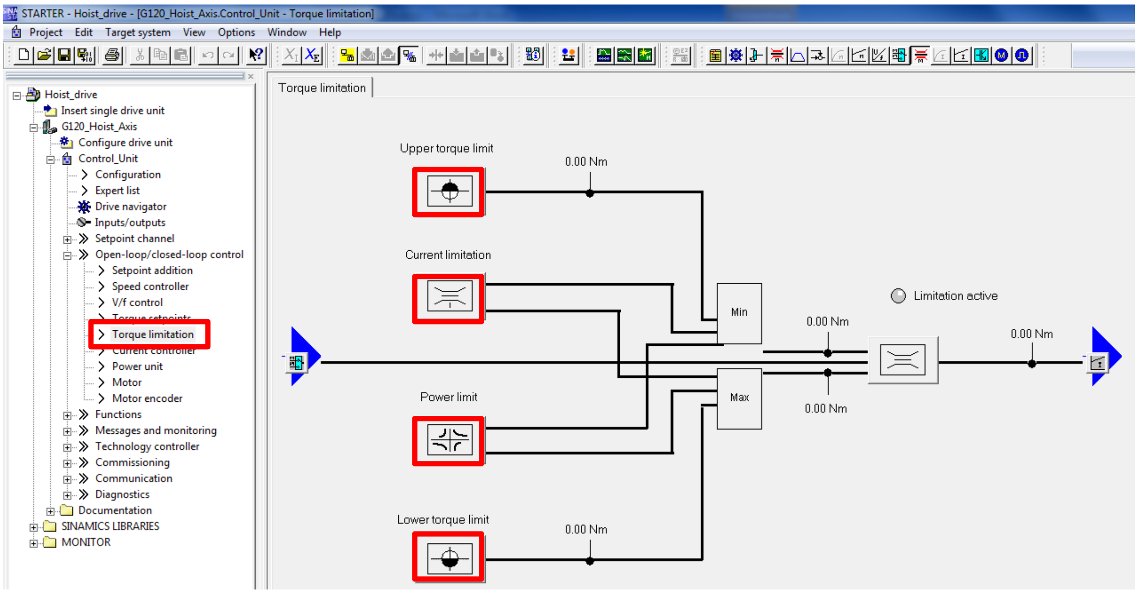
3.3.2 Torque limiting for speed control

To protect the motor against overload, you can enter limits under "Control_Unit > Open-loop/closed-loop control > Torque limiting“. You can increase the preset limit of 150% overload if it is not sufficient. In this case, increase the current limit (P640) up to a maximum of 200% of the rated motor current (P305). The torque limit is calculated from the current limit (P640). For the calculation, set P340 to "[5] Calculate technological limits and threshold values" in order to automatically adapt the torque limiting (you must be connected online with the drive).

NOTICE	When operating with high current limits, ensure that the motor is not overloaded!

If the power limit is active when accelerating with decelerating, you can also increase this limit. In P1530, set the power limit when motoring to three times the motor power. The power limit when generating can, for power units capable of energy recovery, be set to the maximum negative rated power of the power unit.

Fig. 3-7: Limits for vector control



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3.3.3 Temperature monitoring

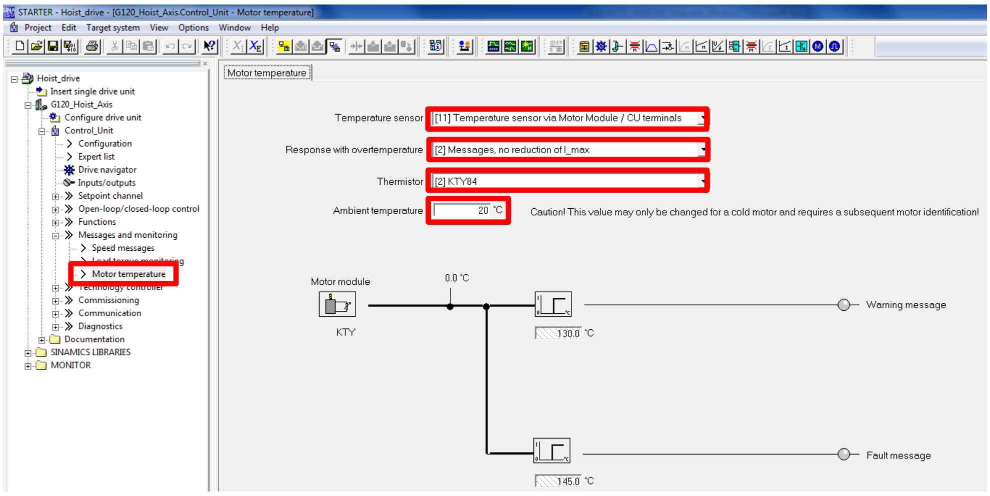
Inverter temperature monitoring

Parameter p290 (power unit overload response) defines how the inverter responds to an excessively high temperature. For hoisting applications "[1] No reduction, shutdown when overload threshold is reached (F30024)" should be set. The response where the output current is reduced should never be selected, as this would result in a loss of torque.

Motor temperature monitoring

You can set the motor temperature monitoring under "Control_Unit > Messages and monitoring > Motor temperature". Keep the response to overtemperature to the preset value "[12] Messages, no reduction of I_max temperature storage". A reduction of the output current should never be selected. Select the temperature sensor, ideally "[2] KTY84". Set the motor ambient temperature at the instant in time of the stationary measurement.

Fig. 3-8: Motor temperature monitoring



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Motor temperature monitoring without temperature sensor

The motor temperature can be calculated using the thermal model if a KTY temperature sensor is not being used. This is only possible for speed control, with or without encoder. Table 3-2 lists the parameters that are used to monitor the motor temperature based on the thermal model.

Table 3-2 Parameters for temperature sensing without temperature sensor

Parameter	Description
p344 motor mass (for the thermal motor model)	For IEC motors, enter the mass in kilograms and for NEMA motors im pounds. When selecting a Siemens catalog motor (p0301) this parameter is automatically written to.
p612.1 activate motor temperature model 2	= 1 (yes)
p621 Stator resistance identification after restart	In this case, after switching on the drive, the temperature can be indirectly measured. If the delay can be accepted, the measurement is most effective when it is carried out each time that the system is switched on.
p622 motor excitation build-up time	Corresponds to the magnetization time in p346 and the duration of the temperature measurement after switching on again
p625 Motor ambient temperature during commissioning	The temperature should be entered at the instant in time that the stationary measurement is carried out.

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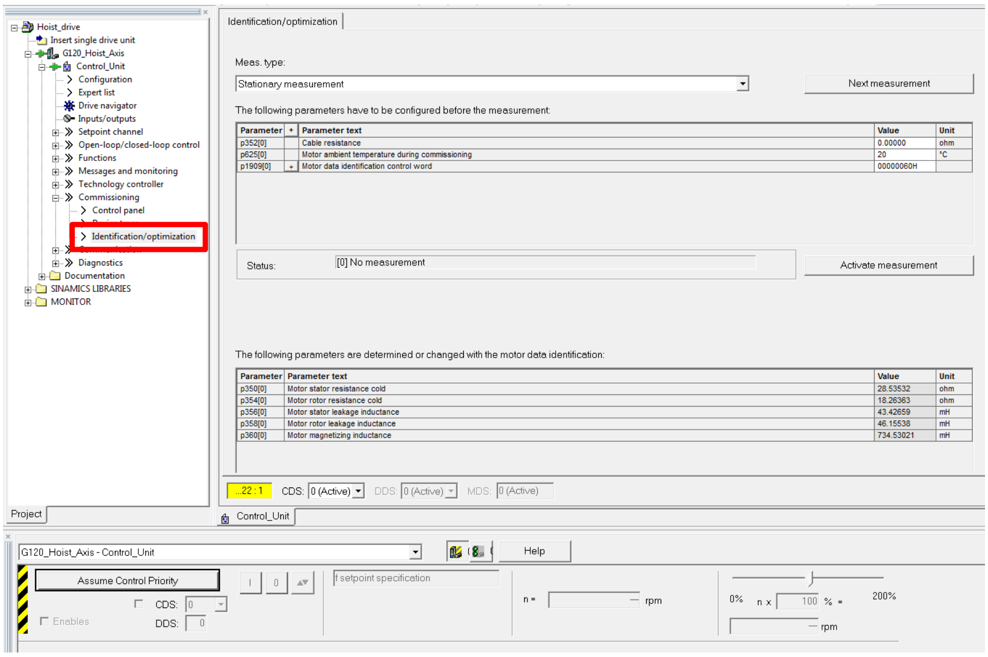
3.4 Motor identification using stationary measurement

After basic commissioning with the commissioning Wizards, the stationary measurement is activated, displayed by alarm A07991. The correct data on the motor rating plate is a precondition for the stationary measurement.

NOTICE	The stationary measurement should be carried out, especially when using third-party motors or long motor feeder cables. Otherwise, important parameters for the closed-loop control or voltage boost can only be estimated.

Open the STARTER screen under "Control_Unit > Commissioning > Identification/optimization" to carry out the stationary measurement. The control panel and the Identification/optimization window are opened.

Fig. 3-9: Identification/optimization of motor parameters



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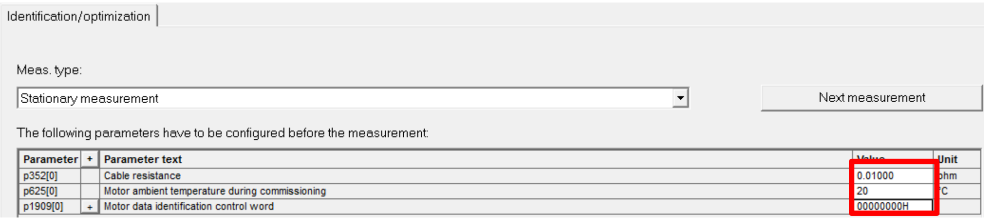
Note The motor must be at the ambient temperature for motor identification with stationary measurement. Further, output options such as motor reactor or sine-wave filter must be parameterized in p230.

Before the measurement, the cable resistance should be entered in p352 in order to achieve the most accurate result possible. It can be calculated using the following formula:

$$R = \frac{\varrho \cdot l}{S},$$

where l is the cable length in m, S the cable/conductor cross section in mm² and ϱ the specific resistance in Ω mm² per m (0.01724 for copper and 0.0278 for aluminum). Further, the ambient temperature must be specified in p625.

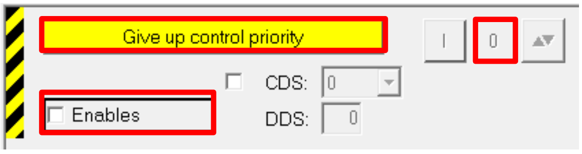
Fig. 3-10: Configuration of the stationary measurement



Note For a motor without connected load, the motor can rotate through half a revolution during the stationary measurement. However, no torque is generated. If possible, open the motor holding brake before the measurement.

Carry out the stationary measurement, by retrieving the master control, enabling the drive and switching it on.

Fig. 3-11: Control panel for the stationary measurement



After the stationary measurement has been completed, "[0] No measurement" and the measured values are displayed in the motor data identification window under status.

Note Back up the results from the stationary measurement by copying from RAM to ROM.

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4 Measures to avoid the load sagging/dropping

The main task of serial hoisting equipment is to hold the maximum payload. The following chapter describes measures when parameterizing the drive if load sag occurs.

4.1 Motor magnetization

Magnetizing induction motors is a basic precondition to hold a load. Please note that frequent load changes stress the power semiconductors and which countermeasures can be applied – see FAQ in \10\.

Magnetizing current

An induction motor draws a magnetizing current (p320 or r331) to establish a magnetic field. This corresponds to the motor reactive power, and is required to provide the rated motor torque. If a magnetizing current is not explicitly specified in p320, then the magnetizing current can be internally calculated from the rating plate data. The stationary and rotating measurements determine the magnetizing characteristic, whereby the rotating measurement is far more accurate. The magnetizing characteristic must be determined as accurately as possible for operation in the field weakening range. This is in order to achieve a high torque accuracy. The FAQ in \11\ provides a description on how to manually determine the magnetizing current. It can also be calculated from the motor rating plate data according to the formula (2.26).

Motor excitation build-up time

The motor excitation build-up time (P346) is the time between the inverter pulses being enabled and the ramp-function generator being enabled. This time is required to magnetize an induction motor. The parameter is calculated from the main and leakage inductance of the rotor, divided by the rotor resistance. When inadequately magnetized, an induction motor can stall under load or accelerating too fast. If the motor excitation build-up time is shortened, during build-up, the current limit can be reached so that the motor is not fully magnetized. As a consequence, we recommend that the excitation build-up time is not shortened.

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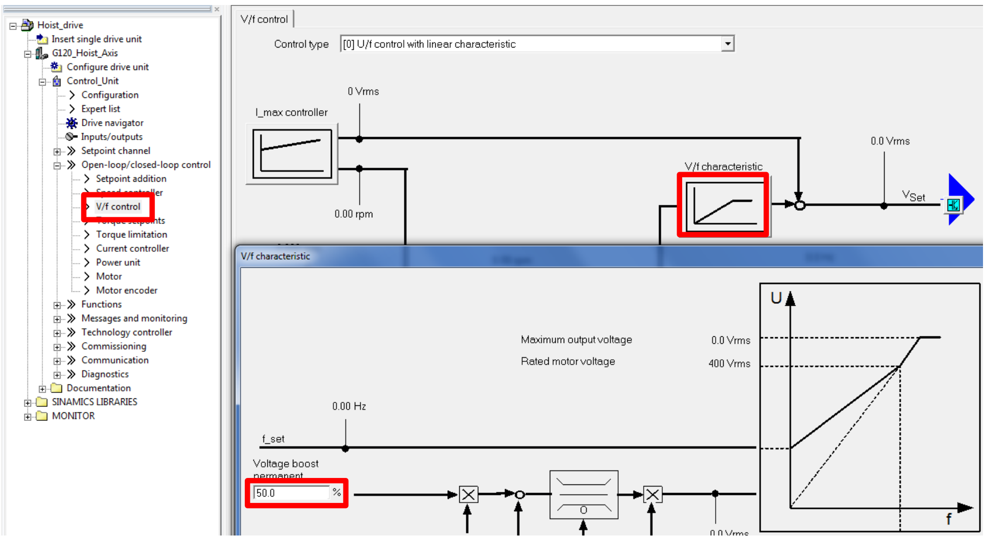
4.2 Load sag when using U/f control

The permanent voltage boost must be used if the load sags when starting or for operation at low speeds. This can be set under "Control_Unit > Open-loop/closed-loop control > U/f control > U/f characteristic button“. Increase the permanent boost in P1310 until the load no longer sags. If the voltage boost at low speeds is too high, an overcurrent fault can occur. In this case, the boost must be reduced. The ramp must be extended if the torque is no longer sufficient to achieve a defined acceleration ramp.

Fig. 4-1: Permanent voltage boost



NOTICE	The voltage boost increases the motor temperature rise at low speeds and at standstill

In order to guarantee the magnetic rated flux, for a U/f characteristic, the output current must always be ≥ the magnetizing current. The rated torque and accelerating torque are then available.

4.3 Load sag with speed control

4.3.1 Encoderless speed control

If the load sags for encoderless speed control, then the static torque setpoint (P1610) should be increased. The value as a percentage refers to the rated motor torque. For encoderless speed control, the drive starts in the open-loop controlled mode; this means that P1610 acts just like the voltage boost in U/f control.

Note Select P1610 so that it is at least 10% higher than the maximum payload of the serial hoisting equipment.

In addition, a supplementary accelerating torque (P1611) can be specified. For a pure accelerating torque, it is always more favorable to use the torque precontrol of the speed controller.

The static torque setpoint (P1610) and the supplementary accelerating torque (P1611) are added to the torque setpoint.

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Additional setting options

For serial hoisting equipment with encoderless speed control, the configuration of the motor model shown in Fig. 4-2 should always be selected. The calculation in the lower speed range is too prone to faults, so that the drive must start in the open-loop controlled mode.

Fig. 4-2: Motor model configuration

⊟ p1750[0]	D	Motor model configuration	3H
p1750[0].0	D	Controlled start	Yes
p1750[0].1	D	Controlled through 0 Hz	Yes
p1750[0].2	D	Closed-loop ctrl oper. down to zero freq. for passive loads	No
p1750[0].3	D	Motor model Lh_pre = f(PsiEst)	No
p1750[0].6	D	Closed-loop/open-loop controlled (PEM) for blocked motor	No
p1750[0].7	D	Use rugged changeover limits	No

When transitioning from the closed-loop controlled mode into the open-loop controlled mode, the drive can maintain the last valid output current. When again transitioning from the open-loop controlled into the closed-loop controlled mode, the current controller continues to calculate with this value. To do this, set "Sensorless vector control freeze I component" in P1400.1 to "Yes".

Fig. 4-3: Speed control configuration

⊟ p1400[0]	D	Speed control configuration	8023H
p1400[0].0	D	Automatic Kp/Tn adaptation active	Yes
p1400[0].1	D	Sensorless vector control freeze I comp	Yes
p1400[0].5	D	Kp/Tn adaptation active	Yes
p1400[0].6	D	Free Tn adaptation active	No
p1400[0]...	D	Torque pre-control	For n...
p1400[0]...	D	Sensorless vector control speed pre-control	Yes
p1400[0]...	D	Moment of inertia estimator active	No
p1400[0]...	D	Acceleration model	OFF
p1400[0]...	D	Obtain moment of inertia estimator value for pulse inhibit	No
p1400[0]...	D	Acceleration model (with speed encoder)	No

4.3.2 Speed control with encoder

If the load sags for speed control with an encoder, when opening the brake, a torque can be entered when opening the motor holding brake, see Chapter 3.2.1.

If the minimum load and the torque required for this are known, then supplementary torques p1511 or p1513 can be used.

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5 Optimizing the hoisting drive

In most cases, SINAMICS G120 with the factory setting of the control parameters, should supply satisfactory results. In exceptional cases, the hoisting drive must either be automatically optimized using the rotating measurement, or manually optimized.

5.1.1 Rotating measurement

For the rotating measurement, an encoder test is carried out, the saturation characteristic and the magnetizing current calculated, the speed controller optimized and the acceleration precontrol set. The saturation characteristic and the magnetizing current must be calculated at the motor with uncoupled load, i.e. ideally, also without coupled gearbox.

⚠ **CAUTION**	**Dangerous motor motion as a result of the rotating measurement** When carrying out the rotating measurement, the drive will cause the motor to move until it reaches the maximum motor speed. As serial hoisting equipment has a mechanical system that has specific limits, it must be carefully ensured that the end positions cannot be approached. If this is not absolutely ensured, then the rotating measurement cannot be performed.

To achieve an optimum result, a rotating measurement without load is first carried out and then the speed control is optimized under partial load conditions.

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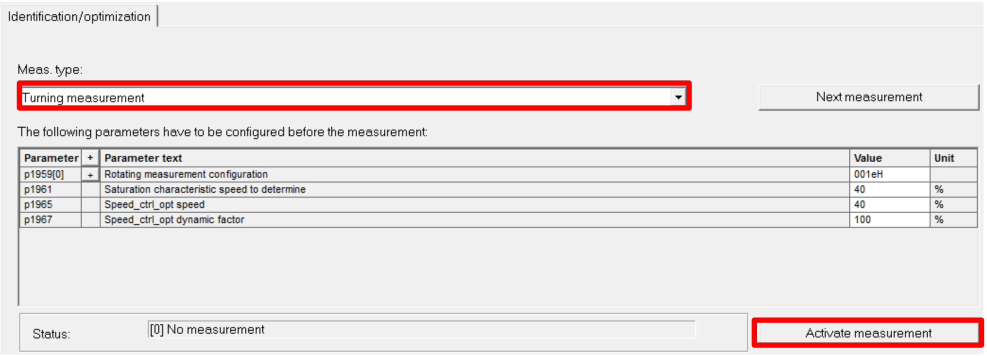
Rotating measurement without load

To carry out the rotating measurement, open the STARTER screen form under "Control_Unit > Commissioning > Identification/optimization". As measuring type, select "Turning measurement" and click on "Activate measurement".

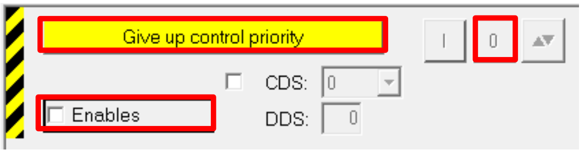
Fig. 5-1: Activating the rotating measurement



NOTE The motor holding brake must be opened for the rotating measurement.

Carry out the rotating measurement, by retrieving the master control, enabling the drive and switching it on.

Fig. 5-2: Control panel for the stationary measurement



After the rotating measurement has been completed, "[0] No measurement" and the measured values are displayed in the motor identification window under status.

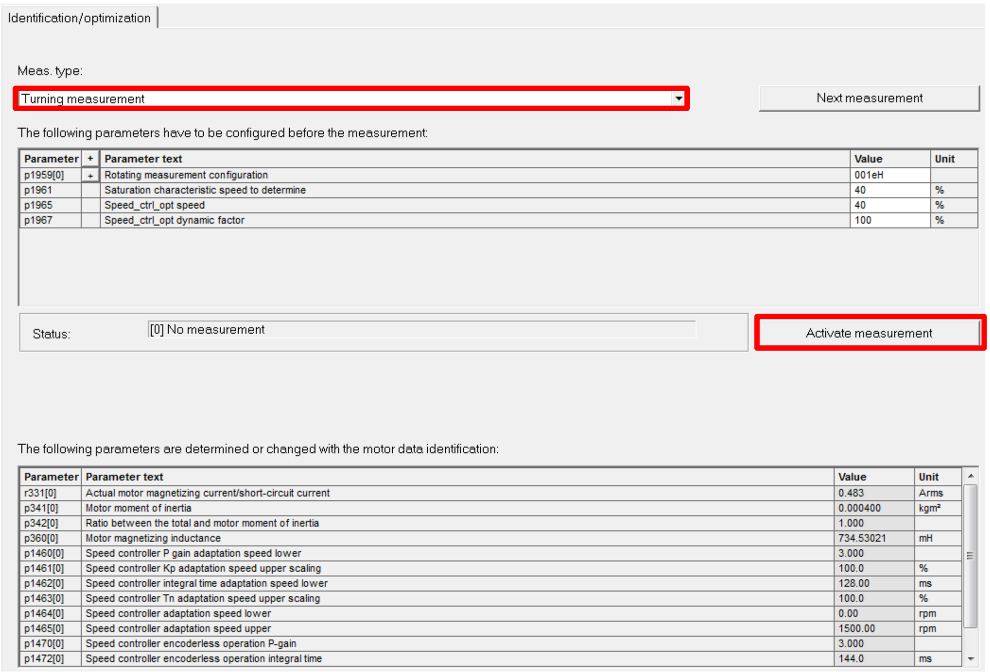
NOTE Back up the results from the rotating measurement by copying from RAM to ROM.

Speed controller optimization with rotating measurement under load

After the rotating measurement without load has been performed to calculate the motor magnetization and saturation characteristic, the speed controller can be optimized by itself under load. To do this, as measurement type, select "Speed controller optimization" as shown in Fig. 5-3 and activate the measurement. When configuring the rotating measurement p1959, the calculation of the motor magnetization and saturation characteristic should be deactivated.

Note For drives with gearbox backlash or belts, the vibration test should be set in the configuration in p1959.4 with zero (no).

Fig. 5-3: Measurement to optimize the speed controller



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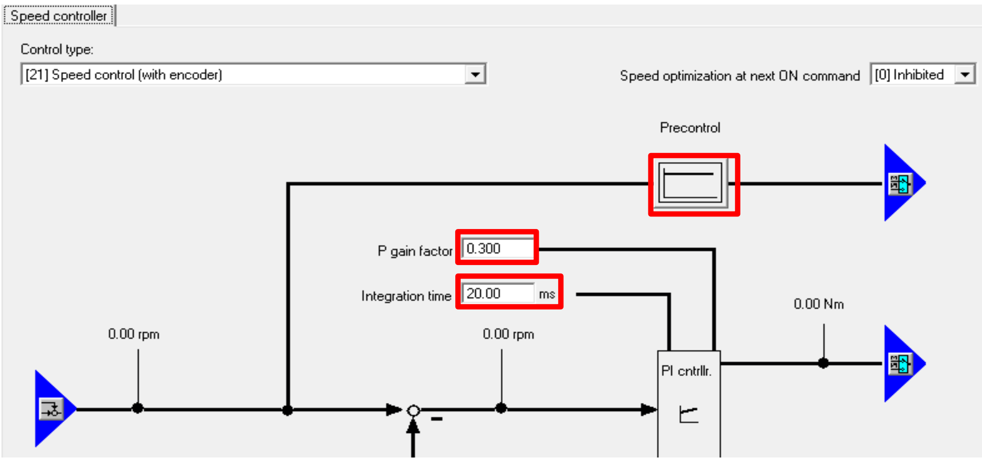
In addition to control parameters Kp gain factor and integral time Tn, the ratio between the total moment of inertia and the motor moment of inertia (p342) is calculated, and the scaling of the acceleration precontrol (p1496) is set to 100%. Copy the settings from RAM to ROM, and save the project after loading to the PG or the PC.

5.1.2 Manual optimization of the speed controller

The speed controller under "Control_Unit > Open-loop/closed-loop control > Speed controller" defines the speed at which the speed actual value tracks the speed setpoint.

Fig. 5-4: Parameterizing the speed controller



Coarse optimization

Using the following rule of thumb, K_p can be roughly determined using the symmetrical optimum. You start at n equal to one. If the dynamic performance is not adequate, then you continue with n equal to two etc.

$$T_n = 4 \cdot T_S \,(sum\ of\ all\ decelerations) \cong 90 - 120\ ms$$

$$K_P = n \cdot \frac{rated\ motor\ starting\ time\ (r0345)}{\text{integral time } T_n (P1462)}\ where\ n = 1, 2, \ldots$$

Manual optimization

Alternatively, the speed controller can be manually optimized according to the symmetrical optimum in the following steps:

1. Increase the P gain factor K_p (P1460) until the speed actual value overshoots the setpoint step by 4.3%. Set T_n to zero or the maximum value.
2. Then reduce integration time T_n (integral time P1462) from approx. 120 ms until the speed actual value overshoots the setpoint step by 43%.

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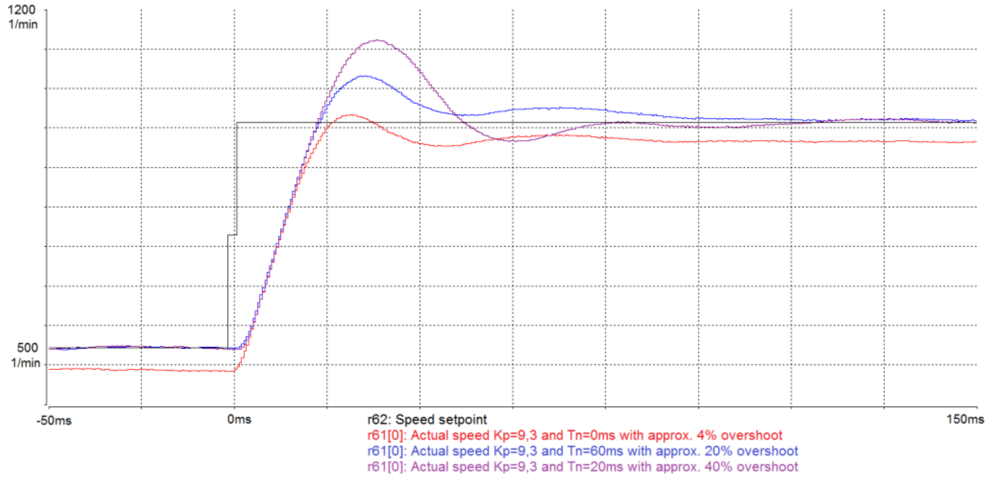
NOTICE

Before optimizing the speed controller

1. Beforehand, ensure that the travel distance is sufficient for the setpoint step.
2. At the control panel, operate in the closed-loop speed controlled mode (f-setpoint input) so that the position controller is not active.
3. The speed setpoint step must be issued from a speed, where the friction can be neglected. Therefore, enter a step of e.g. 500 to 700 rpm.
4. Set the integration time T_n (P1462), the torque precontrol (P1496) and the ramp-up (P1120) and ramp-down time (P1121) to zero.

The system is optimized based on the step response using the control panel. Trace the speed setpoint (r62) and the speed actual value (r61[0]). Fig. 5-5 shows the resulting step response of the speed controller according to the symmetrical optimum.

Fig. 5-5: Step response for various speed controller settings



Note

During the step, ensure that the drive current, torque, voltage or power is not limited (see the next Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Torque precontrol

The acceleration required is obtained based on the setpoint change. The drive can calculate the torque required from the mass moment of inertia and the acceleration. The torque precontrol controls the torque without involving the speed controller. As a consequence, the speed controller only has to compensate disturbing quantities, such as oscillations caused by the belt.

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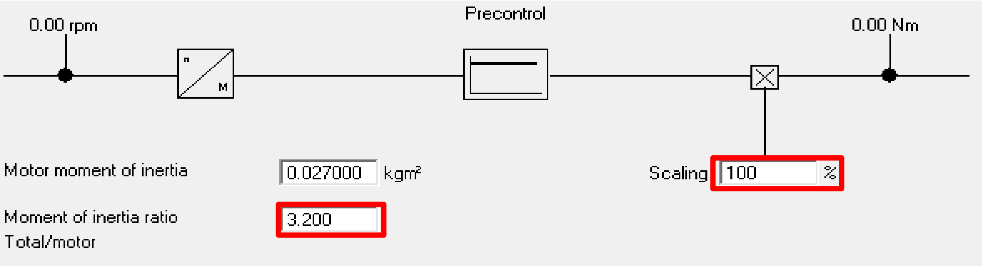
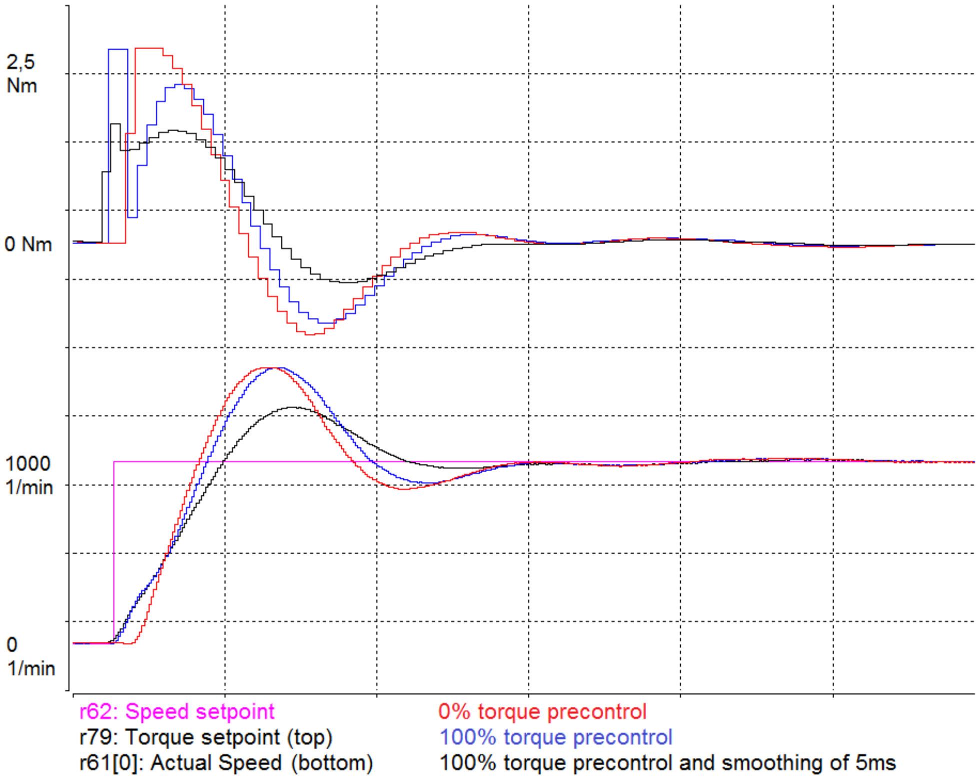
As the turning measurement can usually not be carried out for the lift, the torque precontrol must be manually parameterized. Insert the ratio between the total moment of inertia and the motor moment of inertia into P342. Increase the scaling (P1496) of the precontrol from 50% step-by-step up to 100%.

Fig. 5-6: Torque precontrol in the speed controller



Ideally, trace the torque setpoint (r79) in a current controller clock cycle of 0.5 ms. If, as a result of increasing the torque precontrol, the torque setpoint starts to oscillate, increase the smoothing time constant of the torque setpoint in parameter P1517, e.g. to 10 ms. Fig. 5-7 shows the influence of the precontrol and the setpoint smoothing on the torque setpoint and the speed actual value.

Fig. 5-7: Torque setpoint and speed actual value with precontrol



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6 Safety functions

This chapter explains the safety functions integrated in the drive, relevant for serial hoisting equipment.

WARNING	**Danger for personnel as a result of unintentional lowering** If the holding brake does not provide adequate protection, for vertical axes there is danger for personnel as a result of unintentional lowering of the load. Plant or machine builders must take this danger into account during the risk assessment and must take the appropriate measures to minimize the risk of danger. A description of the technical and organizational protective measures for different operating modes is provided in \10\ Technical information sheet for axes subject to gravity of the German Social Accident Insurance (DGUV). This application document does not describe a machine safety concept that is intended to minimize any danger corresponding to the information sheet of vertical axes. The document only demonstrates how the control-related safety functions of the products presented can be utilized.

Table 6-1 provides an overview of the safety functions integrated in the SINAMICS G120 and G120D drives.

Table 6-1 Safety functions of the SINAMICS G120 and G120D drives

Function	SINAMICS G120			SINAMICS G120D		SINAMICS S120
	CU240E-2	CU240E-2 F	CU250S-2	CU240D-2 CU250D-2	CU240D-2 F CU250D-2 F	
Safe Torque Off - STO	Yes	Yes	Yes	Yes	Yes	Yes
Safe Stop 1 - SS1		Yes	Yes		Yes	Yes
Safe Limited Speed - SLS		Yes	Yes *		Yes	Yes
Safe Direction - SDI		Yes	Yes *		Yes	Yes
Safe Speed Monitor - SSM		Yes	Yes *		Yes	Yes
Safe Brake Control - SBC			Yes			Yes
Safe Brake Test - SBT						Yes

*Requires a license for the extended safety functions.

The use of the safety functions, highlighted in orange color in the Table 6-1 above, is **not** permitted for serial hoisting equipment.

SINAMICS G120/G120D safety functions do not evaluate an encoder, irrespective of whether an encoder is used for the closed-loop control or not. The STO function can be used without any restrictions for all applications.

Note The SS1, SLS, SDI and SSM encoderless functions are only permissible for applications where the load can never accelerate the drive. As a consequence, these functions based on the SINAMICS G120/G120D are not permissible for serial hoisting equipment.

A detailed description of the SINAMICS G120/G120D safety functions is provided in \12\.

6.1 Safe torque off

The safe torque off safety function integrated in the drive (STO) fulfills safety category PLd and safety integrity level SIL2. It can be controlled via the Control

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Unit terminal or PROFIsafe. When STO is selected, the pulses are canceled at the inverter output so that a torque cannot be generated.

The system is commissioned under "Control_Unit > Functions > Safety Integrated" as basis function. The CU250S-2 control module also has the basic function Safe stop 1 (SS1) and safe brake control (SBC).

An acceptance test is required after the safety functions have been commissioned. The application example in \13\ supports you when conducting the acceptance test.

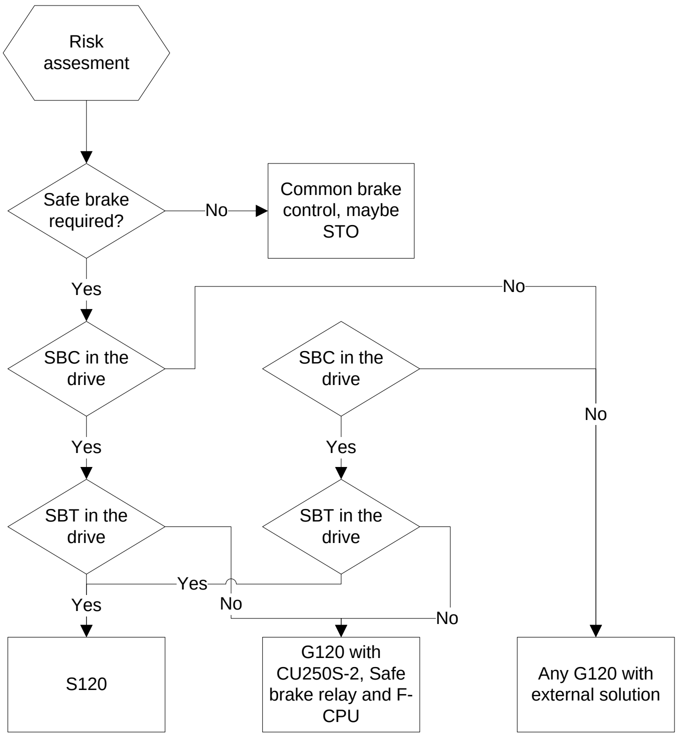
6.2 Safe brake

For serial hoisting equipment, generally the load is held at standstill by the motor holding brake or an external holding brake. The term safe brake refers to complying with a specific safety category. The safety category to be complied with is the result of the risk assessment. The control-related tasks of a safe brake include:

- Safe brake control (SBC)
- Safe brake test (SBT)

Fig. 6-1 shows a flowchart when selecting components if a safe brake is to be implemented based on electronic components. In addition, redundant braking systems can result in a higher level of safety.

Fig. 6-1: Flow chart when implementing a safe brake using SINAMICS



6.2.1 Safe brake control

Safe brake control (SBC) safety controls the holding brake through two channels and monitors the brake control. SBC is always activated in parallel with STO or SS1. This guarantees that the brake is closed when the drive is in a no-torque condition. For the G120 equipped with the CU250S-2, the SBC function is

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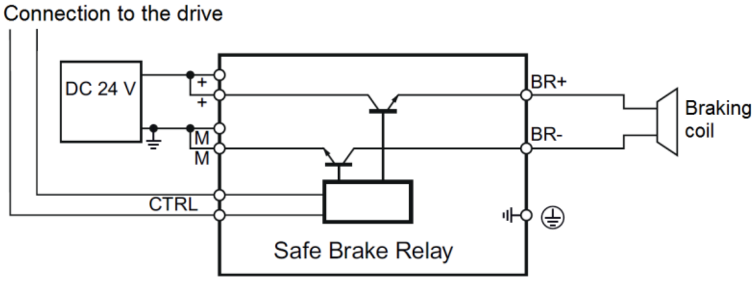
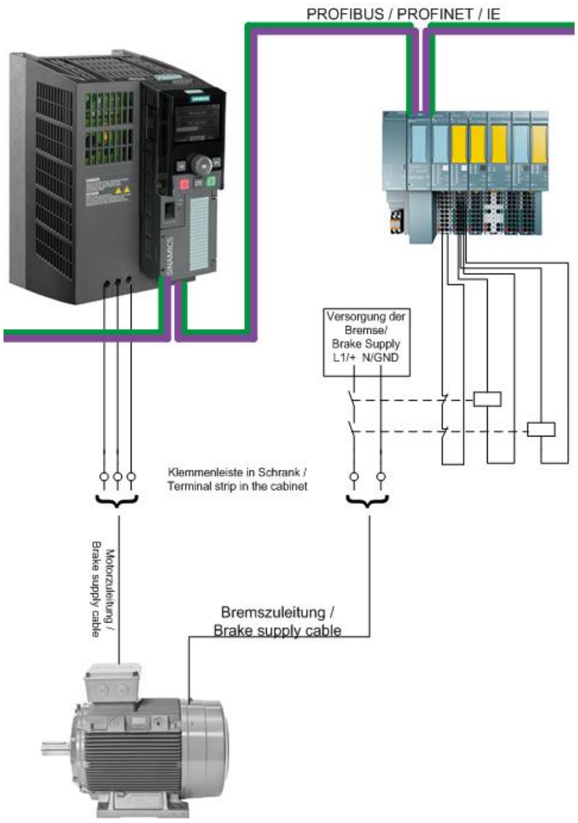
implemented together with the safe brake relay Fig. 6-2 [5]. However, as a consequence only 24 V DC brake solenoids can be controlled.

Fig. 6-2: Safe brake relay circuit



Alternatively, the brake can also be safely controlled using a safety program in an F-CPU. To achieve this, a safety-relevant digital output is connected to two contactors. The control is monitored using a feedback signal contact. In this case, the contactors interrupt the brake solenoid supply voltage. This means that various supply voltages can be used for the brake solenoids; for instance, also function rectifiers with 230 V or 400 V AC.

Fig. 6-3 Safe brake control with F-CPU



With this circuit, the brake control is still implemented in the inverter itself. When a safety function is required (e.g. STO), then a motor holding brake is safely controlled by the safety-relevant control via the contactors.

6.2.2 Safe brake test

The rated brake holding torque can be fallen below as a result of mechanical wear, oiling or a defective brake. Under certain circumstances, it is possible that the load

[5] A safe brake adapter is required for devices in the chassis format.

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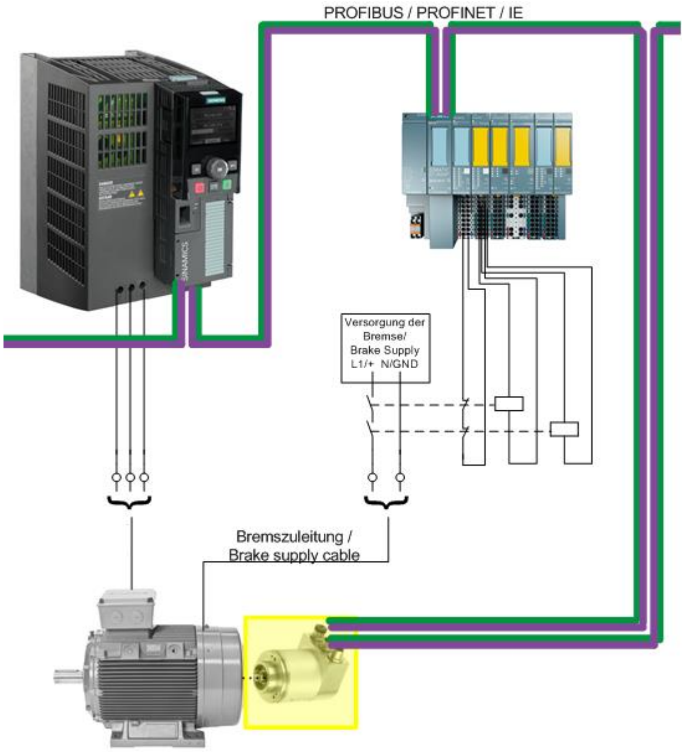
sags or even drops. Safe brakes must be able to diagnose possible fault scenarios. As a consequence, the braking force of a safe brake must be tested on a regular basis (safe brake test – SBT). To do this, the motor operates with a defined torque against the closed brake for a specific time. A safety-relevant encoder or two redundant encoders monitor that the motor shaft does not rotate. For SBT, when in the torque control mode, the drive must apply the rated holding brake torque, or twice the rated torque of the load to the brake.

The SBT function is only available in the SINAMICS S120 drive from firmware 4.6 and higher. External components are required to implement SBT with a SINAMICS G120 – for instance an F-CPU. The F-CPU starts the test run in the drive, and either evaluates the signal of the safety-relevant encoder or two encoder signals for standstill. Three different setups are subsequently shown to implement this functionality.

Brake test with F-CPU and safety-relevant encoder

The application example in \14\ shows how a safety-relevant PROFIsafe encoder can be evaluated using an F-CPU. In addition to a safety-relevant encoder, the encoder must be mounted in the safety-relevant way according to EN 61800-5-2, Table D16. Fig. 6-4 shows the basic setup to implement this.

Fig. 6-4 Safety-relevant brake test with F-CPU and safety-relevant encoder



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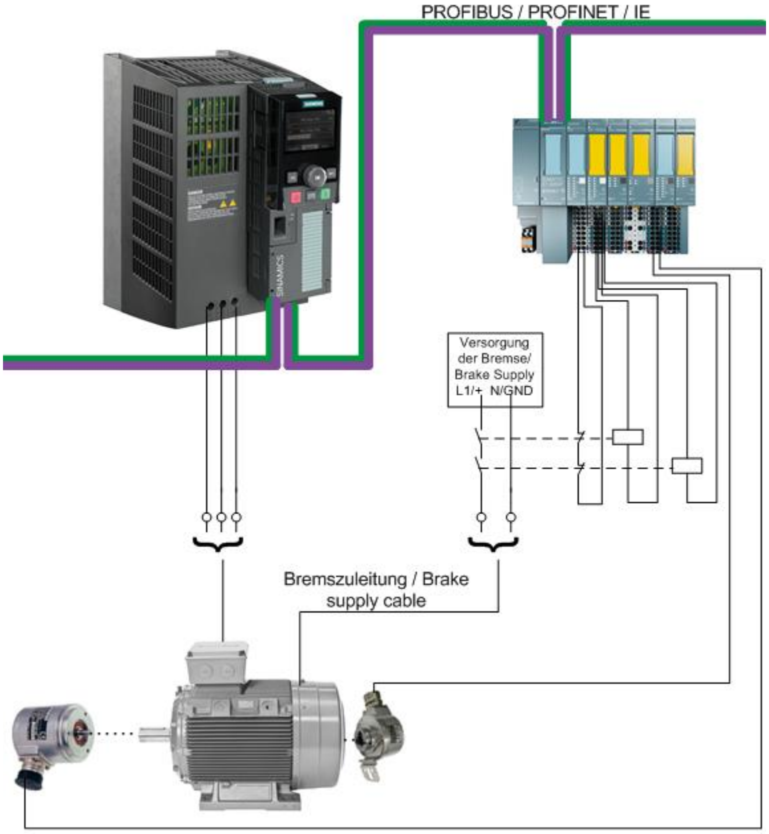
Brake test with F-CPU and two encoders

Alternatively, two different encoder signals can be monitored for standstill and plausibility using one F-CPU. \15\ provides a project example as to how the safety-relevant evaluation of non-safety relevant measured values, which were sensed using two standard components, can be implemented in SIL 3 or PLe.[6]

Fig. 6-5 Safe brake test with F-CPU and two standard encoders



A safety-relevant encoder mounting is not required. However, according to EN61800-5-2, it must be absolutely ensured that if an encoder shaft breaks, this is detected with 100% reliability. Encoder shaft breakage can be diagnosed, for example, by subjecting the two encoder actual values to a plausibility check.

[6] Only available in the Intranet for Siemens personnel

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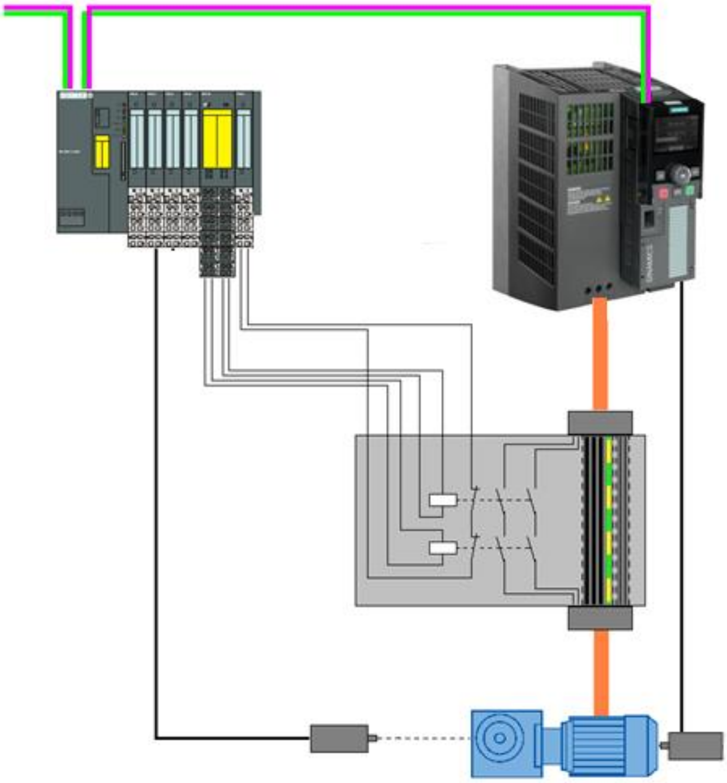
Alternatively, an encoder can also be connected to the CU250S-2. The encoder actual value must then be Incorporated in the fieldbus telegram (Profinet or Profibus) so that it is made available to the F-CPU.

Fig. 6-6: Safe brake test with F-CPU and two separate standard encoders



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7 Related literature and links

Tabelle 7-1: Literature

	Topic	Title
/1/	Information sheet, axes subject to the force of gravity	http://www.dguv.de/medien/fb-holzundmetall/publikationen/infoblaetter/infobl_deutsch/005_vertikalachsen.pdf DGUV, Edition 09/2012, No. 005
/2/	Drive solutions	Drive solutions – mechatronics for production and logistics Published by: Edwin Kiel Springer, 2007 ISBN: 978-3-540-73425-3
/3/	Accident prevention regulation	http://www.bghm.de/arbeitsschuetzer/gesetze-und-vorschriften/bg-vorschriften/ BGV D6, BGHM August 2013

Table 72: Left

	Topic	Link
\1\	Reference to this application	http://support.automation.siemens.com/WW/view/de/103156155
\2\	Siemens Industry Online Support	http://support.automation.siemens.com
\3\	Rapid traverse / crawl changeover with SINAMICS G	http://support.automation.siemens.com/WW/view/de/58399364
\4\	SIZER for Siemens Drives	http://support.automation.siemens.com/WW/view/de/54992004
\5\	Application example Lift with EPos	http://support.automation.siemens.com/WW/view/de/102950703
\6\	Marginal conditions for PM250/D	http://support.automation.siemens.com/WW/view/de/72896051 (Intranet)
\7\	Standby current of the G120D	http://support.automation.siemens.com/WW/view/de/34189181
\9\	SINAMICS S120 function manual drive functions	http://support.automation.siemens.com/WW/view/de/68042590
\10\	Load change of power semiconductors	http://support.automation.siemens.com/WW/view/de/65018352
\11\	Manual determination of the magnetizing current	http://support.automation.siemens.com/WW/view/de/22078991
\12\	Function manual Safety Integrated SINAMICS G120, G120C and G120D	http://support.automation.siemens.com/WW/view/de/70235827
\13\	Acceptance test of the Safety Integrated Functions	http://support.automation.siemens.com/WW/view/de/73102423
\14\	Safe standstill detection with	http://support.automation.siemens.com/WW/view/de/49221879

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	Topic	Link
	PROFIsafe encoder	
\15\	Safety-relevant evaluation of values sensed once	http://support.automation.siemens.com/WW/view/de/45830615 (Intranet)

8 Contact

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9 History

Table 9-1

Version	Date	Modifications
V1.0	01/2015	First version
V1.1	07/2016	Chapter 6 edited

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