Efficient energy management of electric drives
White paper

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STÖBER

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1 Introduction

This white paper deals with the efficient and sustainable energy management of electric drives.

In motor operation, electric drives draw electrical energy from the supply grid as electrical loads and convert it into mechanical energy, e.g. for lifting a weight. When braking mechanical movements, on the other hand, electric drives act as generators. For example, when a weight is lowered, the mechanical energy is converted into electrical energy.

In practice, it is therefore necessary to check whether regenerative operation occurs, depending on the application. In regenerative operation, the electrical energy generated must either be transmitted or stored in order to avoid faults in the plant.

Typical applications with regenerative operation are:

- Motor test benches
- High-bay storage
- Cranes
- Winders
- Wind turbines
- Packaging machines

In the following chapters, various solution concepts for regenerative operation are compared and evaluated.

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2 Options for regenerative operation

There are several options that, individually or in combination, can solve the problem of excess electrical energy.

Transmission

Surplus energy can be transmitted to electrical loads or fed back into the supply grid, e.g.:

- Braking resistors
- DC-DC converters
- Drives
- Regenerative feedback modules

Storage

The following storage units are suitable for storing energy:

- Electrical storage devices such as capacitors
- Electrochemical storage devices such as accumulators
- Mechanical storage devices such as flywheels

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3 Solution concepts

The following chapters first give an overview of the possible flow of energy within the system. This is followed by a description of a common solution on the market, in which the energy is transmitted to a braking resistor. Then come concepts in which the energy is either transmitted to electrical loads, fed back into the supply grid, or stored.

The following table provides an overview of the numbering of the individual components used in the graphics.

No.	Component
1	Supply grid (AC)
2	Rectifier (AC-DC)
3	Inverter (DC-AC)
4	Motor/generator
5	Braking resistor
6	Storage device
7	Brake chopper
8	Supply module (rectifier with brake chopper)
9	Regenerative module (grid-connected inverter)

Tab. 1: Possible system components

3.1 Flow of energy in the system

Converters, inverters, rectifiers, and DC-DC converters are kinds of power converters. With the help of these power converters and the various options for handling surplus electrical energy, there are many solution variants for regenerative operation. The following graphic provides an overview.

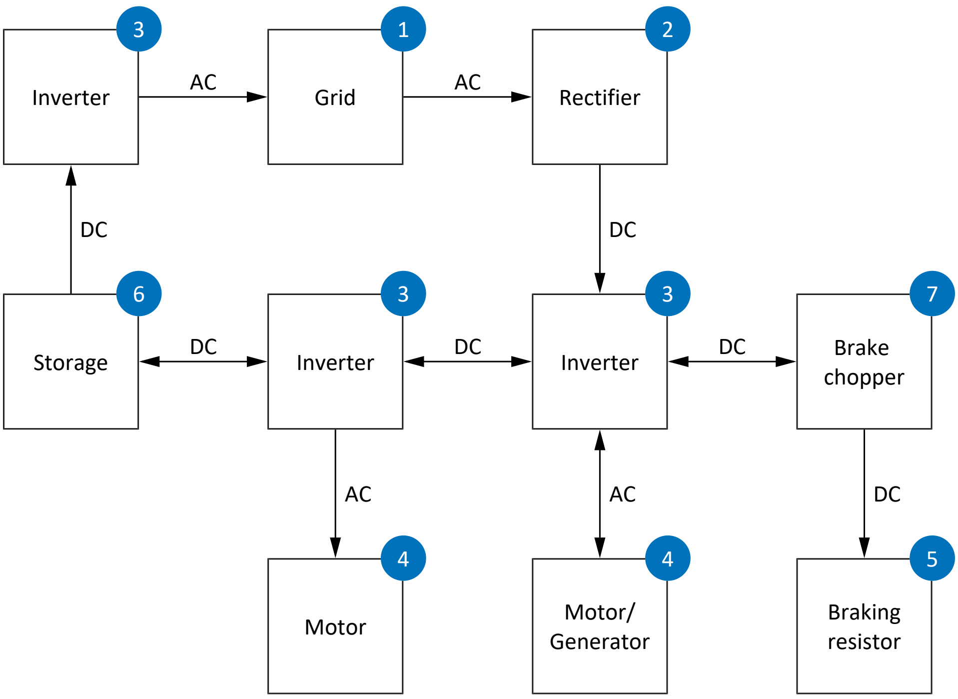

Fig. 1: System overview of the flow of energy in the system

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3.2 Transmission to braking resistor

The braking energy in regenerative operation of the motor is converted into thermal energy with the aid of a braking resistor.

The conversion of electrical energy into thermal energy, e.g. when stopping a machine, is a simple and economical solution that is widely used on the market. The brake resistor is controlled via the supply module, a rectifier with an integrated brake chopper.

The amount of energy converted into heat in the braking resistor depends on the application.

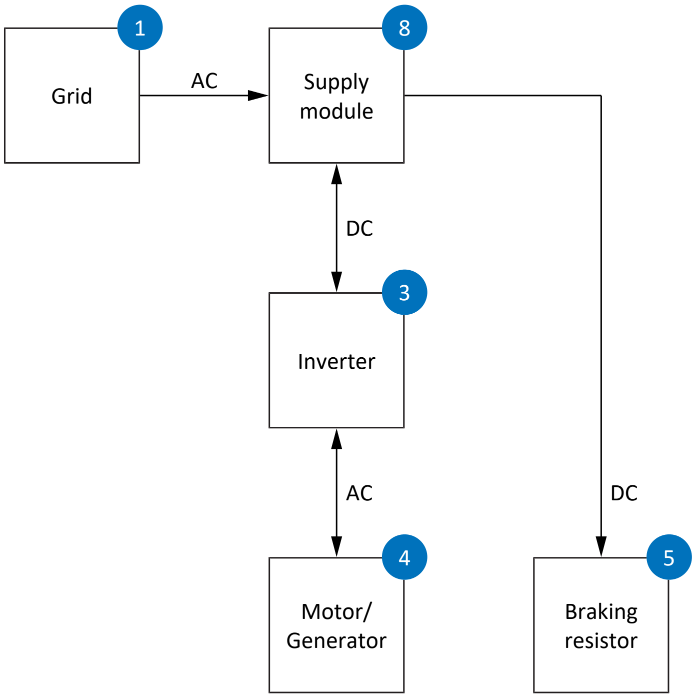

Fig. 2: Transmission to a braking resistor (standard solution)

3.3 Transmission to electrical loads

The braking energy in regenerative operation of the motor is made available to electrical loads.

This solution offers a wide range of possible applications, from motor test benches with two mechanically and electrically coupled motors to packaging machines with several drives.

Static electrical loads in the DC link, e.g. fans or DC/DC converters, represent a base load and can significantly reduce the amount of energy in the DC link.

As a rule, a braking resistor is usually necessary. For economic reasons, the emergency stop is usually implemented with the aid of a braking resistor.

The energy converted into heat in the braking resistor can be reduced depending on the application.

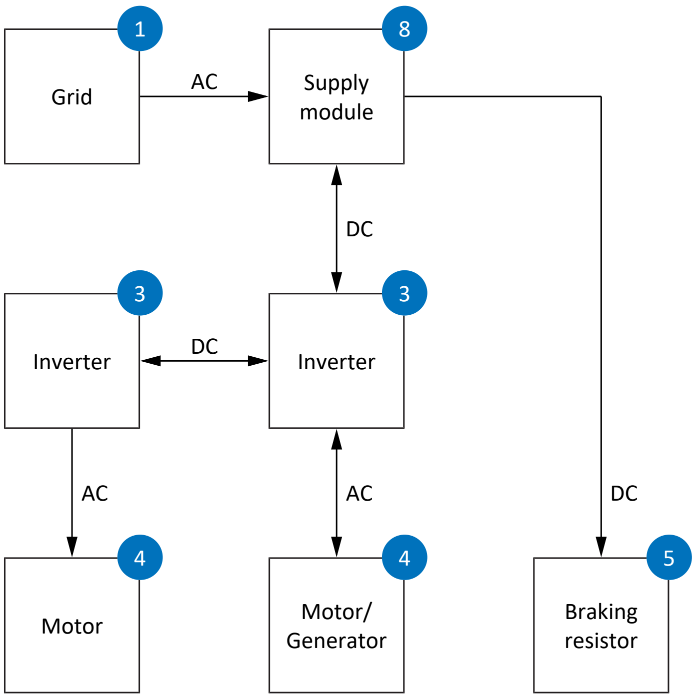

Fig. 3: Transmission to electrical loads

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3.4 Feedback by means of regenerative feedback module

The braking energy in regenerative operation of the motor is fed back into the supply grid with the aid of a regenerative module (grid-connected inverter).

Regenerative modules are typically used for long and intense regenerative operation, such as in high-bay warehouses or cranes.

A braking resistor is generally necessary because an alternative means of handling braking energy is required when the regenerative module is disconnected from the supply grid.

The energy converted into heat in the braking resistor can be minimized during normal operation.

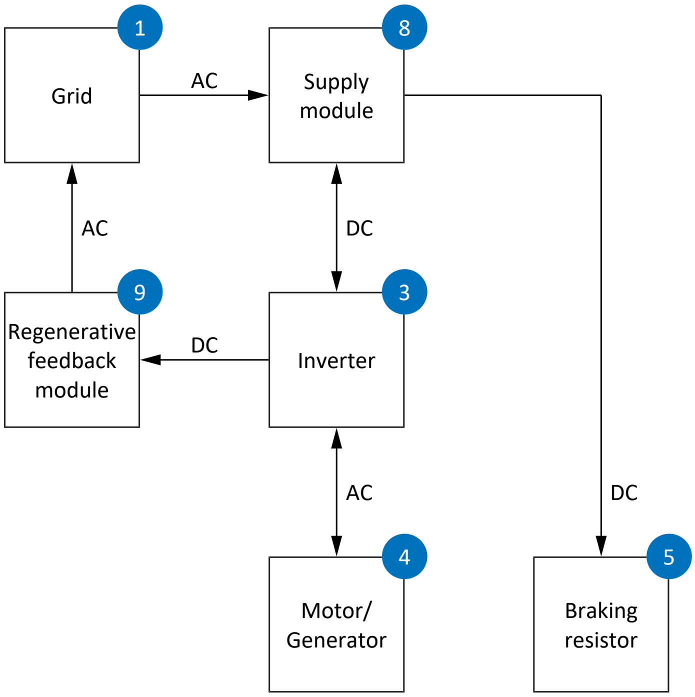

Fig. 4: Feedback to the supply grid by means of a regenerative module

3.5 Storage in capacitor

The braking energy in regenerative operation of the motor is stored in a capacitor. This energy is available again in the next acceleration cycle. In rare cases, accumulators or mechanical storage units are used as an alternative to capacitors.

This solution is often found in fast-cycling machines with multiple drives, such as those involved packaging technology.

As a rule, a braking resistor is necessary in multi-axis applications because the storage capacity of the capacitor is limited. For economic reasons, the emergency stop is usually implemented with the aid of a braking resistor.

The energy converted into heat in the braking resistor can be reduced depending on the application.

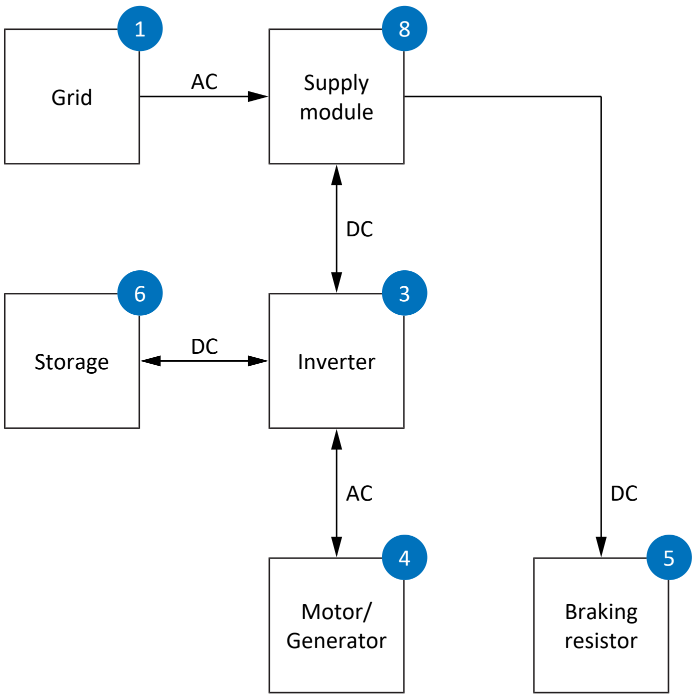

Fig. 5: Storage in a capacitor

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4 Evaluation of solutions

The following table provides a comparison and evaluation of the different solutions for regenerative operation.

Solution	Advantages	Disadvantages
Transmission to braking resistor	▪ Low investment costs ▪ Easy handling ▪ Reduced space requirement ▪ Easy to scale ▪ Easy to upgrade ▪ Large selection	▪ High operating costs ▪ Waste heat
Transmission to electrical loads	▪ Low investment costs ▪ Easy handling ▪ Reduced space requirement ▪ Easy to scale ▪ Low operating costs	▪ Not easy to retrofit
Feedback by means of regenerative feedback module	▪ Stand-alone solution ▪ Decoupling of supply and regenerative power ▪ Easy to scale ▪ Low operating costs ▪ Low fluctuation of the DC link	▪ High investment costs ▪ Large space requirement ▪ High installation effort ▪ Not easy to retrofit
Feedback by means of combined supply/regenerative module	▪ All-in-one solution ▪ Omission of the supply module ▪ Low operating costs ▪ Low fluctuation of the DC link	▪ High investment costs ▪ Large space requirement ▪ High installation effort ▪ Not easy to scale ▪ Not easy to retrofit
Storage in a capacitor	▪ Low investment costs ▪ Easy handling ▪ Low operating costs	▪ Not easy to scale ▪ Low buffer capacity ▪ Short buffer time ▪ Limited selection

Tab. 2: Evaluation of solutions for regenerative operation

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5 Basic connection with regenerative feedback module

The following diagram shows an example of the basic connection of a drive system with a regenerative module.

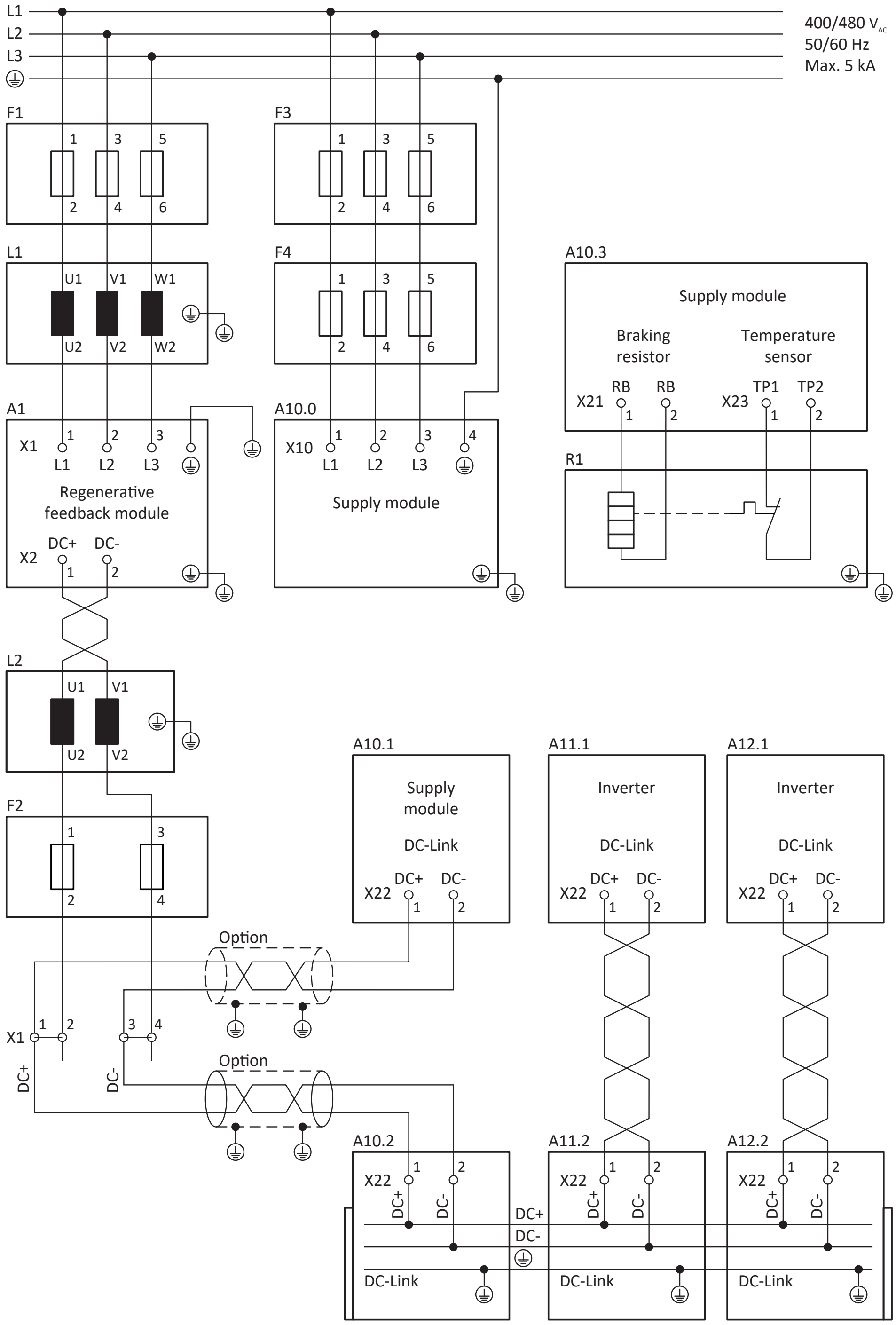

Fig. 6: Schematic diagram with regenerative module

Module	Description		Module	Description
A1	Regenerative module (grid-connected inverter)		F2	Optional DC circuit protection
A10	Supply module (rectifier with brake chopper)		F4	Circuit protection
A10.2, A11.2, A12.2	DC link module		L1	Optional power choke or EMC filter
A11, A12	Inverter		L2	Optional DC link choke
F1, F3	Overload protection		R1	Braking resistor with temperature sensor

ATTENTION!

Device damage due to overvoltage!

If the regenerative module's line fuses fail, electrical loads in the regenerative path may be overloaded.

- Do not install any electrical loads in the regenerative path between the regenerative module and the line fuse.

The A10 supply module (rectifier with integrated brake chopper) is connected to the supply voltage via fuses F3 (overload protection) and F4 (circuit protection).

The rectifier of the supply module converts the AC supply voltage into the DC voltage required by the inverters. With the aid of the A10.2, A11.2 and A12.2 DC link modules, the DC voltage is transmitted from the supply module to the connected A11.1 and A12.1 inverters. The DC link modules also ensure the energy exchange between the inverters.

In regenerative operation, the A10.3 brake chopper converts excess electrical energy into thermal energy with the aid of the R1 braking resistor.

The regenerative module (grid-connected inverter) requires connections to the supply grid and to the DC connection of the inverters.

The easiest way to establish the DC link is to integrate a compact distributor (X1) with terminal blocks between the A10.1 supply module and the A10.2 DC link module of the supply module.

The regenerative module must be integrated in accordance with its intended use. There are manufacturer-dependent differences here. Depending on the manufacturer, the use of DC link chokes, DC fuses, power chokes or EMC filters may be prescribed and other accessories may be required. In particular, check the use of suitable components in order to comply with the EMC limits of EN 61800-3.

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6 General notes

The points listed below must already be considered when planning the drive system.

Intended use

Intended use of the components, e.g.:

- Ambient conditions
- Application restrictions
- Permissible line lengths
- No electrical loads in the regenerative path

Accessories necessary for the intended use, e.g.:

- Chokes
- EMC filters
- Fuses

Connection

Requirements for lines, e.g.:

- Grounding conductor connections
- DC lines:
  - Twisted design
  - Shielded design for a total length > 30 cm

Technical data for the selection of lines and terminals, e.g.:

- Conductor cross-sections
- Current carrying capacity
- Operating voltage

Operation

Quick stop:

- Dimensioning the braking resistors

Fault cases in operation, e.g.:

- Fuse elements trip
- Regenerative module is disconnected from the grid

7 Service

Our application engineers have experience with regenerative modules from various manufacturers.

Contact STOBER System Support if you are interested:

Phone +49 7231 582-3060
systemsupport@stoeber.de

Glossary

Brake chopper

Component of a drive system for monitoring the DC link voltage. This monitoring is required, because overvoltages can occur in the DC link. These arise when braking the motor. The braking resistor, which converts the excess energy in the DC link into thermal energy, is connected to the component.

Braking resistor

Electrical resistor that is switched on by a brake chopper in order to avoid a hazard to electrical components in the event of significant brake energy by limiting the DC link voltage. Braking energy, which is usually only present for brief periods, is converted into heat in the resistor.

Converter

Electrical device that uses one AC voltage to generate a new AC voltage with different frequency and amplitude (AC-AC). A kind of power converter.

DC-DC converter

Electrical device that converts a DC voltage supplied at the input into a DC voltage with a higher, lower or inverted voltage level (DC-DC). A kind of power converter.

Inverter

Electrical device that converts DC voltage into AC voltage (DC-AC). A kind of power converter.

Power converter

Non-moving electrical device (i.e. without moving parts, but not necessarily stationary) for converting one type of supplied electrical current into the other or for changing characteristic parameters such as voltage and frequency.

Rectifier

Electrical device that converts AC voltage into DC voltage (AC-DC). A kind of power converter.

Regenerative feedback module

Grid-connected inverter for feeding into an AC supply grid.

Supply module

Rectifier for feeding into a DC supply grid, optionally with an integrated brake chopper.

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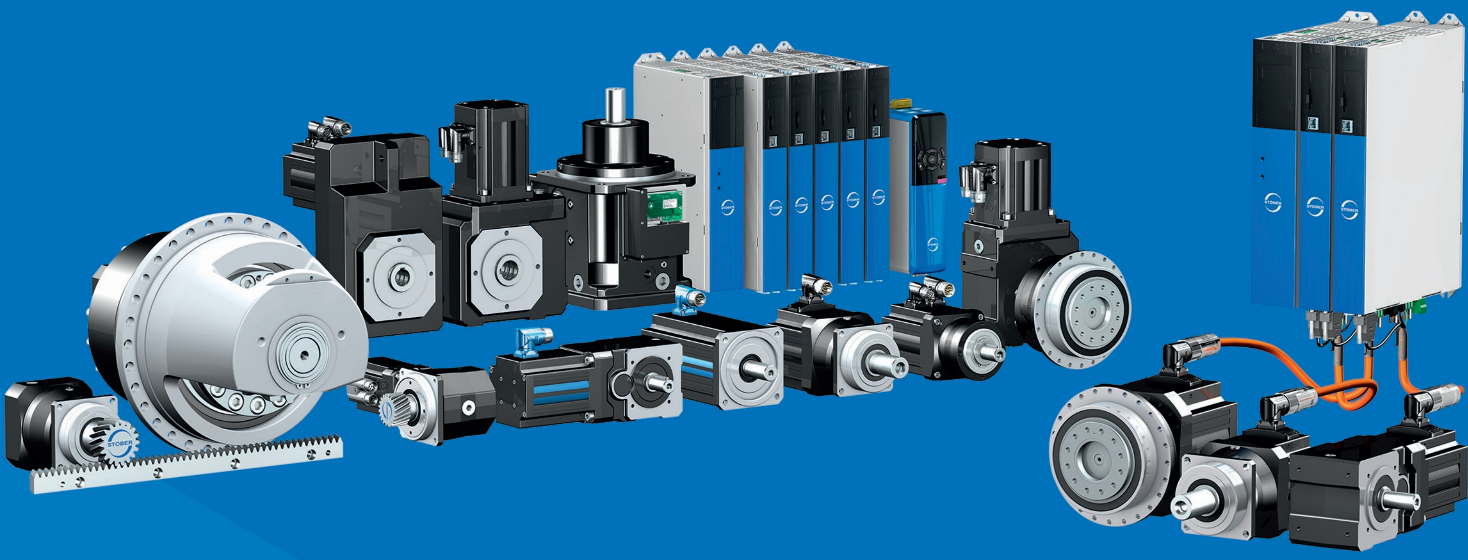

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