ABB machinery drives

Application guide
Common DC system for ACS380 drives

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List of related manuals

Drive manuals and guides	Code (English)
ACS380 hardware manual	*3AXD50000029274*
ACS380 firmware manual	*3AXD50000029275*
ACS380 quick installation and start-up guide	*3AXD50000018553*
ACS380 user interface guide	*3AXD50000022224*
Multilingual general safety instructions	*3AXD50000037978*

You can find manuals and other product documents in PDF format on the Internet. See section *Document library on the Internet* on the inside of the back cover. For manuals not available in the Document library, contact your local ABB representative.

Application guide

Common DC system for ACS380 drives

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Further information

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Introduction to the guide

What this chapter contains

This chapter describes the contents of this guide. It contains information on safety, target audience and the purpose of this guide.

Safety instructions

Obey all safety instructions.

- Read the complete safety instructions in the *hardware manual* and in the generic multilingual safety instructions before you install, commission, or use the drive.
- Read the firmware function-specific warnings and notes before changing parameter values. See the *firmware manual*.
- Read the safety instructions in section *Limitations* on page *13*.

Target audience

This guide is intended for people who plan the installation, install, commission, use and service a common DC system with ACS380 drives.

You are expected to know the standard electrical wiring practices, electronic components, and electrical schematic symbols and the basics of AC drives.

Contents

- *Description of a common DC system*
- *Dimensioning common DC systems* contains a dimensioning instructions and discus of the limitations and recommendations.
- *Dimensioning example*
- *Start-up* describes parameter settings
- *Technical data*
- *Appendix A - Motor's kinetic energy vs. DC capacitors' electrical energy* contains a calculation example showing how a motor's kinetic energy and DC capacitors' electrical energy are related.

Terms and abbreviations

Term/abbreviation	**Explanation**
IGBT	Insulated gate bipolar transistor
EMC	Electromagnetic compatibility
THD	Total harmonic distortion

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Description of a common DC system

What this chapter contains

This chapter describes the operation principle and hardware of a common DC system.

Operation principle

Common DC system consists of two or more drives whose DC circuits are connected together. This allows energy to flow freely between the individual drives.

Drives connected to a common DC system supply motors, which operate as motors (energy flows from the common DC circuit to the motors) or as generators (energy flows from the motors to the common DC circuit).

The energy in a DC bus is always in balance. That is, the energy flow to and from the bus is equal, including the fact that DC capacitors in the DC circuit can store a small amount of surplus energy if the DC voltage can rise temporarily.

In normal operation, the energy flows from the AC power line to the common DC circuit of the drives (through drive rectifier bridges), and further to the motors (through drive inverter bridges). Then, the *generating power* of the system is smaller than the *motoring power*.

The generating power can exceeds the motoring power during a quick ramp stop of a motor. Then, excess energy starts to accumulate in the DC circuit and the DC voltage starts to rise. In order to prevent the voltage rise, the system must prevent the energy cumulation, ie, maintain the energy balance. Practically speaking: the system must convey the surplus energy out of the DC circuit: to another motor (that is in motoring mode), to a brake resistor (to be dissipated as heat) or back to the AC power line. For the last option, the common DC system must include a regenerative drive which can supply the energy back to the AC power line.

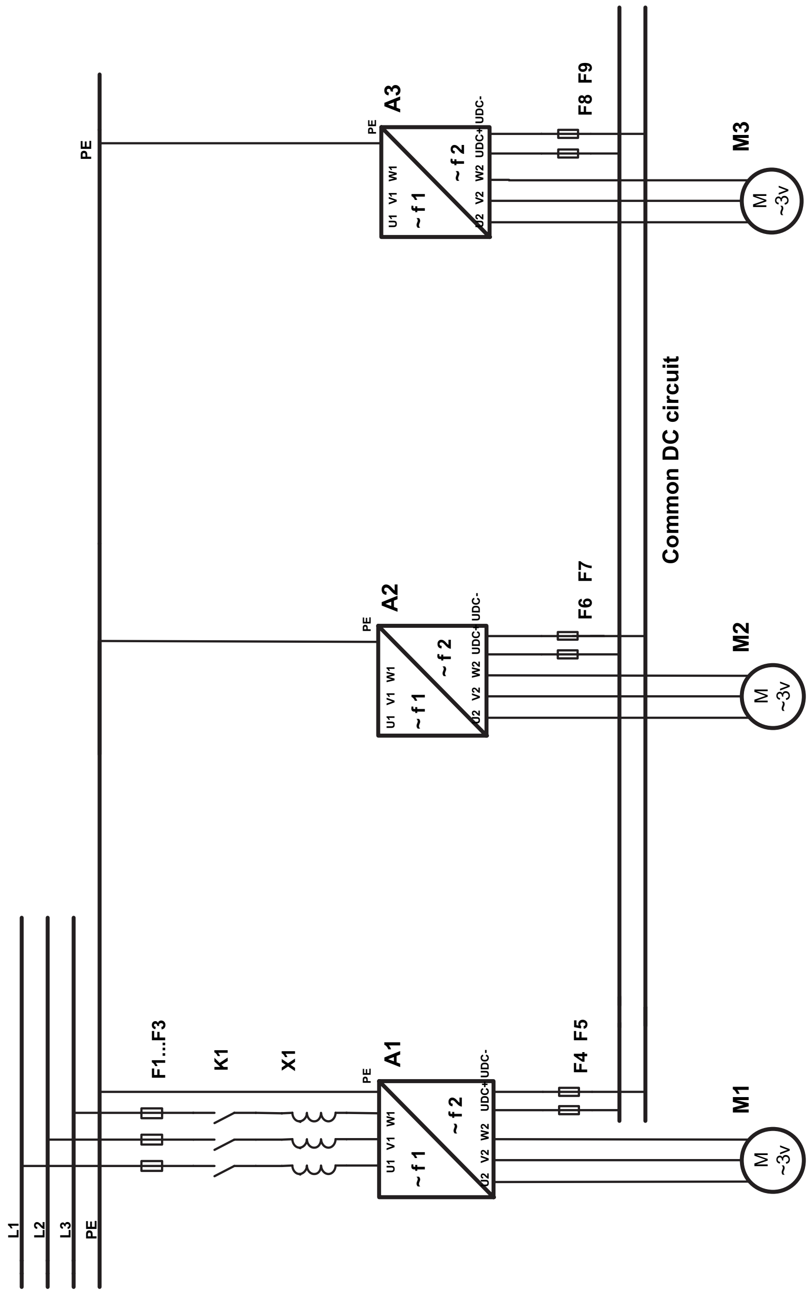
It is possible that some of the drives in a common DC system can take all their energy from the DC circuit, and you do not need to connect them to the AC power line at all. However, this vary and depends on the load cycle of the whole system. In all systems, at least one drive must be connected to the AC power line of course.

Common DC hardware

The hardware of common DC systems is simple: The drive UDC+ and UDC- terminals are connected to a common DC link via DC fuses. If you have one drive connected to the AC power line only, you also need AC choke, fuses, contactor and diconnector for one drive only.

To keep the stray inductance of the common DC circuit small, we recommend a "star connection" compared to a point-to-point connection. This type of connection is also better because drive terminals are neither designed nor dimensioned for linkage.

The diagram below shows a common DC system example.



L1
L2
L3
PE
F1...F3
K1
X1
A1
A2
A3
PE
U1 V1 W1
~ f 1
~ f 2
U2 V2 W2 UDC+ UDC-
F4 F5
F6 F7
F8 F9
Common DC circuit
M1
M2
M3
M
~3v

3

Dimensioning common DC systems

What this chapter contains

This chapter contains a procedure for dimensioning common DC systems and discusses of limitations and recommendations.

Limitations

WARNING! Obey these guidelines. If you ignore them, injury or death, or damage to the equipment can occur.

- The drive cannot feed or receive more power than it's nominal power rating P_N.
- If you connect one drive only to an AC power line, pay special attention to its input bridge load. In case of simultaneous, heavy and unexpected load of all drives, you easily overload the input bridge. As standard, there is no protection against overload: The AC fuses specified in the *hardware manual* for each drive type are not intended for the input bridge thermal protection.
- The DC fuses specified for the drives in the common DC system are only interrupters in case of short circuits. They do not protect drives or components thermally or against short circuits.
- DC voltage remains high during the generating in a common DC system where the surplus generating energy is dissipated in brake resistor. With high DC voltage also the inverter IGBT switching losses increase, and the IGBTs will heat up faster

or slower depending on the load current. The IGBTs are not thermally protected. Thus, high load current is allowed only for short periods at the time.

- Excessive power generating can cause overvoltage trips. If the energy emission capacity of the resistor braking circuit is too low and the overvoltage controller of the drive(s) is disabled, the DC voltage will increase until it reaches the overvoltage trip limit.

Voltage levels and limits

Optimal DC voltage levels:

Type, ACS380-	Low (DC)	High (DC)
U_N = 200...240 V AC 1- and 3-phase	270	324
U_N = 380...480 V AC 3-phase	513	648

Maximum DC voltage limits:

Type, ACS380-	Low (DC)	High (DC)
U_N = 200...240 V AC 1- and 3-phase	220	420
U_N = 380...480 V AC 3-phase	440	840

Recommendations

- If the generated energy is remarkable, use brake chopper and resistor, or consider a regenerative drive in the system.
- DC intermediate circuit can absorb a small amount of energy, but using the circuit requires careful calculation. For a calculation example, see *Appendix A - Motor’s kinetic energy vs. DC capacitors’ electrical energy*.

Dimensioning procedure

No.	Task	Actions to be taken
1.	Select the motors and drives.	Select motors and drives without considering the requirements for your common DC system yet. Concentrate on each individual drive only. **Note:** The nominal voltage of the drives has to be the same: 230 V or 400 V. With a 230 V supply, 1-phase and 3-phase devices can be connected to the same bus. • Check the motoring power needed at maximum and average loads. • Check the generating power needed at maximum and average loads. • Draw a power/current vs. time diagram for each individual drive in normal operation, in special cases, as well as in cases of faults (if it can be calculated or measured).
2.	Draw a system power curve vs. time diagram.	Add the individual power/current vs. time diagrams together and draw a system power curve vs. time diagram. Take the motor and drive efficiency into account. Rule of thumb: ηtot ~ 0.6…0.85 (motor and drive together).
3.	Select the power supply type and plan how to handle excessive generating power.	Depending on the maximum value of the system’s motoring power/current, or generating power or current, consider the following: • Will one drive for AC supply do in case of a non-regenerative supply? If yes, the sum of the charging resistor current peak values must be equal to lower than the drives' allowed charging sum current. See page 27. • Do you need two drives for AC supply (non-regenerative? If yes, they have to be similar typically. One (or two) steps' difference in sizes can be tolerated, but at the user’s own responsibility. • Do you need a brake chopper and brake resistor? • Do you need a regenerative drive for AC supply?

No.	Task	Actions to be taken
4.	Select the DC fuses.	The default DC fuses are presented in section *DC fuses* on page *28*. In some cases, you can use smaller fuses after carefully considering the possible overload and special situations. If you refine the fuse selection, take into account the motor efficiency. Especially small motors may have high losses and low efficiency. • Calculate the power and current taken from the AC power line. Use factor 1.2 to take harmonics into account. • Then, based on the maximum power in the motoring or generating mode, select the DC fuses for each individual drive.
5.	Check special cases.	Go through the duty cycles of each individual drive with the worst possible operational conditions including all normal situations, such as: • Start and acceleration • Ramp down and stop • Quick stop • Emergency stop • Inching and jogging modes. Consider these situations against the diagram drawn in step 2.
6.	Check system fault cases.	System fault cases are cases where one or several individual drives trip. Normally, this leads to an uncontrolled ramp down of the system. In case of system faults, find out the following: • How is the system power balance maintained during a ramp down or shutdown? • Is the excessive generating power abnormally high? • Can the excessive generating power be absorbed into the DC capacitors? (It may be possible, but calculate it carefully.) • Can the brake chopper and resistor handle the excessive generating power or is a regenerative supply unit necessary? If the generating energy exceeds the brake chopper load capacity, the DC voltage will rise and cause overvoltage trip and uncontrolled stop.

No.	Task	Actions to be taken
7.	Plan interlocking and safety.	Depending on the system, consider what kind of mutual interlocking is necessary to protect and control the system, eg, in start, stop, and in case of faults. In most cases, tripping of one drive makes the system invalid and requires all drives to be stopped. Because the number of digital inputs is limited, the interlocking cannot be made complicated. About safety: • Plan the implementation of emergency stop circuit and other safety circuits. If emergency stop trips the main AC contactor what will be the effect in the common DC system? • Note that the drive has Safe torque off (STO) embedded. STO might be useful in implementation of the safety circuits.
8.	Repeat all the steps.	It is better to reconsider the plans thoroughly already in the planning phase.
9.	Check the requirements for total harmonic distrortion (THD) THD and Electromagnetic Compliance (EMC).	If special requirements are set for THD and/or EMC, you need to consider them case by case. **THD:** If the system current taken from the AC power line is over 16 A, the THD is below the limits of the low frequency harmonic standard (IEC 6100-3-2). ABB recommends using AC chokes in ACS380 common DC systems irrespective of the THD requirements. AC chokes reduce the input current rms value compared to a case without AC chokes. See the *hardware manual*. The THD value will also decrease respectively. **EMC:** Always analyze the EMC level needed in the common DC system case by case. Radiated emission is normally below the allowed limits if the drives and supply components are inside a steel cubicle, earthing is well done, and the drive and its cabling has been installed according to the instructions in the *hardware manual*. To minimize the conducted emissions, you can install an eternal EMC filter to the AC input of the drive.

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Dimensioning example

What this chapter contains

This chapter presents an example common DC system and its dimensioning.

Configuration

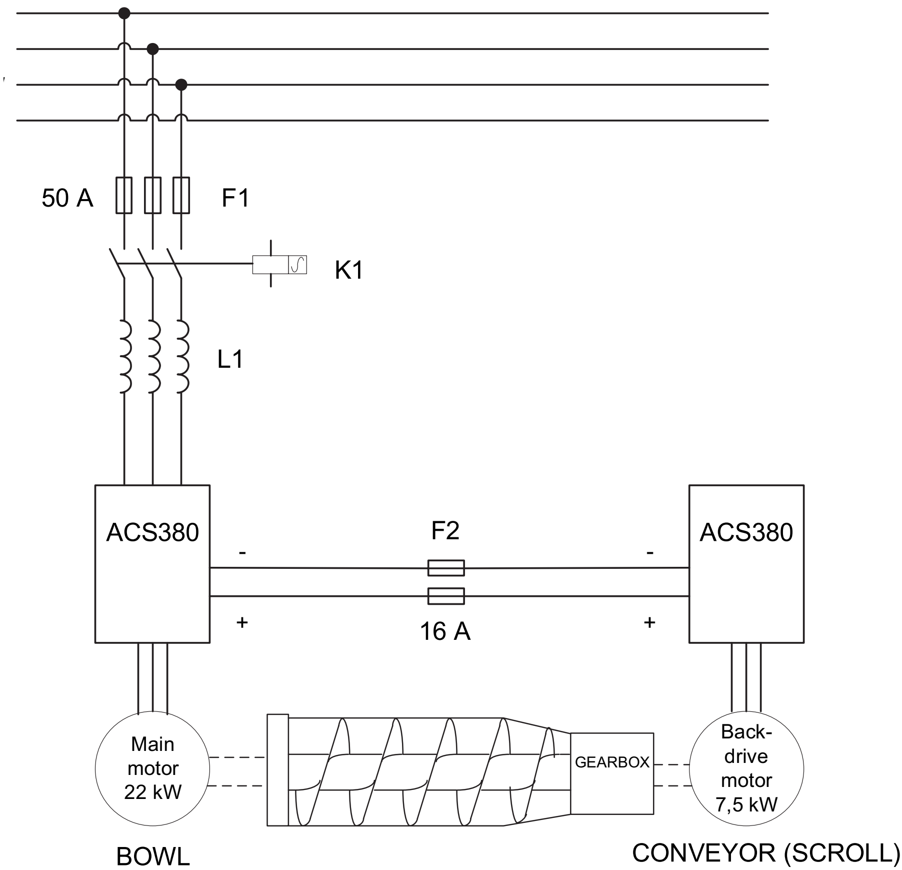
Main motor, 22 kW (bowl):

- For example, ABB M3BP 180L (3GBP 182 102 A)
- 22 kW / 1470 rpm
- η = 93.1%
- cosφ = 0.85

Back-drive motor, 7.5 kW (conveyor):

- For example: ABB M2BA 132 M4 A (3GBA 132 310 A)
- 7.5 kW / 1440 rpm
- η= 89.0%
- cosφ = 0.85

The diagram below shows the example system. The main motor and back-drive motor are interconnected via fluid inside the centrifugal decanter. In a steady state operation, the main drive rotates also the back-drive motor which keeps the scroll rotation speed slightly below the bowl speed. In other words, the back-drive motor brakes and generates energy back to the DC link.



Dimensioning procedure

No.	Task	Actions to be taken
1.	Select the motors and drives.	Motor sizes are given by the manufacturer. The drives you can select based on motor powers because there are no overloads. (See step 5 below.)
2.	Create system power curve vs. time diagrams.	In steady state operation, the larger motor rotates the bowl in motoring mode with shaft power of 22 kW. The smaller motor rotates the screw conveyor in generating mode with shaft power of 7.5 kW. In a steady state, the power taken from the power line is: (bowl motor nominal shaft power + bowl motor losses) - (screw motor shaft power - screw motor losses) = 22 kW + 1.7 kW - (7.5 kW - 0.7 kW) = 23.7 kW - 6.8 kW = 16.9 kW Calculate the losses using rating plate values. If accurate values are not available, use these rules of thumb: $P_N < 3$ kW $\eta = 0.7…0.85$ $P_N > 3$ kW $\eta = 0.85…0.93$
3.	Select the power supply type and plan how to handle excessive generating power.	One common AC supply with fuses will do with a contactor and an AC choke. On the assumption that the motor runs at the nominal speed, the 400 V line current is 33 A, including harmonics. It is calculated from the input power +10% (input cos φ and converter losses), added with harmonics using the rule of thumb of +20%. Because there is no need for regeneration back to the AC power line (see step 5 below), a diode supply will do. One AC supply through the larger drive is sufficient. The smaller drive and motor are supplied through the DC bus only. Brake chopper and resistor are not needed because the decanter is stopped slowly by means of friction (coasting) and in steady state, the generating power is used by the other drive operating in motoring mode.

No.	Task	Actions to be taken
4.	Select the fuses.	The AC power line current is 33 A. You can select out of two fuse sizes, 35 A or 50 A. We recommend 50 A fuses. The DC link fuses between the bowl drive and screw drive are 16 A. The DC fuse size is calculated using the energy flow from the screw motor to the bowl motor. According to step 2, the generating power back to DC link by the screw drive is 6.8 kW. Because the DC link voltage is 540 V in normal operation, the current will be 6.8 kW / 0.54 kW = 12.4 A. Thus, a 16 A fuse (gG, 690 V) is sufficient in this case.
5.	Check special cases.	The system has high kinetic inertia and it is started with long accelerating time (in some cases 1200 s). During the ramp-up, the decanter is empty and the motor load is low. When the final speed has been reached, the decanter is filled. The load as well as the speed is constant. Depending on the system, the working period can be rather long. If a decanter needs to be stopped, it will normally be stopped by means of friction. If it is necessary to stop the decanter more rapidly, a brake chopper and resistor needs to be installed to dissipate the surplus braking energy. However, normally there is no need for that.
6.	Check system fault cases.	No special system fault cases are to be expected, but a drive fault may stop the decanter. The drives are mutually interlocked in such a way that if one drive trips on a fault, it will also trip the other drive, and opens the main contactor. An emergency stop button trips the drives and opens the main contactor in the same way.
7.	Plan interlocking and safety.	Mutual trip interlocking, ie, trip of one drive causes the other drive to trip as well.

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Start-up

What this chapter contains

This chapter describes how to set the ACS380 parameters when starting up a common DC system.

Before setting the parameters below, make sure that you have started up the drives as described in the *firmware manual.*

Parameter settings

No.	Name	Value	Explanation
43.06	Brake chopper enable	Disabled/ Enable/...	If you use resistor braking in the system, use value Enable (or another value that enables the chopper). Otherwise use Disable.
30.30	Overvoltage control	Enable/Disable	If you use resistor braking in the system, use value Disable. Otherwise use value Enable.
23.13	Deceleration time 1		During deceleration, motor generates energy back to DC link of common DC system. If there is no resistor braking in use, generating power must not exceed the simultaneous motoring power (by other motors). You can affect on the generating power of an individual motor by adjusting the drive deceleration time. Prolonging time decreases generating power and vice versa.
23.15	Deceleration time 2		

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Technical data

What this chapter contains

This chapter contains technical data needed in planning and setting up a common DC system. For the general technical data for the drive, see its *hardware manual*.

Ratings with and without external AC chokes

See the drive *hardware manual*.

AC chokes

ACS380-…	Choke
1-phase U_N = 200…240V	
04xx-02A4-1	CHK-A1
04xx-03A7-1	CHK-B1
04xx-04A8-1	CHK-B1
04xx-06A9-1	CHK-C1
04xx-07A8-1	CHK-C1
04xx-09A8-1	CHK-D1
04xx-12A2-1	CHK-D1
3-phase U_N = 380…480V	
04xx-01A8-4	CHK-01
04xx-02A6-4	CHK-01
04xx-03A3-4	CHK-01
04xx-04A0-4	CHK-02
04xx-05A6-4	CHK-02
04xx-07A2-4	CHK-02
04xx-09A4-4	CHK-03
04xx-12A6-4	CHK-03
04xx-17A0-4	CHK-04
04xx-25A0-4	CHK-04

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DC link capacitances

ACS380-…	DC capacitance
1-phase U_N = 200…240V	
04xN-02A4-1	540 µF
04xN-03A7-1	700 µF
04xN-04A8-1	700 µF
04xN-06A9-1	1080 µF
04xN-07A8-1	1400 µF
04xN-09A8-1	1440 µF
04xN-12A2-1	2100 µF
3-phase U_N = 380…480V	
04xN-01A8-4	135 µF
04xN-02A6-4	135 µF
04xN-03A3-4	135 µF
04xN-04A0-4	200 µF
04xN-05A6-4	200 µF
04xN-07A2-4	270 µF
04xN-09A4-4	350 µF

ACS380-...	DC capacitance
04xN-12A6-4	500 µF
04xN-17A0-4	740 µF
04xN-25A0-4	1000 µF

Charging resistors and currents

ACS380-...	Charging resistors	Peak charging resistor current	Allowed charging sum current
1-phase U_N = 200…240 V			
04xN-02A4-1	82 Ohm / 10W	3.8 A	15 A
04xN-03A7-1	82 Ohm / 10W	3.8 A	15 A
04xN-04A8-1	82 Ohm / 10W	3.8 A	15 A
04xN-06A9-1	82 Ohm / 10W	3.8 A	15 A
04xN-07A8-1	82 Ohm / 10W	3.8 A	15 A
04xN-09A8-1	82 Ohm / 10W	3.8 A	25 A
04xN-12A2-1	41 Ohm / 20W	7.6A	25 A
3-phase U_N = 380…480 V			
04xN-01A8-4	390 Ohm / 10W	1.4 A	15 A
04xN-02A6-4	390 Ohm / 10W	1.4 A	15 A
04xN-03A3-4	390 Ohm / 10W	1.4 A	15 A
04xN-04A0-4	390 Ohm / 10W	1.4 A	15 A
04xN-05A6-4	390 Ohm / 10W	1.4 A	15 A
04xN-07A2-4	390 Ohm / 10W	1.4 A	15 A
04xN-09A4-4	390 Ohm / 10W	1.4 A	15 A
04xN-12A6-4	195 Ohm / 20W	2.8 A	30 A
04xN-17A0-4	130 Ohm / 30W	4.2 A	50 A
04xN-25A0-4	130 Ohm / 30W	4.2 A	70 A

DC fuses

The recommended ratings (rule of thumb) are presented in the table below. The voltage rating of the fuses is 690 V.

ACS380-...	Type (IEC 60269)	I_N (A)	I^2t (A^2s)	Voltage rating (V)	Bussmann type
1-phase U_N = 200...240 V					
04xx-02A4-1	00	32	275	690	170M2695
04xx-03A7-1	00	32	275	690	170M2695
04xx-04A8-1	00	40	490	690	170M2696
04xx-06A9-1	00	50	1000	690	170M2697
04xx-07A8-1	00	63	1800	690	170M2698
04xx-09A8-1	00	63	1800	690	170M2698
04xx-12A2-1	00	63	1800	690	170M2698
3-phase U_N = 380...480 V					
04xx-01A8-4	00	25	125	690	170M2694
04xx-02A6-4	00	25	125	690	170M2694
04xx-03A3-4	00	25	125	690	170M2694
04xx-04A0-4	00	32	275	690	170M2695
04xx-05A6-4	00	32	275	690	170M2695
04xx-07A2-4	00	40	490	690	170M2696
04xx-09A4-4	00	40	490	690	170M2696
04xx-12A6-4	00	50	1000	690	170M2697
04xx-17A0-4	00	63	1800	690	170M2698
04xx-25A0-4	00	80	3600	690	170M2699

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Appendix A - Motor's kinetic energy vs. DC capacitors' electrical energy

What this chapter contains

This chapter contains a calculation example showing how the machinery's kinetic energy and DC capacitors' electrical energy are related.

Calculation example

The following calculation is only an example; different parameters lead to different results. However, it helps to understand the orders of energy magnitudes in drive systems.

The calculation shows:

- how much energy can be stored into DC capacitors and
- how much the motor speed drops compared to the nominal speed due to change of kinetic to electrical energy.

The influence of friction and other losses has been ignored.

Motor:

- M3BP 160M
- 11 kW
- 400 V / 50 Hz
- 1465 1/min
- J = 0.067 kgm^2

Drive:

- ACS380-04xx-25A0-4
- 400 V / 11.0 kW
- C_{DC} = 1000 µF

The equation below shows the kinetic energy of the motor running with the nominal speed (unloaded):

$$E_k = ½ J\omega^2 = ½ \cdot 0.067 \cdot (2 \cdot \pi \cdot 1500/60\ 1/\text{rad})^2$$

$$= ½ \cdot 0.067 \cdot (\pi \cdot 50)^2 = 836\ \text{Ws}$$

DC capacitors are normally charged to 540 V DC, and in case of motor generation, the voltage can rise up to 780 V DC before the overvoltage controller starts to limit the voltage rise. The DC circuit capacitance of ACS380-04xx-25A0-4 is 1000 µF. Thus, the additional energy which can be stored is:

$$\Delta E_E = ½CU^2_{Max} - ½CU^2_{Nim} = ½C(U^2_{Max} - U^2_{Nim})$$

$$= ½ \cdot 1000 \cdot 10^{-6}(780^2 - 540^2)\ \text{Ws}$$

$$= 158\ \text{Ws}$$

Thus, with these parameters, only one quarter of the motor's kinetic energy can be stored into the DC capacitors as electrical energy.

The equation below shows to which speed the motor can be decelerated from the nominal speed by means of "electrical" braking:

$$\Delta E_K = \Delta E_E$$

$$½ J\omega_N^2 - ½ J\omega^2 = \Delta E_E$$

$$½ J\omega^2 = ½ J\omega_N^2 - \Delta E_E$$

$$\omega = [\omega_N^2 - 2\Delta E_E / J]^{½} = [24649-4716] = 141\ \text{rad/s} = 1348\ 1/\text{min}$$

The result is approximately 89% of the nominal speed. Thus, even you ignore the friction, motor efficiency, and the inertia and load of the machinery, the possible speed drop is rather small if you only store the braking energy in the DC capacitors of one drive.

Generally speaking, the use of DC capacitor of one drive as the storage for the surplus generating energy has minor role in the system design. However, it is worth considering if the generating motor is small compared to the other motors (and their drives) in the same common DC system.

Further information

Product and service inquiries

Address any inquiries about the product to your local ABB representative, quoting the type designation and serial number of the unit in question. A listing of ABB sales, support and service contacts can be found by navigating to www.abb.com/searchchannels.

Product training

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