ACS850

Application guide
Common DC configuration for ACS850-04 drives

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List of related manuals

Hardware manuals	Code (English)
ACS850-04 drive modules (0.37 to 45 kW) hardware manual	*3AUA0000045496*
ACS850-04 drive modules (55 to 160 kW, 75 to 200 hp) hardware manual	*3AUA0000045487*
ACS850-04 drive modules (200 to 500 kW, 250 to 600 hp) hardware manual	*3AUA0000026234*
ACS850-04 drive modules (160 to 560 kW, 200 to 700 hp) hardware manual	*3AUA0000081249*
Firmware manuals and guides	
ACS850 Standard Control Program firmware manual	*3AUA0000045497*
ABB Drives - Technical Guide Book	*3AFE64514482*

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.

ACS850

Application guide
Common DC configuration for ACS850-04 drives

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Table of contents

Introduction to the manual

What this chapter contains

This chapter describes the intended audience and contents of this manual.

Compatibility

This manual is compatible with the ACS850-04 drive modules and the related options.

Intended audience

This manual is intended for people who plan the installation, install, commission, use, and service the drive modules connected in the common DC link. Read the drive hardware manual before working on the drive.

You are expected to know the fundamentals of electricity, wiring, electrical components, and electrical schematic symbols. This manual is written for readers worldwide.

Safety instructions

Follow all safety instructions delivered with the drive. For complete safety instructions, see the relevant drive manual (see section List of related manuals).

Categorization according to the frame size

Instructions and technical data that only concern certain frame sizes are marked with the symbol of the frame size. The frame size is marked on the drive and in the rating tables in the related hardware manuals. This document applies to frame sizes A, B, C, D, E0, E, G, G1 and G2.

Complete drive documentation

This guide contains only common DC related technical items for the ACS850-04 drive modules. For complete documentation, see section List of related manuals. If there are deviations in the given data between this guide and other manuals, then the document with the latest date will apply.

Terms and abbreviations

Term / abbreviation	Description
EMC	Electromagnetic compatibility
motoring mode	A motor consumes energy in its normal operation mode.
regenerative mode	A motor is braking and the excess energy is fed back to the common DC system.
THD	Total harmonic distortion

Introduction to common DC systems

What this chapter contains

This chapter contains a general introduction to common DC systems and a flowchart of the steps for configuring the common DC system with ACS850-04 drive modules.

Operation principle

Common DC is a system configuration consisting of two or more drives whose intermediate DC capacitor banks are connected together. This allows energy to flow freely through the busbars between the individual drives.

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

The energy in a DC link is always in balance, that is, the energy flow to and from the DC link is equal, including the fact that DC capacitors can store a small amount of energy when the DC voltage is allowed to rise temporarily.

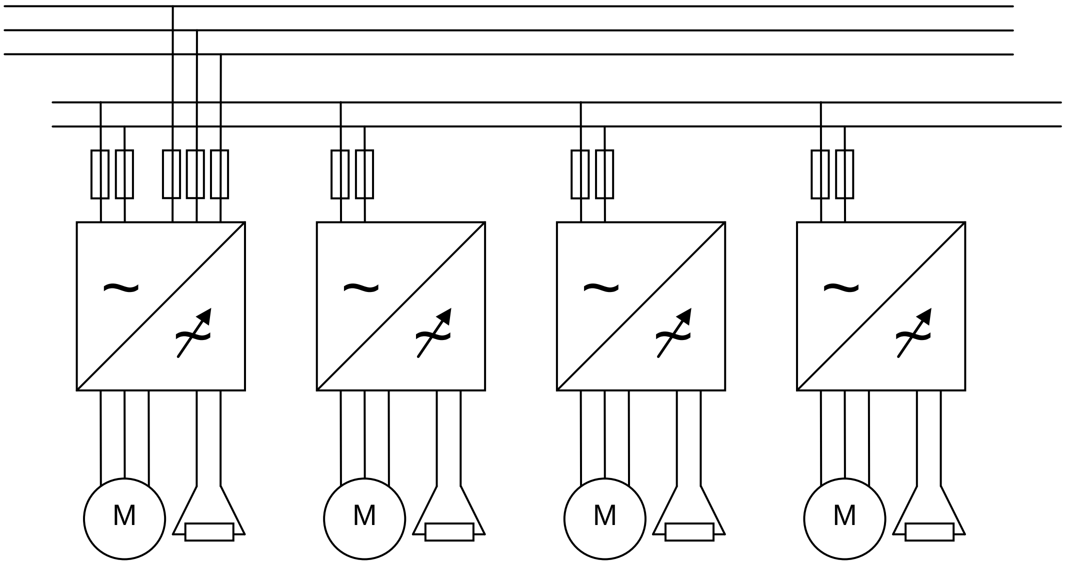
As the main principle, the energy flows from the supply line to the DC link. Cases where the generated energy is higher than the energy used are related to ramp-down, quick stop or emergency stop situations. In these cases, the energy balance can be maintained by using a brake chopper and a brake resistor (excess energy is dissipated to heat).

Drives connected to a common DC link can take all their energy from the DC link only, but one or several drives have to be connected to the supplying AC power line.

The main benefits of a common DC system are:

- Energy savings due to a reduced need for the supply side power.
- A DC link energy storage can be used for short braking energy pulses to avoid the need for an external braking resistor.
- Braking energy can be handled with one unit even if several drives are in the regenerative mode at the same time. However, several units with an active braking chopper can be used simultaneously with the braking resistor if needed.
- In the optimal case, no resistor braking equipment is needed. If braking equipment is still required, the resistor braking capacity can be optimized for the whole system.
- Possibility for one AC input connection. The selected unit feeds also other drives connected to the common DC system.

The figure below shows an example of a common DC system. See also the figure on page 11.



Unequal current distribution and different charging methods cause challenges to common DC systems:

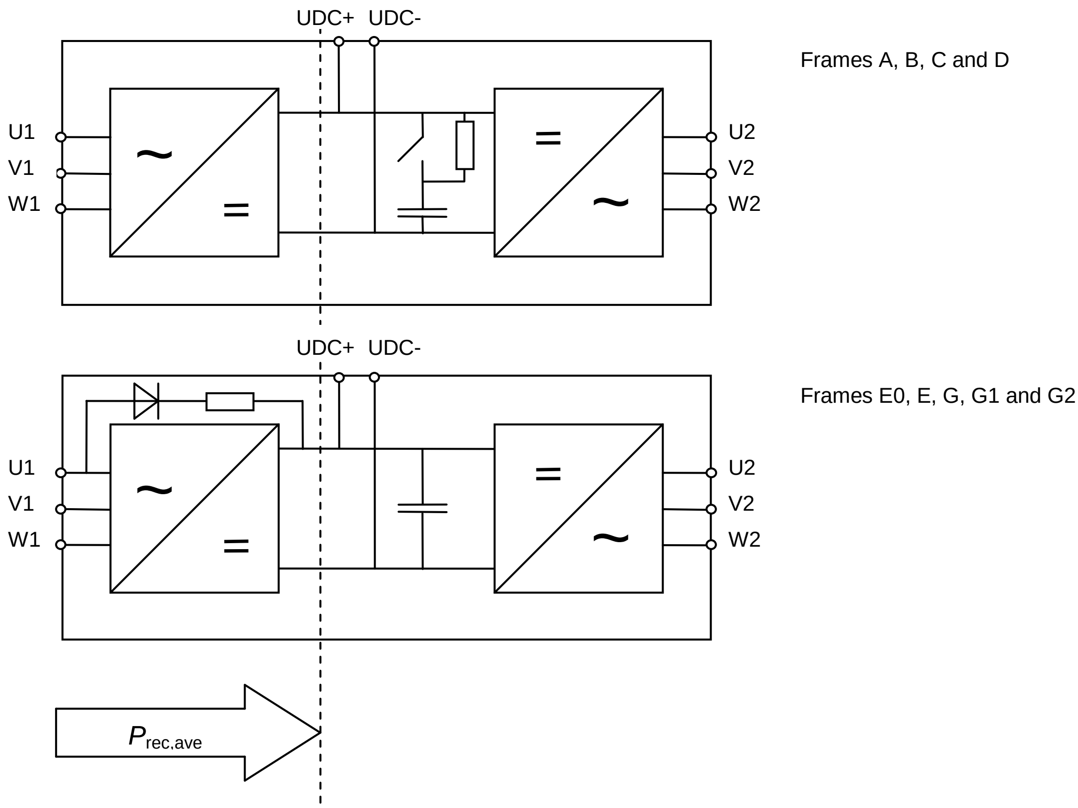
- Unequal AC input current distribution between the drives connected to the same AC power line. This is influenced by input cables, AC or DC chokes and input bridges' forward characteristics. If the voltage reduction over the rectifier and the related components mentioned is not the same in all converters, more current will flow through the rectifier which has a lower voltage reduction. Factors which influence current distribution include temperature, tolerances of components and, in DC choke cases, the input cable's cross-sectional area and length.
- Charging methods vary depending on the converter size (see the block diagram below). Because of this the modules with frame sizes A-D must not be connected to the AC power line if they are connected to same DC link with frame sizes E0, E, G, G1 and G2.

Note: The drive compliance with the EMC Directive on low voltage networks is specified in the appropriate hardware manual. However, please notice that the different common DC systems have not been tested.

For a general introduction to electrical braking and common DC systems, see also *Technical guide No. 8 Electrical braking* in *ABB Drives - Technical Guide Book* (3AFE64514482 [English]).

Power ratings for the DC connection

The converter unit block diagram with related power ratings is shown in the following figure.



Average rectifier power $P_{rec,ave}$

$P_{rec,ave}$ is the maximum average DC power that the input bridge of a drive can supply. The actual average DC power taken from the input bridge should be lower than this value in any 3 minutes time window.

Peak rectifier power $P_{rec,max}$

$P_{rec,max}$ is the maximum short time DC power capacity of a drive. This is the maximum DC power level for the input bridge and the DC connection terminals during 1 s.

ACS850-04 Type	$P_{rec,ave}$	$P_{rec,max}$
	kW	**kW**
03A0-5, 03A6-5, 04A8-5,	3.5	4.4
08A0-5	4.7	5.9
010A-5	6.5	8.1
014A-5, 018A-5	10	13
025A-5, 030A-5, 035A-5	20	25
044A-5, 050A-5	29	36
061A-5, 078A-5, 094A-5	52	66
103A-5	61	77
144A-5	85	90
166A-5	98	103
202A-5	119	133
225A-5	133	154
260A-5	152	197
290A-5	171	215
430A-5	260	315
521A-5	315	351
602A-5	364	442
693A-5	419	511
720A-5	435	511
387A-5	230	340
500A-5	280	340
580A-5	360	600
650A-5	400	600
710A-5	450	660
807A-5	510	660
875A-5	565	660

P_{rec} values are defined at 540 V DC link voltage level, which corresponds to the nominal 400 V AC supply voltage U_{ac}.

In case of other DC voltage levels (U_{dc}), the P_{rec} values in the table are multiplied by U_{dc} /540, where $U_{dc} \approx 1.35 \times U_{ac}$.

Chokes, braking choppers and charging circuits

Drive	Frame size	Choke	Braking chopper	DC supply charging circuit
ACS850-04	A, B	AC Optional	As standard	Built-in
	C, D	DC	As standard	Built-in
	E0, E, G, G1,G2	AC	Optional	External

Configuration steps

The following flowchart describes the configuration steps of a common DC system. Each configuration step is described in more detail in the following sections.

Configuration step	See section
Define the common DC load cycle: • DC link power versus time for each axis • average and maximum total motoring power • average and maximum total regenerative power	Defining the load cycle for the common DC system
Select the drive module(s) to be connected to the AC supply, and define which will be connected to the AC power line.	Selecting the supply unit for the common DC system
Select the mains choke(s) if necessary	Selecting the mains choke
Handle the excess regenerative power	Handling the excess regenerative power
Consider the other design aspects	General system design items

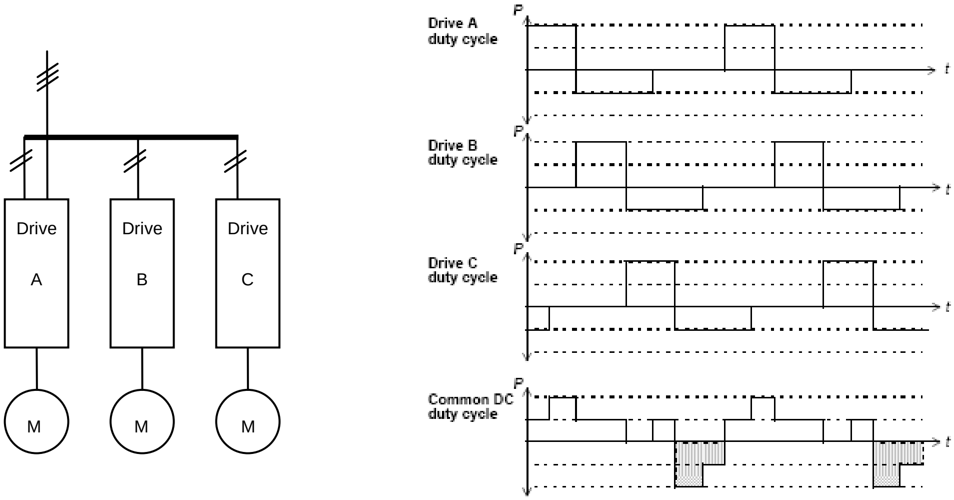
Planning the common DC system

What this chapter contains

This chapter describes how to plan a common DC system with ACS850-04 drive modules.

Defining the load cycle for the common DC system

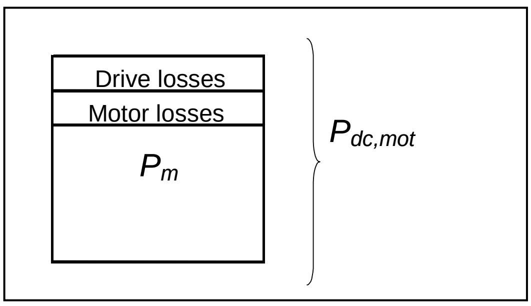
Each drive and motor has its own specific load cycle profile. The sum of these load cycles defines the system load cycle in the DC link as shown in the figure below.



To define the load cycle of the system, you must first define the load cycle for each drive separately, and then calculate load cycle for the whole system based on the definitions and formulas given in the following sections.

DC link power $P_{dc,mot}$ of motoring axis

$P_{dc,mot}$ is the power supplied to the DC terminals to get the required mechanical motoring power on the motor shaft. $P_{dc,mot}$ is higher than the shaft power, because it also covers the losses in the drive and the motor.



$$P_{dc,mot} = k_{eff} \times P_m$$

$$P_m(kW) \approx \frac{T \times n}{9550}$$

P_{dc} : DC link power

k_{eff} : efficiency factor (1/eff) to include drive and motor losses.
If not known, value 1.25 can be used.

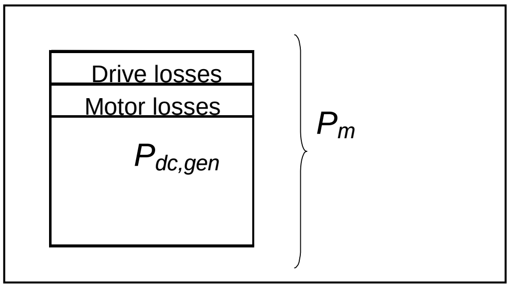
P_m : motor mechanical shaft power

T : torque (Nm) on motor shaft

n : motor shaft speed (rpm)

DC link power $P_{dc,gen}$ of regenerating axis

$P_{dc,gen}$ is now the power supplied from the regenerating motor to the DC terminals. $P_{dc,gen}$ is lower than the shaft power, because the shaft power now covers also the losses in the drive and the motor.



$$P_{dc,gen} = \frac{P_m}{k_{eff}}$$

Based on the system power profile, the following system level DC link power values are defined.

Average motoring power $P_{mot,ave}$

$P_{mot,ave}$ is the average of the *motoring* DC link power over the whole cycle. This power is taken from the AC power line. For long load cycles, $P_{mot,ave}$ should be determined over the worst-case 3 minutes time window.

Peak motoring power $P_{mot,max}$

$P_{mot,max}$ is the positive peak power in the power profile. This value can have a major impact on the selection of the drive module(s) connected to the AC power line if many axes are accelerated simultaneously.

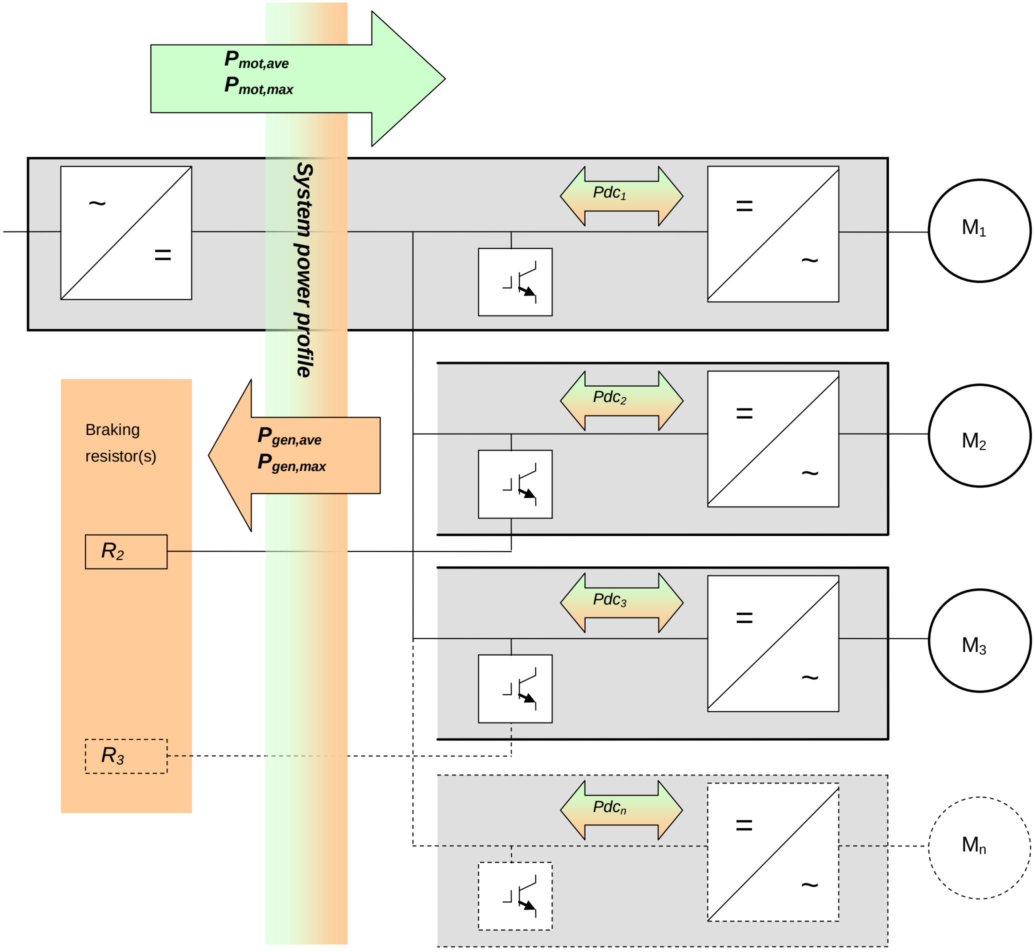
Average regenerative power $P_{gen,ave}$

$P_{gen,ave}$ is the average of the *regenerating* DC link power over the whole cycle. This power must be dissipated in the braking resistor(s) or fed back to the AC power line. $P_{gen,ave}$ should be determined over the worst-case 30 seconds time window if the internal braking chopper of the drive is used.

Peak regenerative power $P_{gen,max}$

$P_{gen,max}$ is the negative peak power in the power profile. This value has a major impact on the number of active braking choppers needed.

The power values defined above are shown in the following diagram.



Selecting the supply unit for the common DC system

The DC link power can be supplied via a suitable drive module for the common DC system. Select the drive module based on the average motoring power ($P_{mot,ave}$) and peak motoring power ($P_{mot,max}$) requirements and the charging circuit capacity requirements as described below.

In addition, in frame sizes E0, E, G, G1 and G2, the charging circuit of the connected module must be able to withstand the total charging energy E_{tot}.

Defining the DC link power supplied via the drive

Single AC input with frames A…D

In the optimum situation, only one drive module is connected to the AC power line and the other drive modules are supplied via the DC link. The following conditions must be fulfilled:

- $P_{mot,ave} < P_{rec,ave}$
- $P_{mot,max} < P_{rec,max}$

If the conditions cannot be fulfilled, either a drive module with higher P_{rec} ratings can be selected (if feasible) or a multiple AC input configuration can be used.

Single AC input with frames E0…G2

To determine whether it is possible to leave other converters unconnected to the AC power line, see section Checking the charging capacity (common AC supply). The following conditions must also be fulfilled:

- $P_{mot,ave} < P_{rec,ave}$
- $P_{mot,max} < P_{rec,max}$
- $E_{tot} < E_{rconnected}$

where E_{tot} is the total charging energy and $E_{rconnected}$ is the charging resistor's energy pulse withstand of the connected converter (for detailed descriptions, see page 22).

Multiple AC input

To determine whether it is possible to leave some converters unconnected to the AC power line, see section Checking the charging capacity (common AC supply).

If two or more drive modules are connected to the AC power line, the same conditions as above must still be fulfilled:

- $P_{mot,ave} < P_{rec,ave}$
- $P_{mot,max} < P_{rec,max}$
- $E_{tot} < E_{rconnected}$

The P_{rec} ratings are calculated from the individual ratings as follows:

- $P_{rec,ave} = P_{rec,ave1} + k(P_{rec,ave2} + P_{rec,ave3} + \ldots.)$
- $P_{rec,max} = P_{rec,max1} + 0.9k(P_{rec,max2} + P_{rec,max3} + \ldots.)$

where $P_{rec,ave1}$ and $P_{rec,max1}$ are the values of the drive module with the highest power ratings. It is recommended that the units connected parallel are of the same size.

Only the converters that are connected to the AC power line are used for the power limit calculations. The power correction factor (**k**) for each combination can be found in the table below.

When several converters are connected to the AC power line, the least efficient power correction factor is chosen from the table, that is, the smallest factor. See *Example 1* and *Example 2* below.

When the charging circuits of the converters are different, it is not always allowed to connect the converters to the same AC power line. The table below shows when the connection cannot be done (No).

ACS850-04 power correction factors

Frame size	A, B	C, D	E0 or E	G, G1, G2
A, B	k=0.8	No	k=0.6 C	k=0.6 C
C, D	No	k=0.5	No	No
E0 or E	k=0.6 C	No	k=0.7	k=0.6
G, G1, G2	k=0.6 C	No	k=0.6	k=0.7

No: Do not connect the supply of the smaller converter. The converters have different types of input chokes. Frame sizes C and D have DC chokes and frame sizes E0…G2 have AC chokes. Frame sizes A and B have AC chokes as an option.

C: If both converters are connected to the AC power line, the DC links must be connected together via a contactor because the converters have different charging circuits. The DC contactors are switched on after all of the DC links are charged and the converters are in the READY state.

Note: The $P_{rec.ave}$ value is higher if the smallest converter is not connected to the AC power line.

Example 1

The DC links of three converters ACS850-04-08A0-5, 4.7 kW, (frame size A); ACS850-04-035A-5, 20.5 kW, (frame size C) and ACS850-04-035A-5, 20.5 kW, (frame size C) are connected together. The input terminals of the 4.7 kW converter are left unconnected. According to the table, k = 0.5 when two converters of frame size C are connected to the AC power line, therefore $P_{rec,ave}$ becomes:

$$P_{rec,ave} = 20.5\ \text{kW} + (0.5 \cdot 20.5\ \text{kW}) = 30.75\ \text{kW}$$

Example 2

The DC links of three converters ACS850-04-103A-5, 61 kW, (frame size E0); ACS850-04-202A-5, 119.3 kW, (frame size E) and ACS850-04-521A-5, 315.3 kW, (frame size G) are connected together. All three converters are connected to the AC power line. According to the table, k = 0.7 when E0 and E are connected to the AC power line, and k = 0.6 when E and G are connected to the AC power line. The lowest factor is used in the calculations, that is, k = 0.6, and $P_{rec,ave}$ becomes:

$$P_{rec.ave} = 315.3\ \text{kW} + (0.6 \cdot 119.3\ \text{kW}) + (0.6 \cdot 61\ \text{kW}) = 423.5\ \text{kW}$$

Checking the charging capacity (common AC supply)

When the power is switched on in the common DC system, the DC link capacitors in each drive module are charged. The charging current is fed through the unit(s) connected to the AC power line. Due to this the charging capacity of the selected supply unit has to be checked so that it is able to withstand the whole charging energy.

The drive modules in frame sizes A-D have a charging circuit in series with the capacitor bank.

- In the common DC system, the charging circuits act in parallel.
- The sum of the charging currents is fed from the supply unit.

In the drive modules in frame sizes E0, E, G, G1 and G2, the charging circuit is in parallel with the input bridge, and the charging circuit(s) of the drive(s) is connected to the supply charge of all the capacitor banks.

The charging circuit data for each drive module is shown in the following table.

ACS850-04 type	**R**	**R_{min}**
	ohm	**ohm**
03A0-5, 03A6-5, 04A8-5, 06A0-5	50	21.7
08A0-5	50	16.5
010A-5	130	14.7
014A-5, 018A-5	130	10.4
025A-5, 030A-5, 035A-5	66	8.5
044A-5, 050A-5	66	4.6
061A-5, 078A-5, 094A-5	33	4.6
103A-5, 144A-5	33	N/A
166A-5, 202A-5, 225A-5, 260A-5 290A-5	27	N/A
430A-5, 521A-5, 602A-5, 693A-5 720A-5	3.3	N/A
387A-5, 500A-5, 580A-5, 650A-5	3.3	N/A
710A-5, 807A-5, 875A-5	10	N/A

R : charging resistance of the drive module.

R_{min} : the minimum value of the total effective charging resistance allowed for the drive module

Single AC input

Define the total effective charging resistance R_{tot} from the drive modules connected to the DC link:

$$R_{tot} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}}$$

where the R values (R_1, R_2,…) are the charging resistances of each drive module.

The following condition must be fulfilled:

$R_{tot} > R_{min}$

where R_{min} is the minimum charging resistance of the drive that is connected to the AC power line.

If the condition cannot be fulfilled, more than one drive module must be connected to the AC power line.

Multiple AC input

Define R_{tot} as in the previous case. Define the effective total minimum resistance as follows:

$$R_{min} = \frac{1}{\frac{1}{R_{min1}} + \frac{1}{R_{min2}} + \cdots + \frac{1}{R_n}}$$

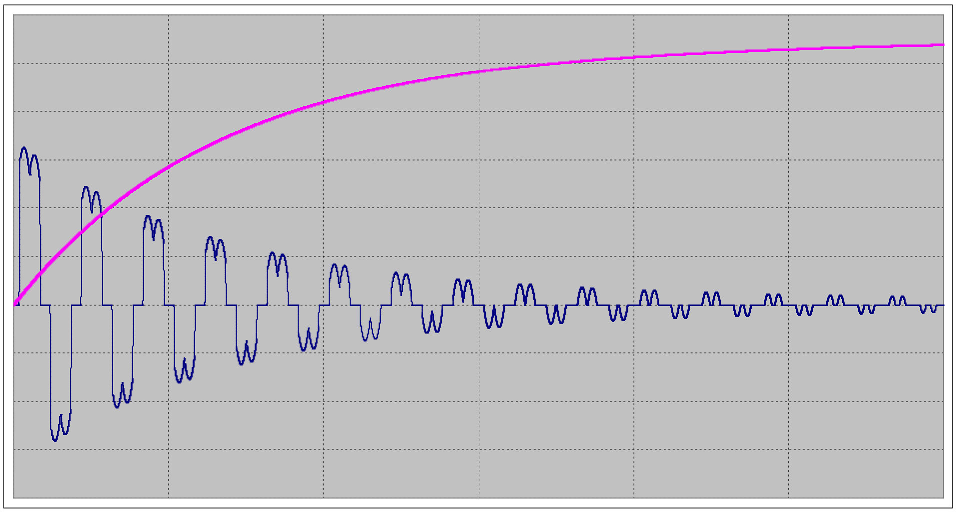
The R_{min} values (R_{min1}, R_{min2},…) are the individual minimum resistance values of the drive modules connected to the AC power line.

The following condition must be fulfilled:

$R_{tot} > R_{min}$

Charging current

A typical AC input line current waveform and the DC link voltage during charging are shown in the figure below.



Check that the AC supply side components (fuses, contactors, etc.) can withstand the peak current.

The peak current $I_{ac,peak}$ is calculated as follows:

$$I_{ac,peak} = \frac{\sqrt{2} \times U_{ac}}{R_{tot}}$$

where U_{ac} is the line to the line supply voltage. The charging time is generally about 0.3 s (U_{dc} > 95% U_{dcN}) with the drive modules (frame sizes A...G). In frame sizes G1 and G2 the charging time is about 1 s.

Frame sizes A…D

In frame sizes A-D the charging resistor is in series with the DC capacitors and all DC links are charged via their own resistors despite of the main supply connection. The inrush current remains at an acceptable level, if the maximum number of unconnected converters per one connected converter is five.

Note: Always connect the biggest converter to the AC power line.

Frame sizes E0, E, G, G1 and G2

In frame sizes E0, E, G, G1 and G2 the charging circuit is in parallel with the input bridge. The charging resistor of the connected converter limits the number of the unconnected converters. The charging circuit of the connected converter must be able to withstand the total charging energy E_{tot}, that is,

$E_{rconnected} > E_{tot}$

where $E_{rconnected}$ = charging resistor's energy pulse withstand of the connected converter

The charging energy of the DC link capacitors of a single converter is calculated as follows:

$E = 1/2 \cdot C_{DC} \cdot (1.35 \cdot U_{net})^2$

where C_{DC} = capacitance of the DC link capacitor. See section DC link capacitance values.

U_{net} = actual supply voltage

The total charging energy of the system E_{tot} is calculated by summing the energies of single converters:

$E_{tot} = 1/2\ (C_{DC1} + \ldots + C_{DCn}) \cdot (1.35 \cdot U_{net})^2$

The energy pulse withstands E_r of the charging circuits are listed in the following table.

Frame size	***Er* / J**
E0	1000
E	2000
G	5600
G1	5600
G2	7380

Note: Always connect the biggest converter to the AC power line. If the charging circuit of the biggest converter is not capable of delivering the demanded charging energy, connect also the next biggest converter to the AC power line.

Example 1

The DC links of three converters ACS850-04-103A-5 (frame size E0), ACS850-04-0202A-5 (frame size E) and ACS850-04-430A-5 (frame size G) are connected together. The main supply voltage is 400 V. The total charging energy of the capacitors is

$E_{tot} = 1/2 \cdot (2400\ \mu F + 4700\ \mu F + 8600\ \mu F) \cdot (1.35 \cdot 400V)^2 \cdot 10^{-6} = 1866\ J$

The charging resistor of the ACS850-04-430A-5 (frame size G) is able to withstand the whole charging energy,

$E_{tot} = 2289\ J < E_r = 5600\ J.$

Example 2

The DC links of two ACS850-04-202A-5 converters (frame size E) and three ACS850-04-430A-5 converters (frame size G) are connected together. The main supply voltage is 500 V. The total charging energy of the DC link capacitors is

E_{tot} = ½ · (2 ·4700 µF + 3 ·8600 µF) · (1.35 ·500V)^2 ·10^{-6} = 6971 J

E_{tot} exceeds the energy pulse withstand of the ACS850-04-430A-5 (frame size G) charging circuit.

Charging resistors of two ACS850-04-430A-5 converters (frame size G) are able to withstand the charging energy,

E_{tot} = 6971 J < E_r = 2 · 5600 J

Checking the charging capacity (external DC supply)

The drive modules can also be supplied from an external DC supply. This can be the case if:

- the needed DC link power cannot be handled with any available drive module. In this case, some other diode supply unit can be used.
- the regenerative power should be fed back to the AC supply.

A 6-pulse or higher pulse number diode supply or a regenerative supply are suitable.

An AC or a DC choke is needed in the external supply circuit to reduce the ripple current of the drive units DC link capacitors to an acceptable level.

The recommended choke relative reactance is 3%. The choke phase inductance is calculated using the formula:

L_v= X · U^2 ÷ 2π · f · P_{DC}

where X = choke relative reactance, U=supply voltage and P_{DC} = needed DC power.

Example

The needed DC power is 250 kW, the supply frequency is 50 Hz, and the supply voltage is 400 V.

L_v = (0.03 · (400 V)^2) ÷ (2π · 50 Hz · 250 kW) = 61 µH.

The recommended charging resistor value is the same as the minimum or nominal resistance of the converter with the highest power (given in the table on page 20).

The peak current during charging is calculated by the same equation as in section Checking the charging capacity (common AC supply):

$$I_{ac,peak} = \frac{\sqrt{2} \times U_{ac}}{R_{tot}}$$

Charging time is longer if a higher resistance value is used.

It must be checked that the AC supply side components can withstand the peak current.

The charging resistor energy withstand (E) is calculated by equation:

$$E = 1.3 \cdot C \cdot U^2$$

where C is the total capacitance of the DC link capacitors, and U is the supply line-to-line rms voltage, for example, 400 V or 500 V. Factor 1.3 covers the upper tolerance limit of capacitance.

If drive units with different charging circuits are used, the DC links must be connected together via contactors.

Frame sizes A…D

If only drive modules with frame sizes A…D are used, there is no need for an external charging circuit with the external DC supply, because the drive modules have internal charging circuits in series with DC link capacitors.

Frame sizes E0, E, G, G1 and G2

In frame sizes E0, E, G, G1 and G2, the charging circuit is in parallel with the input bridge. A separate charging circuit is needed.

The AC fan of ACS850-04 frame G must be powered separately. See section Powering the AC fan in frame G.

Supply units other than ACS850-04

When some other type of supply unit than ACS850-04 is used, its DC voltage compatibility with the drive units must be checked in addition to the earlier described items (see section DC voltage limits).

Selecting the mains choke

In common DC systems, the drive module(s) connected to the AC power line must be equipped with mains choke(s). The mains chokes are needed:

- to get the maximum DC power ratings from the drive module(s)
- to reduce the AC input current (rms, peak) level
- to meet the requirements for harmonic distortion
- to balance the supply current in a multiple AC input.

Mains choke data

Data for the mains chokes is listed in the table below. Drive types not listed below have a built-in choke as standard.

Frame	**Choke type**	***L***	**I_{th}**	**I_{max}**
ACS850-04		**µH**	**A**	**A**
03A0-5, 03A6-5	CHK-01	6370	4.2	6.2
04A8-5, 06A0-5, 08A0-5	CHK-02	4610	7.6	11.4
010A-5, 014A-5	CHK-03	2700	13.1	19.6
018A-5	CHK-04	1475	22.0	26.3

L : mains choke nominal inductance

I_{th} : the maximum allowed continuous current (rms) at 55 °C (131 °F) ambient temperature

I_{max} : the maximum allowed short time current (rms). This current is allowed for maximum of 10 s.

Single AC input

Define the *average motoring line current* $I_{mot,ave}$

$$I_{mot,ave} = 1.15 \times \frac{P_{mot,ave}}{\sqrt{3} \times U_{ac}}$$

where U_{AC} = supply voltage.

Define the *peak motoring line current* $I_{mot,max}$

$$I_{mot,max} = 1.15 \times \frac{P_{mot,max}}{\sqrt{3} \times U_{ac}}$$

The factor 1.15 covers the effects of the line side power factor, the current harmonic distortion, and the rectifier losses.

The following conditions must be fulfilled:

$$I_{mot,ave} < I_{th}$$

$$I_{mot,max} < I_{max}$$

Multiple AC input

If two or more drive modules are connected to the AC power line, the same conditions as above must still be fulfilled, but now for each individual drive module (i) and its mains choke separately. All the connected drives must have a mains choke.

$$I_{mot,ave(i)} < I_{th(i)}$$

$$I_{mot,max(i)} < I_{max(i)}$$

where the total motoring line current is allocated to the individual drive modules according to their power ratings:

$$I_{mot,ave(i)} = 1.20 \times \frac{P_{rec,ave(i)}}{(P_{rec,ave1} + P_{rec,ave2} + ... + P_{rec,aven})} \times I_{mot,ave}$$

$$I_{mot,max(i)} = 1.20 \times \frac{P_{rec,max(i)}}{(P_{rec,max1} + P_{rec,max2} + ... + P_{rec,max\,n})} \times I_{mot,max}$$

where:

- $I_{mot,ave(i)}$ and $I_{mot,max(i)}$ are the AC input currents of the concerned AC input
- $P_{rec,ave(i)}$ and $P_{rec,max(i)}$ are the power ratings of the drive module connected to the concerned AC input
- $P_{rec,ave1} \ldots P_{rec,aven}$ and $P_{rec,max1} \ldots P_{rec,maxn}$ are the power ratings of the drive modules connected to the AC input
- factor 1.20 covers the load unbalance due to the variation of the characteristics of the individual choke(s) and drive module(s) from the nominal ones

- $I_{mot,ave}$ and $I_{mot,max}$ are calculated from $P_{mot,ave}$ and $P_{mot,max}$ as in the single AC input case (see above).

Harmonic distortion

If there are requirements for the harmonic distortion level, a mains choke (CHK-xx) is typically needed in ACS850-04 frames A and B. Other drive types have a choke as standard.

Total harmonic distortion is about 40…45%, when a choke is used according to the default selection. Then also the requirements for harmonic distortion according to standards IEC 61000-3-2, IEC 610003-4, and IEC 610003-12 are typically fulfilled.

A more accurate harmonics analysis can be made with the sizing tool DriveSize. See also *Guide to Harmonics with AC Drives* in *ABB Drives - Technical Guide Book* (3AFE64514482 [English]) for a basic theory about this topic.

Handling the excess regenerative power

Regenerative power is fed by the motor to the DC link when the motor produces negative torque and then brakes. This is typical when the motor is decelerating or when the motor is in a generator mode. If the other drive modules do not take enough active energy from the DC link at the same time, the braking energy is stored in the DC link capacitors and the DC link voltage increases. A low amount of regenerative energy can be handled within the common DC capacitors if the DC link voltage stays below the trip limit.

The regenerative energy should be removed from the system if the energy capacity of the common DC system is not enough. This can be done by braking resistors or by feeding the excess energy back to the supply network. Either resistor braking or an external regenerative supply unit can be used.

Defining the common DC capacitance

Many acceleration and deceleration processes are typical for applications with high performance machinery drives. It is useful for such applications to connect those drives into the common DC link to utilize also the DC link energy storage behavior. In the common DC system, all the capacitor banks of the individual drive modules are connected in parallel and they act as common energy storage. This provides the following advantages:

- The need for the braking resistor in the drive system may be eliminated. The heat dissipation in the control cabinet is considerably reduced.
- The energy stored in the DC link capacitors during the regenerating period can be used afterwards for the motoring power. The energy demand from the supply is then reduced.

DC link capacitance values

Each drive module has its own capacitor bank. The capacitance value of each drive size is given in the table below.

ACS850-04 type	**C_{dc}**
	µF
03A0-5, 03A6-5	120
04A8-5, 06A0-5, 08A0-5	240
010A-5	370
014A-5, 018A-5	740
025A-5, 030A-5, 035A-5	670
044A-5, 050A-5	1000
061A-5	1340
078A-5, 094A-5	2000
103A-5	2400
144A-5	3600
166A-5, 202A-5	4700
225A-5, 260A-5, 290A-5	7050
430A-5	8600
521A-5	10800
602A-5	12900
693A-5, 720A-5	15100
387A-5, 500A-5, 580A-5, 650A-5	15800
710A-5, 807A-5, 875A-5	23700

Energy capacity in common DC

Determine the energy capacity W_{dc} in the common DC system in following way:

$$W_{DC} = \frac{\left(C_{dc1} + C_{dc2} + C_{dc3} + \ldots + C_{dcn}\right)}{2} \times \left(U_{dc,lim}{}^{2} - U_{dc}{}^{2}\right)$$

where:

- $C_{dc1} \ldots C_{dcn}$ are the actual capacitance values of the drive modules connected to the common DC link.
- $U_{dc,lim}$ is the DC link voltage level that is allowed for the system.
- U_{dc} is the actual DC link voltage level in a normal situation.

Calculate the actual DC link voltage to be used in energy calculations as:

$$U_{dc} = \sqrt{2} \times U_{ac}$$

The available energy capacity now depends on the criteria for the $U_{dc,lim}$ and the actual DC link voltage supplied into the common DC system. The selection of the value for $U_{dc,lim}$ depends on the common DC system configuration and its general requirements.

The common alternatives for the $U_{dc,lim}$ based on the drive module DC voltage limits (see also section DC voltage limits) are:

- the absolute maximum limit is defined according to the DC overvoltage trip limit including some safety margin

- $U_{dc,lim} \leq 840\,\text{V DC}$
- DC over voltage control is enabled, but not activated $U_{dc,lim} \leq 810\,\text{V DC}$
- DC link voltage level where the braking choppers are not yet activated $U_{dc,lim} \leq 780\,\text{V DC}$

To determine whether the energy capacity is adequate (that is, the selected $U_{dc,lim}$ voltage level is not reached), the following condition must be fulfilled:

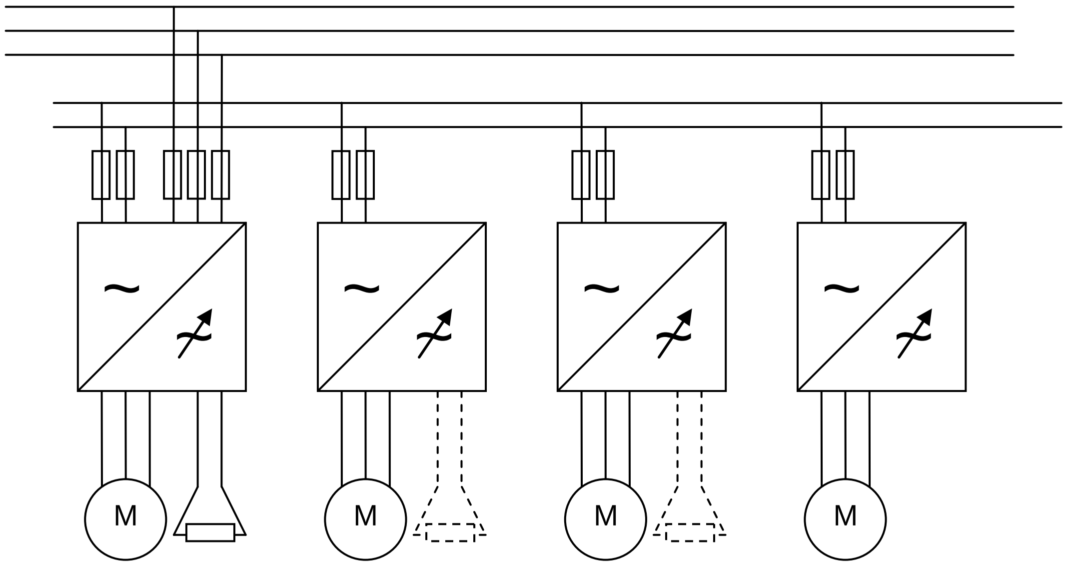
- $W_{dc} > E_{gen}$

where E_{gen} is the regenerative energy to the DC link during the regenerating period:

$$E_{gen} = \int P_{gen} dt$$

Selecting the braking chopper

The braking chopper is either included as standard in the drive modules or it is a built-in option, depending on the drive type (for a list of braking choppers, see section Chokes, braking choppers and charging circuits). The external braking resistor can be connected to the drive module. The braking chopper can then feed the braking energy to the resistor to keep the DC link voltage below the trip limit.



Braking power ratings

When the braking chopper is enabled and a resistor is connected, the chopper starts conducting when the DC link voltage of the drive reaches 780 V. The maximum braking power rating for each drive module is achieved at 840 V.

The braking chopper data of the drive modules is shown in the following table.

ACS850-04 type	$P_{br,cont}$	$P_{br,max}$	$R_{br,min}$
	kW	**kW**	**ohm**
03A0-5	0.9	5.5	120
03A6-5	1.3	5.5	120
04A8-5	1.8	5.5	120
06A0-5, 08A0-5	2.6	5.5	120
010A-5	4.5	7.9	80
014A-5	6.6	14.6	40
018A-5	8.5	14.6	40
025A-5	10.5	30.7	20
030A-5, 035A-5	12	30.7	20
044A-5, 050A-5	17.5	43.9	13
061A-5, 078A-5, 094A-5	36	43.9	13
103A-5	67.5	-	8
144A-5	75	-	6
166A-5	112.5	-	4
202A-5, 225A-5	135	-	4
260A-5	160	-	4
290A-5	200	-	2.7
430A-5	300	-	2
521A-5	234	-	1.8
602A-5	210	-	1.35
693A-5, 720A-5	170	-	1
387A-5	250	-	2
500A-5	250	-	2
580A-5	355	-	1,3
650A-5	355	-	1,3
710A, 807A-5, 875A-5	400	-	0,7

$P_{br,max}$: the maximum braking power of the chopper. The chopper withstands this braking power for 1 second within every 10 seconds.

$P_{br,cont}$: the internal chopper withstands this continuous braking power. The braking is considered continuous if the braking time exceeds 30 seconds.

$R_{br,min}$: the minimum allowed resistance of the braking resistor used with the braking chopper.

Single braking chopper

In this case, only one braking chopper of a drive module in the common DC system is used. It is recommended to use the chopper of the drive module that has the highest braking power ratings. The following conditions should be fulfilled:

- $P_{gen,ave} < P_{br,cont}$
- $P_{gen,max} < P_{br,max}$

If the conditions cannot be fulfilled, either a drive module with higher P_{br} ratings can be selected (if feasible) or a multiple braking chopper configuration can be used.

Multiple braking choppers

When two or more braking choppers of drive modules are active in the common DC system, the same conditions as above must still be fulfilled.

- $P_{gen,ave} < P_{br,cont}$
- $P_{gen,max} < P_{br,max}$

where P_{br} ratings are now calculated from the individual ratings as follows:

- $P_{br,cont} = P_{br,cont1} + 0.8 \times (P_{br,cont2} + P_{br,cont3} + ...)$
- $P_{br,max} = P_{br,max1} + 0.7 \times (P_{br,max2} + P_{br,max3} + ...)$

where $P_{br,cont1}$ and $P_{br,max1}$ are the values of the drive module with the highest braking power ratings.

Selecting the braking resistor(s)

The resistor(s) should be selected according to the regenerative power requirements. The following conditions must be fulfilled.

Single braking resistor

- The resistance must be at least $R_{br,min}$ according to the braking chopper data of the drive module.
- The selected resistance value R_{br} should also fulfil the peak braking power requirements. In the following calculations, the value of U_{dc} is 840 V DC.
  - $R_{min} < R_{br} < \dfrac{(U_{dc})^2}{P_{gen,max}}$
- The selected braking resistor should be able to handle the braking energy generated in fast dynamic situations (time is just a few seconds).
  - $\int P_{gen} dt < E_R$

where E_R is the energy pulse rating of the selected resistor.

- The nominal power rating of the resistor must be adequate for the average regenerative power.
  - $P_{gen,ave} < P_{N,R}$

where $P_{N,R}$ is the nominal power rating of the resistor (steady state continuous load). For a more detailed analysis and more optimal selection, the pulse load curves of the selected resistor should be studied.

Multiple braking resistors

If two or more braking resistors are connected to the braking choppers of the drive modules, the same conditions as above must still be fulfilled.

- The resistance $R_{br(i)}$ of each individual braking resistor must be at least $R_{br,min}$ according to the braking chopper data of the drive module in question.
- The resistance value $R_{br(i)}$ of each individual braking resistor should also fulfil the peak braking power requirements. In the following calculations, the value of U_{dc} is 840 V DC.
- $$R_{min(i)} < R_{br(i)} < \frac{(U_{dc})^2}{\frac{P_{br,max(i)}}{(P_{br,max1} + P_{br,max2} + ...)} \times P_{gen,max}}$$

where $P_{br,max(i)}$ is the braking power rating of the concerned braking chopper.

- The selected braking resistors should be able to handle the braking energy generated in fast dynamic situations (time is just a few seconds).
- $$\frac{P_{br,cont(i)}}{(P_{br,cont1} + P_{br,cont2} + ...)} \times \int P_{gen}dt < E_{R(i)}$$

where $E_{R(i)}$ is the energy pulse rating of the individual resistor, and $P_{br,cont(i)}$ is the power rating of the individual braking chopper concerned.

- The nominal power rating of the resistor must be adequate for the average regenerative power.
- $$\frac{P_{br,cont(i)}}{(P_{br,cont1} + P_{br,cont2} + ...)} \times P_{gen,ave} < P_{N,R(i)}$$

where $P_{N,R(i)}$ is the nominal power rating of the individual resistor (steady state continuous load). For more detailed analysis and more optimum selection, the pulse load curves of the selected resistor should be studied.

Braking resistor types

Resistor types JBR-xx and SAFUR for dynamic load cycles are available for the drive modules. See the relevant hardware manual for detailed data.

General system design items

What this chapter contains

This chapter describes the general system design items that must be taken into account after the components of the common DC system have been selected.

Fuse protection

Fuses are needed on the AC supply side and in the DC connections. These provide protection for the cabling and also limit the damages in case there is a short-circuit in the system. Check the following items for fuse selection:

- fuse class depending on the fault current type and protected items
- fuse voltage rating
- fuse current rating
- standards and regulations. The general guidelines for the fuse selection are given below. In addition, the local and application specific regulations must be taken into account.

Selecting the AC supply fuses

The standard selection table for the AC supply fuses in the single drive configuration can be found in the relevant hardware manual. That selection guideline can be used when the AC supply line current of the drive module(s) connected to the AC power line is according to the table.

The general guidelines for the selection of AC supply fuses are the following:

- IEC fuse classes gG and aR, and UL class T are suitable for the AC supply side.
- Fuse voltage rating of 500 V should be selected for the 380…500 V AC supply.
- Fuse nominal current:

  $$I_{F,N} \approx 1.6 \times I_{mot,ave(i)}$$

  where factor 1.6 covers the influence of cyclic load and ambient conditions.

If the average motoring line current $I_{mot,ave}$ is not exactly known, the nominal power ratings of the drive module can be used. However, the selected fuse current rating and the operation curve should be in line with the supply cable cross section to meet the regulations for the cable protection.

Selecting the DC connection fuses

In the common DC system, each DC connection must be equipped with fuses. Fuses are needed in both branches (+ / -). The general guidelines for the selection of DC link fuses are the following:

- AC fuse class aR (so called high speed fuses) should be used.

- Fuse voltage rating should be 690 V.
- Fuse nominal current:

  $I_{F,N} \approx 1.6 \times I_{dc,ave(i)}$,

where the *average DC link current* $I_{dc,ave}$ can be defined with:

$$I_{dc,ave} = \frac{P_{dc,ave(i)}}{U_{dc}}$$

where $P_{dc,ave(i)}$ is the maximum average (during the 3 min time window) DC link power in the DC connection terminals of the individual drive module, and

U_{dc} is the actual DC link voltage:

$$U_{dc} \approx 1.35 \times U_{ac}$$

Factor 1.6 covers the influence of the cyclic load and ambient conditions. If the average DC current $I_{dc,ave}$ is not exactly known, the power ratings of the drive module can be used. However, the selected fuse current rating and the operation curve should be in line with the used cable cross section to meet the regulations for the cable protection.

The recommended fuse current ratings based on the DC power ratings of the drive modules are shown in the table below.

ACS850-04 type	**Fuse**
	A
03A0-5, 03A6-5, 04A8-5, 06A0-5, 8A0-5	16
010A-5	20
014A-5, 018A-5	32
025A-5, 030A-5	63
035A-5, 044A-5, 050A-5	100
061A-5, 078A-5, 094A-5, 103A-5	160
144A-5, 166A-5	315
202A-5, 225A-5	400
260A-5	500
290A-5	550
430A-5	800
521A-5	1000
602A-5	1250
693A-5, 720A-5	1600
387A-5	700
500A-5	900
580A-5	1100
650A-5	1250
710A-5	1400
807A-5	1600
875A-5	1800

EMC

The compliance of the drive modules with the EMC directive is specified in the relevant hardware manual for the single drive configuration. Notice that different common DC systems have not been tested from the EMC point of view. However, the available mains filters can be used in the AC supply of the common DC system, but the rules to meet the different EMC categories are not available.

Installation

See the relevant hardware manual for the installation (mechanical and electrical) guidelines of the drive modules and external options.

Supply

Use the same supply connection point. All converters must be fed from the same transformer. The supply impedance is an important parameter, which influences the current distribution. All converters must have equal supply impedance.

Phase loss guard

It is recommended to use phase loss guard in the input supplies of all of the converters. If phase loss guard is not used and the fuse of one of the input supply phases blows, the semiconductors of the converters may be overloaded and damaged.

Selecting and connecting cables

Consider the following aspects when selecting and connecting the cables:

• Select the input power cables as described in the appropriate drive hardware manual. The cross-sectional area of the DC cables must be the same as the cross-sectional area of the AC side cables.

• If screened DC cables are used, ground the screen at the other end only.

• The lengths of the supply cables must not differ more than 15%. This applies especially to converters equipped with DC chokes.

• The maximum length of the DC cables between two converters is 50 m (164 ft).

• If the system consists of more than two converters, the DC links must be connected in an external terminal box. Do not use the terminals of one of the converters for this purpose.

Contactors, DC link and brake circuit

If converters with different charging circuits are connected directly to the AC power line, the DC links must be connected together via contactors. With an external or an internal brake chopper a contactor must be used for protection against brake chopper faults.

The contactors must be capable of cutting off the DC current. The maximum operational voltage over the contactor is the DC voltage during the braking, that is:

$1.21 \cdot 1.35 \cdot U_1$.

The DC current rating for the DC contactor can be calculated as follows:

$I_{DC} = P_{DC}/U_{DC}$

$P_{DC} \approx P_{cont.max}$

$U_{DC} = 1.35U_1$

where $P_{cont.max}$ is the drive power rating of the biggest converter and U_1 is the supply voltage of the converter.

The peak current through the contactor in a brake resistor circuit can be calculated as follows:

$\hat{I} = (1.21U_{DC}) / R_{brake}$

The rms current during the braking can be calculated as follows:

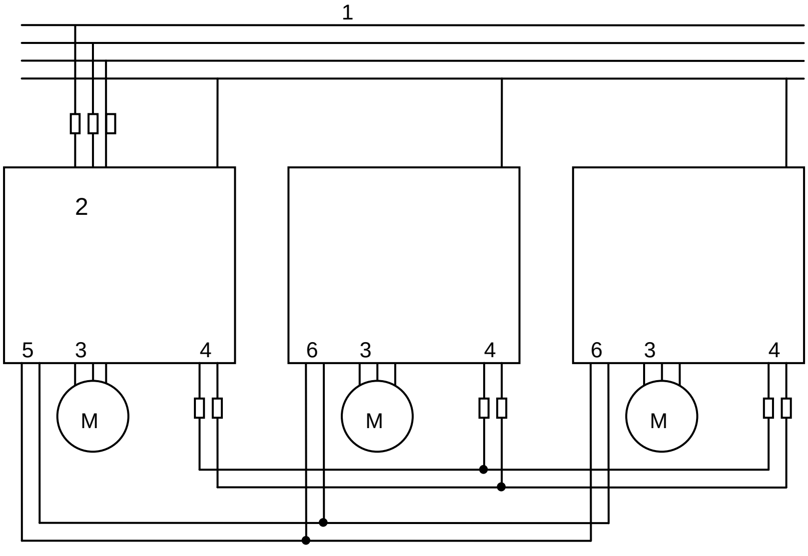
$I_{rms} = (P_{br} / R_{brake})^{½}$

where R_{brake} is the brake resistor's resistance, and P_{br} is the applied braking power.

Connecting the READY signals

To ensure that all of the DC links have been charged before the system is started, the READY signals of the converters must be wired together. If this is neglected, the charging resistor may be damaged.

Wire together the READY signals of all the converters connected to the AC power line and the START INTERLOCK signals of all of the converters not connected to the AC power line. An example is presented below.



1	L1, L2, L3, PE (from top to down)
2	U1, V1, W1 (from left to right)
3	U2, V2, W2 (from left to right)
4	DC+, DC- (from left to right)
5	JCU connectors XPOW:2 and XRO:2 (from left to right)
6	JCU connectors XD24:1 and XDI:A (from left to right)

Drive module settings

Note: The parameter settings mentioned below apply to the ACS850 Standard Control Program.

- It is recommended to set parameter 99.05 MOTOR CTRL MODE to DTC and to adjust parameters 20.12 P MOTORING LIM and 20.13 P GENERATING LIM to limit the maximum power.
  The calculated braking power can also be used as the value of parameter 20.13 P GENERATING LIM.
- When brake chopper is used, set parameter 48.01 BC ENABLE. This activates the chopper when the DC voltage is high. Also the parameter 47.01 OVERVOLTAGE CONTROL must be disabled from all of the converters separately.
- All converters must be in the READY state before starting. See section Connecting the READY signals for instructions on how to connect the READY signals.
- Disable the fault function “Cross connection” (parameter 30.08), if an external DC supply (other than ACS850-04 drive module) is used.

General technical data

DC voltage limits

All drive modules have their own terminals for the DC connection.

Different limit values in drive modules related to the DC voltage level are defined in the table below. The values are applicable for ACS850 Standard Control Program version UIFI2010 or later. See the relevant firmware manual for more detailed descriptions.

Designation	**Symbol**	**Value**	**Example (U_{DC} = 540 V)**
DC voltage range	U_{DC}	436…743 V	540 V
Charging limit	$U_{DC,chr}$	80% U_{DC}	432 V
DC voltage control: Overvoltage control limit	$U_{DC,ovc}$	125% U_{DC} max. 810	675 V
DC voltage control: Undervoltage control limit	$U_{DC,uvc}$	80% U_{DC} min. 400	432 V
DC overvoltage trip limit	$U_{DC,ovt}$	$U_{DC,ovc}$ + 70 V max. 880	745 V
DC undervoltage trip limit	$U_{DC,uvt}$	$U_{DC,uvc}$ – 50 V min. 350	382 V
Braking chopper limit, low	$U_{DC,brcl}$	$U_{DC,ovc}$ – 30 V	645 V
Braking chopper limit, high	$U_{DC,brch}$	$U_{DC,ovc}$ + 30 V	705 V

U_{DC} in the Value column, where the values are defined, is based on the drive module setting for the used supply voltage. The used supply voltage can be set with a parameter (47.03 and 47.04) or identified automatically. The used U_{DC} value is then defined according to the following formula:

U_{DC} = 1.35 · (signal: 1.19 USED SUPPLY VOLT)

- *DC voltage range*: the actual DC voltage level with 3-phase AC supply voltage range (380…480 V AC +10% / -15%). The actual DC voltage with the nominal load can be defined based on the 3-phase AC supply voltage with the following formula:

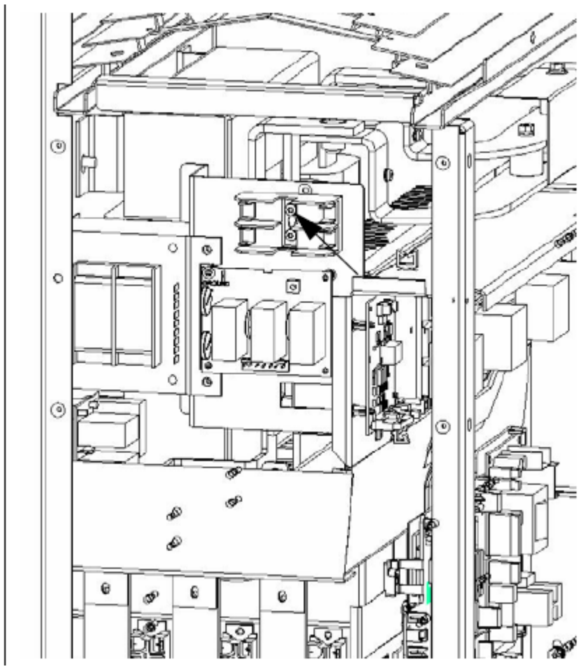
  The average DC voltage: $U_{dc,ave} \approx 1.35 \times U_{ac}$

- *Charging limit*: the charging relay will be closed when the DC voltage level is reached. There are also other criteria (du/dt, time delay) in firmware for closing the charging relay. The charging relay is opened if the DC link voltage is below 75% of U_{DC} when the drive is not running.
- *DC voltage control*: the overvoltage and undervoltage control of the DC link voltage level are enabled by default. Then the drive modules will limit the motoring and generating torque, if there is a need to keep the DC link voltage within the control limits. In common DC systems with enabled braking chopper, the overvoltage control mode should be disabled. See the voltage control parameters in group 47.

- *DC overvoltage and undervoltage trip limit*: these limit values protect the drive modules. The drive module trips and gives a fault message if the DC link voltage reaches these levels.
- *Braking chopper limits*: the braking chopper in the drive module is activated (if the braking chopper is enabled) when the DC link voltage reaches the low level ($U_{DC,brcl}$). If the DC link voltage level reaches the high level ($U_{DC,brch}$), then the braking chopper feeds the braking resistor with continuous current and the maximum braking power level is reached.

Powering the AC fan in frame G

If the supply of frame size G is not connected to the AC power line, the AC fan must be powered separately. Feed the primary of the fan circuit transformer with the converter's nominal main supply voltage, V- and W-phases, via the built-in fan circuit. The original cables between the busbars and the fuses have to be removed. The feeding cable must be protected against short- circuits despite of the used built-in fuses. The fuse location is shown in the following figure.



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/drives and selecting *Sales, Support and Service network.*

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