ACS850

Common DC configuration application guide

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Safety instructions

Chapter overview

WARNING! All electrical installation and maintenance work on the drive should be carried out by qualified electricians only.

Never work on the drive, the braking chopper circuit, the motor cable, or the motor when input power is applied to the drive. After disconnecting the input power, always wait for 5 minutes to let the intermediate circuit capacitors discharge before you start working on the drive, control cabling, motor, or motor cable. Even when input power is not applied to the drive, externally supplied control circuits may carry dangerous voltages. Always ensure by measuring that there is no voltage in the drive, control cabling, motor, or motor cable you are working with.

A rotating permanent magnet motor can generate a dangerous voltage. Lock the motor shaft mechanically before connecting a permanent magnet motor to the drive and before doing any work on the drive system connected to the permanent magnet motor.

For complete safety instructions, see the relevant drive manual. See Drive modules documentation for a list of drive hardware manuals.

Table of contents

Introduction to the manual

This chapter describes the intended audience and contents of this manual. It contains a flowchart of the steps for configuring the common DC system. The flowchart refers to the chapters and sections in this manual and in other manuals.

Compatibility

This manual is compatible with 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. The reader is expected to know the fundamentals of electricity, wiring, electrical components, and electrical schematic symbols. This manual is written for readers worldwide. Both SI and imperial units are shown wherever appropriate.

Categorization according to the frame size

Some instructions, technical data, and dimensional drawings 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.

Drive modules documentation

This guide contains only common DC related technical items for the ACS850 drive modules. For complete documentation, see the table below. If there are deviations in the given data between this guide and other manuals, then the document with the latest date (Effective: xx.yy.20zz) will apply.

Manual	**Code (English)**
ACS850-04 Drive Modules (1.1 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

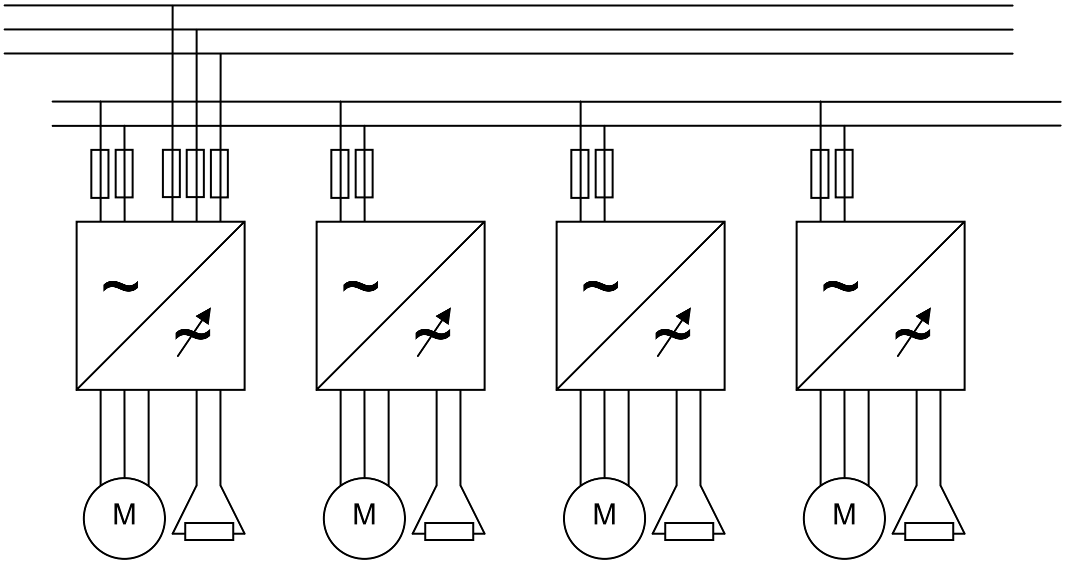
Common DC configurations

Introduction

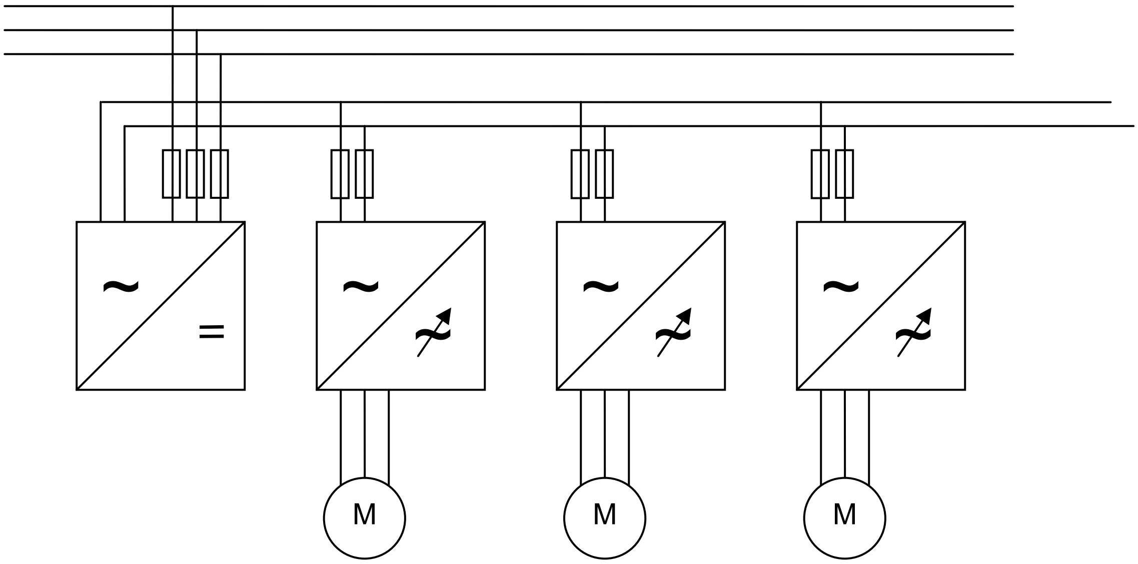
Drive modules can be connected together via DC terminals to have a so called common DC configuration. Within common DC, the drives with regenerative power from the motor can via DC link feed the other drives that are on the motoring mode. The major benefits with this kind of connection are the following:

- Energy saving due to a reduced need for the supply side power. In optimum case, there is also no need for braking resistors if the simultaneous regenerative power is not higher than the motoring power.
- A DC link energy storage can be used for short dynamic 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.
- Possibility for one AC input connection. The selected unit, in addition to its own axis power, feeds also other drives connected to the common DC.

Sample configuration 1



Sample configuration 2



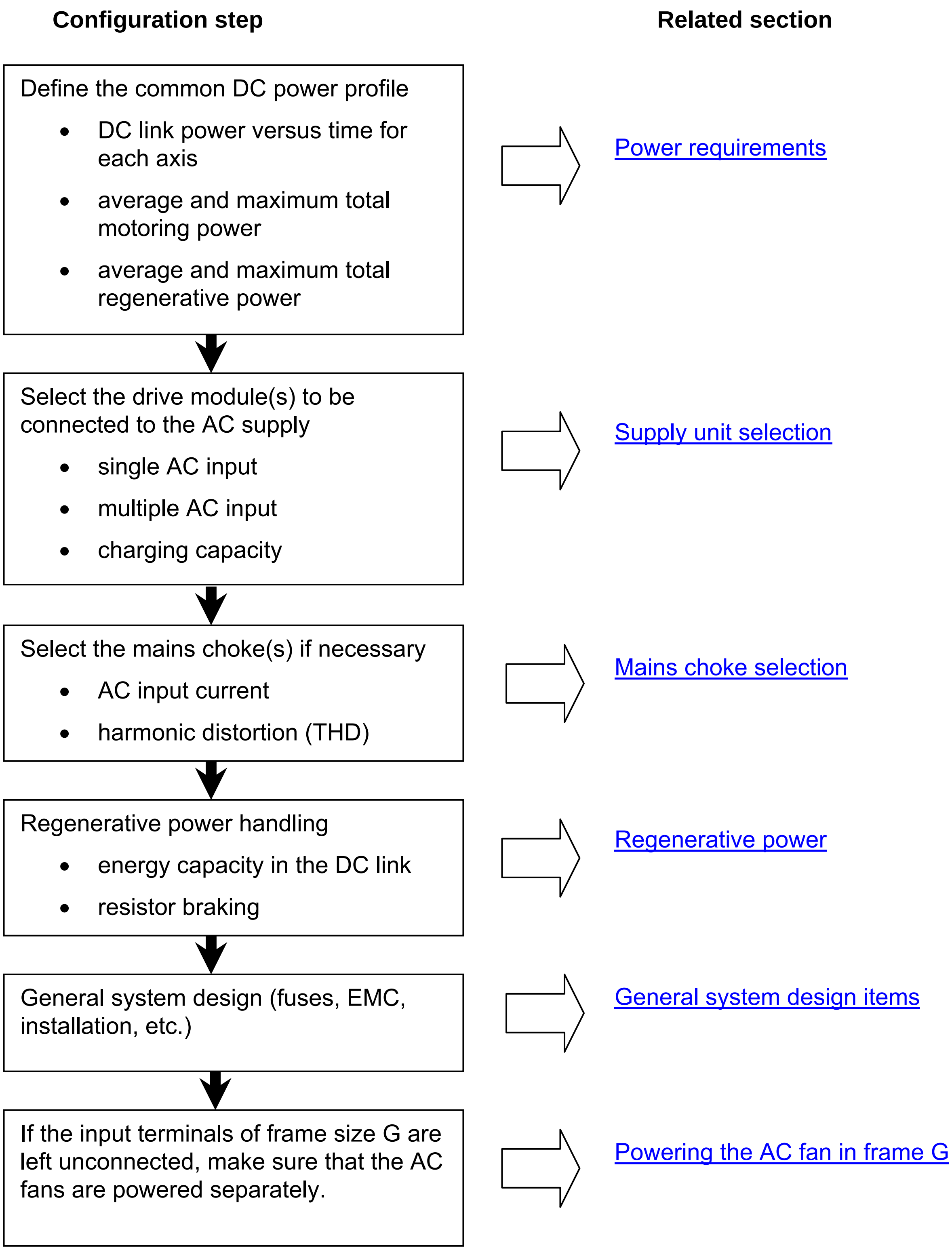
Unequal current distribution and different charging methods cause difficulties to common DC systems:

- Unequal current distribution is influenced by input cables, AC or DC chokes and input bridges' forward characteristics. If the voltage reduction over the supply components mentioned is not the same with all converters, more current will flow through the converter which has a lower voltage reduction. Factors which influence the 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. Because of this in some installations, the supplies of the frame sizes A-D should be disconnected when they are connected parallel with frame sizes E0, E and G.

Note: The drive compliance with the EMC Directive on low voltage networks is specified in the appropriate Hardware Manual. However, please notice that different common DC configurations have not been tested according to the EMC requirements of conducted and radiated emissions.

Configuration steps

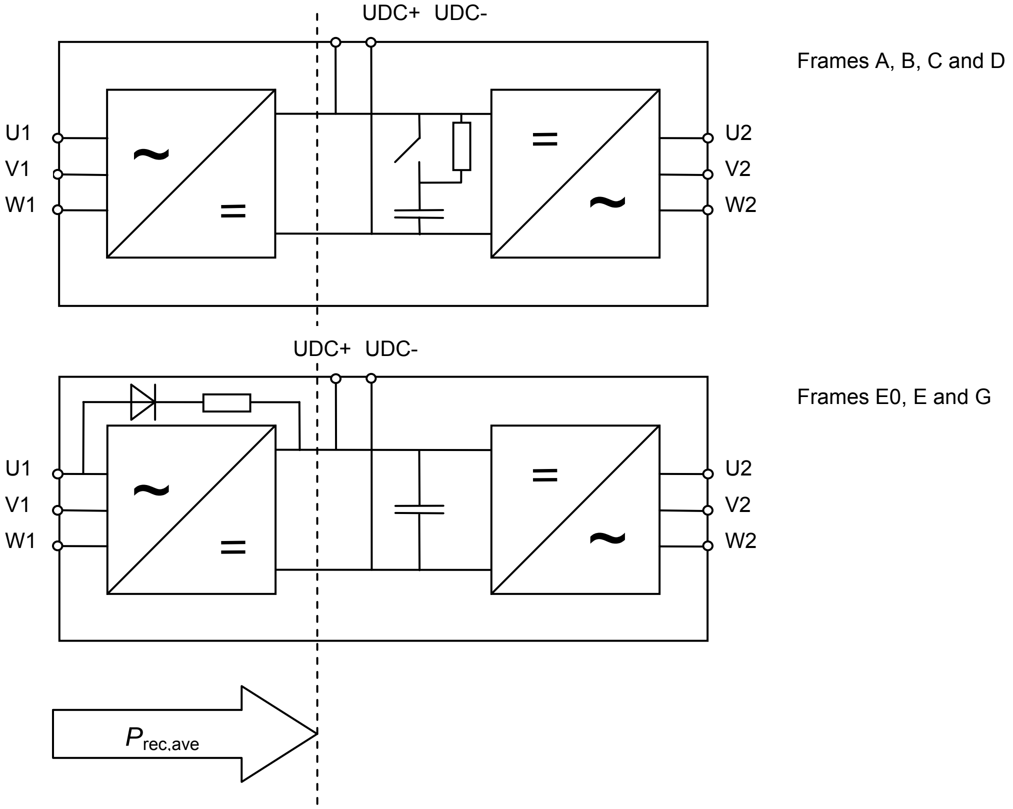
Here is a simple flowchart for configuring a common DC system. Each configuration step is described in more detail in the related sections.


Configuration step
Related section
Define the common DC power profile
DC link power versus time for each axis
average and maximum total motoring power
average and maximum total regenerative power
Power requirements
Select the drive module(s) to be connected to the AC supply
single AC input
multiple AC input
charging capacity
Supply unit selection
Select the mains choke(s) if necessary
AC input current
harmonic distortion (THD)
Mains choke selection
Regenerative power handling
energy capacity in the DC link
resistor braking
Regenerative power
General system design (fuses, EMC, installation, etc.)
General system design items
If the input terminals of frame size G are left unconnected, make sure that the AC fans are powered separately.
Powering the AC fan in frame G

Common DC configuration

Power ratings for DC connection

The power unit 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 Type	$P_{rec,ave}$	$P_{rec,max}$
	kW	kW
03A0-5, 03A6-5, 04A8-5, 06A0-5	3.5	4.4
08A0-5	4.7	5.9
010A-5	6.5	8.1
014A-5, 018A-5	10.8	13.5
025A-5, 030A-5, 035A-5	20.5	25.7
044A-5, 050A-5	29.2	36.5
061A-5, 078A-5, 094A-5	52.9	66.2
103A-5	61.0	77.1
144A-5	85.3	90.1
166A-5	98.2	103.6
202A-5	119.3	133.9
225A-5	133.3	154.8
260A-5	152.2	197.3
290A-5	171.7	215.4
430A-5	260.2	315.6
521A-5	315.3	351.3
602A-5	364.5	442.8
693A-5	419.5	511.2
720A-5	435.7	511.2

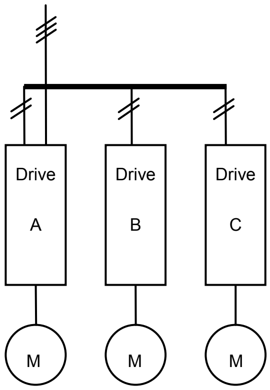
P_{rec} values are defined at 540 V DC link voltage level, which corresponds to the nominal 400 V AC supply voltage U_{ac}. In case of other DC voltage levels (U_{dc}), the P_{rec} values in the table are multiplied by U_{dc} /540 where $U_{dc} \approx 1.35 \times U_{ac}$.

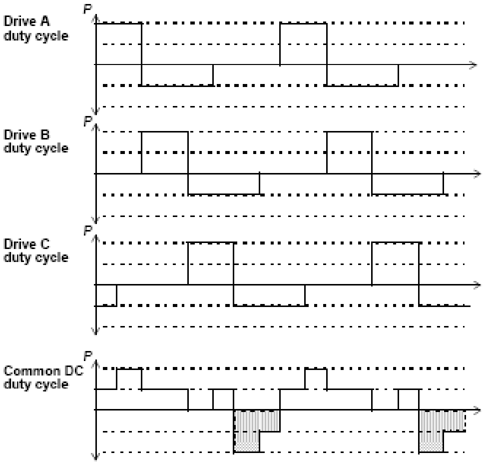
Chokes, braking choppers and charging circuits

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

Power requirements

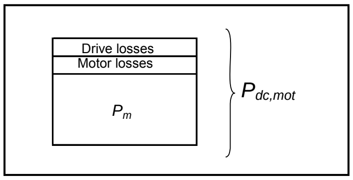
In a common DC system, several drive modules are connected to the DC link. Each drive and motor has its own specific load cycle profile. The sum of these load cycles defines the system power profile in the DC link as shown in the figure below.





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 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.

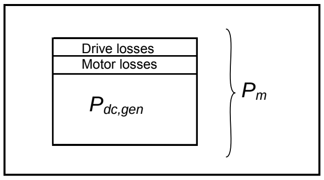
P_m : motor mechanical shaft power

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 motor.



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

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 supply. 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 supply if many axes are accelerated simultaneously.

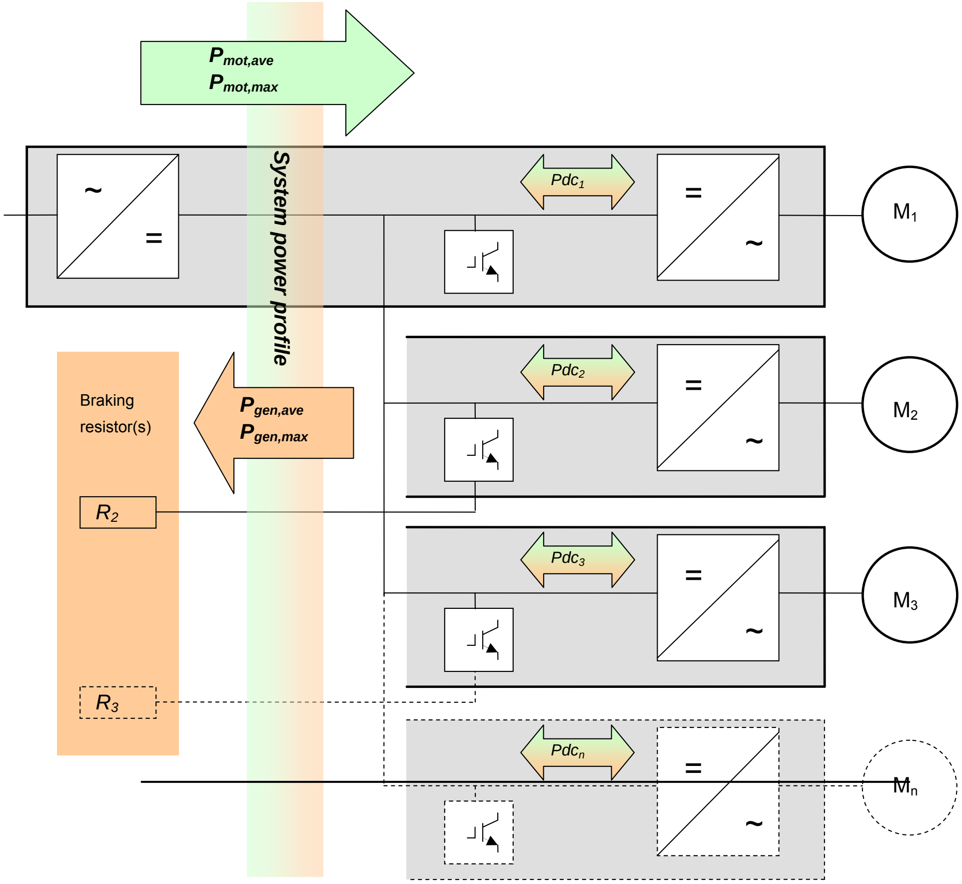
Average regenerative power $P_{gen,ave}$

$P_{gen,ave}$ 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 supply. $P_{gen,ave}$ 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.



Supply unit selection

DC link power supplied via the drive

The DC link power can be supplied via a suitable drive module for the common DC system. The drive module will be selected based on $P_{mot,ave}$ and $P_{mot,max}$ requirements, and charging circuit capacity requirements. In frames E0, E and G the charging circuit of the connected module must be able to withstand the total charging energy E_{tot}.

Single AC input (frames A…D)

In the optimum situation, only one drive module is connected to the AC supply and the other drive modules are supplied via 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 frames E0…G

To determine whether it is possible to leave other converters unconnected to the main supply see chapter Checking the charging circuit capacity. The following conditions must also be fulfilled:

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

Multiple AC input

To determine whether it is possible to leave some converters unconnected to the main supply see chapter Checking the charging circuit capacity.

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

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

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

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

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

Only converters that are connected to the main supply, are used for the power limit calculations. The power correction factor, **k**, for each combination can be found from Table 1. When several converters are connected to the main supply, the least efficient power correction factor is chosen from table 1, i.e. the smallest factor. See *Example1* and *Example2.*

When the charging circuits of the converters are different, this connection is not always allowed. The table below shows when the connection cannot be used.

ACS850 power correction factors

Frame size	A, B	C, D	E0 or E	G
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	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-G have AC chokes.

C: If both converters are connected to the main supply, 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 $P_{\text{rec.ave}}$ value is higher if the smallest converter is not connected to the main supply.

Example 1

The DC buses of three converters ACS850-04-08A0-5, 4.7 kW, (A); ACS850-04-035A-5, 20.5 kW, (C) and ACS850-04-035A-5, 20.5 kW, (C) are connected together. The input terminals of the 3 kW converter are left unconnected. k = 0.5 when two frame C´s are connected to the main supply, therefore $P_{\text{rec,ave}}$ is

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

Example 2

The DC buses of three converters ACS850-04-103A-5, 61 kW, (E0); ACS850-04-202A-5, 119.3 kW, (E) and ACS850-04-521A-5, 315.3 kW, (G) are connected together. All three converters are connected to the main supply. According to *Table 1*, k = 0.7 when E0 and E are connected to the main supply and k = 0.6 when E and G are connected to the main supply. The lowest factor is used in the calculations, i.e. k = 0.6, therefore

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

Checking the charging capacity

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. Due to this, the charging capacity of the selected supply unit has to be checked.

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

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

In frame sizes E0, E and G, the charging circuit is in parallel with the input bridge and the charging circuit(s) of the drive(s) are 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 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

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.

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

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

The following condition must be fulfilled:

- $R_{tot} > R_{min}$

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

Multiple AC input

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

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

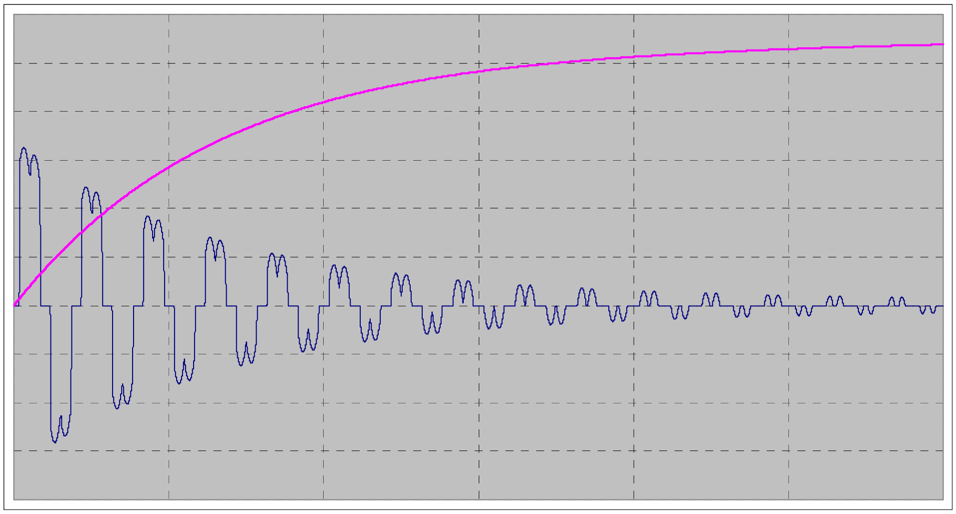
R_{min} values (R_{min1}, R_{min2},…) are the individual minimum resistance values of the drive modules connected to the AC supply.

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 the 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…D

In frame sizes A-D the charging resistor is in series with the DC capacitors and all DC buses 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 main supply.

Frame sizes E0, E and G

In frame sizes E0, E and G 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}, i.e.

$E_{rconnected} > E_{tot}$

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

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

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

C_{DC} = capacitance of the DC-bus capacitor. See DC link capacitance.

U_{net} = actual supply voltage

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

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

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

Frame size	E_r / J
E0	1000
E	2000
G	5600

Note: Always connect the biggest converter to the main supply. 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 main supply.

Example 1

The DC buses of three converters ACS850-04-103A-5 (E0), ACS850-04-0202A-5 (E) and ACS850-04-430A-5 (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 (G) is able to withstand the whole charging energy,

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

Example 2

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

$E_{tot} = ½ \cdot (2 \cdot 4700\ \mu F + 3 \cdot 8600\ \mu F) \cdot (1.35 \cdot 500V)^2 \cdot 10–6 = 6971\ J$

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

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

$E_{tot} = 6971\ J < E_r = 2 \cdot 5600\ J.$

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 can not 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. Then it is possible to use ABB’s regenerative supply units (ISU).

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

AC- or DC-choke is needed in external supply circuit to reduce drive units DC-link capacitors ripple current to acceptable level.

Recommended choke relative reactance is 3%. Choke phase inductance is calculated by formula $L_v = X \times U^2 \div 2\pi f P_{DC}$

Example

Needed DC power is 250 kW, supply frequency 50 Hz and supply voltage is 400 V.

$L_v = (0.03 \times (400\ V)^2) \div (2\pi \times 50\ Hz \times 250\ kW) = 61\ \mu H.$

The recommended charging resistor value is the same as the minimum or nominal resistance of the highest power converter used given in the table in Checking the charging capacity.

The peak current during charging is calculated by the equation in Checking the charging capacity.

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

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

Charging resistor energy withstand is calculated by equation $E = 1.3CU^2$ where C is total capacitance of DC-link capacitors and U is supply line-to-line rms voltage for example 400 V or 500 V. The 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 frames 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 and G

In frame sizes E0, E and G, the charging circuit is in parallel with the input bridge. Separate charging circuit is needed.

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

Supply units other than ACS850

When some other type of supply unit than ACS850 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).

Mains choke selection

In common DC connections, the drive module(s) connected to the AC supply 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		**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 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* $I_{mot,ave}$

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

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 supply, the same conditions as above must still be fulfilled, but now for each individual drive module (i) and its mains choke separately. All of 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:

- $$I_{mot,ave(i)} = 1.20 \times \frac{P_{rec,ave(i)}}{(P_{rec,ave1} + P_{rec,ave2} + \ldots + P_{rec,aven})} \times I_{mot,ave}$$
- $$I_{mot,max(i)} = 1.20 \times \frac{P_{rec,max(i)}}{(P_{rec,max1} + P_{rec,max2} + \ldots + P_{rec,max\,n})} \times I_{mot,max}$$

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
- the 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.

Harmonic distortion

If there are requirements for harmonic distortion level, a mains choke (CHK-xx) is typically needed in ACS850 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 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 ABB’s *Guide to Harmonics with AC Drives* in *AC Drives Technical Guide Book* for basic theory about this topic.

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 so called generator mode (for example, unwinder). If the other drive modules do not take enough active power 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.

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 a 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 bus capacitors during the regenerating can be used afterwards for the motoring power. The energy demand from the supply is then reduced.

DC link capacitance

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

ACS850 Type	**C_{dc}**
	µF
03A0-5, 03A6-5	120
04A8-5, 06A0-5,	240
010A-5	370
014A-5, 018A-5	740
025A-5, 030A-5,	670
044A-5, 050A-5	1000
061A-5	1340
078A-5, 094A-5	2000

ACS850 Type	**C_{dc}**
	µF
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

Energy capacity in common DC

The energy capacity W_{dc} in the common DC system can be determined in following way:

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

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.

The actual DC link voltage to be used in energy calculations should be calculated 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.

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

- the absolute maximum limit is defined according to the DC overvoltage trip limit including some safety margin
- $U_{dc,lim} \leq 840\,\mathrm{V\ DC}$
- DC over voltage control is enabled, but not activated $U_{dc,lim} \leq 810\,\mathrm{V\ DC}$
- DC link voltage level where the braking choppers are not yet activated $U_{dc,lim} \leq 780\,\mathrm{V\ DC}$

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:

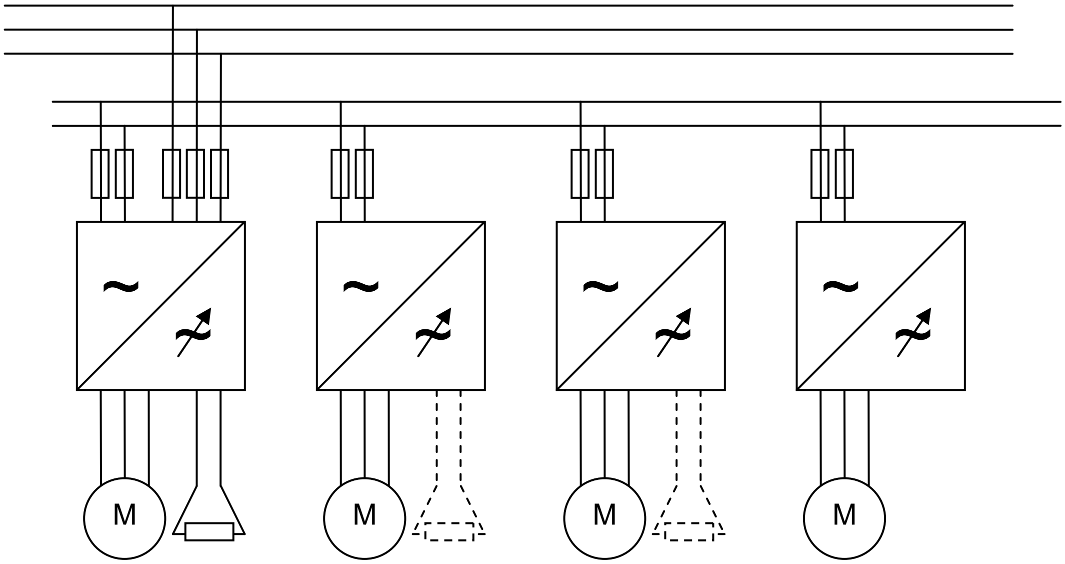
- $W_{dc} > E_{gen}$

Where E_{gen} is the regenerative energy to the DC link during the generating period:

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

Resistor braking

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, see 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	$\mathbf{P_{br,cont}}$	$\mathbf{P_{br,max}}$	$\mathbf{R_{br,min}}$
Type	**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

$P_{br,max}$: 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 can not 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

In case 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:

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

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

Braking resistor selection

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.
  - $R_{min} < R_{br} < \frac{(U_{dc})^2}{P_{gen,max}}$
- 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.
- $R_{min(i)} < R_{br(i)} < \dfrac{(U_{dc})^2}{\dfrac{P_{br,max(i)}}{(P_{br,max1} + P_{br,max2} + ...)} \times P_{gen,max}}$

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).
- $\dfrac{P_{br,cont(i)}}{(P_{br,cont1} + P_{br,cont2} + ...)} \times \int P_{gen} dt < E_{R(i)}$

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

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

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

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. The following items should be checked 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 here. Take always also the local and application specific regulations into account.

Selection of 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 supply 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 AC supply side.
- Fuse voltage rating of 500 V should be selected for 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.

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

- $P_{dc,ave(i)}$ is the maximum average (during the 3 min time window) DC link power in the DC connection terminals of the individual drive module.
- U_{dc} is the actual DC link voltage $U_{dc} \approx 1.35 \times U_{ac}$

The 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	Fuse
Type	**A**
03A0-5, 03A6-5, 04A8-5, 06A0-5, 08A0-5	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

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 configurations 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.

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.
- Maximum length of the DC cables between two converters is 50 m.
- 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 bus and brake circuit

If converters with different charging circuits are connected directly to the main supply, 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.

- **Contactors must be capable of cutting off the DC current.** The maximum operational voltage over the contactor is the DC voltage during the braking, i.e. $1.21 \cdot 1.35 \cdot U_1$.
- DC current rating for the DC contactor can be calculated by as follows:

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

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

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

$U_{\mathrm{DC}} = 1.35U_1$

Peak current through the contactor in brake resistor circuit can be calculated as follows:

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

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

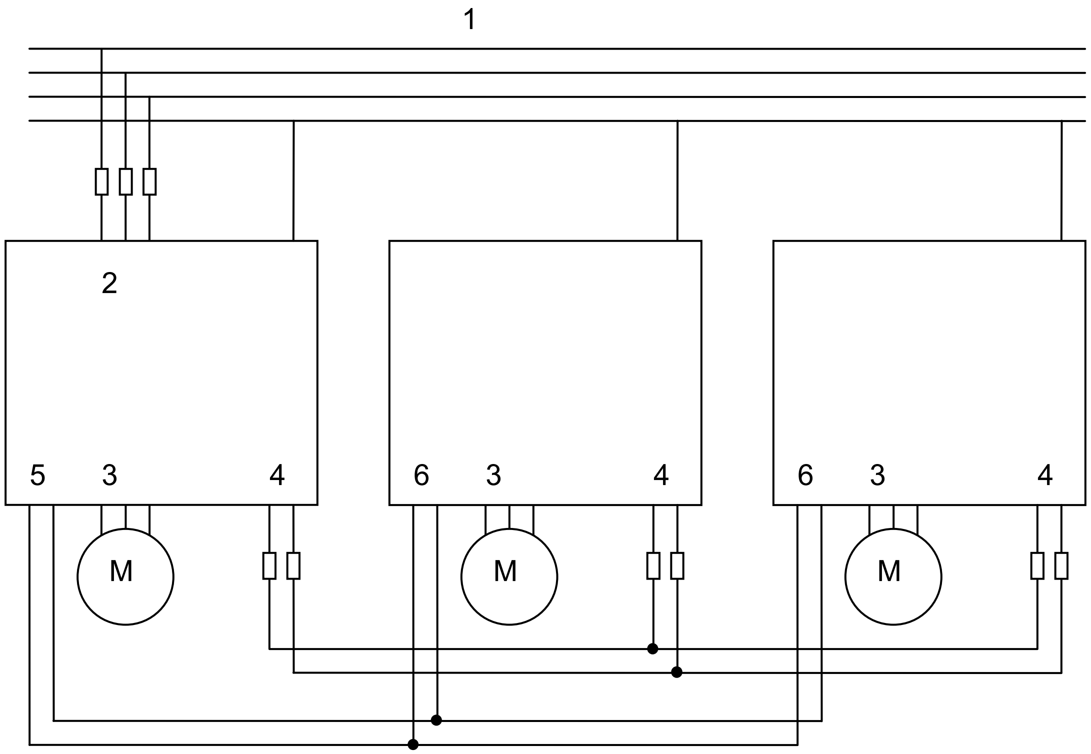
$I_{\mathrm{rms}}=(P_{\mathrm{br}}/R_{\mathrm{brake}})^{1/2}$

R_{brake} is the brake resistor‘s resistance. P_{br} is the applied braking power.

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 can be damaged.

Wire together the READY signals of all the converters connected to the main supply and the START INTERLOCK signals of all of the converters not connected to the main supply. 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 ACS850 Standard Application 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 parameter value of 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 *READY signals* for instructions on how to connect the READY signals.
- Switch on the possible DC contactors based on Table 1 after all of the DC links are charged and the converters are in the READY state, i.e. when the power is on and no faults appear.

- Disable fault function “Cross connection” (par. 30.08), if the *external DC supply* (other than ACS850 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 firmware versions UIFI2010/UMFI15XX and above. 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 (Par. 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:

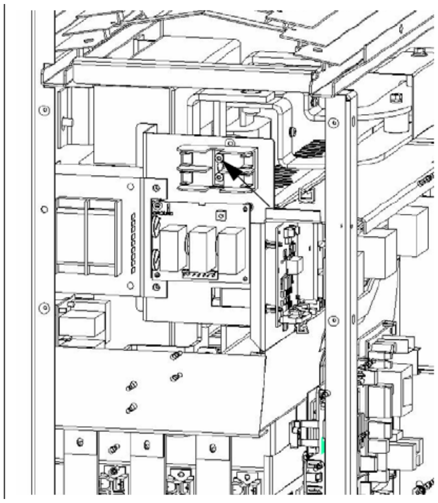
The average DC voltage: $U_{dc,ave} \approx 1.35 \times U_{ac}$

- *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 the 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 configurations with enabled braking chopper, the over voltage control mode should be disabled. See 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 ($U_{\mathrm{DC,brcl}}$). If the DC link voltage level reaches the high level ($U_{\mathrm{DC,brch}}$), 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 main supply, 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 picture.



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