# ACSM1

## System Engineering Manual

# ACSM1-04 Drive Modules

# System Engineering Manual

3AFE 68978297 REV A EN

EFFECTIVE: 08.10.2007

PDM Vault ID: 00579251

# Safety instructions

## Safety instructions

**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 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 no voltage is actually present.

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 a drive system connected to a permanent magnet motor.

For complete safety instructions see the *ACSM1-04 Drive Modules (0.75 to 45 kW) Hardware Manual* (code: 3AFE68797543 [English]).

# Table of contents

# About this manual

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

## Compatibility

This manual is compatible with ACSM1-04 drive modules (frame sizes A to D) and related options.

## Intended audience

This manual is intended for people who plan the installation, install, commission, use and service the drive modules connected in common DC link. Read the *ACSM1 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 which concern only certain frame sizes are marked with the symbol of the frame size A, B, C or D. The frame size is not marked on the drive designation label. To identify the frame size of your drive, see the rating tables in related hardware manuals.

## ACSM1-04 drive module and options documentation

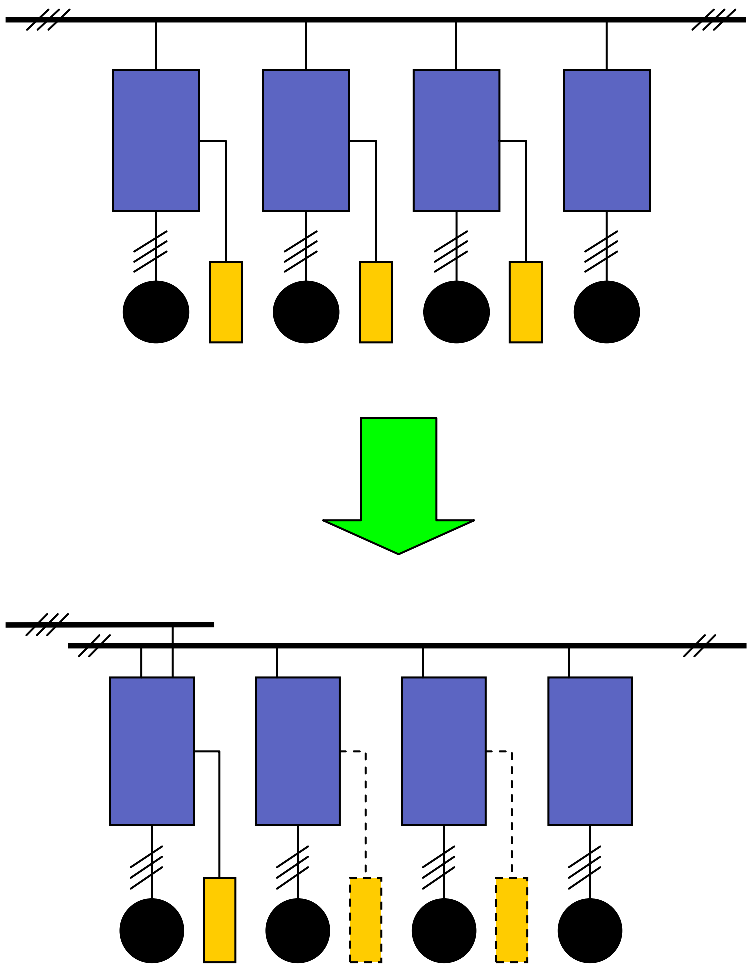
This guide contains only common DC related technical items for ACSM1 drive modules. For complete documentation see the *ACSM1-04 Drive Modules (0.75 to 45 kW) Hardware Manual* (code: 3AFE68797543 [English]). If there are deviations in the given data between this guide and other manuals, then the document with the latest date (Effective: xx.yy.20zz) will apply.

# Common DC configurations

## Introduction

ACSM1 drive modules can be connected via DC terminals together to have so called common DC configuration. Within common DC the drives with regenerative power from motor can feed via DC link the other drives, which are on motoring mode. Major benefits with this kind of connection are the following:

- Energy saving due to reduced need for the supply side power. In optimum case there is also no need for braking resistors, if simultaneous regenerative power is not higher than motoring power.
- DC link energy storage can be used for short dynamic braking energy pulses to avoid need for external braking resistor.
- Braking energy can be handled with one unit even if several drives are at the same time in regenerative mode. However, several units with active braking chopper can be used simultaneously with braking resistor if needed.
- Possibility for one AC input connection. The selected unit is, additionally to its own axis power, feeding also other drives connected to common DC.



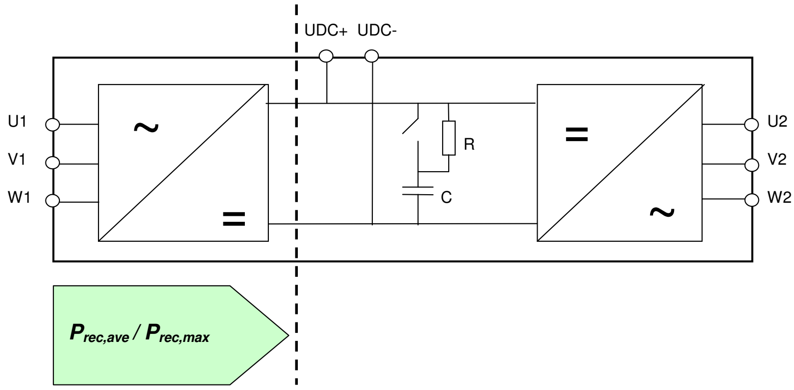
## Configuration steps

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

| Configuration step | Related paragraph |
|---|---|
| Define the common DC power profile<br>• DC link power versus time for each axis<br>• Average and maximum total motoring power<br>• Average and maximum total regenerative power | See “Power requirements” |
| Select the drive module(s) to be connected to the AC supply<br>• Single AC input<br>• Multiple AC input<br>• Charging capacity | See “Supply unit selection” |
| Select the mains choke(s)<br>• AC input current<br>• Harmonic distortion (THD) | See “Mains choke selection” |
| Regenerative power handling<br>• Energy capacity in the DC link<br>• Resistor braking | See “Regenerative power” |
| General system design (fuses, EMC, installation,…) | See “General system design items” |

## ACSM1 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 an ACSM1 input bridge 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 $P_{rec,max}$*

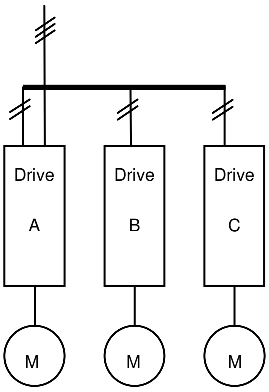
$P_{rec,max}$ is the maximum short time DC power capacity of an ACSM1. This is the maximum DC power level for input bridge and DC connection terminals during 1 s.

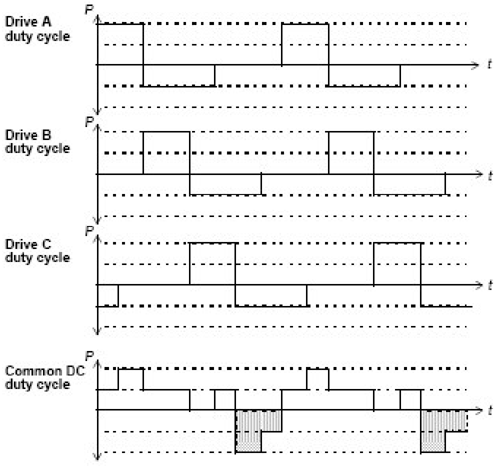
| ACSM1-04xx- | | Prec,ave | Prec,max |
|---|---|---|---|
| Size | Frame | kW | kW |
| 02A5-4 | A | 3.5 | 4.4 |
| 03A0-4 | A | 3.5 | 4.4 |
| 04A0-4 | A | 3.5 | 4.4 |
| 05A0-4 | A | 3.5 | 4.4 |
| 07A0-4 | A | 4.7 | 5.9 |
| 09A5-4 | B | 6.5 | 8.1 |
| 012A-4 | B | 10.8 | 13.5 |
| 016A-4 | B | 10.8 | 13.5 |
| 024A-4 | C | 20.5 | 25.7 |
| 031A-4 | C | 20.5 | 25.7 |
| 040A-4 | C | 29.2 | 36.5 |
| 046A-4 | C | 29.2 | 36.5 |
| 060A-4 | D | 52.9 | 66.2 |
| 073A-4 | D | 52.9 | 66.2 |
| 090A-4 | D | 52.9 | 66.2 |

$P_{rec}$ 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 level ($U_{dc}$), the $P_{rec}$ values in the table are multiplied by $U_{dc}$ /540, where $U_{dc} \approx 1.35 \times U_{ac}$ .

# Power requirements

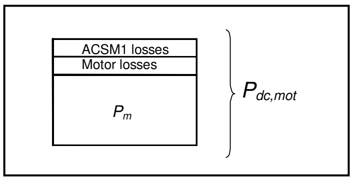
In a common DC system several ACSM1 drive modules are connected to DC link. Each drive and motor has its own specific load cycle profile. The sum of these load cycles will define the system power profile in DC link as shown in the figure below.




### 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 covers also the losses in the ACSM1 and motor.



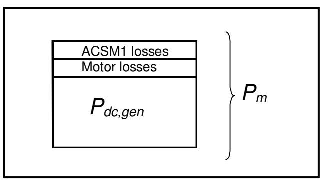

$$P_{dc,mot} = k_{eff} \times P_m$$

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

| | |
|---|---|
| $P_{dc}$ | : DC link power |
| $k_{eff}$ | : Efficiency factor (1/eff) to include ACSM1 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 ACSM1 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.

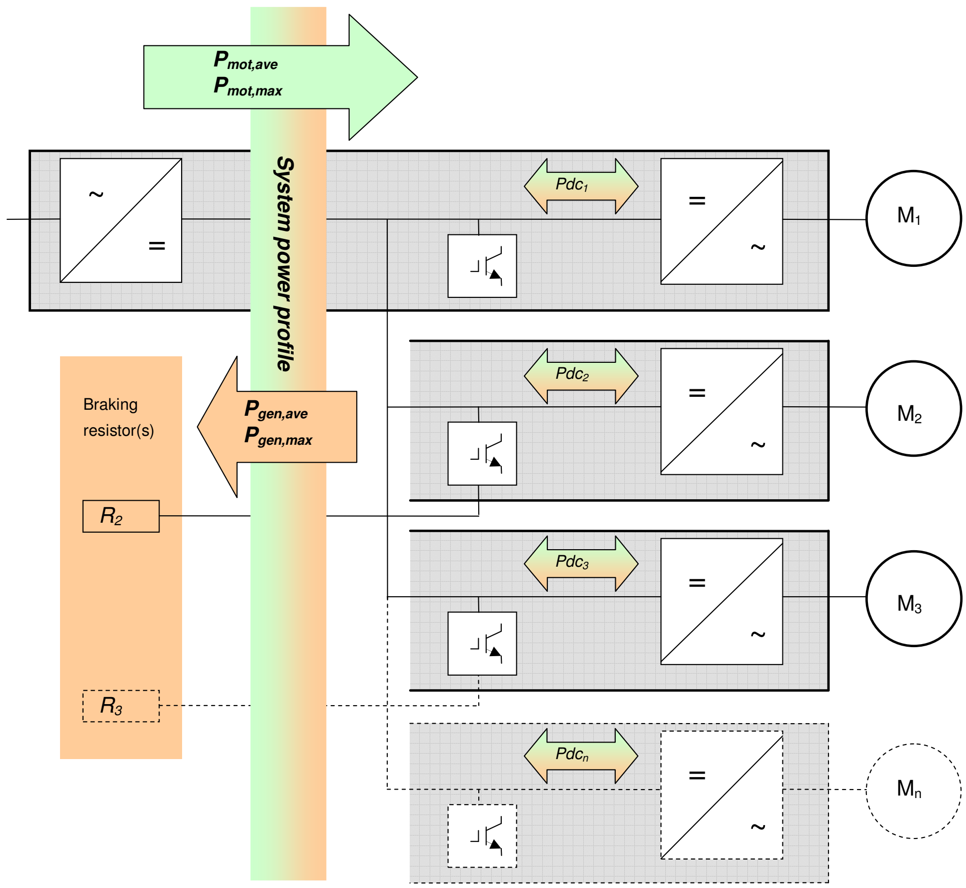
### *Average regenerative power $P_{gen,ave}$*

$P_{gen,ave}$ is the average of the *regenerating* DC link power over the whole cycle. This power must be dissipated in 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 ACSM1 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 ACSM1

The DC link power can be supplied via a suitable ACSM1 drive module for the common DC system. The drive module will be selected based on $P_{mot,ave}$ and $P_{mot,max}$ requirements.

#### *Single AC input*

In the optimum situation only one ACSM1 drive module is connected to 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 can not 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.

#### *Multiple AC input*

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

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

where $P_{rec}$ ratings are now calculated from the individual ratings as follows

- $P_{rec,ave} = P_{rec,ave1} + 0.8 \times (P_{rec,ave2} + P_{rec,ave3} + \ldots)$
- $P_{rec,max} = P_{rec,max1} + 0.7 \times (P_{rec,max2} + P_{rec,max3} + \ldots)$

$P_{rec,ave1}$ 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.

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

ACSM1 drive modules in frame sizes A-D have a charging circuit in series with the capacitor bank.

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

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

| ACSM1-04xx- | | R | Rmin |
|---|---|---|---|
| Size | Frame | ohm | ohm |
| 02A5-4 | A | 50 | 21.7 |
| 03A0-4 | A | 50 | 21.7 |
| 04A0-4 | A | 50 | 21.7 |
| 05A0-4 | A | 50 | 21.7 |
| 07A0-4 | A | 50 | 16.5 |
| 09A5-4 | B | 130 | 14.7 |
| 012A-4 | B | 130 | 10.4 |
| 016A-4 | B | 130 | 10.4 |
| 024A-4 | C | 66 | 8.5 |
| 031A-4 | C | 66 | 8.5 |
| 040A-4 | C | 66 | 4.6 |
| 046A-4 | C | 66 | 4.6 |
| 060A-4 | D | 33 | 4.6 |
| 073A-4 | D | 33 | 4.6 |
| 090A-4 | D | 33 | 4.6 |

$R$ : Charging resistance of the drive module

$R_{min}$ : 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 DC link.

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

$R$ 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 can not 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.

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

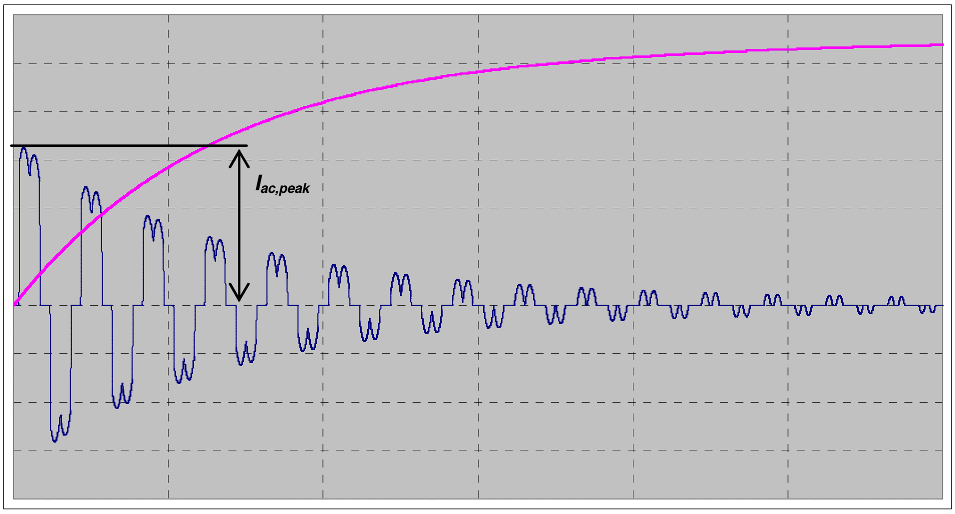
$R_{min}$ values ($R_{min1}$, $R_{min2}$,…) are the individual minimum resistance values of the drive modules connected to the AC supply.

The following condition must be fulfilled:

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

### Charging current

Typical AC input line current waveform and the DC link voltage during the charging is shown in the figure below.




It must be checked that the AC supply side components (fuses, contactors,…) 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 line supply voltage. The charging time is generally about 0.3 s ($U_{dc}$ > 95% $U_{dcN}$) with ACSM1 drive modules.

### External DC supply

ACSM1 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 ACSM1 drive module. In this case some other diode supply unit can be used.
- if the regenerative power should be fed back to the AC supply. Then it is possible to use ABB's regenerative supply units (ISU).

There is no need for an external charging circuit with the external DC supply, because the ACSM1 drive modules have internal charging circuits.

When some other type of supply unit than ACSM1 is used, its DC voltage compatibility with the ACSM1 must be checked in addition to the earlier described items (see paragraph *ACSM1 DC voltage limits*).

# Mains choke selection

In common DC connections, the ACSM1 drive module(s) connected to AC supply must be equipped with mains choke(s). Mains chokes are needed

- to get the maximum DC power ratings from the ACSM1 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 multiple AC input.

### Mains choke data

Data for the mains chokes is given below.

| Type | L | Ith | Imax |
|---|---|---|---|
| | µH | A | A |
| CHK-01 | 6370 | 4.2 | 6.2 |
| CHK-02 | 4610 | 7.6 | 11.4 |
| CHK-03 | 2700 | 13.1 | 19.6 |
| CHK-04 | 1475 | 22.0 | 26.3 |
| CHK-05 | 1130 | 33.1 | 52.6 |
| CHK-06 | 700 | 47.1 | 74.0 |
| CHK-07 | 450 | 63.0 | 98.8 |
| CHK-08 | 355 | 84.5 | 140.0 |

$L$ : Mains choke nominal inductance

$I_{th}$ : Maximum allowed continuous current (rms) at 55°C ambient temperature

$I_{max}$ : Maximum allowed short time current (rms). This current is allowed for maximum 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 line side power factor, current harmonic distortion and rectifier losses.

The following conditions must be fulfilled.

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

### Multiple AC input

In case 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.

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

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,
- $P_{rec,ave1}$… $P_{rec,aven}$ and $P_{rec,max1}$… $P_{rec,maxn}$ 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 harmonics distortion level, then typically a mains choke is needed. Total harmonic distortion is about 40…45 %, when mains choke types CHK-xx are used according to default selection. Then typically also the requirements for harmonic distortion according to standards IEC 61000-3-2, IEC 610003-4 and IEC 610003-12 are fulfilled.

A more accurate harmonics analysis can be made with 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 motor to DC link, when that motor is producing negative torque and is then braking. This is typical, when motor is decelerating or motor is in so called generator mode (e.g. unwinder). If the other drive modules are not taking at the same time enough active power from the DC link, the braking energy is stored in DC link capacitors and the DC link voltage will increase. Low amounts of regenerative energy can be handled within common DC capacitors, if the DC link voltage stays below trip limit.

The regenerative energy should be taken away from system, if the energy capacity of common DC system is not enough. This can be done by braking resistors or feeding the excess energy back to the supply network.

At the moment only resistor braking can be used with ACSM1 drive modules. However, it is also possible to use a suitable external supply unit, which can feed the energy back to network (so called regenerative supply unit).

### 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 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 acting 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 after that for the motoring power. The energy demand from the supply is then reduced.

### *ACSM1 DC link capacitance*

Each ACSM1 drive module has an own capacitor bank. The capacitance value of each drive size is given in the table below.

| ACSM1-04xx- | | Cdc |
|---|---|---|
| Size | Frame | uF |
| 02A5-4 | A | 120 |
| 03A0-4 | A | 120 |
| 04A0-4 | A | 240 |
| 05A0-4 | A | 240 |
| 07A0-4 | A | 240 |
| 09A5-4 | B | 370 |
| 012A-4 | B | 740 |
| 016A-4 | B | 740 |
| 024A-4 | C | 670 |
| 031A-4 | C | 670 |
| 040A-4 | C | 1000 |
| 046A-4 | C | 1000 |
| 060A-4 | D | 1340 |
| 073A-4 | D | 2000 |
| 090A-4 | D | 2000 |

### *Energy capacity in common DC*

The energy capacity $W_{dc}$ in the common DC system can be determined with 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 common DC link.
- $U_{dc,lim}$ is the DC link voltage level, which is allowed for the system
- $U_{dc}$ is the actual DC link voltage level in normal situation

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

Here are the major alternatives for the $U_{dc,lim}$ based on the ACSM1 drive module DC voltage limits (see also the paragraph *ACSM1 DC voltage limits*).

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

  $U_{dc,lim} \leq 840$ V DC

- DC over voltage control is enabled, but not activated.

  $U_{dc,lim} \leq 810$ V DC

- DC link voltage level, where the braking choppers are not yet activated.

  $U_{dc,lim} \leq 780$ V DC

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

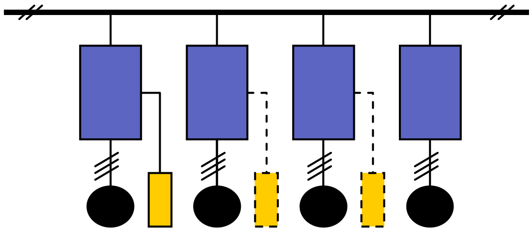
- $W_{dc} > E_{gen}$

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

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

## Resistor braking

ACSM1 drive modules have as standard a braking chopper. External braking resistor can be connected to drive module. Braking chopper can then feed the braking energy to the resistor to keep the DC link voltage below the trip limit. It is also possible to have multiple active braking choppers in common DC system with ACSM1 drive modules.



### *ACSM1 braking power ratings*

When the braking chopper is enabled and a resistor connected, the chopper will start 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. Braking chopper data of ACSM1 drive modules is shown in the following table.

| ACSM1-04xx- | | Pbr,cont | Pbr,max | Rbr,min |
|---|---|---|---|---|
| Size | Frame | KW | KW | Ohm |
| 02A5-4 | A | 0.9 | 5.5 | 120 |
| 03A0-4 | A | 1.3 | 5.5 | 120 |
| 04A0-4 | A | 1.8 | 5.5 | 120 |
| 05A0-4 | A | 2.6 | 5.5 | 120 |
| 07A0-4 | A | 2.6 | 5.5 | 120 |
| 09A5-4 | B | 4.8 | 7.9 | 80 |
| 012A-4 | B | 6.6 | 14.6 | 40 |
| 016A-4 | B | 9.0 | 14.6 | 40 |
| 024A-4 | C | 13.2 | 30.7 | 20 |
| 031A-4 | C | 18.0 | 30.7 | 20 |
| 040A-4 | C | 22.2 | 43.9 | 13 |
| 046A-4 | C | 26.4 | 43.9 | 13 |
| 060A-4 | D | 26.4 | 43.9 | 13 |
| 073A-4 | D | 26.4 | 43.9 | 13 |
| 090A-4 | D | 26.4 | 43.9 | 13 |

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

$P_{br,cont}$ : The internal chopper will withstand 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, which have 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 highest braking power ratings.

### *Braking resistor selection*

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

### *Single braking resistor*

- The resistance must be at least $R_{br,min}$ according to braking chopper data of the ACSM1 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 840V 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 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 resistor (steady state continuous load). For more detailed analysis (and more optimum selection) the pulse load curves of the selected resistor should be studied.

### *Multiple braking resistors*

In case two or more braking resistors are connected to 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 braking chopper data of the concerned ACSM1 drive module
- 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 840V 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 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 concerned individual braking chopper.
- 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 for dynamic load cycles are available for ACSM1 drive modules. Please see ACSM1 hardware manual for the detailed data.

# General system design items

## Fuse protection

Fuses are needed on the AC supply side and in the DC connections. These will provide protection for the cabling and also limit the damage in case of short circuit in the system. Following items should be checked for fuse selection.

- Fuse class depending on fault current type and protected items
- Fuse voltage rating
- Fuse current rating
- Standards and regulations. Here are given the general guidelines for the fuse selection, please observe always also the local and application specific regulations.

### *Selection of AC supply fuses*

The standard selection table for the AC supply fuses in the single drive configuration can be found in the *ACSM1 hardware manual*. That selection guideline can be used, when the AC supply line current of the drive module(s) connected to AC supply is according to that table.

Here are the general guidelines for the selection of AC supply fuses.

- IEC fuse class gG or UL class T are suitable for AC supply side
- Fuse voltage rating of 500 V should be selected for 380…480 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 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 (+ / -). Here are the general guidelines for the selection of DC link fuses

- 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 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 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 of the DC power ratings of drive modules are shown in the table below.

| ACSM1-04xx- | | Fuse |
|---|---|---|
| Size | Frame | A |
| 02A5-4 | A | 16 |
| 03A0-4 | A | 16 |
| 04A0-4 | A | 16 |
| 05A0-4 | A | 16 |
| 07A0-4 | A | 16 |
| 09A5-4 | B | 20 |
| 012A-4 | B | 32 |
| 016A-4 | B | 32 |
| 024A-4 | C | 63 |
| 031A-4 | C | 63 |
| 040A-4 | C | 100 |
| 046A-4 | C | 100 |
| 060A-4 | D | 160 |
| 073A-4 | D | 160 |
| 090A-4 | D | 160 |

## EMC

The compliance of the drive modules with EMC directive is specified in the *ACSM1 hardware manual* for the single drive configuration. Please notice that different common DC configurations have not yet been tested from 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 different EMC categories are not yet available.

## Installation

Please see *ACSM1 hardware manual* for the installation (mechanical and electrical) guidelines of the drive modules and external options.

## Drive module settings

- Parameter settings of ACSM1 drive modules connected to DC
  - Disable fault function “CROSS CONNECTION” (par. 46.08), if the *external DC supply* (other than ACSM1 drive module) is used
  - Disable over voltage control (par. 47.01), if resistor braking is used.
  - For braking chopper parameter settings, please see parameter group 48.

## General technical data

### *ACSM1 DC voltage limits*

All ACSM1 drive modules have own terminals for the DC connection.

Different limit values in ACSM1 drive modules related to DC voltage level are defined in the table below. Please see *ACSM1 firmware manual* for the more detailed descriptions.

| *Designation* | *Symbol* | *Unit* | *Value* | *(Udc=540V)* |
|---|---|---|---|---|
| Nominal DC voltage | $U_{dcN}$ | V | 540 | 540 |
| DC voltage range | $U_{dc}$ | V | 436…713 +/- 0% | 540 |
| Charging limit | $U_{dc,chr}$ | V | $80\% \times U_{dc}$ | 432 (80% Udc) |
| DC voltage control: Over voltage control limit | $U_{dc,ovc}$ | V | 810 | 810 (150% Udc) |
| DC voltage control: Under voltage control limit | $U_{dc,uvc}$ | V | $70\% \times U_{dc}, \geq 400$ | 400 (74% Udc) |
| DC over voltage trip limit | $U_{dc,ovt}$ | V | 880 | 880 (163% Udc) |
| DC under voltage trip limit | $U_{dc,uvt}$ | V | 350 | 350 (65% Udc) |
| Braking chopper limit, low | $U_{dc,brcl}$ | V | 780 | 780 (144% Udc) |
| Braking chopper limit, high | $U_{dc,brch}$ | V | 840 | 840 (156% Udc) |

$U_{dc}$ in the column ("Value"), where the values are defined, is based on the ACSM1 drive module setting for the used supply voltage. The used supply voltage can be set by parameter (Par. 47.03 and 47.04) or identified automatically. Used $U_{dc}$ value is then defined with following formula.

$U_{dc}$ = 1.35 x (signal: 1.19 USED SUPPLY VOLT)

- *Nominal DC voltage*: Average DC voltage level, when 400VAC supply connected to ACSM1 AC input terminals.
- *DC voltage range*: Actual DC voltage level with 3-phase AC supply voltage range (380…480VAC +10% / -15%). Actual DC voltage with the nominal load can be defined based on 3-phase AC supply voltage with following formulas.

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

- *Charging limit*: Charging relay will be closed, when this DC voltage level has been reached. There are also other criteria (du/dt, time delay) in firmware for closing the charging relay. 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 over voltage and under voltage control of DC link voltage level are enabled as default. Then ACSM1 drive modules will limit motoring and generating torque, if needed to keep DC link voltage within control limits. In common DC configurations with enabled braking chopper the over voltage control mode should be disabled. Please see voltage control parameters in group 47.
- *DC over voltage and under voltage trip limit*: These limits values protect ACSM1 drive modules. Drive module will trip and give fault message, if the DC link voltage will reach these levels.
- *Braking chopper limits*: The braking chopper in ACSM1 drive module will be activated (if braking chopper is enabled), when the DC link voltage will reach the low level ($U_{dc,brcl}$). If the DC link voltage level will reach the high level ($U_{dc,brch}$), then the braking chopper is feeding the braking resistor with continuous current and the maximum braking power level is reached.

3AFE 68978297 REV A EN
EFFECTIVE: 08.10.2007

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