ACS 5000

Medium Voltage AC Drives

12 to 24 MVA
For Speed and Torque Control of
Synchronous and Induction Motors

Torque control software (TC SW) for Asynchronous Machine Drive Commissioning manual LKCI5410

This document is for ABB certified service engineers use only!

1 General

All personnel who will install or do maintenance shall be familiar with the safety instructions before opening the door of the frequency converter cubicle. All relevant safety regulations must be followed during the installation, commissioning and maintenance procedures. When installed and used in accordance with instructions, it causes no risk to its associated environment.

Some of the control cards of the frequency converters are at the main circuit potential, causing hazardous voltage levels to be present between the control cards and the frequency converter frame. The doors of the frequency converters must be kept locked while the frequency converter is in operation.

1.1 Commissioning

It is mandatory to follow the commissioning manuals and the user manual safety instructions. The required measurements have to be executed otherwise some equipment might be damaged.

1.2 Operation

The operation of the frequency converter can be entrusted to a person who is not familiar with its basic functions. The operator should, however, be informed of the significance of the diagnostics. In case of an alarm indication, possibly followed by tripping, the operator should be able to decide whether part of the system should be removed from operation or whether the system should be restarted after resetting the alarm. (For example, repeated tripping from overcurrent will not damage the frequency converters). In the event that it is taken out of service, the appropriate maintenance personnel should be called to further investigate the problem.

1.3 Maintenance work

During the warranty period, any repair work must be carried out exclusively by ABB service personnel. After the warranty period repair work can be carried out by ABB service personnel or by qualified personnel who have attended a service training course.

In most cases, the diagnostic displays can be used for preliminary tracing of the fault location and fault resetting can be done without opening the door of the frequency converters.

The following points must be observed before any work is performed on the frequency converters.

1.4 Warnings!

Any installation work must be done with the power off and power is not to be reconnected unless the installation work is complete.

Dangerous residual voltages remain in capacitors when the disconnecting device is opened. Wait 5 minutes after switching off the supply before starting work. Always ensure that the measurement voltage between terminals UDC+ and UDC- of all DC links is close to 0 V and that the supply has been switched off before performing any work on the equipment or making main circuit connections.

If the main circuit of the inverter unit is live, then the motor terminals are also live even if the motor is not running!

Opening the disconnecting device does not remove all voltages. Before starting work, check which circuits remain live after opening of the disconnecting device by referring to the circuit diagrams for your particular delivery. Labels are also provided to identify the live circuits.

The protection with a door opened is minimum IP 20. Removal of any barrier while power is connected shall be done with the utmost care and consideration of personal safety.

NOTE also a possible uninterruptible power supply (UPS)!

Control voltages of 115/230 VAC may be present on the digital inputs or outputs even though the inverter unit is not powered up. Before starting work, check which circuits remain live after opening of the disconnecting device by referring to the circuit diagrams for your particular delivery and also checking the labeling for the live circuits included in the cubicle.

Do not make any voltage tests on any part of the unit while the unit is connected. Disconnect motor cables before making any measurements on motors or motor cables.

The printed circuit boards are sensitive to electrostatic discharge (ESD). When handling the printed circuit boards, ensure that personnel is properly grounded with wrist straps and other appropriate material for handling printed circuit boards.

The control boards of frequency converters may be on main circuit potential. Dangerous voltage levels may be present between the control cards and the frame of the inverter unit, when the main circuit voltage is on. It is critical that the use of measuring instruments, such as an oscilloscope, and their connection to the frequency converter is done using caution and safety always as a priority. The fault tracing instructions give special mention of cases in which measurements may be performed on the control cards, also indicating the measuring method to be used.

Electric arc welding may damage electronic circuits located in the drive sections. To reduce the risk of damage while arc welding, connect the return conductor of the welding equipment to the piece being welded on and within 0.5 meters of the arc welding equipment.

Welding of the cabinet frame is not recommended due to the possible damage which it may cause to the electronics.

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1.5 General Introduction

This document covers the basic commissioning tasks of the torque control software (TC SW). Purpose of this document is to serve as a guideline for the AMC-table parameter initializations and as a check of the motor control operation. Simple basic tuning instructions are given in case of unsatisfactory operation of the drive. It is assumed that professional person trained by ABB does the commissioning work. Commissioning person should have adequate knowledge about the torque control software (TC SW) and motor control in general and should be able to use ABB standard tools (e.g. Drive Window, Drive Debug).

Recommended DriveDebug version is 2.91 (Service pack available for DriveDebug 2.9). DriveDebug versions before version 2.91 cannot access the fast internal Trendlogger (Function "TrendLogWin") because it is located in y-memory.

2 Loading software and firmware

2.1 Introduction

The drive comes from the factory with the AMC software and firmware of the PLDs (referred to as firmware in the following) that was the latest release at the time of testing. It may happen that between testing and commissioning new versions of software and/or firmware were released. In this case the procedure described in this section has to be followed.

From the actual compatibility list it can be seen which version of the firmware has to be used together with the software (see file **ACS 5000 / 6000 SW Compatibility List.xls** of software release on the database).

After first turning on the auxiliary power to the AMC board, check which versions of software and firmware are actually loaded:

- Press the button Drive on the panel: the display must show correct drive type

- Check the following parameters:

  o 101.03 DEVICE NAME   must correspond to the size of the drive (see below)

  o 100.11 SW PACKAGE VER   if this corresponds to the SW version that shall be installed on the drive, the AMC software does not need to be downloaded and the corresponding section below can be ignored.

  Only for ACS 5000:

  o 6.31   INT0 VERSION   this is the version of the PLD firmware on the main interface board (PECINT or INT2 board); if the version is compatible to the wanted AMC software version, the PLD does not need to be programmed and the corresponding section below can be ignored.

  o 6.32   INT1 VERSION
     6.33   INT2 VERSION
     6.34   INT3 VERSION
     The numbers describe the version of the PLDs on the Phase interface boards. They must be equal. If the version is compatible to the wanted AMC software, the PLDs do not need to be programmed and the corresponding section below may be ignored.

It is highly recommended to use a new flash board for downloading a new loading package. Keep the old flash as spare part in case programming of the new SW fails. In any case make a complete backup and a parameter backup of the loaded software before overwriting the existing software with a new version. Use Drive Debug and Drive Windows to make the backups.

2.2 Programming AMC Software

2.2.1 Unpacking the Software Package

- The software package needs about 4Mbytes of free disk space. You need some software tool in your system to unpack the loading package, like PKUNZIP or WINZIP.

- Create a new folder (or directory) on your PC, e.g. C:\LOAD. Later this folder is referred to as ".\".

- Copy and unzip the file LxOy.ZIP to this folder (x may be A for 6000AD, K for 5000AD, L for 5000SD or S for 6000SD; y may be H for AMC33 boards and I for AMC34 boards). All necessary files will be available in this folder and the automatically created subdirectories.

- Delete the zip-file if you want to save disk space.

- The folder .\ must contain at least the following files:
  .\CONFIG.BAT
  .\7za.exe (only with Cx0t.7z)
  .\Cx0t.exe or .\Cx0t.7z
  .\L_ACS.BAT
  .\L_MOT.BAT
  .\VERSION.BAT
  either .\TitlisSD.txt, .\TitlisAD.txt, .\lam.txt or .\akseli.txt.
  .\AmcData\AUTOLOAD.DDF
  .\AmcData\DUMMLANG.csv
  .\AmcData\ENCPARAM.CSV (only in case of SD)
  .\AmcData\ENCPARAM.XLS (only in case of SD)
  .\AmcData\INVPARAM.csv
  .\AmcData\INVPARAM.XLS
  .\AmcData\MOTPARAM.CSV
  .\AmcData\MOTPARAM.XLS
  .\AmcExe\am34.cld
  .\AmcExe\BASELIB.DDF
  .\AmcExe\pa_56303.cld
  .\AmcExe\Task1.ddf

  with all projects except ACS 5000AD and ACS 5000SD these files are expected in the folder:
  .\AmcData\APPLPARS.CSV
  .\AmcData\APPLPARS.XLS

  with ACS 5000AD and ACS 5000SD also the following files are part of the package:
  .\L_HYS.BAT
  .\AmcData\HYSPARAM.CSV
  .\AmcData\HYSPARAM.XLS
  .\

2.2.2 Downloading the AMC Software

The folder .\ contains the ACS 5000 / 6000 AMC software and all tools needed to download to the flash memory of the AMC board.

Due to licensing issues the drivers used to download the loading package are not included in the loading package! You need a running installation of Drive Debug or Drive Window on your PC which offers the needed drivers.

- Connect the PC to channel 3 of the AMC board.

- Open a DOS window and change the directory to .\

- The parameter set has to be chosen according to the installed current measurement subprint (SCA) on the CVMI boards. The rated current of the attached machine is not relevant for this step. The safest way to determine the corresponding current rating is to check the marking of the SCA subprints. The following table gives the appropriate information:

ACS 6000:

Description	SCA type	SAP number	Measurement range	Rated current (rms)	**Inverter type for Download**
ACS6000 11MVA peak	XV C768 AE117	3BHB007211R0117	-4'500 …+4'500A	1648A	**11MVA**
ACS6000 11MVA continuous	XV C768 AE119	3BHB007211R0119	-4'500 … +4'500A	1648A	**11MVA**
ACS6000 9MVA	XV C768 AE101	3BHB007211R0101	-3'684 … +3'684 A	1260A	**9MVA**
ACS6000 7MVA	XV C768 AE102	3BHB007211R0102	-2'865 … +2'865 A	980A	**7MVA**
ACS6000 5MVA	XV C768 AE105	3BHB007211R0105	-2'046 … +2'046 A	700A	**5MVA**
ACS6000 3MVA	XV C768 AE106	3BHB007211R0106	-1'228 … +1'228 A	420A	**3MVA**

ACS 5000:

Description	SCA type	SAP number	Measurement range	Rated current (rms)	**Inverter type for Download**
Double INU Water	XV C768 AE111	3BHB007211R0111	-2200 ... +2200A (per INU)	2000A	**24MVA**
Double INU Water	XV C768 AE112	3BHB007211R0112	-1760 ... +1760A (per INU)	1400A	**18MVA**
Single INU Water – 2nd generation	XV C768 AE121	3BHB007211R0121	-3316 … +3316A	1500A	**18MVA_G2**
Single INU Water	XV C768 AE111	3BHB007211R0111	-2200 ... +2200A	1000A	**12MVA**
Single INU Water	XV C768 AE112	3BHB007211R0112	-1760 ... +1760A	800A	**9_5MVA**
Single INU Water	XV C768 AE113	3BHB007211R0113	-1320 ... +1320A	600A	**7MVA_W**
Single INU Air	XV C768 AE116	3BHB007211R0116	-1300 ... +1300A	586A	**7MVA_A**
Single INU Air	XV C768 AE115	3BHB007211R0115	-650 ... +650A	293A	**3_5MVA**

Table 1: SCA subprints and matching inverter types

- In ACS 6000, if a 9 MVA stack is used, it is important to check the type and select the right type of inverter for download. The following table gives the appropriate information:

Description	Stack type	IGCT	FW-Diode	NP-Diode	**Inverter type for Download**
9 MVA Stack - High Speed with ABB-Diode	S-093N	3BHB013085R001	5SDF1045H002	5SDF1045H002	**9MVA**
9 MVA Stack - High Speed with EUPEC-Diode	S-093H	3BHB013085R001	3BHB006457R0001	3BHB006457R0001	**9MVA**
9 MVA Stack - Low Speed with ABB-Diode	S-093S	3BHB013085R001	3BHL000986P3003	3BHL000986P3003	**09MVA**

Table 2: Stack types for 9 MVA ACS 6000

- Download the software and the inverter parameter set using the command
  l_acs "inverter type"

  "inverter type" is the appropriate name from table 1 (or table 2 for ACS 6000 9MVA type)

  Example for the 1000A unit of ACS 5000: l_acs 12MVA

  At the beginning of the execution of this command you are asked to confirm the version information (press Y or N).

  For ACS 6000 (AD and SD) you are asked in a second step to select the type of drive:

  W   water cooled, master (default)
  A   air cooled master (not used anywhere)
  S   slave (ACS 6000)
  E   no cooling type specified (only used in test environments)

  In ACS 5000AD the necessary parameters are included in the file INVPARAM.XLS/CSV.

  Wait until download is finished. If there is a problem, read the *.lst file for details.

- For all products except ACS 5000AD and ACS 5000SD download the motor parameters using
  l_mot dummy

  This loads a basic motor parameter set which has to be completed according to the procedure described in the later sections of this document.

2.3 Programming Firmware on Main Interface Board (Only ACS 5000)

2.3.1 Using a PECINT Board

To program the firmware on the PECINT board follow the procedure is described in file

Titlis-TN041002-_PEC INT FPGA Main Modulator Programming Manual.pdf

This file is part of the "Latest Software Release" on the database.

2.3.2 Using an INT2 Board

In newer drives the PECINT board is replaced by the INT2 board which is also used as Phase Interface board.

The *.zip file containing the Main INT2 firmware also contains the two files LXEMxxxx.cmd and PROG_LXEM.bat. To download to the interface board the batch-file PROG_LXEM.bat has to be executed from a command window.

2.4 Programming Firmware on Phase Interface Boards

2.4.1 Using an old Phase Interface Board

To program the firmware on the INT boards follow the procedure described in the file

ACS 5000 / 6000 AD&SD Phase INT EPLD Release Notes.pdf

This file is part of the "Latest Software Release" on the database.

2.4.2 Using an INT2 Board

In newer drives the PECINT board is replaced by the INT2 board which is also used as the Main Interface board.

The *.zip file containing the Phase INT2 firmware also contains the two files LXEFxxxx.cmd and PROG_LXEF.bat. To download to the interface boards the batch-file PROG_LXEF.bat has to be executed from a command window for each Phase Interface board individually..

3 Description of the asynchronous motor data initializations

The ACS 5000 / ACS 6000 is delivered with factory default parameters. Factory default parameters do not include asynchronous motor data. Prior to the first start of the drive the motor data must be initialized to the AMC-table. The data needs to correspond to the motor connected to the drive. All parameters presented in this chapter have to be initialized.

Commissioning personnel can use the ABB standard tool (Drive Window) for data downloading. The drive has to be in the RDY ON state (MCB open and no voltage on the DC link) when parameters are initialized.

This chapter describes the data needed to initialize the torque control software After motor data initializations the Control SW is ready for electrical commissioning.

At this point is assumed that all the Application parameters are already set correctly (Parameters below Group 100).

3.1 Asynchronous motor data

In order to control an asynchronous motor with DTC a set of motor parameters has to be set. Parts of these parameters are available directly from a motor's name plate, other parameters have to be calculated, as described below

First check the parameter 111.06 Drive Type. Setting:
ACS 5000: "5000 AD".
ACS 6000: "6000 AD"

3.1.1 Internal frequency scaling

For internal frequency scaling reasons the parameter 110.13 FREQUENCY SCALING has to be set to a range that fits with the motor nominal frequency. This parameter has to be set before any other parameter is changed. After changing, upload the parameter table again and check all frequency values (see below)!

For standard machines the default value applies "6.75-75HzDEF".

For other machines:

The frequency scaling needs to be closely defined based on operating frequency range of the drive e.g. for machine rated at *245Hz* it should be:

    110.13 FREQUENCY SCALING   27-300Hz (5)

Similarly, e.g. for machine rated at *187Hz* it should be:
    110.13 FREQUENCY SCALING   20.25-225Hz (4)

Attention! After defining the correct frequency scaling, please also check, if all other frequency (speed) related parameters have been changed accordingly.

For internal frequency scaling reasons the parameter 110.13 FREQUENCY SCALING has to be set to a range that fits with the motor nominal frequency.

This parameter has to be set before any other parameter is changed. After changing, upload the parameter table again and check all values!

The following parameters have to be checked and corrected if they are used:

110.03 MOTOR NOM FREQ
132.07 FREQUENCY MAX
132.08 FREQUENCY MIN

186.07 FREQUENCY TRIP
186.63 W ENA ZV PROT
189.44 PWM TRUN FREQ

If "SCALAR" or "SCALAR RCM" is used as DRIVE CTRL MODE (111.01):
111.03 FREQUENCY REF
155.18 StepUpBoostFreq
155.19 StepUpMinFreq
155.54 W ENA US CTRL
155.56 W ENA IS LIM

3.1.2 Default motor parameters

ACS 6000AD:

Before the motor data are changed according to the nominal motor plate data, the default motor data have to be loaded. This is done after loading the SW to the AMC3 board using the following command:

l_mot dummy (only ACS 6000)

ACS 5000AD:

Nothing needs to be done.
(Accidentally downloading dummy parameters does not harm the drive)

ACS 5000AD High speed drives:

With the following loading command predefined high speed parameter are set:

l_mot high_speed

3.1.3 Nominal rating plate data

Following rating plate data is needed for motor initialization:

Parameter	Name	Unit
110.01	Motor nominal voltage [U]	V
110.02	Motor nominal current [I]	A
110.03	Motor nominal frequency [f]	Hz
110.04	Motor nominal speed [n]	rpm
110.05	Motor nominal shaft power [P]	kW

110.06	Motor nominal power factor [*cos φ_n*]	-

Parameter number refers to the TC SW AMC-table index

ACS 5000 minimal rated currents

The rated current in parameter 110.02 must be in a certain range to guarantee that the current scaling calculation does not saturate. For ACS 5000 the following table shows the minimal rated currents for all supported inverter types:

Inverter type	Max. measurable current (190.02)	Minimal rated current (110.02)
24MVA	2200 A	389 A
18MVA	1760 A	312 A
18MVA_G2	3316 A	587 A
12MVA	2200 A	389 A
9_5MVA	1760 A	312 A
7MVA_W	1320 A	234 A
7MVA_A	1300 A	230 A
3_5MVA	650 A	115 A

3.1.4 Motor model parameters

Following electrical parameters are needed for motor model initialization:

Parameter	Name	Unit
150.01	Stator resistance [Rs]	Ohm
150.02	Stator inductance [Ls]	mH
150.03	Machine stray inductance [σLs]	mH
150.04	Rotor time constant [Tr]	ms

Parameter number refers to the TC SW AMC-table index.

3.1.5 Calculation of motor model parameters

Calculation of motor model parameters listed above depends on what kind of motor data is available. The procedure is done with the help of an EXCEL file, which is named

"AD Motor Parameter calculation.xls"

This file is delivered as part of the release structure. It contains a "Read Me" sheet on which detailed instructions are given. For all worksheets it is crucial to fill in the name plate parameters of the motor, i.e. rated voltage, current, frequency, speed, mechanical power and power factor.

- The preferred way of getting the correct motor parameters is to use the values from a data sheet given by the manufacturer of the machine. In the EXCEL file there are two worksheets supporting this procedure ("**Equivalent 1-phase**"), one for the data in SI-units and the other for the data in normalized form (per unit). The values of the so called T-equivalent circuit are filled in and the corresponding L-equivalent circuit parameters are calculated.

- If no data sheet is available (or for comparison purposes) perform the simple ID-Run that is related to the DC magnetization start method. The ID-Run can only be performed after the drive is ready to run. In a first step it is therefore necessary to set a rough estimate of the motor parameters to be able to get the drive free of trips. If no other data is available use the worksheet "Plate Data" of the EXCEL file. Later perform the ID-Run as described here. The result of the ID-Run is the stator resistance and the overall leakage inductance of the machine (including the filter choke if existing). They are shown in parameters 154.19 IDStart: Rs and 154.20 IDStart: sigmaLs. These values can be filled into the worksheet "**Measured Lsigma**" of the mentioned EXCEL file to get the remaining motor parameters. See the corresponding section under "No Load Run" for details on the ID-Run.

- If only motor name plate data are available, use the worksheet "**Plate Data**" of the EXCEL file to get an estimate of motor parameters. These values can also be used as a first guess which is later refined.

  Attention! Note that calculation of the motor parameters based on the plate's data is valid for 50/60Hz machines only.

  In case of high speed drives (fundamental frequency in the range $100 \div 250$Hz), the proposed parameters from the "Plate Data" worksheet may differ significantly from the real motor parameters. The simple ID-Run with DC magnetization must be performed on the drive first to identify the correct stator winding parameters if no data sheet is available. See the section under "No Load Run" for details on the ID-Run.

3.2 Inverter parameters

Following electrical parameters have to be set manually:

ACS5000:

The values in brackets are default values and may be changed if necessary.

For the latest HW release of the **air-cooled ACS 5000** the DC Charging Level (parameter 17.02) should be set to at least 5450V (instead of 5300V) in order to avoid charging faults.

Parameter	Name		Value	Unit
17.01	MCB ClosingLevel		(5200)	V
17.02	DC ChargingLevel		(5300/5450)	V
17.04	DischargeTimeout:	water cooled drives	(200)	s
		air cooled drives	(300)	s
17.08	ModulationDischrg:	water cooled drives	DISABLED	
		air cooled drives	ENABLED	

17.09	VLU Ctrl&Monitor: water cooled drives	ENABLED	
	air cooled drives	DISABLED	
112.04	NOM DC VOLTAGE	(5000)	V
191.18	DISCHARGE FT LVL:water cooled drives	0	V
	air cooled drives	(500)	V

ACS6000:

Parameter	Name	Unit
112.04	NOM DC VOLTAGE	V

In most cases, the nominal DC voltage depends on the application:

AD with ARU supply: **4840V**
AD Industry: **4410V**
AD Marine: **4220V**

3.2.1 Operational parameters

The following operational parameter has to be set:

Parameter	Name	Unit
21.01	StartFunction **ACS 5000:** Select between CONST DC MAGN or SCALAR FLY (FLYING START and FLASH START are not supported as a standard starting method) **ACS 6000:** Select between CONST DC MAGN, FLYING START or SCALAR FLY	

3.2.2 Pulse encoder

The drive can operate encoderless or with a pulse encoder depending on the operational mode set in parameter 111.02

If parameter 111.02 ENCODERLESS DRIVE is set to TRUE no pulse encoder is needed to run the drive. **If the AMC board is booted with parameter 111.02 set to TRUE, the initialization for TACHOLESS operation is executed.**

If parameter 111.02 ENCODERLESS DRIVE is set to FALSE a pulse encoder is needed, parameters from group 165 have to be checked and the NTAC module has to be initialized. **If the AMC board is booted with parameter 111.02 set to FALSE, the NTAC module initialization is executed.**

After changing of parameter 111.02 the AMC board needs to be rebooted in order to execute the correct initialization.

Parameter 111.07 ENCODER MODE SEL is used to select different operating modes for the encoder. During commissioning it may be helpful to select the mode "TEST ENCODER" which initializes the encoder correctly but does not use the measured speed for any function inside the control. The measured speed can thus be compared to the estimated speed to check for deviations. Do not forget to set 111.07 back to the value "DEFAULT" which lets the encoder be used for speed control and motor model.

Note: For high speed drives, encoders are not supported!

3.2.3 Other parameters

Check that following AMC-table parameter groups have reasonable values for drive system in question (refer to the drive/ process requirements):

> 110 Drive configuration data
> 111 Operation mode
> 112 Inverter data
> 116 Torque selector word
> 120 Reference modifications
> 121 Speed control parameters
> 130 Flux control
> 131 Magnetizing
> 132 Dynamic torque limiter (usual: value of the gains at least 1000%)
> 133 Static torque limiter
> 134 SF + NP control
> 135 Frequency/ speed limits
> 136 Torque/ current limits
> 141 Stop
> 150 Motor parameters
> 153 Motor model tune
> 159 Damping Udc
> 165 Tacho
> 186 Trip levels
> 192 BCU/RBU/VLU

Pay special attention to the following indices:

> 130.03   FLUX REF IN (default value for all drives is 100% except for **ACS 5000 7MVA air cooled** drives for which 102% is used)
> 130.05   FLUX RAMP TIME (default 0.1sec for use with UV limiter)
> 132.07   FREQUENCY MAX
> 132.08   FREQUENCY MIN
> 132.09   FREQ LIM GAIN
> 133.06   USER MAX MOT CUR
> 133.07   USER MAX GEN CUR
> 186.07   FREQUENCY TRIP

3.3   High speed drives

3.3.1 Important parameter settings for high speed drives

Set the following parameters accordingly:

134.22 NP CURR FILT   1 ms   (f = 50…150 Hz)

	0.1 ms (f >150 Hz)
134.23 NP 1ST HYST	65 V
134.24 NP 2ND HYST	110 V
134.25 NP 3RD HYST	150 V
153.08 ENLESS COR D-GAIN	0.02 (for DTC 0.2)
153.09 ENLESS COR Q-GAIN	0.02 (for DTC 0.2)
155.54 W ENA US CTRL	600 Hz (= disabled)
155.56 W ENA IS LIM	600 Hz (= disabled)
186.63 W ENA ZV PROT	600 Hz (= disabled)
191.08 DI/DT-MON ILIM	5000 A (= disabled)

Make sure that the **switching frequency trip limits** are correctly set:

186.07 FREQUENCY TRIP	110% of motor nominal frequency
186.08 SF 1ms TRIP	Default value
186.09 SF 50ms TRIP	Default value
186.10 SF 250ms TRIP	TBD
186.11 SF 1s TRIP	TBD

For **ride through** the following parameters are recommended:

130.02 MIN FLUX REF	50 %
130.05 FLUX RAMP TIME	0.01 s
132.38 UNDERVOLT P-GAIN2	1000 %

For **scalar flying start** (SCAFLY) the suggested parameter settings are:

131.01 START FUNCTION	SCALAR FLY
131.21 SFLY FLUX REF	10 %
131.23 SFLY FREQFWD	100% or defined by process
131.30 SFLY CURR THRES	400 %

If there is an **output choke** between converter and motor, it must also be included in the parameters:

152.01 FILTER INDUCTANCE	(project specs)
152.03 FILTER RESISTANCE	(project specs)

3.3.2 Vector control - PI controllers

The PI controllers parameters must be initialized prior the run. There are two alternative operating modes of the vector control module: Stator Flux Oriented Control (SFOC) or Rotor flux Oriented Control (RFOC), which can be selected by the parameter switch (TRUE / FALSE):

The **default** selection is **Stator Flux Oriented Control (SFOC)**. If not stated differently for a special project, select SFOC.

If SFOC mode is selected then the following group of parameters must be set:

157.27 SFOC ENABLED	**TRUE**
157.01 KP-SFLUX MAX	100% (*)
157.02 TI-SFLUX CTRL	100ms (*)
157.03 PI-SFCTRL MAX LIM	1000%
157.04 PI-SFCTRL MIN LIM	-1000%

157.05 KP-SFLUX START	~ 1/3 * KP SFLUX MAX
157.06 CUT-OFF SFLUX ACT	200Hz (*)
157.07 KP-TORQUE MAX	20% (*)
157.08 TI-TORQUE CTRL	10ms (*)
157.09 PI-TCTRL MAX LIM	1000%
157.10 PI-TCTRL MIN LIM	-1000%
157.11 KP-TORQUE START	~ 1/3 * KP TORQUE MAX
157.12 CUT-OFF TORQ ACT	200Hz (*)

If RFOC mode is selected then the following group of parameters must be set:

157.27 SFOC ENABLED	**FALSE**

157.80 KP-RFLUX MAX	100% (*)
157.81 TI-RFLUX CTRL	100ms (*)
157.82 PI-RFCTRL MAX LIM	1000%
157.83 PI-RFCTRL MIN LIM	-1000%
157.84 KP-RFLUX START	~ 1/3 * KP RFLUX MAX
157.85 CUT-OFF RFLUX ACT	200Hz (*)
157.86 KP-ISDQ MAX	50% (*)
157.87 TI-ISDQ CTRL	10ms (*)
157.88 PI-ICTRL MAX LIM	1000%
157.89 PI-ICTRL MIN LIM	-1000%
157.90 KP-ISDQ START	~ 1/3 * KP ISDQ MAX
157.91 CUT-OFF ISDQ ACT	200Hz (*)

The suggested settings of phased locked loop (PLL) should be selected as shown below:

157.13 KP-PLL CTRL	200% (*)
157.14 TI-PLL CTRL	10ms (*)
157.15 CUT-OFF PLL ACT	1000Hz (*)
157.16 CUT-OFF FX REF	1000Hz
157.17 CUT-OFF PLL WF	0Hz

(*) _Use given default values first!_ If the behaviour of the drive is not satisfying and additional tuning is needed contact the MV Supportline.

3.3.3 Vector control – optimized pulse patterns

In case of high frequency machines, it is possible to switch from PWM modulator to the implemented pulse pattern modulator at higher operating speeds.

At higher speeds the drive can only run with three optimized pulse patterns (i.e. PP1… PP3) defined by number of angles used (e.g. 1x, 2x, 3x) respectively. The areas of PP are defined by three frequency change-over points which specify the correct modulation indexes. Hystereses are included to prevent from using the same PP on the boundary of two areas. The actual motor frequency multiplied with the actual PP shows approximately the switching frequency. The SF may be slightly higher if there are additional switching's due to NP control.

Attention: The information regarding which pulse pattern at given operating area must be selected is project specific. Contact support line for the project specific settings.
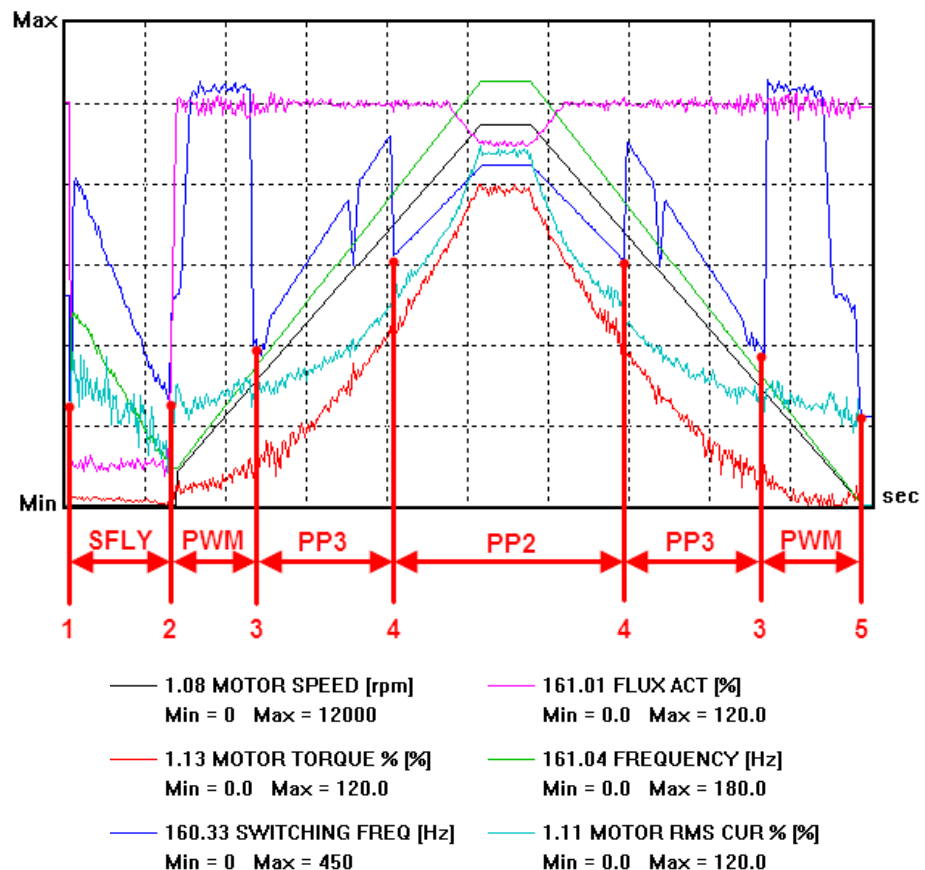
Carrier:

157.18	CARR-FREQ MAX	1600 Hz
157.19	CARR-FREQ 0Hz	1600 Hz
157.25	CARRIER MIRRORED	TRUE

Pulse patterns:

157.41	FREQ-SW HYST	1 Hz
157.50	1st PP SELECT	(project specs)
157.51	FREQ SW LEV_1	(project specs)
157.60	2nd PP SELECT	(project specs)
157.61	FREQ SW LEV_2	(project specs)
157.70	3rd PP SELECT	(project specs)
157.71	FREQ SW LEV_3	(project specs)*

* If 3rd PP is not used set a frequency which the drive will never reach to disable it.

Example of high speed drive:

——	1.08 MOTOR SPEED [rpm]	—— 161.01 FLUX ACT [%]
	Min = 0 Max = 12000	Min = 0.0 Max = 120.0
——	1.13 MOTOR TORQUE % [%]	—— 161.04 FREQUENCY [Hz]
	Min = 0.0 Max = 120.0	Min = 0.0 Max = 180.0
——	160.33 SWITCHING FREQ [Hz]	—— 1.11 MOTOR RMS CUR % [%]
	Min = 0 Max = 450	Min = 0.0 Max = 120.0

1. Start Scalar flying start
2. Magnetization and start turning motor with PWM modulation
3. Switch between PWM ←→ 1st PP

Switch point:	157.51 FREQ-SW LEV_1	48 Hz
PP	157.50 1st PP SELECT	3
Hysteresis:	157.41 FREQ-SW HYST	1 Hz

4. Switch between 1st PP $\leftarrow\rightarrow$ 2nd PP
   Switch point: 157.61 FREQ SW LEV_2   115 Hz
   PP   157.60 2nd PP SELECT   2
   Hysteresis: 157.41 FREQ-SW HYST   1 Hz
5. Stop

Note:
- The SF dip at 97 Hz (Mod Index 0.463) is normal. The dip comes from the switching definition of PP3
- PP1 is not used in the example above

4 No Load run

4.1 Operation modes

The drive may be operated with or without speed encoder. Depending on the system configuration select:

- o   with an encoder   (parameter 111.02 set to FALSE)
- o   without an encoder   (parameter 111.02 set to TRUE)

The AMC board has to be rebooted after changing parameter 111.02.

For ACS 5000:

There are several control modes:

- o   DTC   (111.01 = 0)
- o   SCALAR DTC   (111.01 = 1)
- o   FACTORY TEST   (111.01 = 2)
- o   VECTOR_CONTROL   (111.01 = 3)
- o   SCALAR RCM   (111.01 = 4)
- o   SCALAR STEP-UP   (111.01 = 5)

For high speed machines (nominal frequency typically > 75 Hz), "VECTOR CONTROL" needs to be selected. All other machines are operated with DTC.

4.2 Check DC Magnetization

As a first test it is proposed to check DC magnetization.

1. Set the current trip value to about 70% of the original value for the first start.

2. If there is a tacho, set 111.02 to FALSE and boot the AMC board. Set 111.07 to "TEST ENCODER". This mode runs the machine in encoderless mode but shows additionally the speed measured by tacho. Estimated speed in 160.38, measured speed 160.37.

3. Set the speed reference to 0 rpm.

4. Set magnetizing mode 21.01 to CNST DC MAGN.

5. Monitor the phase currents
   > 1.01 PHASE U CURRENT
   > 1.03 PHASE V CURRENT
   > 1.05 PHASE W CURRENT

6. Start the drive and stop it again after about DC magnetization is over. Check the phase currents as described in the following:

   For ACS 5000
   - Check the currents during magnetization
   - The currents should look according to Figure 1
   - (i_ref is the current reference defined by parameters 131.02 DC MAGN FLUX and 150.02 LS)
      > positive current in phase a   ia = i_ref

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negative current in phases b and c   ib = ic = - 1/2 i_ref

DC magnetization uses the voltage vectors (+1 0 0) and (0 0) and therefore only creates voltage in the positive x-axis.
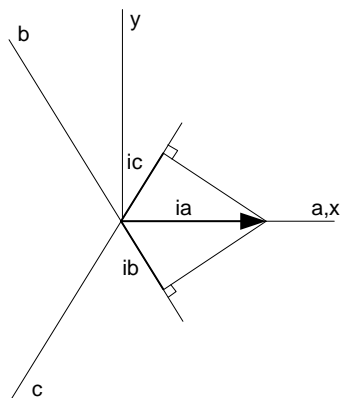

Figure 1: Illustration of DC magnetizing current in the three phases

For ACS 6000
- check current during magnetizing
- currents should look according to Figure 2
  positive current in phase a   ia = i_ref
  negative current in phase c   ic = -i_ref
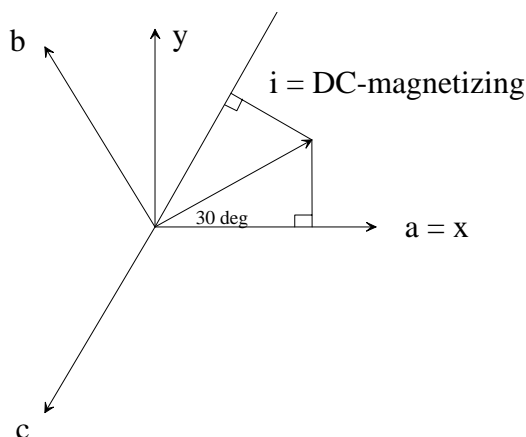 no current in phase b   ib = 0

Figure 2: Illustration of DC magnetizing current in the three phases

4.3 Revise Motor Model Parameters

During DC magnetization the stator resistance Rs and the overall leakage inductance of the motor are estimated. The slope of the current when starting DC magnetization is used to estimate the leakage inductance and the voltage that is needed to maintain the DC current is used to estimate the stator resistance.

The following procedure only needs to be done if the motor parameters are not known from a data sheet. In case that a data sheet is available, the simple ID-Run can be performed to cross-check the set parameters but the identified parameters do not need to be used in group 150.

1. Set the parameters 131.02 DC MAGN FLUX to 100% and 131.03 DC MAGN TIME to 500% (must have this value otherwise estimation of stator resistance will fail).

2. Set the speed reference to 0rpm.

3. Start the drive and stop it again after DC magnetization is over (torque control state machine leaves the magnetization state). Check 170.05 TC State = 10 = RDY_REF to be sure.

4. Read parameters 154.19 IDStart: RS and 154.20 IDStart: sigmaLs and write them down.

5. Repeat steps 3 and 4 for about 5 times. Write down the estimated values. If the values do not differ too much from each other (10%) use the average of the results to proceed. Otherwise use the worksheet "Plate Data" of the EXCEL file "AD Motor Parameter calculation.xls".

6. If between inverter and motor a **filter choke** is used, the resistance and the inductance of this filter choke are included in the estimated values. For the resistance the impact is small and can be neglected therefore. The value of the filter inductance as set in parameter 152.01 has to be subtracted from the estimated inductance value in 154.20 to get the value of the leakage inductance of the motor.

7. Transfer the average values of the estimated stator resistance and leakage inductance into the worksheet "Measured Lsigma" of the EXCEL file "AD Motor Parameter calculation.xls". Complete this worksheet with the name plate data of the motor. From this data the worksheet calculates the parameters of the motor model.

8. Transfer the data from the EXCEL worksheet to group 150. It is important to use as stator resistance value (**150.01 RS**) only about **75%** of the value that is identified and used in the EXCEL worksheet !! This helps to stabilize the flux estimation of the motor model at low frequencies.

4.4 First Start

Follow the procedure described below to check whether the phase order of the motor and the direction of the speed encoder coincide (if there is a tacho). Some torque limitations may also result in unexpected rotation.

The first start without load as described here helps to avoid uncontrolled motor operation due to wrong settings. Follow the described procedure to ensure proper operation.

1. Check visually the phase order between the inverter and the motor if possible

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2. Reduce the current trip limit to about 70% of its original value. Reduce the frequency and speed trip levels to about 50% of their original value.

3. If there is a tacho, set 111.02 to FALSE and boot the AMC board if the value was changed. Set 111.07 to "TEST ENCODER". This mode runs the machine in encoderless mode but shows additionally the speed measured by tacho. Estimated speed in 160.38, measured speed 160.37.

4. Check sense of rotation without speed encoder:
   - Set a low speed reference (as an example 20% of nominal speed) and start the motor.
   - Check the sense of rotation of the motor: Does it correspond to the customers need?
   - Check the speed signal 160.34: it must be close to the reference speed
   - Stop the drive

5. Check sense of rotation with speed encoder (only necessary if tacho is available)
   In group 165 there are parameters and signals concerning tachometer; check that these parameters are set according to the data sheet and that the wiring is correct.

   Compare estimated (160.38) and measured (160.37) speed at a speed of again about 20%. If both values coincide in magnitude and sign and correspond to the reference value, the tacho can be used for speed feedback (set 111.07 to "DEFAULT").
   If the signs of the estimated and measured speed are not equal, check whether the phase order of the motor cables or the sense of rotation of the tacho needs to be adapted (111.29).
   Repeat the test also in negative direction (-20%) if possible.

6. Reference for tacholess control:
   In tacholess control a low speed reference may be problematic. Therefore use high enough speed reference on starting: lowest speed reference can be set to a suitable value (135.04 MINIMUM SPEED or 135.02 MAXIMUM SPEED depending on the rotation direction). Also accelerating ramp time and speed controller should be chosen according to the starting behavior.

7. Set the current, frequency and speed trip limits back to their original values.

8. Checking torque limitation chain:
   o Try both rotation directions if the mechanical system allows it.
   o Check the maximum and minimum speed limitations. For example if the reference is negative the minimum speed has to be negative. The combination of minimum (maximum) and zero speed should allow stopping (n,zero > MIN(|n,min|, |n,max|). For example if the drive is only used in the negative direction:
      135.02 MAXIMUM SPEED   -20 rpm
      135.04 MINIMUM SPEED   -1000 rpm
      135.07 ZEROSPEED LIMIT   50 rpm
   o Check other limits given to the speed controller chain.
   o Check static torque limitation chain. The output is given in 133.12 USED MAX TRQ LIM and in 133.13 USED MIN TRQ LIM.

- Check dynamic torque limitation chain. The output is given in 132.18 USED TRQ REF. It should be close to the actual torque in 1.13 or 1.22.

9. Checking motor model: This procedure can be used to cross-check the used stator inductance of the motor.
   - Run the uncoupled (or at least unloaded) motor at rated frequency and rated flux which corresponds to rated. Measure the stator current RMS value Is_RMS. Calculate the stator inductance using the equation:

     $$Ls = V\_rated/(sqrt(3)*2*\pi*f\_rated*Is\_RMS)$$

     The resulting value should not deviate more than 10% from the value used in parameter 150.02.

4.5 Start modes

There are several start modes available.
ACS 5000: DC magnetization or scalar flying start
ACS 6000: DC magnetization, flying start, scalar fly start, flash start

4.5.1 DC magnetization

If it is known that the machine is at standstill when starting use the DC magnetization method. (Parameter 21.01 = CNST DC MAGN). This method is much faster than the flying start, so if possible this method should be used.

Default parameters for the mode are:
21.01 START FUNCTION	= CNST DC MAGN
131.02 DC MAGN FLUX	= 100
131.03 DC MAGN TIME	= 300

4.5.2 Flying start mode

This mode starts directly modulating with DTC having zero torque reference.

ACS 5000:
Not available for ACS 5000.

ACS 6000:
Default parameters for the mode are:

21.01 START FUNCTION	= FLYING START
131.11 FLY FLUX REF INIT	= 70
131.12 FLY FLUX RAMP	= 200
131.13 FLY HOLD TIME	= 0
131.14 RS OVERESTIM	= 300

Before tuning of flying start, the hysteresis has to be tuned. See the corresponding section for details.

Tuning information about the flying start parameters:

The parameter 131.11 defines the value of the initial current pulse to the motor. It should be as big as possible, but over current has to be avoided.

The Parameter 131.12 defines the ramping time for the flux. 100% corresponds to 150.04, the rotor time constant. Longer ramps lead to improved stability of the flying start and avoid pull out.

Parameter 131.14 can be increased when the estimated speed drops to zero and the motor is still rotating. Too high value leads to over current.

4.5.3 Scalar flystart

Default parameters, proposed settings, and descriptions for the mode are:

ACS 5000 with DTC:

21.01 START FUNCTION	= SCALAR FLY
131.21 SFLY FLUX REF	= 10%
131.22 SFLY FLUX RAMP	= 300% (or less)
131.23 SFLY FREQFWD	= 100%
131.24 SFLY TORQUE REF	= 0%
131.25 SFLY KP CONTROL	= 100%
131.26 SFLY TI CONTROL	= 20s
131.27 SFLY BACKWARD EN	= FALSE
131.28 SFLY FREQ REVERSE	= -100%
131.29 SFLY FREQ MIN	= 2%
131.30 SFLY CURR THRES	= 145%

ACS 5000 with Vector Control:

157.95 KP-SFLUX SFLY	= 100 %
157.96 TI-SFLUX SFLY	= 100 ms
157.97 CUT-OFF FLUX SFLY	= 200 Hz
157.98 KP-TORQUE SFLY	= 100 %
157.99 TI-TORQUE SFLY	= 10 ms
157.100 CUT-OFF TORQ SFLY	= 200 Hz

ACS 6000:

AMC-table	Default value	proposed value	Description
131.21 SFLY FLUX REF	25%	10%-25%	Flux init value % of rated flux
131.22 SFLY FLUX RAMP	300%	500% = 5*Tr	Ramp time for flux
131.23 SFLY FREQFWD	100%	depending on the application	start frequency for searching
131.24 SFLY TORQUE REF	0%	2% if the drive runs forward -2% if the drive runs reverse	This parameter helps in low speed area to prevent a overvoltage trip.
131.25 SFLY KP CONTROL	100%	depending on the application	Correction for gain for fly_controller
131.26 SFLY TI CONTROL	20s	depending on the application (fan ≅ 60s)	ki_fly = Ts/Ti Ts = sample time (1ms) Ti = integration time
131.27 SFLY BACKWARD EN	FALSE	depending on the application	Enable Backward Search
131.28	-100%	depending on	reverse frequency for

SFLY FREQ REVERSE		the application	searching
131.29 SFLY FREQ MIN	1%	1%-3%	Minimum frequency for searching
131.32 SFLY SEARCH SPEED	50*Tr	Depending on the application	Search speed of flystart

4.6 Motor model tuning with high speed drives

This sections is valid for high speed drives (nominal frequency typically > 75Hz).

In general the same procedure to identify correct motor parameters applies as for standard machines (50/60Hz). The basic tool used to get the parameters is the EXCEL file "AD Motor Parameter calculation.xls". Whereas with standard machines the worksheet "Plate Data" usually gives reasonable results, this is not the case with high-speed motors.

It is highly recommended to use the motor parameters from a data sheet of the manufacturer if available. Entering these data into the worksheets "Equivalent 1-phase (SI or pu)" yields the parameters that need to be set in the AMC-table.

If no data sheet is available an initial parameter set is determined using the worksheet "Plate Data".

The sequence described in section 4.3 of this document shall be used to identify the stator resistance and the leakage inductance of the motor. Together with the worksheet "Measured Lsigma" the other parameters of the motor model and controllers are determined.

Follow this sequence for tuning:
1. Start Motor with DC Magnetization and low speed
2. Increase motor speed and check behavior:
   - Stable Torque
   - Stable Flux
   - Stable Current
3. Run a Ramp from 0 – Max speed and check SF:
   - The switch over points are as defined in the AMC table parameters
   - The actual motor frequency multiplied with the actual PP gives the SF. If the SF is significantly higher it needs to be checked where the additional switchings are coming from (for example NP control).

Contact the MV Supportline if the above mentioned procedure does not lead to satisfactory results.

5 Motor model at no load

The operation of the motor model can be checked with a slow speed reversal at no load. Monitor the magnetizing current during the speed reversal.

1. Make the speed reversal from nominal speed with slow ramp times
   - Observe the used torque reference e.g. 3.02 during reversal. Set accelerating (22.02) and decelerating times (22.03) to high values so that the torque reference is close to zero (e.g. 60 s or longer)
   - When operating below nominal speed the flux of the motor is constant. With a long speed reversal time the motor torque is negligible. Magnetizing current should be approximately constant during speed reversal and the current level corresponds to the no-load current (compare with the motor data sheet)

2. Save the trend of the speed reversal test.
   - Record the trends of 1.17 FLUX ACT, 1.11 MOTOR RMS CURRENT %, 1.09 MOTOR SPEED %.
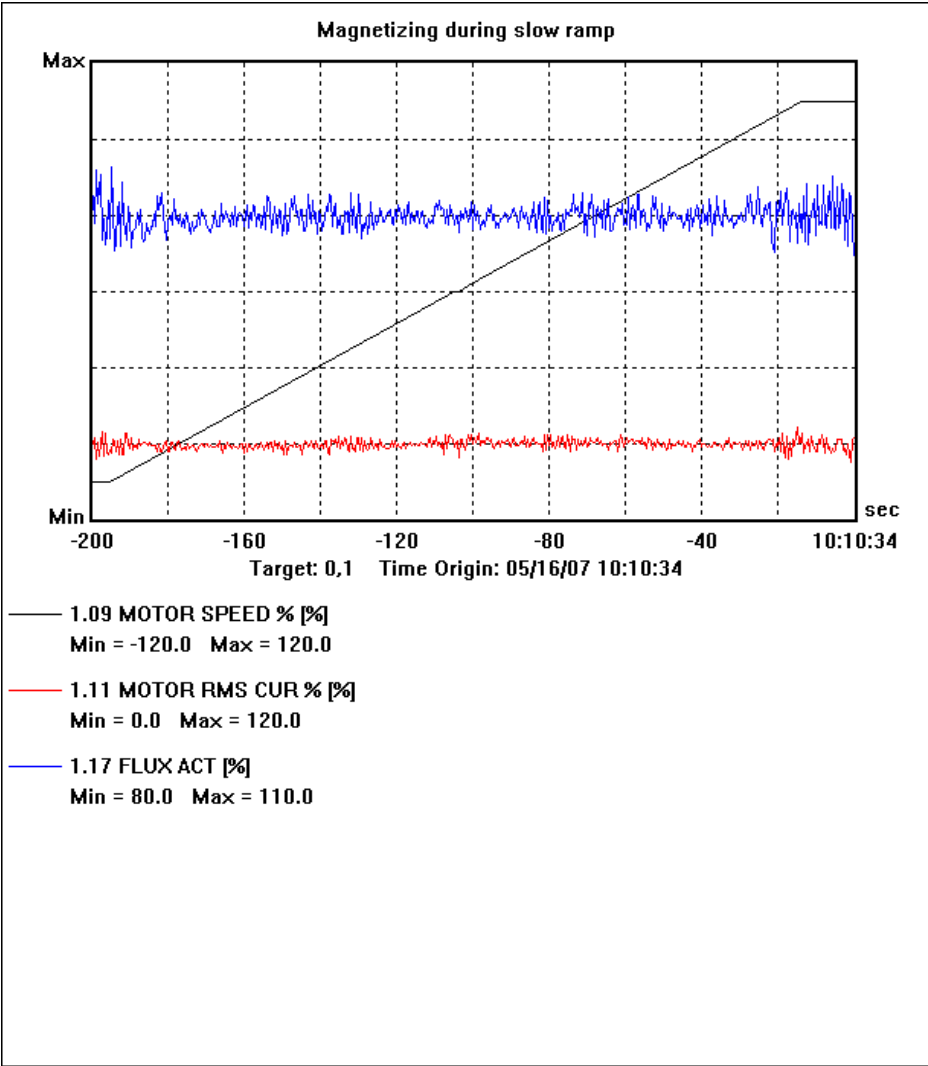

Figure 3: Motor (magnetizing) current during slow ramp

3. If the magnetizing current is higher than it should be (especially at low speeds), this could indicate that the motor parameters are not correct. In this case increasing the stator inductance (parameter 150.02) might help.

5.1 Magnetizing current at no load

The magnetizing current should be given in the motor data sheets or in the test report of the motor. The test report is normally more reliable than the data sheet.

One can also estimate the magnetizing current by calculating it with the following formula:

$$I_0 = \frac{U_1}{\sqrt{3} \cdot 2 \cdot \pi \cdot f_s \cdot L_s} \qquad I_0 = \frac{U_1}{\sqrt{3} \cdot (Xh + X1sig)}$$

With I_0 = no load current [Arms], U_1 = motor terminal voltage (line-to-line) [Vrms], f_s = stator frequency [Hz], L_s = stator inductance (150.02) [H]; the no-load current in Arms can be found in 1.10.

Voltage drop over stator resistance and copper and iron losses are neglected in this formula.

Please see Appendix 1 Asynchronous motor equivalent circuit for symbol names.

5.2 Saturation of main inductance

The saturation of the main inductance is a function of the magnetizing current and the torque. The parameters of this function can be set in group 150. Saturation coefficients are defined so that a value of 100% corresponds to the factor 1.0 (at nominal flux). The main inductance used by the control is multiplied with these saturation coefficients.

The default value of all table elements is 100%.

5.2.1 Saturation as a function of magnetizing current

The saturation of the main inductance as a function of the magnetizing current is given by 3 points of the no-load curve of the motor:

1. point A is measured at **less than nominal flux** (parameters 150.24 and 150.25)

2. point N is measured at **nominal flux** (parameters 150.26 and 150.27)

3. point B is measured at **higher than nominal flux** (parameters 150.28 and 150.29)

Parameters 150.24, 150.26 and 150.28 are the current values in [%] of the motor nominal current for three different flux levels (points A, N and B).

Parameters 150.25, 150.27 and 150.29 are the saturation coefficients corresponding to points A, N and B.

The following example shows how the static saturation coefficients are fed into the AMC table. The no-load curve is given by the motor manufacturer in the form of a table.

Example for an ACS 5000:

U[V]	1210	1602	2420	3240	4820	6300	6740	7300	7900	8360	8700
Io[A]	11.0	14.5	22.0	29.0	44.0	60.0	68.0	78.0	90.0	107	124

With known nominal voltage and current: Un = 6300 V, In = 220 A

Example for an ACS 6000:

U[V]	605	801	1210	1620	2410	3150	3370	3650	3950	4180	4350
Io[A]	11.0	14.5	22.0	29.0	44.0	60.0	68.0	78.0	90.0	107	124

With known nominal voltage and current: Un = 3150 V In = 220 A

1) Calculate the percent notation of the above table and the static saturation coefficients. The saturation coefficient for nominal voltage is 100% (= 1). Other saturation coefficients (S) are given relative to this one.

$$U[\%] = 100\% * U[V]/Un[V]$$
$$I[\%] = 100\% * I[A]/In[A]$$
$$S[\%] = 100\% * (U[\%]/I[\%]) / (Un[\%]/In[\%])$$

With Un[%] = 100 %:
$$S[\%] = (U[\%]/I[\%]) * In[\%] \text{ in this case } In[\%] \ 27.3\%$$

The table now looks like this:

ACS 5000:

U[%]	19.2	25.2	38.4	51.4	76.5	100	107	115.9	125.4	132.7	138.1
I[%]	5.0	6.6	10.0	13.2	20.0	27.3	30.9	35.5	40.9	48.6	56.4
S[%]	105	105	105	105	104	100	94	90	84	74	67

ACS 6000:

U[%]	19.2	25.2	38.4	51.4	76.5	100	107	115.9	125.4	132.7	138.1
I[%]	5.0	6.6	10.0	13.2	20.0	27.3	30.9	35.5	40.9	48.6	56.4
S[%]	105	105	105	105	104	100	94	90	84	74	67

2) Now this table has to be adapted to the parameters of group 150. The following points of the no-load curve have been chosen from the table:

Point A   150.24 = 20.0   150.25 = 104.0

Point N   150.26 = 27.3   150.27 = 100.0

Point B   150.28 = 35.5   150.29 = 90.0

3) It is recommended to have point N as close as possible to nominal voltage. The voltage at point A should be 15-25 % below nominal voltage and at point B 15-25 % above nominal voltage.

5.2.2 Saturation as a function of torque

The purpose of parameters 150.06 up to 150.22 is to express the main inductance saturation as a function of motor torque. Parameter 150.06 corresponds to T = 0% (no-load) and parameter 150.22 to T = 200%, torque steps between parameters are 12.5%.

The default value of all table elements is 100%.

5.3 Switching frequency at no load

ACS 5000

The default hysteresis bands are tuned for operation with the following configurations:

- Water-cooled ACS 5000 (any size) under any load conditions
- Air-cooled 3.5MVA ACS 5000 under any load conditions
- Air-cooled 7MVA ACS 5000 with square load characteristics

For the air-cooled 7MVA ACS 5000 with constant torque load characteristic, special hysteresis bands must be loaded. This is done by typing the following command line at the prompt in the DOS command window:

l_hys 7MVA_A_CN

ACS 5000 and ACS 6000

The switching frequency can also be checked using a similar speed reversal test at no load. During the speed reversal the switching frequencies for different time windows are monitored.

1. Make the speed reversal from the maximal positive speed to the maximal negative speed with a long reversing time.

2. Save the trend from the speed reversal.

3. Take the trend of

   ACS 5000:
   134.06 SF 1ms MAX,
   134.07 SF 50ms MAX,
   134.08 SF 250ms MAX,
   134.09 SF 1s MAX,

   ACS 6000:
   134.05 SF 1ms MAX,
   134.06 SF 50ms MAX,
   134.07 SF 250ms MAX,
   134.08 SF 1s MAX,

   1.09 MOTOR SPEED and 130.10 MODULATION INDEX.

Allowed values for different switching frequency windows are:

ACS 5000:

SF 1s MAX ≤ 250 (average)

SF 250ms MAX ≤ 75 (average)

SF 50ms MAX $\leq 20 - 25$ (maximum)

SF 1ms MAX $\leq 1 - 3$ (maximum)

ACS 6000:

SF 1s MAX ≤ 300 (average)

SF 250ms MAX ≤ 75 (average)

SF 50ms MAX $\leq 20 - 25$ (maximum)

SF 1ms MAX $\leq 1 - 3$ (maximum)

For the 11 MVA modules the tuning target is:

SF 1s MAX ≤ 230 (average)

SF 250ms MAX ≤ 67 (average)

SF 50ms MAX $\leq 20 - 25$ (maximum)

SF 1ms MAX $\leq 1 - 3$ (maximum)

For 9 and 11MVA modules the switching frequency has to be decreased for high currents. This is mentioned more detailed in the load tuning.

The switching frequency is dropping below these levels at low stator frequencies, as can be seen from the following plots. The reason is that at low stator frequencies the switchings are not equally distributed on all switches. In order not to overload the active switches the average switching frequency has to be reduced. The effect can be seen in the long time windows of 250ms and 1sec.
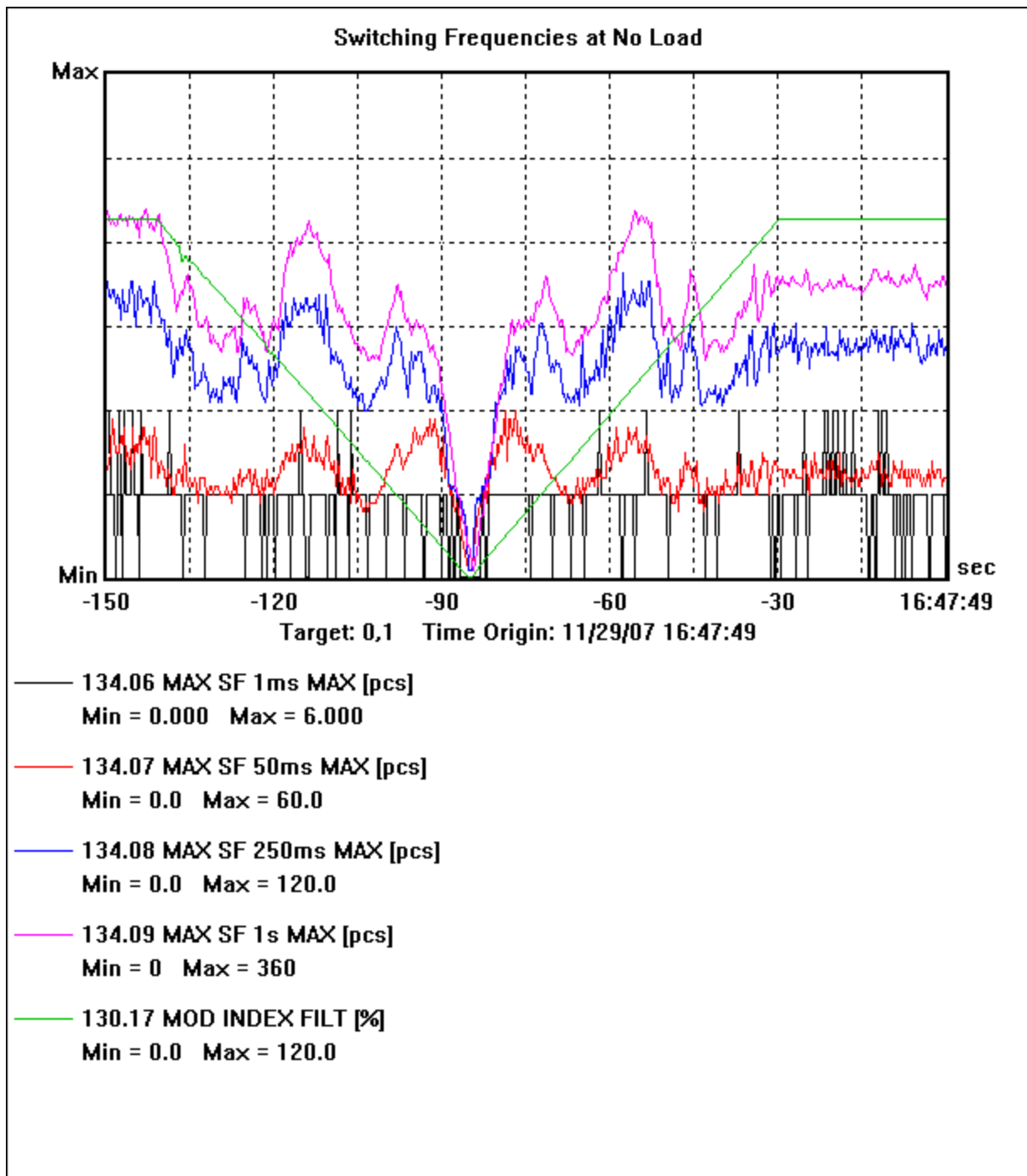
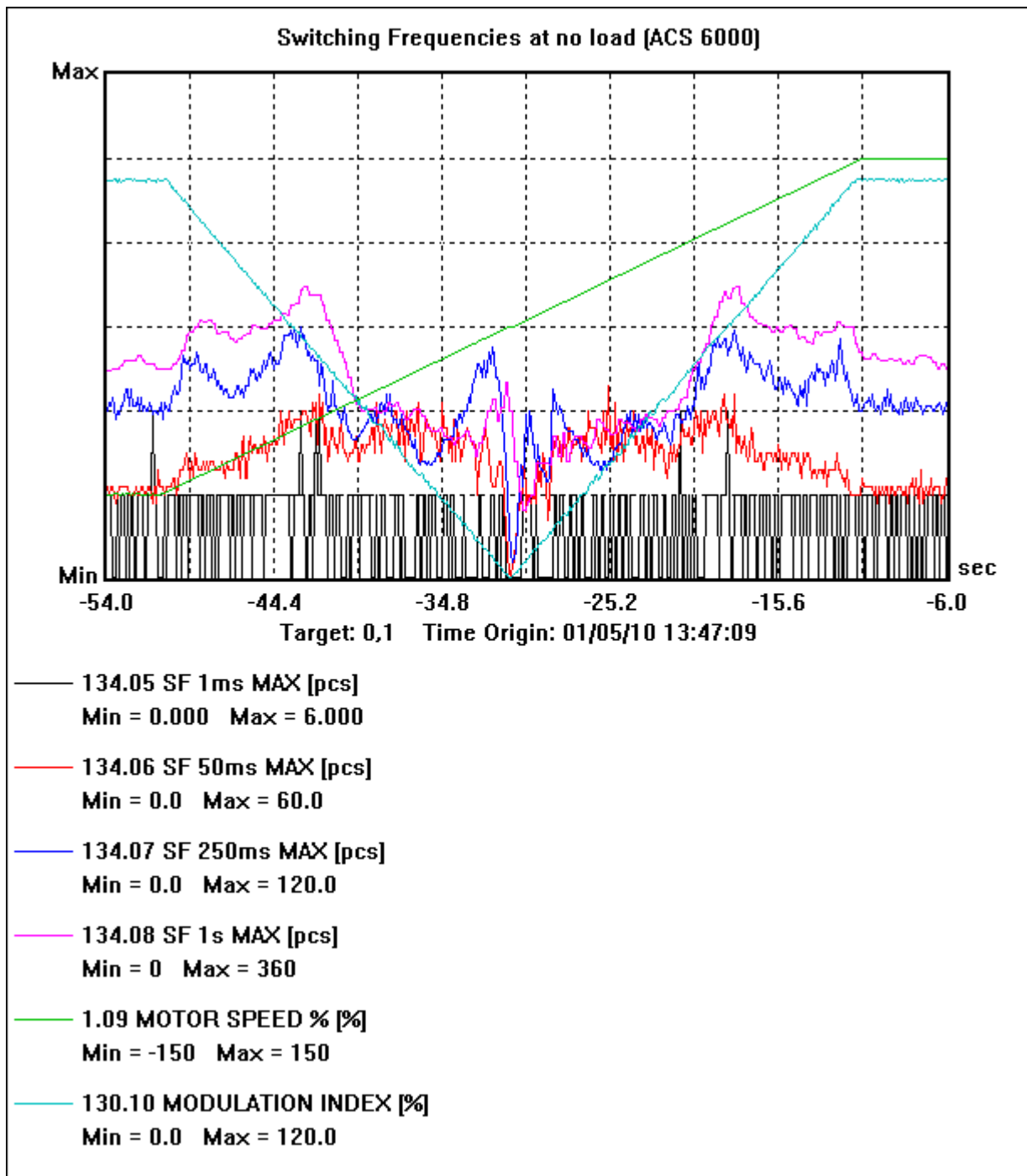*Figure 4: Switching frequency test at no load operation for **ACS 5000***

*Figure 5. Switching frequency test at no load operation for **ACS 6000***

In case the operation is unacceptable, the following hysteresis band tuning-method can be used:

Case 1: if supply frequency >20 Hz and SF 1s MAX > 250 (in average)

- Calculate error $\Delta = \dfrac{\text{SF 1s MAX(in average)} - 250}{250}$

- Set parameter 134.27 (ACS 5000) / 134.14 (ACS 6000) HYST BOOST MIN to a new value using eq.

$$\text{HYST BOOST MIN}_{\text{tuned}} = (\Delta + 1) \cdot \text{HYST BOOST MIN}$$

Case 2: if supply frequency <20 Hz and SF 50ms MAX > 25 (maximum)

- Calculate error $\Delta = \dfrac{\text{SF 50ms MAX(maximum)} - 25}{25}$

- Set parameter 134.26 (ACS 5000) / 134.13 (ACS 6000) HYST BOOST 0HZ to a new value using eq.

$$\text{HYST BOOST 0HZ}_{\text{tuned}} = (\Delta + 1) \cdot \text{HYST BOOST 0HZ}$$

ACS 5000:

The parameter 134.26 HYST BOOST 0Hz should be 100% by default.

ACS 6000:

The parameter 134.13 HYST BOOST 0Hz can be much higher, especially for low frequency machines. Values up to 300% are normal.

6 Motor model at loading conditions

Motor model parameters can be defined with several different approaches:

- electrical values of equivalent circuit given on motor data sheet
- motor rating plate data
- test reports
- measured values by the ACS 5000 / ACS 6000

The first approach is to use the motor parameter calculation tool (AD Motor Parameter calculation.xls).

If a data sheet of the motor is available use the worksheets "Equivalent 1-phase (SI or pu)" to get the correct settings in the AMC table. Use the sheet "Measured Lsigma" to evaluate the simple ID-Run that is included in the DC magnetization routine. The initial parameter set used with ID-Run can be determined with the sheet "Plate Data". If the ID-Run does not give stable results with several attempts and no data sheet of the motor is available, use the values calculated by means of the worksheet "Plate Data"

6.1 Rotor time constant

The value of the rotor time constant is dependent on the temperature value:

$$\Delta \tau_R = \frac{L_R}{R_R(\Delta T_R)}$$

The maximum rotor temperature rise can be estimated from the measured stator winding temperatures or from the temperature rise class of the motor. Rotor temperature rise can be higher than the stator temperature rise. The original value can also be inaccurate. Saturation can also change the inductance value and result in a different rotor time constant value.

The resistance of copper changes 0.4% / 1K. For example a 100 K temperature rise results in a 29 % lower value for the rotor time constant at loading conditions. Reduce the value of the parameter 150.04 ROTOR TIMECONST according to the temperature rise on maximum loading condition.

Please pay special attention to this parameter when the drive is equipped with a tachometer.

6.2 Stator resistance

An inaccurate stator resistance value may result in an unstable control, because flux estimation is based on integration. The stator resistance has a big impact on this integration especially at low frequency. This is a common problem for different kinds of control methods (for example PWM, DTC).

In practice the stator resistance value (150.01 RS) should be set to a lower value (50%. 75%) than given by the motor parameter calculation tool (AD Motor Parameter calculation.xls). It is preferable to set this parameter too small than too big.

Please pay special attention to this parameter when the drive is not equipped with a tacho.

If the drive is started with DC Start mode: Parameter 131.01 START FUNCTION = CNST DC MAGN the stator resistance (including cable resistance) is measured during the DC Start and displayed in Parameter 154.19 IDStart: RS. The used RS value (150.01 RS) should always be smaller than this value.

6.3 Stator main inductance

NO-LOAD TUNING
The stator main inductance value (150.02 LS) can be tuned with help of the no load current values. Please see chapter "Motor model at no load".

6.4 Stator stray inductance

PULL-OUT LIMITER
Motor main and stray inductances influence the calculated pull-out torque limit. Please refer to chapter "Pull-out torque limit" in dynamic limiters. At the nominal operation point the calculated limit should correspond to 90% of the motor pull-out torque.

1. If the value of the main inductance (150.02 LS) has been tuned according to the no load measurements, it can be expected to be reliable, especially if the value corresponds to a value calculated with the "Equivalent 1-phase" sheet of the motor parameter calculation tool (AD Motor Parameter calculation.xls).

2. If the drive is started in DC Start mode: Parameter 131.01 START FUNCTION = CNST DC MAGN the stator stray inductance (including cable inductance) is measured during the DC Start and displayed in Parameter 154.20 IDStart: sigmaLS. Use the worksheet "Measured Lsigma" in the parameter calculation tool to get the remaining parameters. These data can be used to confirm data given in the data sheet or estimated with the Excel sheet.

3. Then the estimated value of the pull-out torque limiter should be dependent only on Stator stray inductance (150.03 SIGMALS). Try to tune this value so that the pull-out torque limiter gives a reasonable value. This method is rather inaccurate.

6.5 Motor nominal cosfii

The cosfii actual value of an asynchronous motor varies for different operation points. If a high load (overload) is needed in the field weakening area a smaller value may have to be given to the motor nominal cosfii (110.06 MOTOR NOM COSFII).

7 Switching frequency tuning at loading conditions

The checking and tuning presented in this chapter has to be done with normal loading conditions (=normal operation of the process). Actions presented in this chapter are only needed if drive operation is not satisfying.

7.1 Switching frequency at loading conditions

This chapter does not apply for high speed drives.

During first normal loading conditions perform the following checks:

1. Take the trend of all switching frequencies:

   ACS 5000:
   134.06 SF MAX 1ms, 134.07 SF MAX 50ms, 134.08 SF MAX 250ms, 134.09 SF MAX 1s, 160.07 MOTOR RMS CUR and 160.34 MOTOR SPEED.

   ACS 6000:
   134.05 SF 1ms MAX, 134.06 SF 50ms MAX, 134.07 SF 250ms MAX, 134.08 SF 1s MAX, 160.07 MOTOR RMS CUR and 160.34 MOTOR SPEED

2. Check that the switching frequencies are below the allowed average values for different switching frequency windows and the presented characteristics are not exceeded:

   ACS 5000:
SF 1s MAX	**$\leq$ 250**
SF 250ms MAX	$\leq$ 75
SF 50ms MAX	$\leq$ 20 - 25
SF 1ms MAX	$\leq$ 1 – 3

The following maximum switching frequencies may not be exceeded for the following drive configurations:

- **ACS 5000 water-cooled for all load characteristics**
- **ACS 5000 3.5MVA air-cooled for all load characteristics**
- **ACS 5000 7MVA air-cooled for square load characteristic**

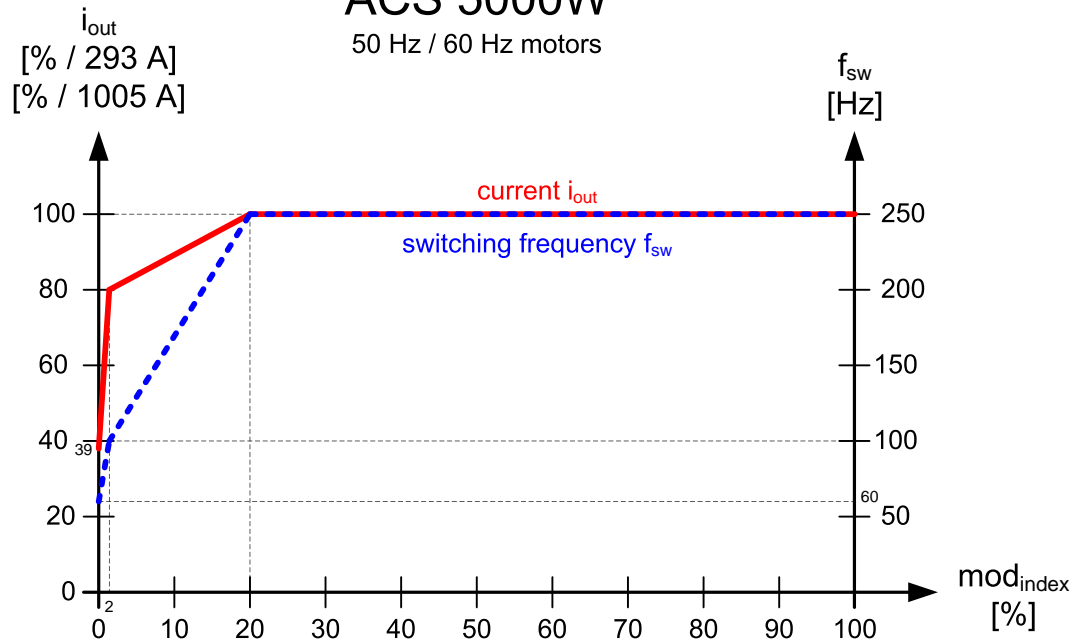## ACS 5000A 3.5 MVA
ACS 5000W
50 Hz / 60 Hz motors

Figure 5: Current and Switching frequency limitations for all ACS 5000 with square load torque and for ACS 5000W and ACS 5000A 3.5MVA with constant load torque

For the **7MVA air-cooled ACS 5000 with constant torque load characteristic** the following levels may not be exceeded:

ACS 5000A – 7 MVA
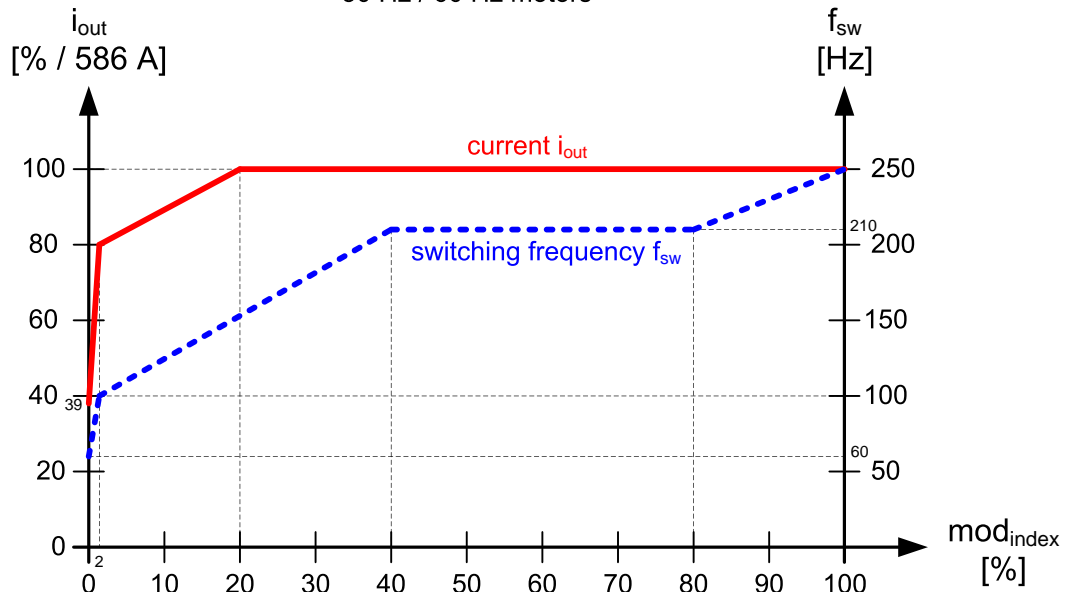### 50 Hz / 60 Hz motors

Figure 6: Current and Switching frequency limitations for air-cooled 7MVA ACS 5000

In **ACS 5000SD** two parameters are available to tune the switching frequency:
    134.75 FLUX HYST FACTOR (only acts on flux hysteresis band)
    134.76 TORQ HYST FACTOR (only acts on torque hysteresis bands)
This tuning should be done **under load**. Results when tuning under no-load condition may be misleading.
The switching frequency reacts rather sensitive to flux hysteresis band. Nevertheless it must be considered that the **flux** hysteresis band is important for the quality (THD) of the stator currents. If it is too big the current quality deteriorates. Therefore it is recommended to use 134.75 very carefully.
If possible tune the switching frequency by adapting the parameter 134.76 which only acts on the torque hysteresis (equally on all bands).
Keep in mind that these parameters are constant and therefore have an influence in all operating points. If these two parameters need to be changed, check the whole operating range of the drive to avoid areas where the switching frequency exceeds the aforementioned limits.

   ACS 6000 3, 5 and 7MVA units:
    SF 1s MAX   **≤ 300**
    SF 250ms MAX   ≤ 75
    SF 50ms MAX   ≤ 20 - 25
    SF 1ms MAX   ≤ 1 – 3

For the high power modules in ACS 6000 the switching frequency target is current dependant:

ACS 6000 9MVA units:

SF 1s MAX $\leq$ **250 @ 1640A**

                   $\leq$ 300 @ $\leq$ 1280A

ACS 6000 11MVA units: (for max 41°C Water temp):

SF 1s MAX $\leq$ **102 @ 2156A**

                   $\leq$ 138 @ 2010A

                   $\leq$ 230 @ $\leq$ 1640A

SF 250ms MAX = (SF1s MAX /4) +10

For 11MVA modules the 1sec and the 250ms SF trip levels are current dependent and will be reduced starting from 1650A rms.

The proposed values for the switching frequency are valid for "normal" conditions. In case of extreme operation conditions (like hot cooling water), use the calculated values of the system design group.

If the switching frequencies during load conditions of the drive stay below these limits no further tuning is needed. In case the switching frequency considerably exceeds the value for the 1s time window, the functions described below have to be used.

7.2 Tune switching frequency based on frequency and power

This chapter does not apply for high speed drives.

1. Determine for which motor frequencies and powers the switching frequency exceeds the allowed limits. This defines the frequency-power plain (Switching frequency = f(freq,P)) where tuning is needed.

2. Set the frequency range of the boost according to the determined values.

ACS 5000:

134.32 PWR CORR FREQ MIN	minimum frequency (relative to motor nominal frequency) where boost is activated.
134.33 PWR CORR FREQ MAX	maximum frequency (relative to motor nominal freq.) where boost is deactivated.
134.34 FREQ DELTA	defines the slope of a weighting factor (see fig.4; is ramped from 0 - 100 %.

ACS 6000:

134.19 PWR CORR FREQ MIN
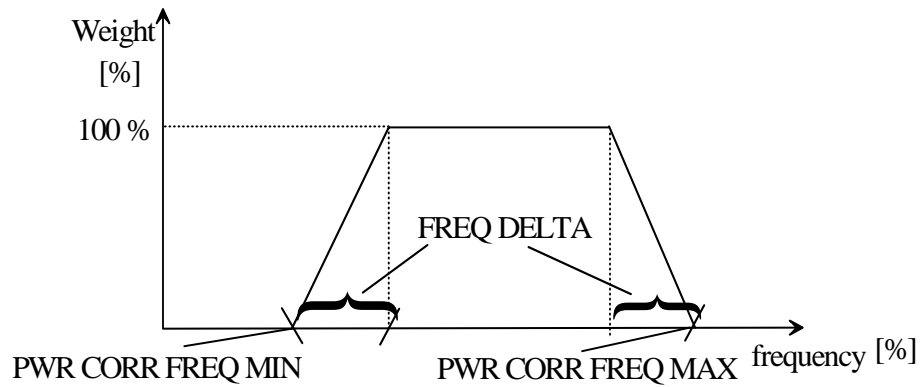134.20 PWR CORR FREQ MAX
134.21 FREQ DELTA

Figure 7: Boost weighting as a function of the frequency.

3. Set the power range of the boost according the determined values.

ACS 5000:

134.29 START CORR POWER	power limit where boost is activated.
134.30 POWER DELTA	defines the slope when boost is ramped from 0 – POWER CORR MAX %.

ACS 6000:

134.16 START CORR POWER
134.17 POWER DELTA

Calculate error $\Delta = \dfrac{SF1s\,MAX - SF1s\,target}{SF1s\,target}$

Set 134.31 POWER CORR MAX (**ACS 5000**) / 134.18 POWER CORR MAX (**ACS 6000**) (maximal widening of the hysteresis bands) to new value using eq.

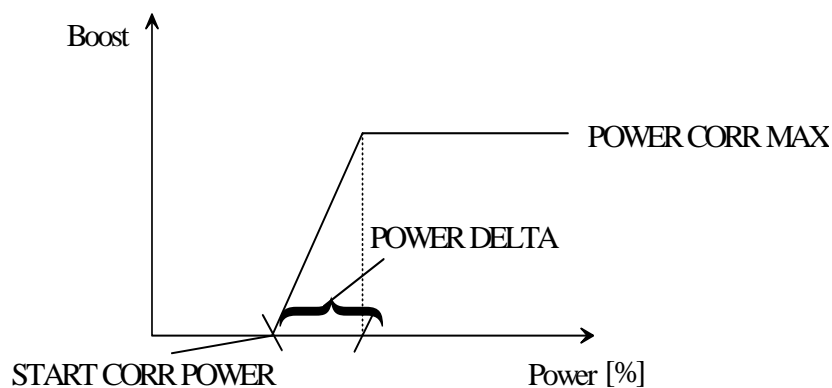$$POWER\ CORR\ MAX_{tuned} = (\Delta + 1) \cdot POWER\ CORR\ MAX$$

Figure 8: Hysteresis widening as a function of the power.

7.3 Tune switching frequency based on current

This chapter does not apply for high speed drives.

This function can be used to lower the switching frequency for high inverter currents. The function is mainly used to achieve the current dependant switching frequency levels defined at the beginning of the chapter for the 9 and 11 MVA modules of ACS 6000.

The related parameters and default values are:

ACS5000:

134.35 INV.CURR. CORR.	100 %	
134.36 CURR. CORR. VALUE	0 %	

ACS6000:

134.22 INV.CURR. CORR.	100 %	
134.23 CURR. CORR. VALUE	50 %	

The function increases the hysteresis and thus decreases the switching frequency if the current is above the value given in INV. CURR CORR.

ATTENTION:

The parameter INV CURR CORR is related to inverter current (not motor current). For this function the maximum inverter current is equal to 150%.

This means that with the default setting for INV.CURR. CORR = 100% the function starts to decrease the switching frequency at 66% of maximal inverter current.

The parameter CURR.CORR.VAUE defines how much the hysteresis is increased at maximum inverter current. If the switching frequency does not go down enough at higher currents the parameter CURR.CORR.VALUE can be increased.
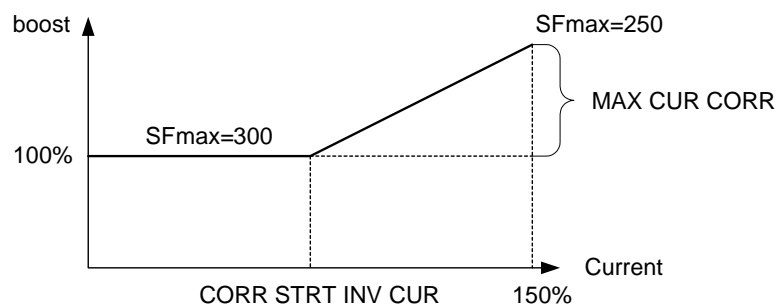

Figure 9: Hysteresis widening as a function of Inverter current.

7.4 Neutral point control

The neutral point (NP-) control is done differently for ACS5000 and ACS6000. ACS5000 can be forced to switch for NP, in ACS6000 NP is only controlled if there already is a switch due to torque or flux. That is why there are 3 levels for NP- control in ACS5000 and only 2 levels for ACS 6000.

In any case it is recommended to run the drive with a certain margin in the output voltage. This simplifies NP control. Set the parameter 130.04 VOLTAGE RESERVE to 5%.

Only for ACS 5000:

The NP control uses hysteresis controllers to regulate the NP voltages of the three phases (160.15 NP VOLTAGE 1, 160.23 NP VOLTAGE 2, 160.31 NP VOLTAGE 3). The control of the NP voltage is done independently for each DC link. The performance of the control can be tuned via parameters:

134.23 NP 1ST HYST (deactivation level)

134.24 NP 2ND HYST (activation level)

134.25 NP 3RD HYST (forcing level)

The values are given in absolute Volts. For the air cooled ACS 5000 the levels are bigger than for the water cooled types. Below the NP 1ST HYST the NP control is not active. If NP rises above the value of NP 2ND HYST the control becomes active. If NP is bigger than the value of NP 3RD HYST a switching is forced to control NP. The inner two NP hysteresis bands are chosen to be very small which activates NP control almost continuously. This helps to distribute switching losses evenly on all semiconductors (loss balancing). The switching frequency is not influenced.

Monitor the NP-voltage actual values (160.15, 160.23 and 160.31 NP VOLTAGE1, 2 and 3) with 1ms sample time. For speeds < 50% the third level of NP deviation should be reached only seldom. For speeds > 50% the third level is hit regularly.

It should not be necessary to tune the NP hysteresis bandwidths. The trip level for the NP-voltage is 660V (186.06 NP VOLTAGE TRIP). Changing this value is prohibited.

Only for ACS 6000:

The NP control uses a hysteresis controller to regulate the NP voltages voltage (160.15 NP VOLTAGE). The performance of the control can be tuned via parameters:

134.11 NP 2ND HYST (deactivation level)

134.12 NP 3RD HYST (activation level)

Below the NP 2ND HYST the NP control is not active. If NP rises above the value of NP 3RD HYST the control becomes active. The trip level for NP-voltage is 800V (186.06 NP VOLTAGE TRIP). The value is chosen to match with the over voltage trip value. Changing the value is prohibited.

Monitor the NP-voltage actual value (160.15 NP VOLTAGE) with 1ms sample time. If the value exceeds 500V then the control may trip to NP-voltage later on. Change the NP-control hysteresis to keep the NP-voltage under 500V. Too narrow NP-hysteresis (deactivation and activation level are too close to each other) may result to switching frequency trips; especially 50 or 250 ms SF faults. Then tune the other hysteresis boost parameters.

In low motor frequency, high power metal applications, where the NP voltage can increase very fast, the unfiltered NP voltage can be used by setting parameter 134.40 NP VOLT FILTER to disabled. The drawback would be a increase of the switching frequency of around 30Hz in average.

In ACS6000 NP mainly occur if the SF or in SD in case the current is too low. In case of NP trips check the SF and try to increase it to the values given at the beginning of the chapter. In case of an SD motor at no load the stator current can be very low, this can also result in problems for the NP control. Use the "Minimum Current" function described below to increase the stator current.

An inaccurate power feed forward term to ARU can result on unstable dc-link (pumping or NP-voltage spikes). During tuning the power feed forward term can be disabled with a parameter 112.07 PFF ENABLE.

Trips can also occur in case only the ARU is running (= no INU running). The problem can be solved by activating 134.36 NP LIMITER in case there is a VLU/RBU/BCU. The VLU will be switched on, if the NP voltage exceeds 400V and will be switched off as soon as the NP VOLTAGE drops below 300V. This parameter has no influence when the VLU is not enabled (e.g. slave drives).

Another way to get rid of the problem is by only starting the ARU in case an INU starts. (Check the ARU Signal & Parameter table on how to do this).

7.5 Dynamic switching frequency control

This chapter does not apply for high speed drives.

This function dynamically widens the hysteresis bands when the switching frequency exceeds a threshold. The idea is that the general tuning is done **without** this function. At the end of the commissioning, after the basic tuning is done, the dynamic switching frequency control should be enabled to prevent switching frequency trips.

Enable this function only after tuning of the hysteresis bands!

Parameters related to this functionality are located in group 134 of AMC table.

DYNAMIC BOOST	widening factor of the hysteresis in % when the boost is active.
DYN BOOST RAMPING	slope, which returns the hysteresis back to normal, after the boost is released (in %/ms).
BOOST ACTIVE CNT	counts how many times the function has become active
DYN BOOST 50 ACT	switching frequency level at which the boost is activated in the 50ms window (in % of actual switching frequency trip level).
DYN BOOST 50 REL	switching frequency level at which the boost is released in the 50ms window (in % of actual switching frequency trip level).
DYN BOOST 250 ACT	switching frequency level at which the boost is activated in the 250ms window (in % of actual switching frequency trip level).
DYN BOOST 250 REL	switching frequency level at which the boost is released in the 250ms window (in % of actual switching frequency trip level).

For ACS 6000SD there are also following parameters:

DYN BOOST 1s ACT switching frequency level (in % of actual switching frequency trip level) in 1s window where boost is activated.

DYN BOOST 1s REL switching frequency level (in % of actual switching frequency trip level) in 1s window where boost is passivated.

Tuning of the **250ms dynamic switching frequency control** function:

If the switching frequency in the 250ms window exceeds the value defined by parameter DYN BOOST 250 ACT all hysteresis bands are widened. The increase is given by the parameter DYNAMIC BOOST. This parameter is scaled so that 100% corresponds to the factor of 1. To activate the function values of more than 100% have to be chosen (e.g. 150% gives a scaling factor of 1.5). When the switching frequency in the 250ms window is below the value defined by parameter DYN BOOST 250 REL all hysteresis bands are ramped back down to the original values. Ramping time is defined by parameter DYN BOOST RAMPING.

The following figure shows how the function works.
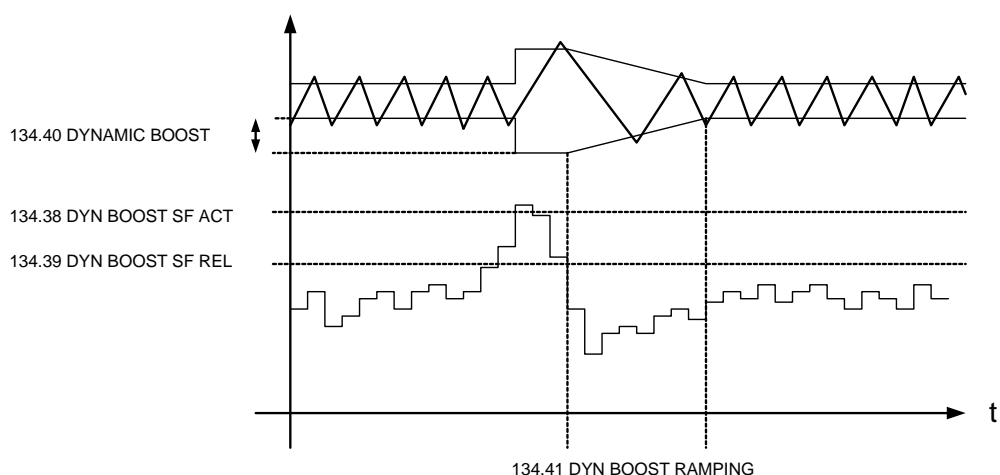
Figure 10: Dynamic Boost functionality

The DYN BOOST 250 ACT value has to be set below the trip level for the 250ms window, otherwise the drive trips before the function becomes active. The parameter should be set ca 20% below the trip value to ensure the function becomes active before the drive trips.

The parameter DYN BOOST 250 REL is the release level. If the switching frequency is below this value the hysteresis limits are started to be ramped down to their nominal value. This value has to be lower than the activation level, but slightly higher than the tuning target. Otherwise the function will stay active all the time, and performance is deteriorated.

The amount the hysteresis is widened is given by the parameter DYNAMIC BOOST. Normally values of 130 – 140% are sufficient to prevent any SF trips.

Tuning of the 50ms and 1 s dynamic switching frequency control function are analog to the 250ms function.

The parameter BOOST ACTIVE CNT counts how many times the dynamic boost was active. Check this parameter to see if and under which loading conditions the function becomes active.

Recommended values at the end of commissioning:

DYNAMIC BOOST   = 140%

DYN BOOST RAMPING =   1

7.6 1ms Switching frequency

In case there are problems with the 1ms switching frequency first check the cable specification to ensure the installed cables and the cable length fulfils the requirements. Inform MV AC Supportline if there is any uncertainty.

If the cables are ok the following functions can be used to prevent 1ms SF trips:

- Filter the current. In the PEC-INT (ACS 5000) or the INT (ACS 6000) a current filter can be activated. It uses the full sampling rate of the current measurement (200kHz) and therefore allows to implement filtering functions without adding significant delay to the current measurement.

ACS 5000:

The user can choose between a second order low-pass filter and a second order band-stop filter. The cut-off frequency respectively the center frequency of the filters can be selected in a certain range. For the band-stop filter also the relative bandwidth can be chosen.

Parameters (with default values):

134.45 PH CUR FILTER SEL   NO FILTER

134.46 FILTER CHAR FREQ   50 kHz

134.47 REL BANDSTO WIDTH   20 %

ACS 6000:

The filter can be activated by parameter 134.24 LONG CABLE MODE. Start by setting the parameter to filter 1. (CABLE <125m). If dampening is not enough, switch to the second filter setting (CABLE <150m). (Valid from EPLD Version 2100)

- Use the estimated current instead of the measured current. In the control software an observer model estimates the stator current. The estimated value is corrected with the measured value, such that the estimated current value follows the true current very nicely but avoiding the high frequency disturbance components.

For ACS 5000 this function often has to be enabled.

The parameters for this function are located in group 153. Defaults:

I EST ENABLE   = DISABLE

DAMP COEFF   = 100 %

I MEAS RATE   = 5 %

Monitor the influence by temporarily changing the Datalogger 1 settings. Set the CH2 monitoring signal to Parameter 154.23 Phase U CUR EST [A].

Take several Datalogger measurements at different loading conditions and compare the estimated current to the measured current. If they do not match stop using the function or contact MV AC Supportline for support. At the end restore the default settings of the Datalogger 1 (CH2 = Par. 1.03 Phase V Current).

Only for ACS 6000:

- If this is not enough to prevent 1ms switching frequency trips, then activate the 1ms switching frequency limiter. Change Parameter 134.33 SF 1ms LIMIT from 10 to 4 (starting level of the 1ms limiter).

  Adjust then the blocking time 134.34 only if really necessary. Default value is 8. If the value is too big, then the control can get unstable and this results in high torque ripple and high current peaks.

  Parameter 134.35 counts up how many time this function was active.

  Recommend values:

  134.33 SF 1ms LIMIT   4 pcs

  134.34 SF BLOCK TIME 25u   8 pcs

  Please use this function with care, because it is interfering with the modulation.

8 Auto Restart

The Auto Restart functionality prevents long interruptions of the process in fault cases. If this functionality is enabled, drive will restart automatically after the faults source which requires an auto restart has disappeared.

Commissioning of the Auto Restart functionality requires profound knowledge of the system and the environment where it is working in. It should only be commissioned after consultation with the costumer.

An Auto Restart will stop modulation, but MCB will not open and DC link will not discharge. The overriding control will stay in Rdy_Ref state.

8.1 Enabling/ Disabling

There are different root causes for Auto Restart (Auto Restart Classes). For each class it is possible to enable or disable Auto Restart.

Default settings: Auto Restart for all Classes is disabled

Enabling/ disabling of different Auto Restart Classes is made via **parameter 111.20 (AUTORESTART CW)**. Please refer to the Signal Parameter Table to select the correct bits.

8.2 Timer Settings

Several **timer settings** need to be done in **parameter group 111**. The properties of all timers are discussed in the Signal Parameter Table.

111.22 (AR TIMER MAX)	This specific parameter is depending on the system (Default value: 3 s).
111.23 (AR DELAY)	Set this parameter to an adequate value to delay the restart actions (Default value: 0.5 s).
111.24 (AR WAIT MAX)	app. 20 ms
111.26 (TIME SUCC AR)	app. 30 s

8.3 Observing Auto Restart

Find in **parameter 111.21 (AUTORESTART SW)** all necessary information about the status of the functionality.

The maximum number of allowed successive Auto Restart is set in **parameter 111.25** (Default value: 5).

The number of Auto Restarts is stored in the Powerfail File and is accessible via **parameter 191.21**.

9 Static torque limiters

9.1 Pull-out torque limiter

This limiter is only used with AD motors

When the load exceeds so called pull-out (breakdown) torque the motor stalls. To avoid this, the pull-out torque is calculated out of the formula below. The calculated value with a reduction (margin) factor equal to 0.9 is used to limit the output torque. This limit is shown in [%] of nominal torque in AMC table, signal 133.15.

$$t_{\lim it}[\%] = k_{gain} \cdot t_{spull-out} \cdot 100, \text{ value shown in signal 133.15.}$$

k_{gain} is set in parameter 133.16 (default 90%)

If parameter 133.16 does not exist, the used gain is 90%

$$t_{spull-out,pu} = \frac{1 - \sigma \cdot}{2 \cdot \sigma L_{S,pu}} \cdot \frac{\Psi_S^2, pu}{\cos\varphi_n} \text{ where}$$

$$\sigma = \frac{\mathbf{150.03}[mH]}{\mathbf{150.02}[mH]}$$

$$\sigma L_{S,pu} = \frac{\mathbf{150.03}[mH]}{1000} \cdot \frac{2 \cdot \pi \cdot \mathbf{110.03}[Hz] \cdot \sqrt{3} \cdot \mathbf{110.02}[A]}{\mathbf{110.01}[V]}$$

$$\Psi_{S,pu}^2 = \frac{\mathbf{130.09}[\%]^2}{10000}$$

$$\cos\varphi_n = \mathbf{110.06}$$

Please see also chapter "Stator stray inductance" on "On-line tuning at loading conditions".

9.2 Overloadability (or derating)

The thermal overloadability function is based on measured temperatures of cabinets (thermostats), cooling water and ambient air. In case of elevated temperatures the inverter current is derated to certain level with certain rates according to parameter settings.

The following parameters are related to the function.

112.02 INU MAX CURRENT	maximum current of inverter unit
133.01 INU MAX CONT CUR	maximum continuous current of inverter unit
133.02 WATER DERATE 1	inverter current derating factor % per degree. First slope.
133.03 AMBIENT DERATE	inverter current derating factor % per degree
133.02 WATER DERATE 2	inverter current derating factor % per degree. Second slope.

The following signals are related to the function.

160.42 TEMP DIFF INU	de-ionized water temperature over derate level
160.43 TEMP DIFF AMBIENT	ambient temperature difference over alarm level
160.69 TEMP ALARM INU	de-ionized water temperature alarm level
170.09 TC AUX CW	Bit0 = 1: cabinet temperature over alarm level

Inverter current can be derated due to three sources:

- high cabinet temperature

- high cooling water temperature

- high ambient air temperature

If none of these sources is active (160.42 = 0 and 160.43 = 0 and 170.09 bit0 = 0) the allowed inverter current is determined by parameter 112.02.

If the cabinet temperature is above the alarm level, the allowed inverter current is set to the level of parameter 133.01.

If the ambient temperature is above the alarm level the inverter current is derated. Starting from the level set by parameter 112.02, the current is decreased with the rate specified by parameter 133.03.

If the de-ionized water temperature is above the derating level (160.42 > 0) the inverter current is derated with slope_1 defined by parameter 133.02, starting from the maximum current defined in parameter 112.02.

Only for ACS 6000:

If the temperature is above the alarm level (160.42 > 160.69) the derating is carried on with slope_2 defined in parameter 133.25. This behavior is illustrated on the following picture.
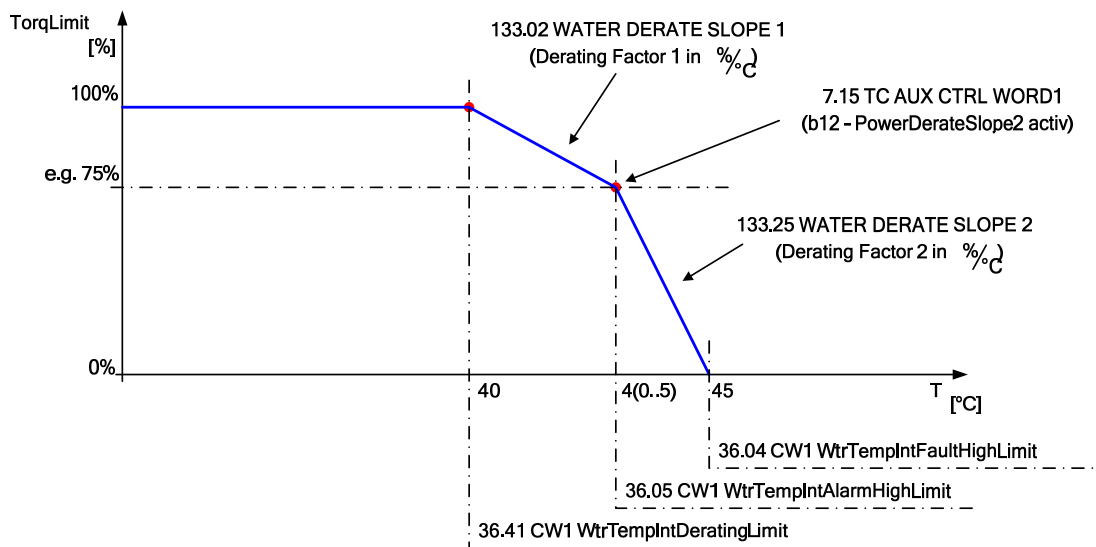
N.B.

- 100% torque means: Hypothetical torque on used machine when running with maximum INU current (parameter 112.02).

- Limiting the current is done by limiting the torque.

10 Dynamic torque limiters

There are several dynamic torque limiters. They are able to change (limit) the torque reference in order to prevent trips such as overvoltage, undervoltage or too high angular frequency. The dynamic limiters are located after the static limiters. Except the braking limiter the dynamic torque limiters are P-controllers with a threshold level and a gain as parameters.

Each limiter has a parameter indicating what the maximal torque is that the limiter allows and a parameter indicating if the limiter is active. In case any limiter is active the torque reference coming form the speed controller is changed. In these cases the motor speed will not follow the speed reference any more.

10.1 Overvoltage limiter

The purpose of this limiter is to prevent the DC link voltage to exceed the threshold value defined by parameter 132.02. In case the drive is breaking this limiter is needed to reduce the breaking torque and prevent an overvoltage trip. However if the overvoltage is coming from the network the limiter will also increase the torque and thereby the motor speed. This might not be tolerable for some applications. In these cases the limiter has to be disabled.

The limiter also has a problem if it becomes active at zero speed. In this case it is not clear if the torque should be positive or negative, it might even happen that the reference toggles between these two states.

The torque reference is calculated from the formula:

$$T_{ref}\left[\%\right] \approx P_{gain}\left[\%\right] \cdot \frac{U_{DCact}\left[V\right] - U_{DC\lim}\left[V\right]}{U_{DCnom}\left[V\right]}$$

In ACS 5000 the maximum of all six half DC link voltages (multiplied by two) is used as actual DC voltage.

In this formula:

$U_{DC,act}$ actual value of DC voltage in volts, (ACS 6000: 160.09; in ACS 5000 the maximum of 160.11, 160.13, 160.19, 160.21, 160.27 and 160.29 multiplied by two is used)

$U_{DC,lim}$ threshold level of DC voltage in volts defined by parameter 132.02

$U_{DC,nom}$ nominal DC voltage defined by parameter 112.04

P_{gain} controller gain in % defined by parameter 132.03

Example 1: If the actual voltage is 10% (% refer to the DC nominal value defined by parameter 112.04) below the threshold level and P_{gain} is 1000%, the torque is limited to minimally -100%, i.e. the drive is still allowed to brake with nominal torque.

Example 2: If the actual voltage reaches the threshold level in parameter 132.02, the allowed torque is limited to minimally 0%, i.e. the drive is not allowed to brake any more.

The limiter can be enabled / disabled by parameter 132.01. For ACS 5000 and ACS 6000AD it is enabled by default.

The other default values for the control are:

ACS 5000:

132.02 OVERVOLT LIMIT	= 6300 V
132.03 OVERVOLT LIM GAIN	= 1000 %

ACS 6000:

132.02 OVERVOLT LIMIT	= 5400 V
132.03 OVERVOLT LIM GAIN	= 1000 %

The output torque of the limiter can be seen in the parameter "overvoltage torque reference." In AD drives this is parameter 132.10, in SD drives parameter 132.12

The status of the limiter is displayed in parameter "overvolt limiting". In AD drives this is parameter 132.14 in SD drives 132.17.

10.2 Undervoltage limiter (Ride through)

In the SD machines the ride through function does not work for long times since the EXU trips with undervoltage. There is a special EXU ride-through function which restarts EXU after power loss without tripping the main drive.

The purpose of the undervoltage limiter is to keep the DC-voltage from dropping below the threshold level defined by parameter 132.36 (**ACS 5000AD**), 132.26 (**ACS 5000 SD**) or 132.05 (**ACS 6000**). The torque reference is calculated from the formula:

$$T_{ref}\left[\%\right] \approx P_{gain}\left[\%\right] \cdot \frac{U_{DCact}\left[V\right] - U_{DC\lim}\left[V\right]}{U_{DCnom}\left[V\right]}$$

In this formula:

$U_{DC,act}$ actual value of DC voltage in volts (ACS 6000: 160.09; in ACS 5000 the average of the three actual full DC voltages 160.09, 160.17 and 160.25 is used.)

$U_{DC,lim}$ threshold level of DC voltage in volts (ACS 6000: 132.05; ACS 5000AD: 132.36; ACS 5000SD: 132.26)

$U_{DC,nom}$ nominal DC voltage defined by parameter 112.04

P_{gain} controller gain in % (ACS 6000: 132.06; and ACS 5000SD: 132.28; ACS 5000AD: 132.37 and 38 respectively); in ACS 5000AD the RT controller gain depends on the sign of the voltage error:

if $(U_{DC\_act} >= U_{DC\_lim})$, P_{gain} = 132.37

else P_{gain} = 132.38

Example: If the actual voltage is 5% (% refer to the DC nominal value defined by parameter 112.04) below the threshold level and P_{gain} is 100% the torque is limited to values smaller than minus 5% of nominal torque.

The output torque of the limiter can be seen in the parameters 132.11 (ACS 6000AD), 132.13 (ACS 6000SD) or 132.30 (ACS 5000).

The status of the limiter is shown in parameters 132.15 (ACS 6000AD), 132.16 (ACS 6000SD) or 132.23 (ACS 5000).

Only for ACS 5000SD:

The voltage used as input to the limiter is shown in 132.24 and the resulting torque limit is shown in 132.30. Experience has shown that with a gain 132.28 significantly bigger than the default value of 100% the three DC links in the ACS 5000 converter may start to oscillate against each other keeping the average still nicely under control. It was therefore necessary to implement a trigger level (defined in 132.25) for the beginning of ride-through operation which is lower than the reference value in 132.26. As long as the drive is in ride-through mode, the torque reference coming from the speed controller is overwritten by the torque reference that is calculated according to above equation.

As soon as the DC link voltage passes an upper level (defined in 132.27) the drive returns to normal operating mode.

ACS 5000AD and SD:

The duration of ride-through operation is limited to the time given in 132.33. After this time is exceeded the drive trips. Setting this parameter to 0 disables the supervision of ride-through time. In addition the speed is supervised. Below the threshold given by parameter 132.32 the drive trips because it is assumed that below that speed there is not enough energy taken from the rotating machinery to support the DC link voltage.

The ride-through functionality is enabled by default. The default values for the control are:

ACS 6000:

132.05 UNDERVOLT LIMIT	= 3580
132.06 UNDERVOL LIM GAIN	= 1000 %

ACS 5000AD

132.21 UNDERVOLT ENA	= TRUE
132.36 UNDERVOLT UDC REF	= 3700 V
132.37 UNDERVOLT P-GAIN1	= 1000 %
132.38 UNDERVOLT P-GAIN2	= 100 %
132.32 UNDERVOLT N MIN	= 10 %
132.33 UNDERVOLT MAX LEN	= 0 ms (0 means infinite time)

ACS 5000SD

132.21 RIDETHRU ENA	= TRUE
132.25 UDC NORM2RT	= 3800 V

132.26 UDC REF RT   = 4200 V

132.27 UDC RT2NORM   = 4400 V

132.28 GAIN UDC CTRL RT   = 100 %

132.32 N MIN RIDETHRU   = 10 %

132.33 MAX RIDETHRU LEN   = 0 ms (0 means infinite time)

10.3 Frequency limiter

The purpose of this limiter is to limit the frequency (speed). The frequency of the motor is limited to the value defined by parameter 132.07 for positive and by parameter 132.08 for negative direction of rotation. The torque reference is calculated from the formula:

$$T_{ref}[\%] \approx P_{gain}[\%] \cdot \frac{f_{\lim}[Hz] - f_{act}[Hz]}{f_{nom}[Hz]}$$

In this formula:

$f_{\lim}$ limit level of frequency defined by parameter 132.07 or 132.08

f_{act} actual value of frequency signal 161.04

f_{nom} nominal value of frequency parameter 110.03

P_{gain} controller gain in % defined by parameter 132.09

Example: If the actual frequency is 10% (% refer to the nominal frequency f_{nom}) below the limit frequency and P_{gain} is 1000% the torque is limited to 100% (nominal value T_{nom}).

The output torque of the limiter can be seen in the parameter "frequency torque reference." In AD drives this is parameter 132.12, in SD drives parameter 132.14

The status of the limiter is displayed in parameter "frequency limiting". In AD drives this is parameter 132.16 in SD drives 132.19.

10.4 Load Angle Limiter

This limiter is only used for SD machines.

The purpose of this limiter is to keep the load angle of the machine below a certain limit in order to avoid pull-out of the machine. The load angle limit is set in parameter 132.10 and the gain of the P-controller is set in 132.11. The torque limit is calculated according to the following equation

$$T_{ref}[\%] \approx \max\left[P_{gain}[\%] \cdot \frac{\Psi_{sd\_fw}[Vs] - \Psi_{sd\_la\lim}[Vs]}{\Psi_{s\_nom}[Vs]};0 \right]$$

In this formula:

Ψ_{sd_fw} Actual stator flux in d-axis (corrected if in field weakening)

Ψ_{s_lalim} $\Psi_{s\_nom}*\cos(delta\_limit)$ D-axis stator flux if machine is at load angle limit 132.10

Ψ_{s_nom} Nominal stator flux

P_{gain} Controller gain in % calculated from parameter 132.11

The controller gain is calculated from the difference of the load angle for which the torque is reduced from 100% to 0% (at exactly the load angle limit 132.10).

The torque limit calculated according to above equation is shown in 132.15.

Example: If the actual load angle limit is 85 deg (132.10), the delta of the load angle is set to 5 deg (132.11) and the actual load angle is 80 deg 1000%, the torque is limited to 100% (nominal value T_{nom}).

The output torque of the limiter can be seen in the parameter 132.15 "load angle torque reference."

The status of the limiter is displayed in parameter 132.20 "load angle limiting".

10.5 Braking limiter (BCU/RBU)

The following only applies for ACS 6000.

This function limits the dc-link voltage rise while braking with BCU/RBU.

The following parameter values have to be defined based on the HW dimensioning as they are used to protect the braking unit HW.

Torque is limited to a value, which corresponds to the nominal RBU/BCU braking power value given by 192.16 RBU ON BRK POWER, unless one of the dc-link half voltages exceeds certain level given by 192.21 LIMIT BRAKING VOL [V].

Then the torque is limited with a ramp to a value, which corresponds 40% of the nominal RBU/BCU braking power. Ramp time is given by the parameter 192.23 BRA LIM RAMP TIME [ms].

When all of the dc-link half voltages are under certain level given by 192.22 RECOVER BRAKING V [V] then the limitation is ramped back to a value, which corresponds the nominal RBU/BCU braking power value given by 192.16 RBU ON BRK POWER.

The calculated value is shown on 132.13 BRAK UNIT TRQ REF [%] and the status on 132.17 BRA UNIT LIMITING [LIMITING / NOT LIMITING].

This limiter does not limit the braking power, torque and current to acceptable level alone. The maximum braking current has to be limited by the static limiters chain to a certain value especially on low speeds to keep the braking current on certain level. See chapter of static limiters!

10.6 Damping the dc-link voltage ripple (diode rectifier)

This function should be disabled for ACS 6000 drives with ARU.

This function is not a limiter, but it can also change the torque reference. The torque reference is modified after the speed controller (or torque reference

given from FA) and before the dynamic torque limitations. The static torque limitations are already taken into account inside the FA.

This functionality was developed for weak supply networks. In these networks a stiff torque control may result in oscillations of the DC-link voltage. In case of a weak supply network, the DC-link voltage oscillations typically have the same frequency as the supply network frequency. Under certain conditions this may lead to saturation of the line transformer and to trips. The oscillations can be damped if the torque reference value is modified as a function of the actual DC-link voltage.

Set the limitation 159.04 ALLOWED DAMPING to a reasonable value (for example 5%).This parameter determines how strong the torque can be modified due to DC oscillations. The value is given in % of the nominal torque.

Set 159.02 UDC FILT TIMECONS to 20ms and 159.03 DAMPING GAIN to 100%. The larger the time constant (159.02) is set, the bigger the resulting delay and thus phase shift between the filtered and the original signal.

Enable the function. Monitor the behavior of the DC-link voltage. Increase the gain by steps of 5 – 10 %. Keep in mind that the gain of this function should be as small as possible in order to keep the noise of the resulting torque reference small. Compare the output of this function with the torque reference given by the FA.

The maximal value of the torque change (159.04 ALLOWED DAMPING) should be set higher than the value needed to remove the oscillation. Otherwise a sudden change of the torque reference could excite the oscillation again. This risk can be checked using the TORQ STEP input (parameter 26.03). Choose a small value and keep in mind that this acts directly on the torque reference coming from FA and that all limiters will act on the modified torque reference.

Do not forget to clear the parameter 26.03 TORQ STEP after the tuning is terminated.

159.01 ENA DAMPING	Enables the functionality
159.02 UDC FILT TIMECONS	T < 159.02 < 5 * T
	T is the cycle time of the supply network (20ms/50Hz)
159.03 DAMPING GAIN	Normally 100%, an increased value can be used to achieve a stronger damping
159.04 ALLOWED DAMPING	Maximally allowed damping in % of nominal torque. For example 5 % results in maximal change of the torque of ±5 %.
	Increase this value with steps of 1-5 % during tuning if necessary
159.05	not in use
159.06 TORQ REF MODIFIED	Compare this value to the torque reference value given by the FA during tuning
159.07 ENABLING SPEED[%]	Speed above which damping is enabled.
	For example a value of 10 % enables the damping function, as soon as the motor

speed is higher than 10% of the motor nominal speed.

159.08 ENA GENERAT. MODE   Generator mode must be set to FALSE for ACS5000 and ACS6000 single drives. Contact supportline in case needed with an ACS6000 multidrive.

159.09 ENA P-CONTR. MODE   This parameter changes the control principle of the UDC damping function. If this parameter is set to true, then a simple P controller is used to dampen the DC-link. Normally this parameter should be FALSE.

11 Speed controller

The speed controller must be tuned to the motor and the driven load.

The tuning of the speed controller is performed with the coupled motor by applying a speed step directly to the input of the controller. The response of the controller on the speed step is monitored and, if necessary, the default settings of control parameters are changed in such a way that the response of the controller is optimal for the driven process. After the tuning, sudden load changes should be corrected without stressing the mechanical equipment (gear box, belts, etc.) and affecting other control loops.

When tuning the speed controller, only one control parameter should be changed at a time. The effects of the parameter change with respect to step response and possible oscillations have to be monitored over the whole speed range.

Speed response tests should be carried out at different speeds between the minimum and the maximum speed of the motor. The speed intervals should be small enough to be able to detect possible resonance points.

Due to varying friction at different speeds of the driven load the response time can vary as well. In this case, it is recommended to adjust the appropriate response time to about half of the process speed.

Speed steps of 2% of the maximum speed or bigger are applied to see the response behaviour of the actual speed.

Proceed as follows to tune the speed controller using speed steps:

1. Accelerate the motor to the selected speed setpoint.

2. Select parameter 120.10 SPEED_STEP.

3. Set the speed step to 2% of the maximum speed and the duration for 3000 ms as shown in the figure below.
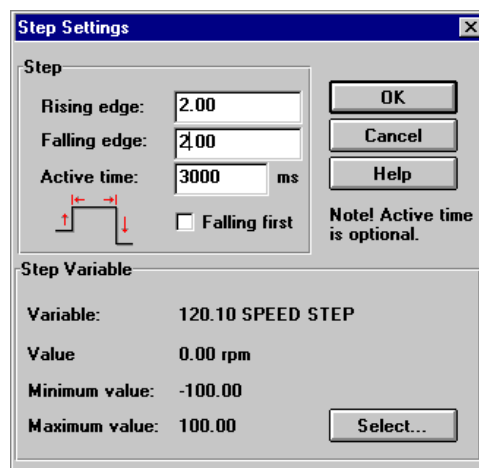
4. Set the datalogger to trigger from signal 120.10 SPEED_STEP.

5. Add signals 120.10 SPEED_STEP, 122.4 MOTOR SPEED, 122.14 TORQUE_REF_5 and 161.2 TORQUE_NOFILT to the datalogger as shown below.

Datalogger Settings

Variables
- 120.10 SPEED STEP
- 122.4 MOTOR SPEED
- 122.14 TORQUE REF 5
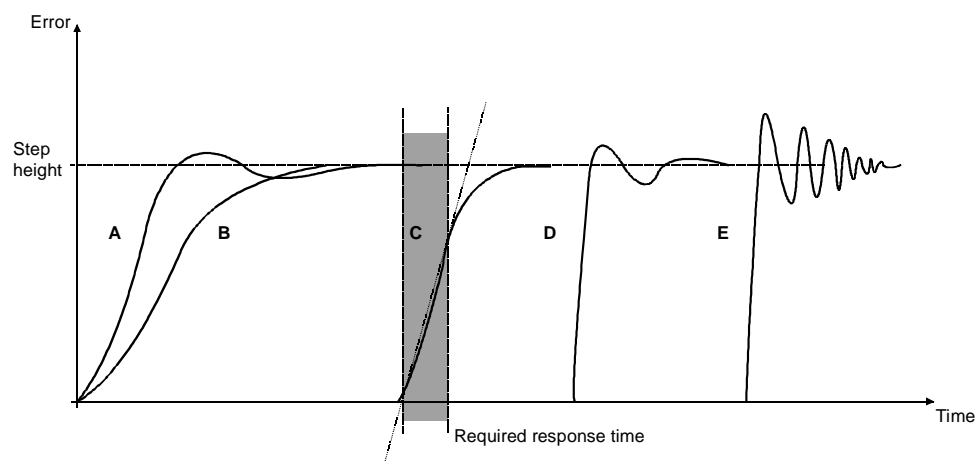- 161.2 TORQUE_NOFILT

Select...

Initialize
Cancel

Scaling...
Open...
Save As...
Help

Samples

Number of samples before   100
Sample interval (ms)   1

Triggering Conditions
- ☒ Faults
- ☐ Warnings
- ☐ Limits
- ☒ Level
- ☐ Difference
- ☒ External

Trigger Variable (for Level or Difference triggering)

Trigger   120.10 SPEED STEP   Select...
- ◉ Rising edge   1.0
- ○ Falling edge   Hysteresis: 0.0

6. Start the datalogger and apply the steps. Tuning is performed by using parameters 121.01 KPS (proportinal to the gain) and 121.05 TIS (integration time of speed controller).

7. Reduce the integral time constant 24.08 T until an overshoot is observed in the response.

The integral time constant is then adjusted such that there is no overshoot or only a slight overshoot (depending on the drive application). The function of the integral part is to remove as quickly as possible the difference caused by the proportional control between the reference and the actual value.

If the drive is stable and allows a high proportional gain, the integral time constant can be set to a short value to obtain an overcompensated step response.

If the torque limit is reached during a step, a further compensation of the response should not be attempted.

See figure below for different step responses.

A = undercompensated, too short intergration time and low proportional gain

B = undercompensated, too low proportional gain

C = normal

D = normal, when better dynamic performance is needed

E = overcompensated, short intergration time and high proportional gain

12 Update to newer software release

Before executing any update, please check the compatibility list.

Read the txt file included in the loading package carefully to check what has changed compared to the previous version.

1. **BACKUP OF OLD PARAMETERS**

   Make a backup of the used parameters as first action. In Drive Debug save the parameter list as a text file **and** as a *.PAC file.

2. **SAVE THE PREVIOUS FLASH AS BACKUP**

   Remove the previous Flash and store it in a safe place as backup in case programming of the loading package fails.

3. **DOWNLOADING THE NEW RELEASE**

   Download the new SW release.

   After downloading the new SW release take a backup of the new default parameters.

4. **RESTORING OF PARAMETERS**

   After backing up the parameters with DriveDebug, downloading the new software package and restoring the backup file, **check that the loading package version in the AMC Table Index 100.11 SW PACKAGE VER is correct.**

   Otherwise you have to update the name of the software package manually:

   102.01 PARAM LOCK   OFF

   100.11 SW PACKAGE VER 'LxOIxxxx'   (xxxx=version of new loading package)

   102.01 PARAM LOCK   ON

5. **COMPARE THE NEW RESTORED PARAMETERS AND THE BACKUP PARAMETERS**

   Please note that between different SW releases the parameters of the AMC-table may be modified. Parameters may have been shifted to different places or the meaning or scaling of the parameter may be different. **After restoring the parameters to the new release always compare all of the names and values with the old release!**

   Compare the new default parameters with the old values. In case a default value mismatches check the release documents. If no information is given please contact the manufacturer. Check the invparam.xls file to see the default values for the given inverter type (updated file is included in the new loading package).

13 Backup of the software and parameters

Before leaving the site, make a backup of all the loaded software in the flash and the used parameters: (Don't forget the excitation units in case of a synchronous machine drive).

Also make sure that the Dataloggers have been set back to their default values. This can be done easily by using Parameter 106.18 and 106.19. Also check if both Dataloggers have been started afterwards.
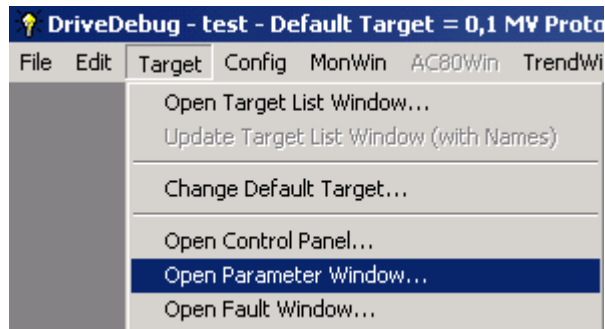
Use both tools, DriveDebug and DriveWindow 2.xx

13.1 DriveDebug:

Select the target drive in the target list window (double click on the required target)

Open the Parameter table, upload the parameters:

Save the Parameters as text file.

This has to be done for all boards (INU / ARU). Don't forget the CCB board / DCS in case of an SD drive.
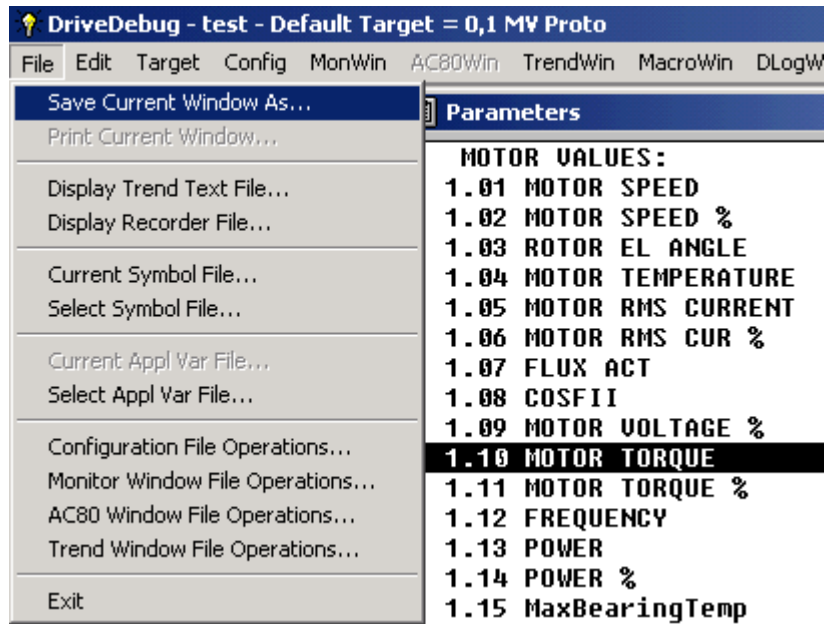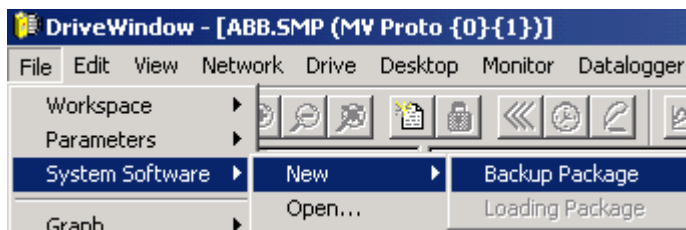
Save the Parameters as binary file:
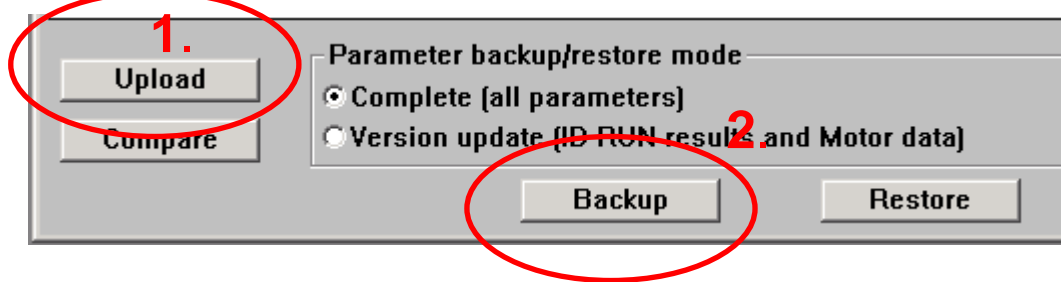
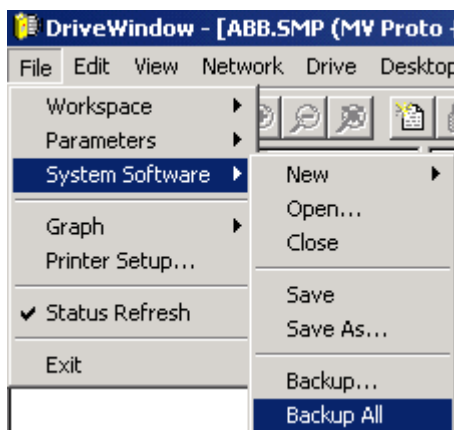Save the whole flash file content to a *.tar file (not supported for CCB)
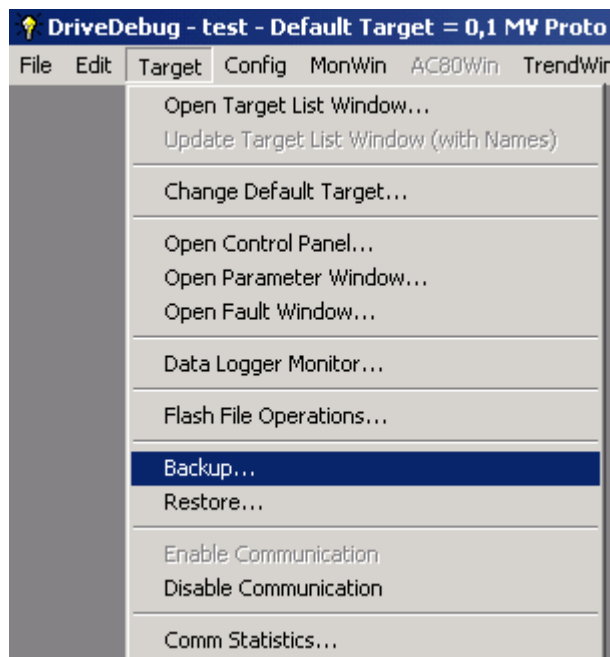
13.2 DriveWindow:

Also make a backup with DriveWindow
1. Create a new backup package:

2. Make a backup of all connected drives if a branching board exists, otherwise select the drives individually.


3. After finishing save the backups to a file: File, System Software, Save As…

13.3 Programming of the spare boards

The spare boards of the customer have to be programmed with the same software version as is installed in the drives. This can be done using the DriveWindow Restore function. The boards must be powered using an external 24V DC power supply. It also has to be checked that the spare INT boards (with ACS6000 also ARU and PUB) have the correct EPLD versions loaded. Otherwise the correct EPLD's have to be loaded and labeled.

1. Connect DriveWindow to the control board with the empty flash.
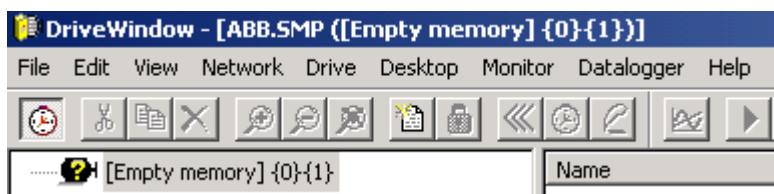
If the connection is not possible because the operating system is not compatible with the software on the flash, execute the following steps:

a) Connect the DDCS link to the AMC34 control board CH3 and the PC

b) Switch off the 24V power supply of the board

c) Open a DOS window and execute "ntnisa" (for NT/2000/XP operation system)

d) In the DOS window, execute "bootint 1"

e) Switch on the 24V power supply of the board

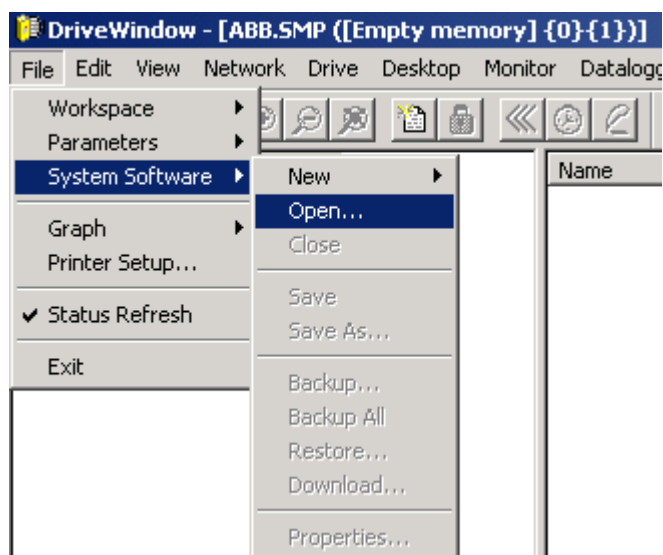Following messages should be displayed:

```
D:\>bootint 1

BOOTINT :

Forbid boot to automatically st
...

Autoloading prohibited - OK!

D:\>_
```
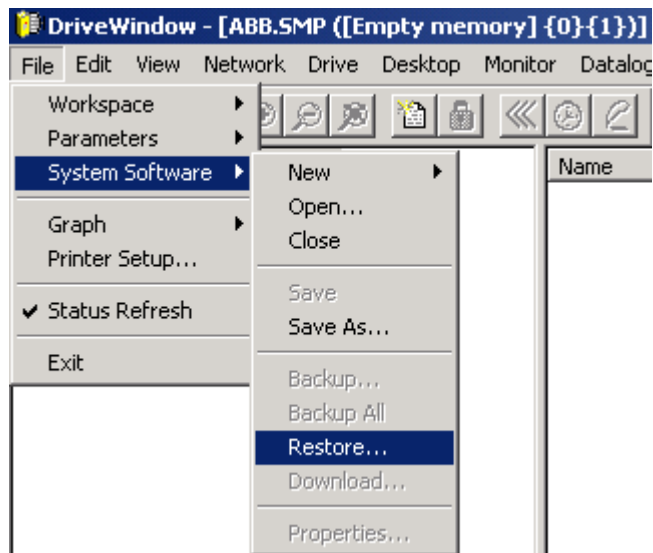
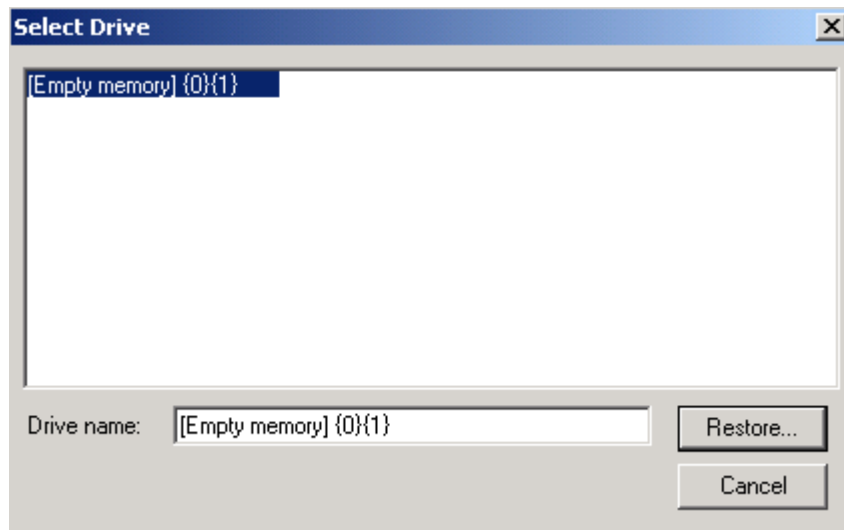Continue restoring the empty flash:

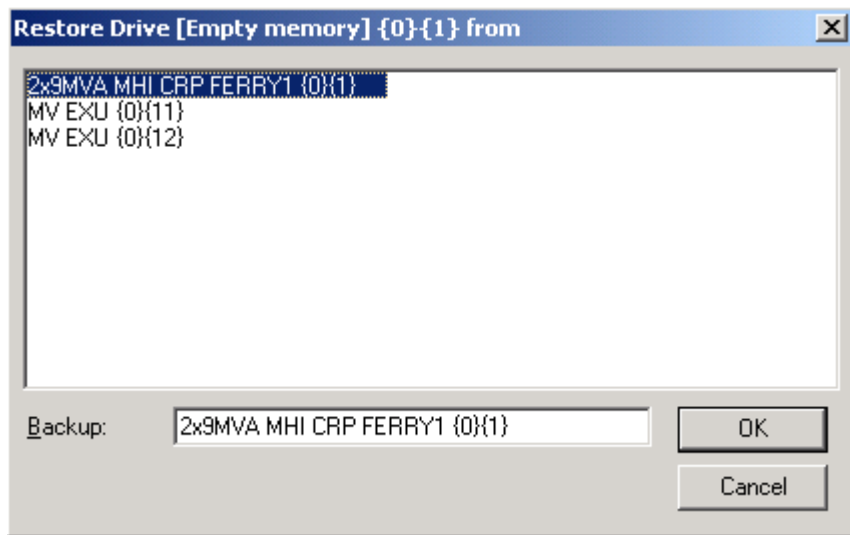2. Open the Backup package

3. Select System Software, Restore (Menu item is now enabled)
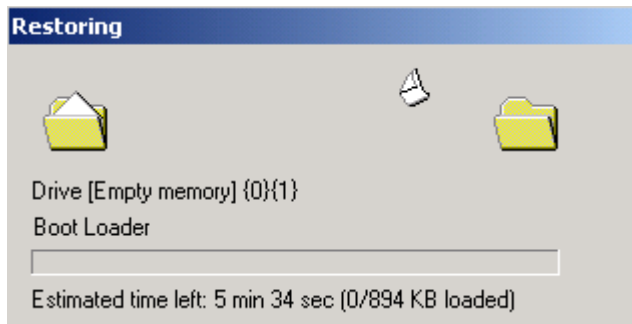
1. Select the restore target

2. Select the correct backup and press OK to start restoring

3. After accepting the warning message, the restoring will start

Appendix 1: Asynchronous motor equivalent circuit

Usually the datasheet of an asynchronous machine contains the parameters of the T-equivalent circuit, which has stray reactances both on primary and on secondary side and agrees with the physical understanding of the machine. Nevertheless, in the motor control the L-equivalent circuit of the machine is used, this equivalent circuit uses one parameter less and describes exactly the same machine. The two equivalent circuits cannot be distinguished regarding stator voltage and current behavior.

It has to be considered that the parameters of the two equivalent circuits are not identical

T-equivalent circuit	**L-equivalent circuit**
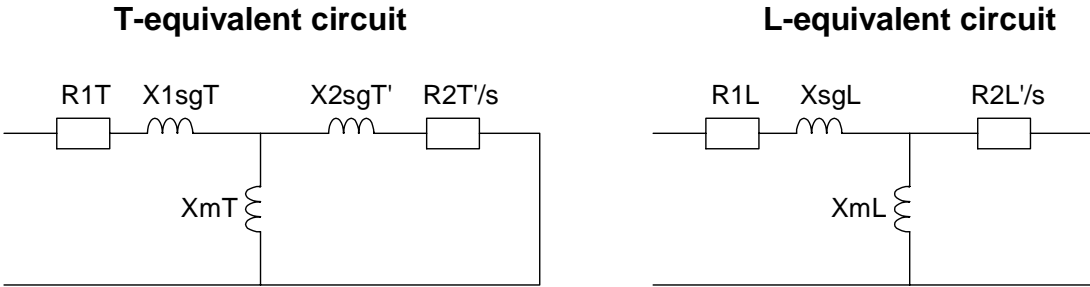
T-equivalent circuit:

Parameter:	Unit:	Description:
$X1sgT$	[Ohm]	Stator leakage reactance
$X2sgT'$	[Ohm]	Rotor leakage reactance
XmT	[Ohm]	Main or magnetizing reactance
$R1T$	[Ohm]	Stator resistance
$R2T'$	[Ohm]	Rotor resistance

L-equivalent circuit:

Parameter:	Unit:	Description:
$XsgL$	[Ohm]	Overall leakage reactance
XmL	[Ohm]	Main or magnetizing reactance
$R1L$	[Ohm]	Stator resistance
$R2L'$	[Ohm]	Rotor resistance

Transformation from one equivalent circuit to the other:

All parameters that can be identified from the terminals are equal in both circuits:

Stator resistance $\quad R1 \quad = R1T = R1L$

Stator inductance $\quad X1 \quad = X1T = X1L = XmT + X1sgT = XmL + XsgL$

Stray coefficient $\quad \sigma \quad = \sigma T = \sigma L$

Stray inductance $\quad Xsg \quad = \sigma \cdot X1T = \sigma X1L = XsgT = XsgL$

Rotor time constant $\quad Tr \quad = TrT = TrL$

Based on these equalities the T-circuit parameters can be transformed into L-circuit parameters:

$$R1L = R1T$$

$$\sigma L = \sigma T = 1 - \frac{XmT^2}{(XmT + X1sgT)\cdot(XmT + X2sgT')}$$

$$X1L = X1T = XmT + X1sgT$$

$$XsgL = \sigma \cdot X1L$$

$$XmL = X1L - XsgL$$

$$T2L = T2T = \frac{XmT + X2sgT'}{2\cdot\pi\cdot frated \cdot R2T'}$$

$$R2L' = \frac{XmL}{2\cdot\pi\cdot frated \cdot T2L}$$

frated = rated motor frequency

The values of the L-equivalent circuit are used in the AMC table parameters 150.01 - 150.04.

Appendix 2: Related document and SW tool list

Motor data sheet from machine factory

Motor type test report

EXCEL file for parameter calculation

Users Manual

TC SW AMC table

Signal and Parameter table

FA manual

Drive window

Drive debug

Appendix 3: Description of the IGCT conducting test function

For ACS5000 the IGCT conducting test function is available. With this function one can test if inverter switches are conducting or not. When enabled, the test is executed automatically after inverter has been charged. The test is based on execution of different switch sequence combinations and DC current flow. The inverter has to be connected to the motor to get current flow. If no current can flow, the test results will not be correct.

After test drive stays in READY REF state, if all IGCT are conducting and is ready to run the motor.

When the test has found non-conducting IGCT drive trips with CLASS 1 and opens the main circuit breaker.
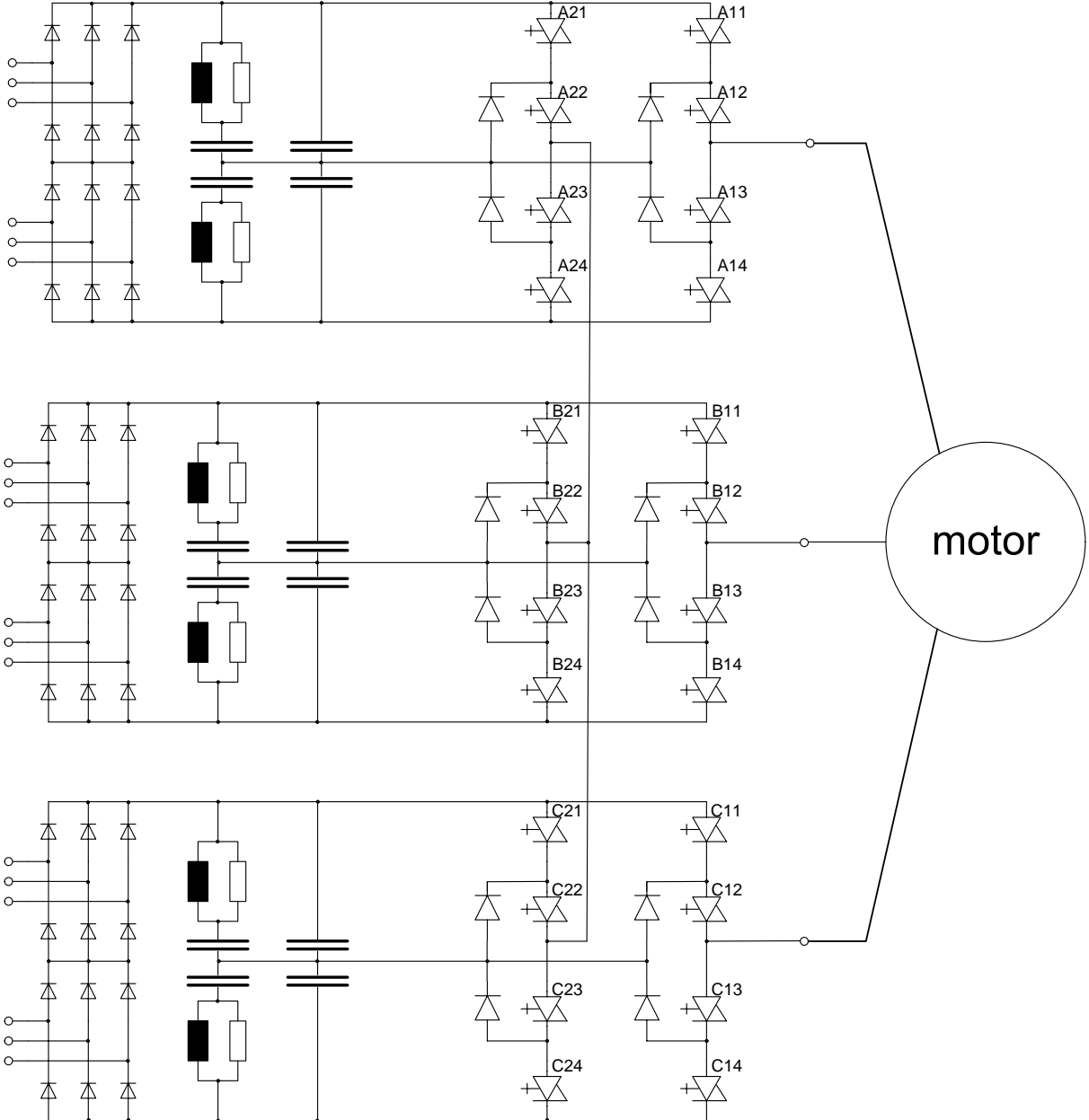
Inverter circuit

Fig.1 Switch notation

Test parameters and results

The test has only one parameter 131.36 used to enable the test with ENABLE.

After the test the value is set to DISABLE automatically.

131	Group name:	*FLUX REF CONTROL*
	Description:	

36		**IGCT CON TEST ENA**				
Index	Description:	Enabling/disabling IGCT conducting test			
Unit:	Type:	Min: 0	Max:	Def:	Int. scaling:

37		**TEST RESULT INU 1**				
Index	Description:	24 bits status of IGCT "0" OK , "1" not conducting			
Unit:	Type:	Min: 0	Max:	Def:	Int. scaling:

38		**TEST RESULT INU 2**				
Index	Description:	24 bits status of IGCT "0" OK , "1" not conducting			
Unit:	Type:	Min: 0	Max:	Def:	Int. scaling:

The test results are put to location 131.37 in case of single inverter and also to location 131.38 in case of double inverters. Below the meaning of bit position in those two locations is presented.

C24	C23	C22	C21	C14	C13	C12	C11	B24	B23	B22	B21	B14	B13	B12	B11	A24	A23	A22	A21	A14	A13	A12	A11

The test result is shown as a bit value: "0" meaning conducting

"1" meaning not conducting

Because of inverter configuration "outer" IGCTs with number 1 or 4 are indicated precisely if not conducting, the "inner" ones 2 or 3 are shown as a pair with "outer" 1 or 4.

Examples of results:

C24	C23	C22	C21	C14	C13	C12	C11	B24	B23	B22	B21	B14	B13	B12	B11	A24	A23	A22	A21	A14	A13	A12	A11
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

All IGCT are conducting

C24	C23	C22	C21	C14	C13	C12	C11	B24	B23	B22	B21	B14	B13	B12	B11	A24	A23	A22	A21	A14	A13	A12	A11
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

IGCT A14 is not conducting

C24	C23	C22	C21	C14	C13	C12	C11	B24	B23	B22	B21	B14	B13	B12	B11	A24	A23	A22	A21	A14	A13	A12	A11
0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

IGCT C22 and A14 are not conducting

Test flow

The test has to be enabled before drive is charged e.g in READY ON state.

- Set parameter 131.36 **IGCT CON TEST ENA** to ENABLE
  (The test has to be enabled before drive is charged
   e.g in READY ON state.)

- Charge the drive
  (The test execution is activated in the last step of RDY_ON to
  RDY_RUN action, follow it with window like below fig.2))

- After the test execution the enabling signal 131.36 is set to DISABLE
  automatically
  torque control state machine stays in READY RUN if no faults
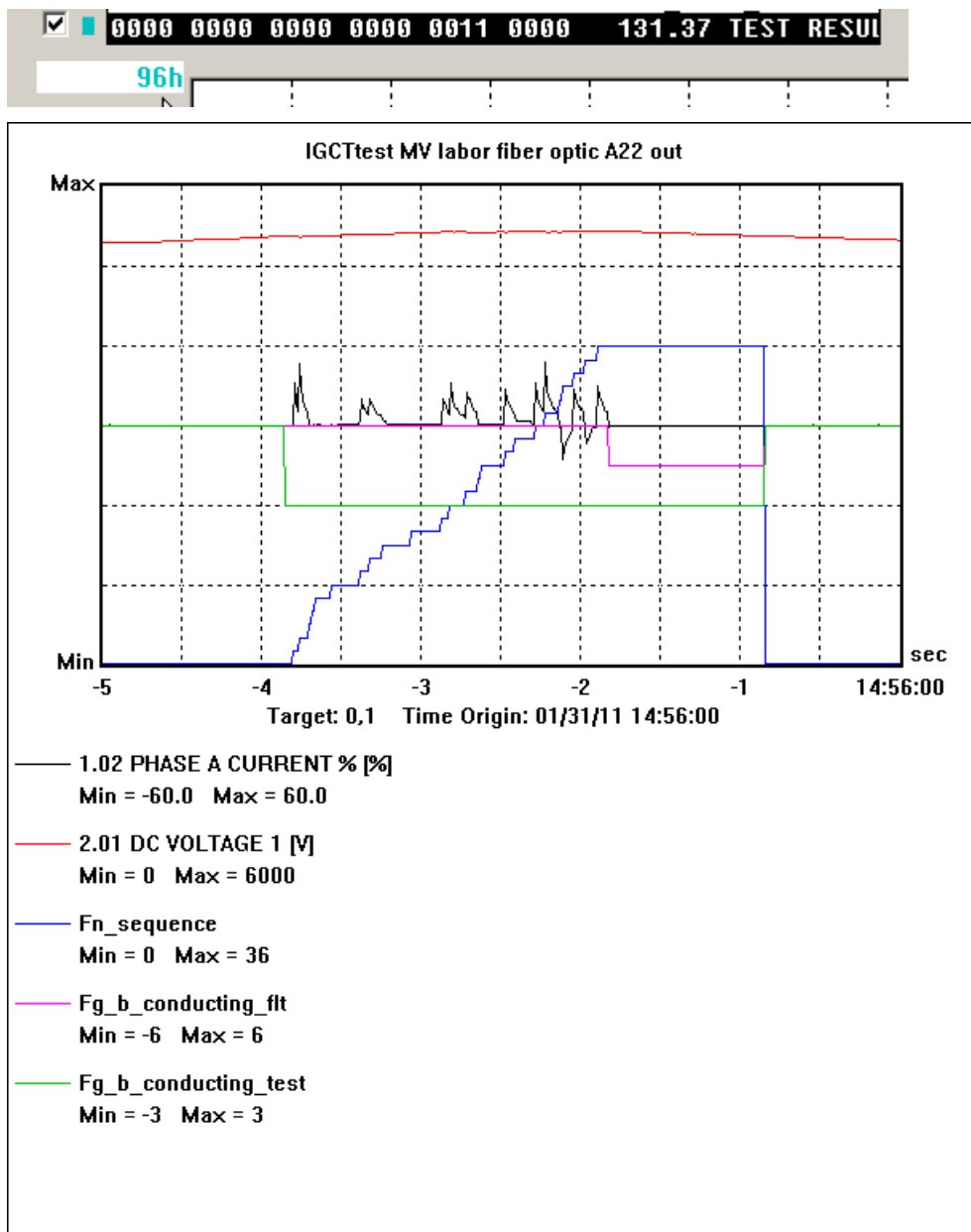 otherwise fault message is generated and drive trips with Class 1.

Fig.2 IGCT A22 non conducting