SIEMENS

FAQ for SINAMICS DCM; 6RA80

Question:
How do I perform diagnostics if a fault occurs?

Answer:
Several different ways of performing diagnostics on the SINAMICS DCM 6RA80 are described below. You do not have to read the entire text, only the item relevant to your problem. This permits you to perform the necessary preliminary investigation, which you can then discuss with Technical Support (for contact address, see the "Preface" Section of the Operating Instructions).
For further documentation, please go to the following link:
http://support.automation.siemens.com/WW/view/en/38157755/133300

Note: When commissioning a SINAMICS DCM for the first time, work through Section 8 of the Operating Instructions.
Commissioning is performed with the BOP20 or AOP30 or the STARTER commissioning software (Version 4.3.3 or higher; USB to Profibus Interface; Order number;
MLFB: 6GK1571-1AA00) starting from the factory setting of the SINAMICS DCM.

⚠ **WARNING**

The units listed here contain dangerous electrical voltages and control rotating mechanical parts (drives). Failure to follow the relevant Operating Instructions may result in death, serious injury or considerable material damage.

Only qualified personnel who are familiar with all the safety information contained in the Operating Instructions, as well as the assembly, operating and maintenance instructions, should carry out work on these units.

Perfect, safe and reliable operation of the units is conditional upon them having been professionally transported, stored, mounted, and installed, and having been carefully operated and maintained.

The output of the power section for the armature and field is not electrically isolated from the input, which means that dangerous voltages will be present at the output when the supply voltage is applied to the input. Please also remember that dangerous voltages are also present on the power interface and field module. Before working with the unit wait for the discharge time of the TSE capacitors and the capacitors of the power supply to elapse.

The power supply for electronics module CUD and other electronic expansion modules is however electrically isolated from the line voltage. Their reference ground "M" is at ground potential.

About this document: Firstly the CUD, memory card and device standards are described, then interrelationships for controlling and setpoint value specification, followed by diagnostics in the case of fault codes. You will find basic theory on converters and procedures for performing measurements further on in the documentation to refresh you knowledge. This document is rounded off by an introduction to control engineering. Please use the index in the appendix to find the items you require.
The cross-references apply to the documentation for software 1.4.

CUD (Control Unit DC):
Control unit for the SINAMICS DCM.
The CUD is available in two versions:
Standard CUD: No connection option for the CBE20 (PROFINET module) and no DRIVE-CLiQ interface.
Advanced CUD (G00 option). This is required for operating a CBE20 module and for connecting the following components: TM31, TM15, TM150(From Firmware V1.4) SMC30 (maximum of 3 of the listed components TM31/TM15/TM150 possible per CUD, and one of the SMC30).
The Advanced CUD is characterized by the incorporated slot for the CBE20.

Second CUD
The Standard version of the SINAMICS DCM (without options) comes equipped with a Standard CUD on the left-hand side, from which the entire SINAMICS DCM is controlled.
If a Standard CUD or Advanced CUD is inserted in the right-hand slot, an Advanced CUD is always required in the left-hand slot.
See Section 10.30. of the Operating Instructions.
A second CUD is used if more inputs/outputs, more interfaces or additional computing power for function blocks are required.

The LEDs on the CUD:
See Section 10.33.4 of the Operating Instructions

Basic Operating Panel BOP20 (in the device):
See Section 9.2 of the Operating Instructions.
For control (switch on) via the BOP20, see Section 9.2.4 of the Operating Instructions.

Advanced Operating Panel AOP30 (accessories):
See Section 9.3 of the Operating Instructions.
The new AOP30 with order number 6SL3055-0AA00-4CA4 or -4CA5 must be used.
For each device (with up to 2 CUD) a own AOP30 necessary.

Software update
See Section 11.1 of the Operating Instructions

Memory card:
A memory card is not required for operating the SINAMICS DCM.
A memory card must be used for the following applications:
For a software update.
If the AOP30 is used for additional languages (except German/English).
If a controller – controller direct data exchange (SINAMICS Link via the CBE20) is used (possible from software version 1.2). (SINAMICS Link. See Chapter 10.6 of Operating Instructions)
For a DCC database update.
When using the diagnostic memory and trend recorder function.
Allowed are MMC or SD with 64 MB to 2 GB. .See Section 9.1.4 of the Operating Instructions

Drive Objects, DO
A drive object is a self-contained software function with its own parameters, faults and alarms.
A CUD (Control Unit DC) has 2 DOs.
Control unit, CU_DC: DO1
Drive control, DC_CTRL; DO2
Furthermore, each additional component has its own DO e.g. TM31.
See Section 9.1.3 of the Operating Instructions

Access level for the BOP20:
The access level (parameterization enable) for the BOP20 is set via
p0003 in DO1.
p0003 = 3 Expert: the access options (reading and editing) are thus available on all relevant
parameters.

Restoring the factory settings:
In this case, the device parameters are restored to the delivery condition. The parameters set
in the factory are transferred to the RAM (volatile memory).
Parameter reset:
1. p009 = 30
2. Set p976 = 1
These parameters can be found in DO1.
See the parameter description in Section 1 of the List Manual.
When fault indication at RAM to ROM occur
1. p009 = 30
2. p976 = 200

Saving the parameters to the ROM (non-volatile memory):
Any parameter changes are initially only made in the RAM (volatile memory),
i.e. the set values are lost once the electronic power supply is switched off.
If at least one parameter has not yet been permanently saved, an "S" is displayed on the
BOP20 or a flashing "S" is displayed in the top right of the AOP30.
To save the parameters in a non-volatile way, a transfer to the ROM is required.
The following options are available for this:
• Set parameter p977 = 1 (DO1)
• "Copy from RAM to ROM" using STARTER
• Press and hold the P key on the BOP20 for 3 seconds
• On the AOP30: When confirming the parameter transfer, press the OK key for longer than 1
sec. and then answer the prompt by selecting Yes.
If a memory card is inserted in the CUD, the parameters will also be saved on the memory
card.
For the CUD on the left or right-hand side, the parameters in the ROM are saved on the
CUD. If the CUD is replaced, a parameter download is required after the CUD replacement
(either by using a memory card or STARTER, or by entering the parameters via the AOP30
or BOP20). Then perform a copy from RAM to ROM.

In the following cases, power-up is interrupted with display value 33 on BOP20:
See also operating instruction Appendix B, Section B.2
In this state, the unit can be parameterized using BOP20, AOP30 and STARTER
• Differences have been identified between the reference and actual topology:
Transfer the actual topology into the reference topology by setting p9905 = 1 or p9905 =2.
Power up is continued
• A memory card with a parameter data set, which comes from a SINAMICS DCM with
different Order Number (MLFB) is inserted in the Drive:
Accept the parameter data by setting p9906 = 3.Power-up is continued.
• A memory card with a parameter data set from another CUD type is inserted in the drive
(e.g. a parameter set from the right-hand CUD was loaded into a left-hand CUD, a parameter
data set of a standard CUD was loaded into an advanced CUD)
Accept the parameter data set by setting p9906 = 3. Power-up is continued.

Device data and device standards:
pxxxxx: Setting parameters; these parameters can be modified.
rxxxxx: Display parameters or BICO output parameters; these parameters can be read only and cannot be modified,
r50000:Display of the operating state.
r50070[xx]: Display of the MLFB (order number) of the device in the ASII code. (xx stands for the parameter index)
r50060[6]: Software version of the SINAMICS DCM
r50063[x]: CUD information
p50067: For adapting the rated device current based on the rating class, continuous current applies if p50067 = 1, but if p50067 > 1, the 100% current applies as actual rated DC device current for the armature, see also p50076.
r50068: Options in accordance with the rating plate in the ASCII code.
r50069[xx]: Factory serial number of the SINAMICS DCM in the ASII code
r50071: Device rated line-side voltage armature
r50072[0]: Rated device DC current for armature acc. to the rating plate
r50072[1]: Actual rated DC device current for the armature after adaptation by means of p50067 and p50076[0]; the smaller of the resulting values is active. Based on r50072[1], the device can have a current load rating with a factor of up to 2.0x.
r50073[0]: Rated DC device current for the field acc. to the rating plate
r50073[1]:Actual rated DC device current for the field after adaptation with p50076[1]
r50074: Device rated line-side voltage field
p50075: Control word for overload capability for armature power unit, where p50075 = 1 or 2: Overload capability enabled, maximum 1.8x the rated device current acc. to rating plate (r50072[0]) possible.
p50076[0]: Adjustment of rated DC device current for armature to 1% to 100% rated current.
p50076[1]: Adjustment of rated DC device current for field to 1% to 100% of rated current
p50077: Total thermal derating factor as a function of the ambient temperature and installation altitude of the device.
p50078[0]: Rated line voltage for converter armature
p50078[1]: Rated line voltage for converter field
p50082: Operating mode for the field
Note: Always quote MLFB (r50070), r50060[6]: Software version:
Ideally, you should send us your entire STARTER project as soon as possible.
support.automation@siemens.com

Motor-related data:
p50100: Rated motor current, armature
p50101: Rated motor voltage, armature; for 2Q, maximum line voltage x 1.2;
for 4Q, set maximum line voltage x 1.05.
p50102: Rated motor current, field
p50171: Positive current limit for armature with reference to p50100 (set positive values)
p50172: Negative current limit for armature with reference to p50100 (set negative values)
p50180: Positive torque limit with reference to rated motor torque (set positive values)
p50181: Negative torque limit with reference to rated motor torque (set negative values)
p50104 – p50108: Settings for speed-dependent current limiting, see Section 10.19 of the Operating Instructions. For special applications, do not use speed-dependent current limiting for standard applications, set p50109 = 0, parameter settings p50104 – p50108 will then not be evaluated.
Note: Notice/Danger; if positive values are set for p50172 or p50181 (or negative values are set for p50171, p50180), the motor will accelerate uncontrolled to its maximum possible speed limit.

Operating the 4Q device as a 2Q device:
Set p50150 = 5 and p50172 = 0

The function block diagrams:
These can be found in Section 2 of the List Manual.
In the following description, we refer to their sheet numbers, e.g. "2070 E stop sheet".
The function block diagrams can be read like an analog circuit diagram and represent the entire controller structure with the parameters, connectors, and binectors used. The control loops are shown in the sequence in which they are calculated by the processor, reading from page 1 to the next, and from left to right.
If a function does not work correctly, the content of the connectors and binectors in the function block diagram starting from the signal source and the display of a read-only parameter rxxxxx, (xxxxx representing the number of the r-parameter) can be checked for measured values. This is a simple way of ascertaining up to which part of the circuit diagram the value is still OK.
This procedure helps to localize the cause of an error and remedy it.
The parameter factory setting is always given in brackets next to the parameter numbers in the function block diagram, e.g. on sheet 6855, p50191[D](0); screen time of current setpoint p50191[DDS parameter], with factory setting (0).

Connectors and binectors: BICO:
The device can be parameterized flexibly using the digital signals, the connectors CO (connector output) 16-bit or 32-bit or floating point value for indicating analog variables, such as actual current value or speed controller output, and the binectors BO (binector output) for indicating digital control signals/conditions with the value 0 or 1 (for each bit of the BICO parameters: binector-connector parameter). The selection parameters, CI (connector input), and BI (binector input) are used to select at which intervention point the connector or binector in question will take effect.
To do so, the number of the CO parameter is set at the CI parameter, and the parameter number of the BO that should take effect is set at the parameter for the BI.
See Section 9.1.5 of the Operating Instructions and sheet 1020, 1030 from Section 2 of the Parameter Manual.

Display of connector and binector contents:
See parameter rxxxxx, CO, BO

Standard normalization of CO connectors in the case of transmission via a serial interface:
16-bit value, 14 bit = 16384 decimal = 4000 hexadecimal corresponds to 100%
-16384 dezimal = C000 hexadezimal ist Minus 100 %.
7FFF hexadecimal = 32767 decimal = 199.993% (maximum displayable positive number)
FFFF = -32767 = -199.993%
8000 = -32768 = -200% (minimum displayable negative number)
Resolution: 0.0061%
-10% = -1638 dec = F99Ahex
 10% = 1638 dec = 666 hex
Calculated with the Windows calculator.
Settings:
View = scientific
With the calculator set to dec., enter the value -1638.
Change over to hex and select the Word button
Result F99A
Connector scaling 32 bits:
32-bit value,
1073741824 decimal = 4000 0000 hexadecimal is 100%
-1073741824 decimal = C000 0000 hexadecimal is minus 100%
Resolution: 9.3132E-8%
The word is read from right to left,

extreme right: bit zero, extreme left: bit 15 or bit 31.
Actual speed value: 100% corresponds to p2000
Actual current value: 100% corresponds to p2002

Normalization of the closed-loop controller signals
Armature circuit.
Actual speed value: 100% corresponds to the pulse encoder evaluation of the set maximum speed in p2000; for the analog tachometer, 100% corresponds to the tachometer voltage in accordance with P50741. The following applies with EMF as the actual value: 100% speed corresponds to an EMF in accordance with
p50078[0] * p50115. The same applies for speed setpoint normalization.
Speed controller output r52160, Parameter Manual Section 2 Sheet 6815 dependent on
p50170, p50170 = 0: 100% corresponds to the actual rated DC device current for armature
(r50072[1]); p50170 = 1: 100% corresponds to the torque of actual rated DC device current
(r50072[1]) and 100% flux PHI (is p50102 for rated field current).
From r52134, Sheet 6835 and to the right of it, 100% corresponds to r50072[1].
Actual current value for armature r52117, Sheet 6855: 100% corresponds to r50072[1]
Delay angle r52110, r52121, r52102, Sheet 6855; r520101, r52100, Sheet 6860:
100% corresponds to 0 degrees, 0% corresponds to 90 degrees, -100% corresponds to 180 degrees.
Field circuit:
Actual EMF value r52286, r52285, Sheet 6900: 100% corresponds to r50078[0] * 1.35
Output EMF control loop, r52280, r52293, field current setpoint r52277 to r52268:
100% corresponds to the actual rated DC device current field (r50073[1]).
Output field current control loop (firing angle, field), Sheet 6910 :
r52260, r52271, r52252:
100% = 0 degrees, 0% = 90 degrees, -100% = 180 degree delay angle.

Fixed values:
See Sheet 3100 in Section 2 of the List Manual
Fixed values in %, fixed values decimal, fixed control bits, constant fixed values and control bits.

Free function blocks:
With SINAMICS DCM, an abundance of function blocks (52 in total) can be utilized at no additional cost. The blocks can be selected and have parameters assigned to them by means of BOP20, AOP30 or STARTER. These can be selected at various DOs (even in the case of several).
Select via BOP20, e.g. for DO2:
These parameters are in DO1,
p003   =   3 Expert
p009   =   2 Definition of drive type/function module
p108[1]   =   Bit 16 Technology controller: hex 00010000
               Bit 18 Free function blocks; hex 00040000
               Bit 31 Profinet; hex 80000000
               80010000 hex: bit 16 + bit 31, 80040000 hex: bit 18 + bit 31,
               80050000 hex: bit 16 + bit 18 + bit 31
p009   =   0 The device is now reinitialized

Drive Control Chart, DCC

The DCC software can be used for more complex technological controls, however a license must be purchased in this case. The function blocks are graphically configurable and are subsequently loaded into the drive with STARTER and downloaded to the memory card. In addition to this, the free function blocks can be used.
See Section 10.36 of the Operating Instructions

DDS (Drive Data Set), CDS (Command Data Set) and EDS (Encoder Data Set):

See Section 9.1 of Operating Instruction and the parameter list in the List Manual.
DDS: 4 x DDS exist, with which, for example, switchover to different controller settings is possible, for example, during alternating operation of different motors on the SINAMICS DCM, for changing gear stage, or for switching to C axis mode with main spindle drives.
Procedure for assigning parameters:
Start by entering all parameters for DDS0, then copy the parameters from DDS0 to DDS1 via p819[x], see Sheet 8565 in Section 2 of the Parameter Manual. Then make any parameter changes necessary for DDS1.
Selection DDS bit 0: p0820, selection DDS bit 1: p0821.See also selected DDS in r0837
CDS: For selecting the command source. 2 x CDS are available. Proceed in the same way for the CDS parameters. Copy CDS parameters via p809[x], Sheet 8560.
Selection CDS bit 0: p0810, see also selected CDS in r0836.
EDS: 2 x EDS are available, the switchover is performed via the DDS.
See Section 9.1 of the Operating Instructions

The operating state of the device:

The respective operating state of the device can be read out from parameter r50000. See parameter description for r50000. The operating state is also available in connector CO r52800, for example, for transmission as PCD (process data) via a serial interface.
If the device does respond as required, always check the operating state. A relevant control signal might be missing.

Display of the signal states of the binary inputs and outputs:

See BO rxxxxx in Section 2 of the List Manual

Note: The function descriptions are to be found in Chapter 10 of the Operating Instructions, a short-hand summary of the most frequently used functions is given below:

Operation via bus (USS or PROFIBUS or PROFINET)

When using software version V1.1, only one of the interfaces can be activated.
For PROFIBUS, see Section 10.4 of the Operating Instructions
For PROFINET, see Section 10.5 of the Operating Instructions
For USS interface, see Section 10.8 of the Operating Instructions
The data is transmitted serially via a bus connection.
PCD: Process data for transmission of connector contents CO rxxxxx (16-bit word), e.g., control word 1, main setpoint value as one PCD each. Setting the transmit data via p02051.
For 32-bit connectors (CO), the 32-bit value is transmitted to two subsequent positions of the PCD with 16 bits each. Setting the transmit data via p02061.
Always set only p02051 or p02061.
The first PCD to be transmitted from the master to the SINAMICS DCM must always be control word 1, and the 11th bit (bit number 10, counting starts from zero) in control word 1 must carry the high signal, otherwise the process data received in the SINAMICS DCM will not be updated (no PCD transmission).
Parameter identifier value: Parameter data: Parameter number, parameter index, parameter value, depending on the respective DO.
See Sheet 1520, 2410, 2420, 2440, 2442, 2450, 2452, 2460, 2470, 2481, 2483 in Section 2 of the Parameter Manual.

Controlling via the binary signals of the converter or via control word 1 (CW1):
See Section 10.9.1 of the Operating Instructions for OFF1
Terminal X177.12: ON/OFF1, starting from operating state o7.0, relay contact terminal 109/110 is closed (relay for controlling the main contactor, valid in the case of p51619 with factory setting). Then voltage must be applied to power unit; otherwise F60004 will occur.
If OFF1 is set (e.g. terminal 12 LOW signal), setpoint zero is set before the ramp-function generator and the drive slows down to zero speed along the deceleration ramp from the ramp-function generator. On reaching n < nmin (p50370), the current is reduced to zero, followed by pulse inhibit and the main contactor relay, terminal 109/110 drops out, then the supply voltage for the power unit can be disconnected.
Note: To allow the device to respond to a switching command, "Ready to switch on": Operating state o7.x must be present. When applying the supply voltage of the electronics supply, the ON command must not be set until the device is initialized (lasts approx. 45 seconds if no option modules exist) and subsequent status o.7x, otherwise the ON command will not be executed.
Exception: Restart parameterized and return of the supply voltage within the parameterized restart time in p50086. –End of note-
Terminal X177.13: Operating enable (controller enable and pulse enable) operating state o1.x: Waiting for operating enable. If ON signal and operating enable exist, the current converter switches to the "Run" state, operating state: o0.0 (no torque direction engaged) or o0.1 (torque direction 1 exists) or o0.2 (torque direction 2 exists).
If operating enable is removed, Alpha W shift always occurs immediately without delay to reduce the current to zero followed by a pulse inhibit when current = zero is reached.
The drive coasts down, the main contactor is not switched off.
When controlling via bus, ensure that bit 0 (ON/OFF1) and bit 3 (operating enable) of the control word from the bus are each "ANDed" with terminal X177.12 and X177.13, i.e. a high signal must exist at both sources for executing the control command. This AND logic operation not applies for controlling via the AOP30 and the STARTER.
If controlling is only required via bus, terminals X177.12 and X177.13 must be securely clamped to the High potential (e.g. connect P24, terminal X177.9).
Note: For operation via PROFIBUS, the 1st word of the PCD (control to SINAMICS DCM) must always be control word 1 and the 11th bit (bit no. 10) must assume a high signal before process data transmission can take place.
Note: The ON signal and operating enable may also be performed simultaneously; the controller located within the device ensures that internal operation enable is delayed until the right conditions for line infeed and field supply exist for transition to the Run state.
This allows efficient setting of P24 (24 V, e.g. of terminal X177.9) at terminal X177.13 so that the device can be controlled via terminal X177.12 only, for example.
If controlling via bit zero (1st bit) of control word 1, its bits 1 to 6 and 10 must be set to high.

OFF2, voltage enable
See Section 10.9.2 of the Operating Instructions;
Bit 1 in CW1.
Bit 1 in CW1 zero signal leads to Alpha W shift for reducing current to zero. On current zero, pulse is inhibited and the main contactor relay terminal 109/110 opens.
The drive coasts to a standstill.

OFF3, fast stop
See Section 10.9.3 of the Operating Instructions
Bit 2 in CW1.
Bit 2 in control word 1 low signal causes the fastest possible deceleration of drive (4Q device required) to n < nmin (p50370). When n < nmin is reached, the current is reduced to zero current, and when zero current is reached, pulse inhibit occurs and main contactor relay terminal 109/110 opens. Upon rapid stop, the ramp-down times of ramp-function generator p50296, p50297, p50298 apply.

Priority of control signals

Cancellation of the operating enable (terminal X177.13, bit 3 in CW) always causes immediate Alpha W shift irrespective of the other control signals, to current reduction to current = zero with subsequent pulse inhibit when current = zero is reached.

Operating state with a higher number (see r50000),

e.g. o11 before o10 has a higher priority

o10 ...OFF2 (voltage enable): High priority

o9 .....OFF3 (fast stop): Average priority

o7 .....OFF1 (shutdown) : Low priority

If several control signals are pending simultaneously, the command is executed with a higher priority, e.g. if OFF2 and OFF1 are set simultaneously, command OFF2 is executed.

If a current actual value of zero cannot be reached for current reduction with Alpha W shift, the drive never enters pulse inhibit and the "OFF" status can therefore not be reached. In such cases, only the "immediate pulse inhibit" specification via a binector settable in p50177 can help.

The function "immediate pulse inhibit" via binector should be used with care. When applied during active regenerative feedback operation, for example, this function causes an overcurrent.

Note: Sequence of the control signals: Before setting the ON signal via bit 0 of the control word (e.g. terminal X177.12), the signals for OFF2 (bit 1 CW) and OFF3 (bit 2 CW) must have a high signal so that operating state o7 (ready to switch on) exists; only then is it possible to switch on via OFF1 (bit 0 CW).

If operating state o8 exists (switching on inhibited), set OFF1 to enter operating state o7.

Controller structure for OFF1 and OFF3

To be able to execute OFF1 and OFF3 during current-controlled operation, the controller structure is adapted with a switch in the software. With current-controlled slave devices, for example, in master-slave operation or in a 12-pulse parallel connection of devices, it is therefore important to ensure that signal OFF1 or OFF3 is not passed on to the slave devices until the master has completed the shutdown and is no longer in the Run state.

Setpoint value specification:

p50433[C]: For selecting the connector for the setpoint prior to the ramp-function generator, see Sheet 3113 in Section 2 of the List Manual

Setpoint channel, in p50433, if this is a CDS parameter, the source of the setpoint is entered by entering the parameter number for the CO.

p50433[0] = 52011 (Command Data Set 0, factory setting 52011: Setpoint via CO r52011, main setpoint via analog input, terminal X177.25/26 (see Sheet 2075 in Section 2 of the Parameter Manual).

Switchover of the setpoint source possible by switching over the CDS.

With p50672[C] and p50671[C], the direction of rotation of the motor is specified. If both have the value 1, the direction of rotation is determined by the polarity of the setpoint (valid for 4Q operation, both directions of current possible, see also below). See Sheet 3135 in Section 2 of the List Manual.

Fixed setpoint: One or more fixed setpoints can be activated, Sheet 3115. Only becomes active if the Run state exists via the OFF1 high signal (e.g. via terminal X177.12). In p50430[0...7] (8 indices available, an individual fixed setpoint command can be used under each index) the BO of the source is entered, which takes effect as the fixed setpoint activation. In p50431[0...7], the CO of the setpoint is entered.

Jog setpoint: Sheet 3125. Jogging has its own ON function, as such OFF1 must have low signal, the ON function is implemented through the Jogging signal via control word 1 or via the BO defined by p50435[0...7]. p50436[x] defines the CO for the setpoint. When the jogging command is canceled, the delay parameterized in p50085 is used as the delay time for the drop-out of the main contactor, to prevent drop-out of the main contactor between repeated jogging commands.

Creeping setpoint: Sheet 3130. Creeping has its own ON function for OFF1 low signal and a fixed setpoint function when the creeping setpoint is used in the Run state.

Main contactor control terminal 109/110:
Control of the main contactor via terminal 109/110 ensures the correct switch-on and switch-off sequence of the main contactor, this is therefore the preferred method of implementation. Main contactor control in the case of setting p51619 = 53051.0 (factory setting should be retained), see Sheet 2070 in Section 2 of the Parameter Manual:
Terminal 109/110 is closed on ON command. Voltage must now be applied to the power unit. In the case of Off1, the setpoint before the ramp-function generator is set to zero, the drive decelerated to speed n<nmin (p50370) along the ramp-function generator ramp, and then the current is reduced to zero and the controllers and pulses are disabled. Only then will 109/110 open to switch off the main contactor. The voltage on the power unit can now be removed. For controlling the field supply, see parameter p50082. When the main contactor is controlled by an external contact, e.g. via the automation, the above conditions must be observed as otherwise F60004 will occur.
Note: EMC requires that the contactor coil be connected to a suppression element:
For a coil with DC current excitation, with an anti-parallel diode, for AC current excitation with an RC element.

E-stop, terminal 105/106:
No E-stop, terminal 105/106 closed. If the function is not used, a jumper must be placed between terminal 105/106.
See Sheet 2070 in Section 2 of the List Manual
If E-stop is pending, the main contactor is switched off immediately via terminal 109/110; only a slight time delay of 15 ms takes effect to de-energize the drive before the main contactor drops out.
As the main contactor relay in SINAMICS DCM has no forcibly guided contacts (in the worst case this means that the relay contact may be welded and therefore does not open), the failsafe contactor combination 3TK28 must be used if emergency switching-off is implemented according to EN60204-1. 3TK2825 for immediate switch-off (STO: Safe Torque Off) and 3TK2827 with delay via the integrated safe time element, e.g., to first execute the shutdown function in SINAMICS DCM via fast stop (SS1: Safe Stop 1). The normally closed contacts of 3TK28 are switched in series to the main contactor relay terminal 109/110 to implement the safety functions. Approx. one contactor switching time should first be confirmed in the SINAMICS DCM by the E-stop so that the main contactor opens in a de-energized state and so that F60004 does not occur. If the STO function is used, a main contactor is always required for the infeed of the SINAMICS DCM or a contactor in the DC circuit. A pulse inhibit cannot prevent the current flow (motor torque) in case of a power unit fault. For category 3, two main contactors are to be used in series.
http://support.automation.siemens.com/WW/view/en/67191091

Brake control:
Control logic has been implemented in the software to control the mechanical motor brake.
See Sheet 2750 in Section 2 of the List Manual
and Section 10.16 of the Operating Instructions

Automatic restart:
If supply faults occur (F60004, F60005, F60006, F60007, F60008, F60009), automatic restart is possible on return of the power supply for 1U1/1V1/1W1, 3U1/3W1, 5U1,5W1 within the time parameterized in p50086. This is possible provided that the ON signal for the SINAMICS DCM is maintained for this duration.
P50086 can be set from 0.00 (automatic restart switched off) to 10.00 seconds, however in the case of electronic power supply failure (5U1, 5W1, 5N1) a maximum possible failure time of 2.00 seconds is permitted – if required. The electronics supply can therefore be provided by a UPS for restart times > 2.00 sec.

Diagnostic memory: The diagnostic memory provides support in the case of troubleshooting and handling problems experienced at the SINAMICS DCM. In this case, diagnostic data is stored in a file format. A memory card is needed for saving the file. With p50832 = 1, the file is copied to the memory card.
Send your recorded diagnostic file to: support.automation@siemens.com for evaluation.
See Section 10.33.1 of the Operating Instructions and Sheet 8052 from Section 2 of the List Manual.

Trend recorder function: The trend recorder function enables data from 4 channels to be recorded over an extended period with a large memory depth. A memory card is needed for saving purposes.
The evaluation and visualization can be performed, for instance, with Excel.
See p51700 – p51706.
See Section 10.33.2 of the Operating Instructions and Sheet 8050 from Section 2 of the List Manual

Thyristor test with p50830:
See Section 10.33.3 of the Operating Instructions
Perform a thyristor test with p50830 = 3. A test of the thyristors is run after the On command (operating state o3.0). The thyristors are OK if the unit then starts operation without disruptions.
The load (motor) on the SINAMICS DCM must be connected.
Note: The thyristor test does not return clear information on whether the thyristor cannot be fired for all load states, particularly in the case of an inductive load.
The thyristor test cannot be applied in the event of series or parallel connection of SINAMICS DCM.

Faults: See Sheet 8060, 8075 in Section 2 and Section 3 of the List Manual
Should a fault occur, Fxxxxx (xxxxx is the fault number) is displayed on the BOP20.
To change the fault reaction, see parameters p02100, p02101.
To change the type of message fault/alarm/no message: p02118, p02119
Acknowledge mode: p02126, p02127
In the case of a fault, bit 3 switches from status word 1 to high.
Acknowledge all faults via BI p2102. The source of the acknowledge command (BO) is entered here. p2102 = 19.7 Acknowledge via the FN key at BOP20.
In the case of an alarm message, the diagnostic parameter r0949[0...63] must always be read out.
See also parameters r0945, r0947, r 2109, r2130, r2133, r2136, r50047.
Current fault code in CO r02131.

Alarms: See Sheet 8065 in Section 2 and Section 3 of the List Manual
If an alarm occurs, Axxxxx (xxxxx is the number of the alarm) is displayed on the BOP20.
Bit 7 from status word 1 is set to high.
The occurrence of an alarm indicates a special state of the device, but does not initiate a device response and has no effect on operation. The alarm message disappears automatically when its cause has been eliminated.
See also r2122, r2124, r2123, r2150
Type of message fault/alarm: p02118, p02119
Current alarm code in the CO: r02132.

Diagnostics for some fault/alarm messages

Fault in the armature input circuit:
F60004 occurs
F60004 occurs whenever a device is switched on:
Evaluate fault value of F60004 acc. to Operating Instructions to locate the cause.
Check the following parameters:
p50078[0]: Rated voltage of supply network for the armature circuit (neither output voltage of SINAMICS DCM nor rated motor voltage)
p50353: Response threshold of phase failure monitoring as a percentage of p50078[0]
p50086: Duration of voltage failure on automatic restart
p50089: Maximum waiting time for voltage on power unit
p50090: Stabilization time for line voltage
Observe setting instructions of parameter descriptions.

Check voltages of the armature circuit infeed:
Acknowledge pending alarm messages, set shutdown by opening terminal X177.12
Switch off field supply with p50082 = 0
Suppress F60004 with p02118 and p02119 (set to no message)
Switch on via terminal X177.12 but do not set operating enable via terminal X177.13
Operating state at r50000 must be between o4 and o1 (check r50000)
Operating state o4: Wait for voltage (armature)
Measure voltage with a voltmeter between all phases 1U1 / 1V1 / 1W1 directly at the device input
r50015: Compare display of line voltage (armature) with measured voltage
If measured voltages are not OK:
Check line fuses
Measure voltage in front of and behind the main contactor
Measure voltage at the contactor coil.
Check output for the main contactor relay terminal 109/110.

If measured voltage is OK, but operating state o4 and r50015 still not OK:
The line voltage is recorded via the ignition cables for thyristors; check whether all are correctly plugged in.
On devices with arm fuses (> 900 A rated DC current), check arm fuses.
If all checks are OK but still operating state o4:
Fault on the power interface module of the SINAMICS DCM
After diagnostics / repair, set p50082, p02118 and p02119 back to the original values.

F60004 occurs sporadically:
Evaluate fault value of F60004 acc. to Operating Instructions to locate the cause.
Check parameters as above. Check control of main contactor.
Perform trace recording with triggering in response to fault.

Field fault
F60005 occurs:
Evaluate fault value for F60005 to locate the cause
p50078[1]: Rated voltage of supply network for field circuit (neither output voltage of SINAMICS DCM nor rated motor voltage for the field)
p50353: Response threshold of phase failure monitoring as a percentage of p50078[1]
p50351: Check undervoltage threshold, refers to p50078[1]
p50352: Check overvoltage threshold, refers to p50078[1]
p50086: Duration of voltage failure on automatic restart
Observe setting instructions of parameter descriptions.
Check voltages of field circuit infeed 3U1 / 3W1:
Check fuses.

Acknowledge pending faults; set shutdown by opening terminal X177.12
Set p50082 = 1 for field supply
Perform trace recording with trigger for fault with error message activated. Set trace recording p50086 = 0.
Suppress F60005 with p02118 and p02119 (set to no message)
Switch on via terminal X177.12 but do not set operating enable via terminal X177.13
Operating state at r50000 must be between o5 and o1 (check r50000)
Operating state o5: Wait for voltage (field)
Measure voltages with a voltmeter between all phases 3U1 / 3W1 and 3C /3D.
r50016: Compare display of line voltage (field) with measured voltage

If measured voltages are not OK:
Check field input fuses, check cause of line voltage field supply fault.
If r50016 does not agree with the measured line voltage, the field module is faulty.

F60105 occurs:
p50397:Time for field current monitoring, increase time for very high inductances.
Check p50102, measure field current with ammeter.
Field current builds up slowly, this is due to the inductance of the field: Check p50396, p50397
Measure resistance of connected field coil, value should be approx. nominal field voltage divided by nominal field current as specified on rating plate of motor.
Perform diagnostics using r50034, r50035, r50036:
r50036 shows setpoint, actual value r50035 is zero, however field current is flowing and r50034 shows firing angle zero, in which case a fault has occurred in the field current actual value acquisition of the SINAMICS DCM. Replace the field module.
r50036 and r50035 deviate from one another, but field current is flowing: Check field coil. The field resistance must have the approximate nominal voltage divided by nominal field current as the ohmic value.
Calculate output voltage from firing angle r50034 and input voltage r50016 (for calculation see below) and verify voltage at 3C-3D with voltmeter; if measured output voltage shows only approx. half the calculated value, this indicates that the field power unit or field module is faulty.
Too little current flowing (but resistance of field circuit is OK), r50034 = 0 and field output voltage is not greater than the line input voltage * 0.8, a thyristor does not fire (cause thyristor, field module) or diode or thyristor in field power unit is faulty.

Undervoltage of armature/field occurs
F60006 occurs:
Check parameters p50078[0] and [1], corresponding to the rated line voltage
Check parameter p50351, refers to p50078.
p50361: Observe delay time undervoltage monitoring as setting option.
Voltage dips due to high load with weak power supply?
Perform trace recording with triggering in response to fault.

F60042 occurs:
Fault value 1: Temporarily set device to operation without tachometer p50083 = 3.
For analog tachometer, check the voltage for speed at terminal 103 / 104 and via connector r52013.
For pulse encoder, check speed via connector r00061 (in RPM) and pulse encoder input using an oscilloscope. Check setting of parameters p0400 and beyond.
Measure speed n and calculate expected EMF.
(with Ud: r50038, EMF: r50037 and Id = r50019);
EMF for rated motor speed = rated motor voltage – p50110 * rated motor current.
EMF is proportional to n between n = 0 and n = nNom

If there is a larger deviation between the measured EMF and EMF to be calculated, the motor (field circuit or armature circuit) is faulty.

Possibly increase threshold a of monitoring (p50357).

For fault value 2 (r0949) exchange input terminal 103 / 104 with analog tacho, for pulse encoder, exchange input for both tracks.

Note: The pulse encoder is evaluated by means of a differential amplifier; if the inverted tracks are not used, the minus input of the differential amplifier (terminals X177.44/46/48) must be wired to ground.

F60043 occurs:

Usually field current for active speed too high, possibly perform field weakening and reduce p50101 (rated armature voltage of the motor).

Perform trace recording with triggering in response to fault.

Note: Triggering of this alarm message can be suppressed by activating field weakening and setting p50272 = 1, see parameter description for p50272. As a result, the field current of the motor is reduced in order to lower the motor voltage to permissible values for a given speed. As a result of this necessary reduction of the field current, a delay time up until the torque direction switches over occurs as a result of the time constant of the field current reduction. This method can therefore not be used when a highly dynamic change in the torque direction is required or, for example, in hoisting applications with a suspended load, an overspeed could occur.

This setting can also be used if a higher maximum output voltage of the SINAMICS DCM is required for 4Q operation. For p50272 = 1, it is permissible to additionally set the firing angle Alpha G to smaller values than 30 degrees, e.g. 15 degrees.

If the SINAMICS DCM is not used for the armature supply of a DC motor but, for example, to feed a motor field or a solenoid, suppress F60043.

Settings:

p50051 = 27, tuning field characteristics

p50081 = 1, enable field weakening

p50272 = 1

F60167 or A60166 occurs

Check the fan's direction of rotation. The fan must rotate in the counter-clockwise (CCW) direction. Switch off of fan is allowed when the time set in p50096 is elapsed.

As soon as the voltage is applied to the power section, a fuse blows:

Armature infeed when fuse tripped without operation enable: Two or more thyristors of the power section broken down. Deenergize device infeed, disconnect motor and check resistance between all terminals 1U1 / 1V1 / 1W1 / 1C1 / 1D1, value must be greater than 100 kΩ. See also below as well as circuit diagram of power section, Section 6.4 of Operating Instructions.

Armature infeed, fuse tripped with controller enable: Resistance of load (including cable) 1C1, check against 1D1 and both against ground. No output short-circuit must be present. Perform insulation measurement of armature circuit (conductor plus motor). Perform measurement on power section as described above to check whether a thyristor has broken down.

Check current controller optimization.

Fuse tripped in the field infeed: Check resistance between 3U1 / 3W1 / 3C /3D with ohmmeter. See circuit diagram of power section Section 6.5 of the Operating Instructions. As diodes are also used here, the value between 3C/ 3D and between 3W1 – 3C / 3D is high resistance for the voltage polarity of the ohmmeter; for the others it is low resistance. See circuit diagram Section 6.4 of the Operating Instructions.

In the case of the 2Q field, all measurements must be high-resistance.

Fuse tripping of the armature infeed occurs sporadically:
Set p50086 = 0 and perform trace recording with triggering in response to fault.
Note: If line undervoltage or line failure occurs during braking this can cause the conduction-through with a tripped fuse. In braking operations (4Q-SINAMICS DCM or 2Q-SINAMICS DCM with field switchover), the line supply voltage of the power section must be faultless, any short interruptions will cause a tripped fuse. If the voltage supply is made available via sliprings (material transport vehicle, hoisting drives), equip the sliprings with multiple contacts to guarantee an uninterruptible power supply throughout.
For an article on this physical effect (conduction-through), see:
http://support.automation.siemens.com/WW/view/en/24120447
As a remedy to bad lines and frequent brake operation, the product CCP (Converter Commutation Protector), which is also available, can be implemented.
More at: http://support.automation.siemens.com/WW/view/en/21688372

Irregular speed:
Temporarily set parameters to EMF control with p50083 = 3, if speed is then regular check speed actual value with Trace (r52013 for analog tacho, r50061 for pulse encoder). Check whether encoder is correctly mechanically adjusted.
Check speed controller optimization, see also below: Notes about the optimization run:
Depending on the drive mechanism it may sometimes be necessary to re-optimize the speed controller manually.
The following values can provide some orientation help:
Crane drives:
p50225 = 7 - 11, p50226 = 0.2 - 0.4 s
Drive with large masses (main drive printing machine, dry end on paper machine):
p50225 = 20 - 30, p50226 = 0.6 - 1.0 s
Cross cutter (good mechanical system is a requirement):
p50225 = 25 - >30, p50226 = 0.1 - 0.2 s
Extruder, rolling mills:
p50225 = 5 - 10, p50226 = 0.4 - 0.6 s
Positioning tasks (e.g. synchronized crane traveling gear):
p50225 = 5 -10, p50226 = 0.2 s
Constraint: Rated converter current = 1.5 * rated motor current.
If the converter/motor ratio is larger, Kp must be reduced proportionally.
On no account may the speed controller output exhibit periodic vibration or rattling in the gear unit. In this case, p50225 must be reduced and possibly p50226 increased.
If necessary, additionally set slight speed actual value smoothing of 0 - 50 ms for a pulse encoder or analog tachometer, approx. 40 ms for EMF control in p50200.

Drive vibrates mechanically at a particular speed:
There is mechanical resonance in the system. As a remedy, a band filter can be inserted in the speed actual-value channel (two for suppressing two frequencies exist). Sheet 6810.
p50623 = 52177. Set the resonance frequency, quality depends on the width of the resonance band. Use of a band filter makes it possible to set a larger Kp for the speed controller without vibration occurring.

Irregular current:
Check current controller optimization, it is usually sufficient to perform a current controller optimization run with p50051 = 25.
If non-linear load inductances are present, for example, if iron core smoothing inductors used, as recommended for 12-pulse parallel connections or for old motors, set p50153 = 2.
For supply of DC voltage links with smoothing capacitors, set p50153 = 2.
If irregular current occurs close to current zero: Set p50162 = 0 and p50163 = 1.
The dynamic response of the current actual value during current control is usually due to the load and therefore normal, if the required speed is correctly controlled. Re-optimize the speed controller if the current actual value oscillates periodically.

Current peaks can also be caused by commutation problems on old motors. On old motors set p50157 = 1 and p50158 = approx. 0.04 seconds.
Even a weak network can cause current fluctuations if the undervoltage threshold p50351 is reached when the automatic restart time p50086 is set to a value greater than zero. For test set p50086 = 0.

Motor speed oscillates when stopping in the opposite direction via:

This is due to the I-component of the speed controller; because it must first integrate down toward zero, this must cause overshooting in the other direction of rotation.
Remedy: Activate automatic switchover to P control for low speeds. Setting:
Set switchover threshold p50222 = 2 to 5 %. The content of the binector, the parameter number of the binector set in p50698 must be 1, e.g. set p50698 = 1. You can selectively activate automatic switchover with this binector selection, for example, to suppress it during a positioning action.

The motor produces no torque although the necessary armature current is flowing:

Check the current load current with r50019 and measure with an ammeter, any deviations may point to a fault in SINAMICS DCM. Check current controllers, load resistors (R805 phase U, R806 phase W, see Section 6.4 Operating Instructions) of the current measurement, check voltage drop at the load (device-specific and dependent on p50076[0]).
Possible fault on the Power Interphace Board.
Perform trace recording.
Check field supply, measure field current and if existent, measure field voltage. If field current OK and field voltage not OK, an interturn fault in the field winding, which means that the motor flux is too small could be the cause.
Approx. 25% deviation from the rating plate data for the motor field as a function of the winding temperature is normal.
Any ground fault of the field winding can have a similiar effect.
Check armature circuit of motor.
Measure insulation resistance field circuit and armature circuit.

Motor does not reach voltage:

The SINAMICS DCM device only generates so much output voltage that the current actual value does not exceed the set current limit.
The motor voltage is proportional to the product of speed and motor field (flux Phi: Φ). If the speed is low for the rated flux of the motor, a relatively low motor voltage will result.
However, if the speed is high and practically no motor flux Φ exists, for example, because of a fault in the field winding, in this case, too, a low motor voltage will result. The physical relationship is explained below.

Motor turns several percent too slowly when an analog tachometer is used:

The high-resistance input for the analog tacho (terminal 103/104) may mean that the load on some tachometers is too low and so therefore output a voltage that is too high compared with the rating data. As a remedy, an additional base-load resistor can be placed parallel to the tacho output – observe the rating plate data on the tachometer.

Module replacement:

Before installing the replacement module, compare its part number with the old number.
C98043-Axxxx-Ly-zz; xxxx: Number of the module, e.g. 7100; y: L number.
The number up to the L number y must be the same. The version zz of the module is irrelevant; all previously supplied versions of the module bearing a part number identical up to the L number are compatible.

Item number	Designation	Order number (MLFB)	For firmware
C98043-A7100-L1	Standard CUD	6RY1803-0AA00	V1.1, V1.2, V1.3
C98043-A7100-L2	Advanced CUD	6RY1803-0AA05	V1.1, V1.2, V1.3
C98043-A7100-L100	Standard CUD painted	6RY1803-0AA20	V1.1, V1.2, V1.3
C98043-A7100-L200	Advanced CUD painted	6RY1803-0AA25	V1.1, V1.2, V1.3
C98043-A7100-L3	Standard CUD	6RY1803-0AA00-0AA1	All versions
C98043-A7100-L4	Advanced CUD	6RY1803-0AA05-0AA1	All versions
C98043-A7100-L103	Standard CUD painted	6RY1803-0AA20-0AA1	All versions
C98043-A7100-L204	Advanced CUD painted	6RY1803-0AA25-0AA1	All versions

Replacement of the CUD: When replacing the left or right-hand (optional) CUD, the parameters must be loaded to the replacement module e.g. using the STARTER or memory card. Alternatively, system-specific parameters can be entered via the BOP20 or AOP30 at the left-hand CUD or with the AOP30 at the right-hand CUD.
Once the parameters have been loaded, "copy from RAM to ROM" must be performed. When using the DCC, the memory card of the old module must be inserted in order to load the DCC plan and the program library into the CUD.
Note: If a memory card is inserted in the CUD during the copy RAM to ROM procedure, the parameter is not only saved in the ROM of the module but also on the memory card. This memory card can now be inserted into the replacement module. In the case of a subsequent "Power ON", the parameters are then loaded from the memory card into the RAM of the module.
Note: If the parameter assignment is loaded to a drive with a different MLFB 6RA80..., the software is able to detect that the parameter assignment does not match the drive. In this case, the device remains in power up with "33" displayed at the BOP20, as the device and motor-related parameters are no longer applicable. The user must confirm that this data should be accepted. Set p9905=2 to continue powering up.
Note: Before replacing the modules, all the inputs and outputs of the SINAMICS DCM, including those of the electronics voltage supply, must be de-energized.

Replacing a device:
Same procedure as replacing the CUD.
Note: Prior to returning the faulty CUD or device, remove the memory card and use this in the replacement product for loading the parameters.

Distribution of functions to the modules in the SINAMICS DCM:
The purpose of this list is to show which modules are involved in the various actual value acquisitions, to help ascertain which modules need to be replaced if a fault occurs. You will find the part number of the module in the screen print on the module. It is C98043-A.....
You will find the order number for spare part orders in spare part list on Spares on Web.
www.siemens.com/sow

CUD: See block diagram in Section 6.3 of the Operating Instructions.
Processor electronics for open-loop and closed-loop control; part number:
C98043-A7100-L1/L3 (Standard CUD), C98043-A7100-L2/L4 (Advanced CUD).
Evaluation of the analog and binary inputs and outputs
Evaluation of motor temperature sensor KTY84 / PTC / PT100 / NTC
Serial interfaces, parallel connection interface,
Pulse encoder evaluation: For possible pulse encoders, see the parameter description for P00400.
Note: Evaluation of the tracks of the pulse encoder is performed by means of differential amplifier for evaluating the push-pull tracks of pulse encoders. A-A/, B-B/. If only signals A, B, and not cross-signals A/ and B/ exist, the negative signal inputs of the differential amplifiers, terminals: X177.44, 46, 48 are to be connected to the electronics ground.

Note: Analog inputs are evaluated by means of the differential amplifiers, meaning that the minus input of the amplifiers must be connected to the ground of the respective measured signal.

Output reference voltages P10 and N10

Output P24, for controlling the binary inputs.

This is a pure output, feeding of external voltages at these terminals is not permitted.

Output P15, 200 mA for pulse encoder power supply

24 V digital outputs can each be loaded with 100 mA via a transistor.

Generation of firing pulses for the thyristors of the armature and field power unit.

Calculation of all open-loop and closed-loop control functions for armature and field with direct generation of the firing pulses for the thyristors.

Power interface module:

See block diagram in Section 6.3 of the Operating Instructions.

Part number: C98043-A7105/7106/7106/7108 -Lx, x stands for the module variant e.g. for 2Q/4Q and depends on the rated voltage of the SINAMICS DCM.

Input electronics power supply: 400 V: via 5U1/5W1, 5N1 open, or 230 V: connected via 5U1-5W1 and 5N1, fuses F200/F201 to protect the input. 24 V power supply for L05 option.

Terminals 105106 for E-stop

Terminals 103/104 for analog tachometer input and prescaler 159 kOhm.

Relay output terminal 109/110 for main contactor control

Recording of the fan speed monitoring XV1, XV2, XV3

Recording of the line voltage armature infeed (synchronization for the armature gating unit is also derived from this) and output voltage armature. The voltage is recorded via the firing pulse cables: The voltage measurement is isolated

Note: Direct measurement of the line voltage on the power unit does not result in dependency of the assignment of the phase angle for the power unit with respect to the electronics current supply. The electronics infeed can therefore be provided by a UPS without reservation.--

The power infeed can have a clockwise and counter-clockwise rotating field (rotating field-independent synchronization is provided). –End of note-

Isolation of the firing pulses to the thyristors via pulse transformer.

Power transistors to control the pulse transformers.

10 ohm load resistors for the current transformers (input X7, X8) of the actual current sensing.

Connector XT5 for connecting temperature sensor NTC 10 kOhm (R100), mounted on the heatsink, for the heatsink temperature acquisition and for devices with 6RA80..-4 disk-type thyristors mounted in the supply air flow of the device (optional) for monitoring of the ambient temperature.

Field module:

See block diagram in Section 6.3 of the Operating Instructions.

Part number: C98043-A7115 / A7116

Firing pulses for field supply by electrical isolation provided by pulse transformers

Shunt resistors for actual value sensing of the field supply:

Evaluation of actual field current value

3U1/3W1 power terminals, infeed, field supply and output 3C/3D

Line voltage measurement infeed, field supply isolated. The synchronization for the field gating unit is also derived from this.

Note: Sensing directly at the field supply infeed means that any phase angle is possible. Assignment to the phase angle of the infeed of the armature power unit or the electronics infeed is immaterial.

Power unit 15 and 30 A devices:

Part number: C98043-A7111

Power unit wiring and surge absorbing capacitor circuit, power unit (thyristors, diodes) armature and field

Gate pulse transformers for floating control of the thyristors of the field supply

Power terminals: Field supply.
Field current actual value acquisition, shunt resistors and AD conversion
Line voltage measurement field infeed, also used for synchronizing the field gating unit.
Allocation Board:
Part number C98043-A7126, provides the terminal with plug connection to further modules
The EEPROM, the non-volatile memory for device data, is located on this module.
The device parameters are not saved on the allocation board, but in the ROM of the CUD.
If ordering this module as a spare part, specify the factory serial number and the MLFB
(order number 6RA80...) of the device so that the manufacturer can load this data into the
module before delivery.
Surge absorbing capacitor circuit:
Various modules depending on the rated data: Voltage / current of the devices.
The thyristors are synchronized by means of an RC element, the surge absorbing capacitor
circuit. Transition from a conducting to a non-conducting thyristor state occurs with a fast
current change. A fast current change in the circuit leads to overvoltages as a result of
available inductances ($u = L * di / dt$). The surge absorbing capacitor circuit is dimensioned in
such a way that any overvoltages resulting from commutation will be below the blocking
voltage of the thyristors.
Note: A fault in the surge absorbing capacitor circuit can cause thyristor failure due to
overvoltage.

Controller structure of the SINAMICS DCM

The structure of the controller for the armature circuit:
Ramp-function generator:
See Sheet 3150, 3151, 3152 in Section 2 of the List Manual and Section 10.11.1 of the
Operating Instructions The ramp-function generator changes speed setpoint that suddenly
changes by means of an ascending ramp (ramp-up time p50303) and a descending ramp
(ramp-down time p50304) In addition, a lower transition rounding (p50305) at the beginning
and an upper transition rounding (p50306) at the end of the ramp-up function can be set. See
also p50611 to p50614.
The ramp-up/ramp-down time should be set high enough that the speed actual value can
follow the setpoint of the ramp-function generator output. This is the case if the set
current/torque limit of the drive is not reached during the ramp-function generator action and
the drive is still located in the possible control range.
the ramp-function generator times must be set to zero during positioning control with a
higher-level automation.
Setting the ramp-function generator to the content of the connector number in p50639:
P50639[0], set for the ramp-function generator output on a high signal from the binector
selected via p50640
p50639[1], setting the ramp-function generator output when Run state is no longer active
and the content of the binector selected in p50640 is low.
See also parameter p50295, p50302, p50317, p50318 and p50636 to p50641, p50646 and
p50647
Display of active times: r50315, display of ramp-function generator state: r50316.
Speed setpoint:
At ramp-function generator input: r52192; at ramp-function generator output: r52190,
at speed controller input: r52170.
Actual speed value:
Sheet 6810
Analog tachometer as the actual speed value (p50083 = 1), r52013, Sheet 2075
Normalization via p50741;
Pulse encoder as actual speed value (p50083 = 2), r00061 in RPM, Sheet 4710.
Normalization via p2000,
Pulse number of encoder p0400;

EMF as the actual speed value (p50083 = 3). Sheet 6810, normalization p50115.
CO: r52287. The EMF is the calculated induced motor voltage, generated from the measured device output voltage and the voltage dips I*R and L*di/dt of the motor.
The precision of this type of control is largely determined by the change in resistance of the armature winding of the motor via the temperature and amounts to approx. 5%.
For EMF control: Set speed actual value filtering p50200 = approx. 40ms.
Freely selectable speed actual value source (p50083 = 4), the number of the connector parameter from which the actual speed value is derived is set in p50609. Sheet 6810.
P50083 = 5: Actual sped evaluation via SMC30.
If necessary, set a small filtering time for the actual speed value: p50200 = approx. 5 to 40ms. Actual speed value at speed controller input: r52166 as absolute value, r52167 as bipolar signal. Irrespective of the signal used for the control and selected with p50083, the other evaluated speed actual value quantities are also always available, e.g. for the required display of the EMF actual value when controlled with a pulse encoder or analog tachometer, or by using a second encoder for technological control.

Speed controller:
The output of the ramp-function generator is the speed setpoint value for the following speed controller, Sheet 6810, 6815.
It calculates the deviation between the speed setpoint and actual value and prescribes the setpoint for the following lower-level current controller after an intermediate torque calculation.
The speed controller is implemented as a PI controller (an additional D component can be connected via the derivative element p50205 / p50206). One characteristic of a PI controller is that it adjusts the error variable, in this case, between the setpoint and actual value for speed, to zero if the setpoint is constant.
The characteristic quantities of the controller, the gain Kp (p50225) and the reset time Tn (p50226) can be adjusted based on an additional variable, such as an actual speed value. Sheet 6805. This permits stable operation within a broad control range even with special applications.
Used, for example, with low speeds on feed drives.
A droop function, Sheet 6805, is also available. The droop function, for example, is used to achieve smooth load distribution for several drives coupled via the material.
Control method depends on the parameter assignment:
p50224 = 1, p50234 = 1, PI controller: Factory setting
p50224 = 0; p50234 = 1, P controller
p50224 = 1; p234 = 0, I controller
For optimization, see below.
Speed controller as the voltage controller: Some applications require control to a constant output voltage of the SINAMICS DCM.
Settings of the voltage actual value for control: p50083 = 4; p50609 = 52292 (connector actual voltage value).
The speed control stability is specified in the technical data of the Operating Instructions. This is a long-term stability referred to a longer measuring time, e.g. 10 seconds. Deviations within a short monitoring period, e.g. as the result of a load surge, are higher than specified. Specific values cannot be given as these short-term deviations depend on the actual conditions of the system and optimizations. See also below.

Speed controller pre-control:
Sheet 6820.
Compensation of the moment of inertia: The torque required for the speed change depends on the moment of inertia of the load and the desired speed rate of change. The necessary correcting quantity is calculated from the dv/dt of the ramp-function generator output (rate of change of speed) and is added to the speed controller output.
Friction compensation: The friction is speed dependent, the torque required to overcome the friction is derived and added to the speed controller output.
The above correcting quantities can be derived automatically with optimization run

P50051 = 28. These compensations offload the speed controller and permit a higher speed control dynamic response.

Selection of compensation via p50223 = 1, Sheet 6815

Torque calculation:

Sheet 6820. Depending on the setting for p50170, the output of the speed controller indicates the torque setpoint or the current setpoint. The motor torque is determined using flux Phi of the motor. For theory, see below

Setting: p50170 = 0, the speed controller output is the current setpoint that can be passed on to the current controller without any further calculation (except limitations).

P50170 = 1, the speed controller output indicates the torque setpoint, the current setpoint for the current controller is determined by the next calculation M/ Φ. One advantage here is that the controlled system gain of the speed control loop is adapted suitably automatically within the field weakening range of the motor, producing a stable speed control response.

Torque setpoint before limitation: r52145, after limitation: r52141.

The precision of the torque control dependent on the device is approx. 3%. (influence of actual current sensing, armature and field, taken into account and field characteristic curve recording performed, if there is field weakening). The influence of the motor is low for a fully compensated motor, but motor-related for a non-compensated motor.

Note: If the motor is only operated in the armature setting range (no field weakening), flux Φ is always 100% and setting p50170 = 1 has no effect.

If p50170 = 1, p50169 = 0 must be set.

Current setpoint integrator / Reduced gearbox stressing

Sheet 6845, p50157 = 1, current setpoint integrator: The ramp-function generator for the current setpoint is effective for every current setpoint change of r52120, recommended setting.

P50157 = 0, reduced gearbox stressing: The ramp-function generator time is only effective for a change of torque direction.

p50158 = Ramp-up time in seconds

On old motors, set p50157 = 1 and p50158 = approx. 0.04 s, required for good commutation of the current in the old motor.

Actual value of current

The armature current is sensed on the AC input side by one current transformer in each of the U and W phases. The current transformer load for each current transformer is on the power interface module and is 10 ohm. The load voltage is evaluated on the power interface board. The rated DC current of the SINAMICS DCM is adapted via the transformation ratio of the current transformer and electronically on the power interface board.

The DC actual value is formed from the two load voltages of the current transformers on the power interface board with electronic rectification (A/D converter). 100 % are the value of r05072[1] after normalization via p50076[0] and/or p50067.

The precision of the sensed armature current is 1% of the nominal value.

Note: Both of the current transformers must always be loaded with a load resistor, otherwise they will be damaged by internal overvoltage on current flow.

Current control loop

Sheet 6855

The current control loop adjusts any deviation of the current setpoint: r52118 (100% corresponds to the value of r50072[1] and of the current actual value: r52019 (100% corresponds to the value of p50100) to zero. In the current control loop the current controller acts as the PI controller. Current controller precontrol is active at the same time. The output of the current controller and the precontrol are added and the sum of the two quantities forms the firing angle.

Current controller: The current controller is a PI controller; its parameters for optimization are the Kp (p50155) and the reset time Tn (p50256). For optimization, see below.

Depending on the parameter settings can also be run as a P or I controller.

p50154 = 1, p50164 = 1; PI controller, factory setting

p50154 = 0, p50164 = 1; P controller

p50154 = 1, p50164 = 0; I controller

The current controller adjusts the setpoint/actual value difference of the current via its PI characteristic curve by forming the suitable firing angle for the gating unit.
Precontrol: The precontrol acts simultaneously with the current controller and ensures the dynamic response of the current control loop both for discontinuous and continuous current. Above all, the precontrol ensures that the firing angle for the existing non-linear control characteristic and the varying firing angle requirement for a change in the actual current value for discontinuous and continuous current is calculated and precontrolled to the correct extent.
From Firmware V1.2 an adaption for the current controller is implemented. See List manual chapter 2 sheet 6853.
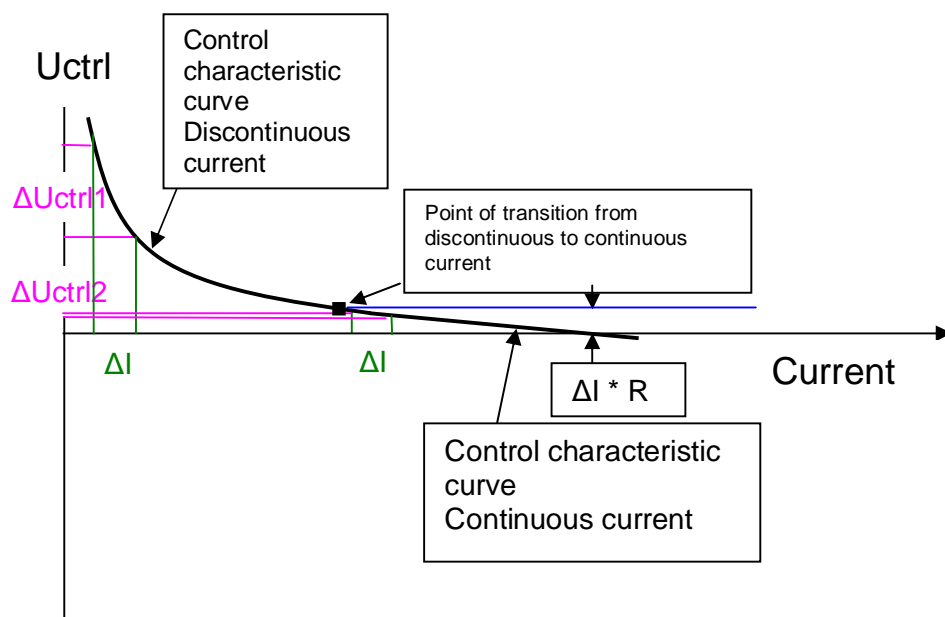
To effect a current change ΔI a firing angle change ΔUctrl must be applied. If ΔI is equal, the necessary control firing angle ΔUctrl1 in the discontinuous current range is much higher than ΔUctrl2 in the continuous current range. The firing angle change only has to take account of the armature-current-related linear voltage drop I * R in the continuous current range.
The point of transition from discontinuous to continuous current (see below) is determined by the inductance in the load circuit and the current motor EMF.
The control characteristic above applies to a particular motor EMF, the curve moves up or down depending on the current EMF.
The precontrol calculates the firing angle depending on the current setpoint and the EMF of the motor, uses it to compensate the above non-linearities and sets the required firing angle without delay for the following gating unit. The current controller now only has to correct by a small amount. This ensures that even for greater dynamic requirements such as cross-cutters, for example, the required dynamic response of the current control can be provided.
p50153 = 0, The precontrol is not active
p50153 = 1 Factory settings, precontrol dependent on current setpoint and EMF active
p50153 = 2 Current-setpoint-dependent precontrol active, EMF influence not active, with torque direction change or on start via controller enable, the I component of the current controller is set to the firing angle component as a condition of the EMF. Recommended

settings if non-linear smoothing reactors exist in the armature circuit, e.g. two-value reactor in 12-pulse operation or iron-cored reactors on applications for old motors.

P50153 = 3 Precontrol assumes EMF zero, this is for applications that do not use EMF and for high inductance loads in field supply or solenoid applications.

Gating unit

The gating unit is the interface to the power section. The firing instant of the thyristors is defined by the offset of the firing angle from which an alternating variable direct voltage is formed. Phase control of the AC input voltage with suitable assignment of the thyristors to be fired is performed in such a way that a variable direct voltage occurs at the output, see below. The firing angle is calculated as a function of the zero crossing of the line voltage (voltage measurement of 1U1/1V1/1W1 on the power interface board).

The gate pulses are formed on the CUD, the gate pulse transformers are located on the power interface module. The gate pulse transformer receives the chopped pulses, see below. The duration of the firing pulse burst is 0.89 ms for a short pulse setting of p50079 = 0 (factory setting). For a long pulse setting of p50079 = 1 the duration of the pulse burst is 0.1 ms before issue of the subsequent firing pulse.

Note: For normal applications always use short pulses with p50079 = 0. p50079 =1 Long pulses, intended for supplying large inductance to ensure that thyristors trigger. In the case of long pulses, the thyristors might not block on some network configurations, detailed support on this effect is available from Technical Support. When supplying large inductances with short pulses, a resistance must be implemented parallel to the load with a current of approx. 500 mA at nominal voltage for the load, to ensure that the thyristor attains the holding current of approx. 200 mA for the duration of the firing pulse. The thyristor will only remain conductive when the holding current is reached.

Example of parallel resistance: Nominal direct voltage 310 V / 0.5 A = approx. 680 ohm, load capability in watts: (line voltage $* 1.35)^2$ / resistance in ohms. In the above example, a 400 V line voltage and 680 ohms results in approx. 450 watts load capability for the resistance. – End of note-

Operation on weak networks (generator with diesel drive):

On weak-frequency networks, frequency changes of up to 10 Hz per second are permissible. For this, parameter p50152 Line frequency correction armature (factory setting 20) must be set to lower values. The correct setting depends on the system conditions and must be verified with trace recordings. The current measured should exhibit a steady current without current peaks. Parameter p50252 must be observed for the integrated field supply.

Note: A diesel generator cannot absorb regenerative current. In such a case, it is therefore important that load resistors on the AC infeed side of the SINAMICS DCM are switched on during braking mode with a resistance value that is high enough to ensure that the generator always works generatively. Engineering support on request.

Firing angle limits

Sheet 6860.

Control limit Alpha G: The setting of Alpha G (p50150) determines the maximum possible output voltage of the SINAMICS DCM. Smaller angle values mean higher voltage possible. For calculation see below. Factory setting 5 degrees for 2Q devices, and 30 degrees for 4Q devices and for 2Q with field switchover 30 degrees like for 4Q is required to ensure that the output voltage in motor operation is not too high and that on transition to braking mode with Alpha W 150 degrees enough back-EMF can be accumulated. If the output voltage of the device before transition into braking mode is too high, F60043 is output in order to protect the drive from conduction-through. See also the description for F60043.

Inverter stability limit Alpha W: Alpha W is set at p50151, factory setting 150 degrees. Limit Alpha W is required to provide the necessary protection angle to allow the thyristor to block before commutation to the next thyristor. On weak power supply networks it may be necessary to reduce Alpha W, for example, set 145 degrees. For discontinuous current, the angle can be larger because the thyristor no longer carries current during commutation, so that Alpha W 165 degrees becomes active if zero current is signaled. This offset to 165 degrees can be prevented with p50192 = 1, then p50151 is always active.

Command stage

The command stage controls the torque direction change for 4Q drives.

Sheet 6860. The requested torque direction is derived from the polarity of the current setpoint of connector r520119. If the requested torque direction does not correspond to that which is currently active, the torque direction is changed. The firing angle is pushed across the firing angle limitation to Alpha W in order to reduce the actual value for current to zero. The torque direction change is then performed 0.5 ms after the current zero is issued. The signal of the binector set on p50165 (factory setting 53190.0) is taken into account as an additional interlock. The interlock is required for 12-pulse parallel connections to ensure that both converter systems have the same active torque direction. See also the description of applications for 12-pulse operation.

An additional number of Alpha W pulses can be set via p50161 and p50179, which are executed before the torque direction is changed, and which is required for supplying large inductances. A torque-free pause can be set with p50160.

Torque direction 1 set: Firing pulses for MI1 to MI6 present.

Torque direction 2 set: Firing pulses for MII1 to MII6 present.

Limits

Limits can be set between the control loops in order to adapt the maximum values to the system requirements.

Limitation before the ramp-function generator, Sheet 3135

Limitation after the ramp-function generator, Sheet 3155

Torque limitation, Sheet 6830

Speed limitation controller, Sheet 6835

Current limitation, Sheet 6840

Firing angle limitation, Sheet 6860

Example of limitation before ramp-function generator:

Positive limitation: The connector number is set at p50642[x], which acts as a positive limitation. Four values can be set via the four indices, of which the lowest value of the connector contents acts as the limitation.

Negative limitation: The connector is set at p50643[x], which acts as a negative limitation. Four values can be set via the four indices, of which the highest value of the connector contents acts as the limitation. Here, mathematically, minus 10 % is larger than minus 40 %, for example.

Technology controller

See Chapter 10.15 of instruction manual

Controller structure for the field circuit

EMF control loop

Sheet 6900. If p50081 = 1, field weakening possible, the following applies: If the EMF actual value (r52286) is higher than the EMF setpoint (r52288), the EMF control loop is activated and reduces its output variable, field current setpoint (r52268), to reduce its EMF with field weakening of the motor.

EMF controller:

p50274 = 1, p50284 = 1 The controller acts as the PI controller, factory setting, recommended setting

p50274 = 0, p50284 = 1 The controller acts as the P controller

p50274 = 1, p50284 = 0 The controller acts as the I controller

Optimization variables for the controller: Gain Kp (p50275) and reset time Tn (p50276).

The EMF controller is responsible for the fine adjustment of the setpoint/actual-value difference; the precontrol functioning in parallel with this performs that main dynamic tasks. The input variables of the precontrol are the EMF setpoint and the speed, the output is precontrolled depending on this by means of the recorded field characteristic curve. This means that a recorded field characteristic curve (motor-specific) is a requirement for P50081 = 1. If a non-remediable fault occurs during recording of the field characteristic curve (p50051 = 27), the field characteristic curve must be recorded manually.

In many practical cases, however, the following parameter settings are possible:

P50081 = 1, p50117 = 1, p50253 = 0.

In this case, the precontrol of the EMF control loop is disabled and the field weakening control is only performed by the EMF controller, field characteristic curve recording is then not necessary.

If p50081 = 0 no field weakening control is performed and the field current is input as a constant quantity, the EMF control loop is not active.

Field current setpoint limitation

After the output of the EMF control loop, a field current setpoint limitation takes effect.

The upper limit value is determined by r50073[1], the rated field current for the SINAMICS DCM. Additionally, multiplying influence on the limit is possible by entering the required connector number in p50613.

The field current setpoint lower limit is determined by p50103 and a connector variable with a multiplying effect for the connector selected in p50614.

Actual value for field current

The actual field current value is sensed by means of shunt resistors on the field module. The shunt resistance complement is dependent on the device data. The voltage drop of the shunt resistors is converted by a A/D converter on the field supply board.

100 % of r50073[1] corresponds to the current field nominal current for a 100% actual field current value for the field current control. The rated device field current r50073[1] results in the currently applicable rated device current, field after adjustment with p50076[1] (1 to 100%) for the field current control.

The precision of the actual value sensed for the field current is 1% of the nominal value.

Field current control loop

Sheet 6910, field current controller:

P50254 = 1, p50264 = 1 The controller acts as the PI controller, factory setting, recommended setting

P50254 = 0, p50264 = 1, The controller acts as the P controller

P50254 = 1, p50264 = 0, The controller acts as the I controller

Optimization variables for the controller: Gain Kp (p50255) and reset time Tn (p50256).

the PI field current controller adjusts the field current to a setpoint/actual value difference of zero and provides the firing angle for the field current gating unit as the output.

A precontrol is active at the same time and has a different characteristic curve than the armature current control loop because it includes a half-controlled bridge circuit.

Firing angle limitation

The firing angle limitations in the factory settings are p50250 = 0 degrees for Alpha G and p50251 = 180 degrees for Alpha W.

If the field winding has a low nominal voltage, Alpha G can be set to higher values to limit the maximum output voltage in the case of a fault and thus protect the field winding of the motor from overload. For calculation, see below.

Gating unit

The gating unit synchronizes to the line voltage of the field supply (measured on 3U1/3W1 on the field module) and, according to the current firing angle, supplies the firing pulses for the thyristors for the generation of the variable output DC voltage to inject the required load current.

Optimizing the controller with optimization runs

.Optimization runs provide effective support for controller optimization. See Section 8.2 of the Operating Instructions.

For optimization runs set p010 = 0.

Possible faults during the optimization runs are F60050 or F60052. The causes are described in r50047[0] (fault value)

Field current controller optimization run p50051 = 24:

Armature current controller optimization P50051= 25. This optimization run must be executed whenever possible and results in nearly all cases in sufficient optimization of the current control loops. If a permanently excited DC motor (excitation via permanent magnets in the motor stator) is used, the rotor must be locked during current controller optimization.

Note: During current controller optimization the motor must be at standstill; if necessary, lock the motor shaft.

On highly dynamic drives, such as are used for cross cutters or feed drives, it may be necessary to manually optimize the armature current controller, for this, the controller is supplied with current setpoint step changes and the step response at the output of the controller is evaluated with the Trace (using the STARTER), see below.

The optimization run optimizes the current controller based on the absolute value optimum.

Speed controller optimization run with p50051 = 26. Optimization of speed control loop and moment of inertia.

Supplies satisfactory results for many normal applications. In the case of high moments of inertia, a high Kp (p50225) is often determined by the automatic optimization; if the mechanical system is not optimum, it may frequently be necessary to reduce this derived Kp by approx. a factor of 2.

Before performing the optimization run with p50236, set the required extent of dynamic response of the speed control loop (100% corresponds to the highest dynamic response). Recommended values: 100% is possible for optimum mechanical systems. In practice, a setting of p50236 = 30 is usually sufficient and suitable.

In the case of backlash in the gear: p50236 = set approx. 30%. If the optimization is performed under load, both the centrifugal force of the motor and the load for the optimization is taken into account.

The optimization run optimizes the speed controller based on the symmetrical optimum.

If the motor is operated in field weakening, the field characteristic curve recording must be performed with p50051 = 27. (If no field weakening is required, this optimization run need not be performed). After the optimization run, activate field weakening with p50081 = 1.

Do field characteristics manually::

http://support.automation.siemens.com/WW/view/en/41165031

p50051 = 29 Optimization run on an mechanically oscillating system (long shaft or belt drive)

Manual controller optimization using the square-wave generator

Step changes in the setpoint can be defined for the controllers using the square-wave generator, Sheet 3120. The controllers can be adapted manually by suitably setting the controller variables, the gain Kp and the reset time Tn, and analysis of the step response.

The setpoint step change and the step response of the controller can be recorded and evaluated using the Trace function of the STARTER.

The setpoint step change should only be high enough to keep the controller within the control range, i.e. so that the controller does not reach a limit, e.g. the current limit.

Extent of step change approx. 2% to 5%, depending on the system configuration.

Setting of the square-wave generator:

p50480: Higher value of the setpoint step change

p50482: Lower value of the setpoint step change, e.g. 2% lower than p50480

p50481: Duration for the setpoint as per p50480, e.g. 0.1 seconds

p50483: Duration for the setpoint as per p50482, e.g. 0.1 seconds

Activation of the output of the square-wave generator of connector r52208, by setting the binector number in p50485.B; e.g. p50485 = 1 (permanently "Oscillation On").

Setpoint step change for current control loop:

p50601[4] = 52208, couple output of square-wave generator with input of current control loop (current controller plus current controller precontrol). Sheet 6840.

Operate motor at standstill. Switch off field with p50082 = 0 and enter an ON signal plus operation enable via terminal X177.12 and .13.

Check effects of settable filters p50191 and p50190.

Step reponse for discontinous current, e.g. p50480 = 15% and continuous current

check e.g. p50480 = 40%. The point of transition from discontinuous to continuous current is influenced by the inductance in the load circuit and is approx. 30 % of the rated motor current (test for any system-related deviations). Perform controller optimization with Kp, p50155 and Tn, p50156 in the continuous current range.
If F60031 occur increase p50388.
Optimization is performed based on the absolute value optimum.
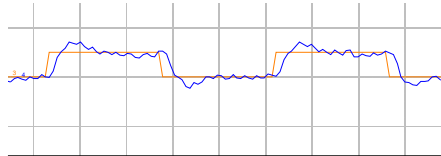
Automatic current controller optimization
Setpoint step-change from 40 to 50 % current setpoint (orange);
Actual current value (blue)
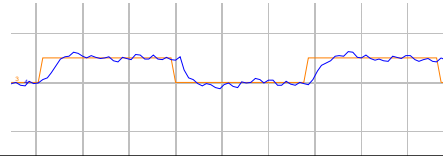
Automatic current controller optimization
Setpoint step change from 40 to 50 % with current setpoint filtering
P50191 = 9 ms

Setpoint step change for the speed controller:
p50625 = 52208, couple output of square-wave generator with input of speed controller.
Sheet 6810.
Activate field with p50082, enter ON command and operating enable via terminal X177.12 and 13. Record step response.
E.g. step response from 15% to 18% speed setpoint.
Perform controller optimization with Kp, p50225 and Tn, p50226.
Optimization is performed based on symmetrical optimum, see below.
Test affect of filtering on p50228, optimum conditions (only slight overshooting) occur when the filter time p50228 is equal to the reset time Tn (p50226) of the speed controller.
Notice: The setting for p50226 is in s, the setting for p50228 is in ms.
When F60031 occur increase p50388.

P50236 = 75 %
P50226 = p50228 [ms]

55%

100%

P50236 = 75 %
P50228 = 0

P50236 = 30 %
P50226 = p50228 [ms]

12%
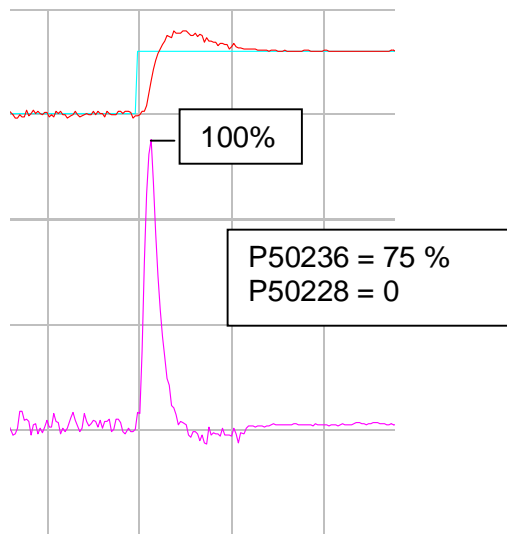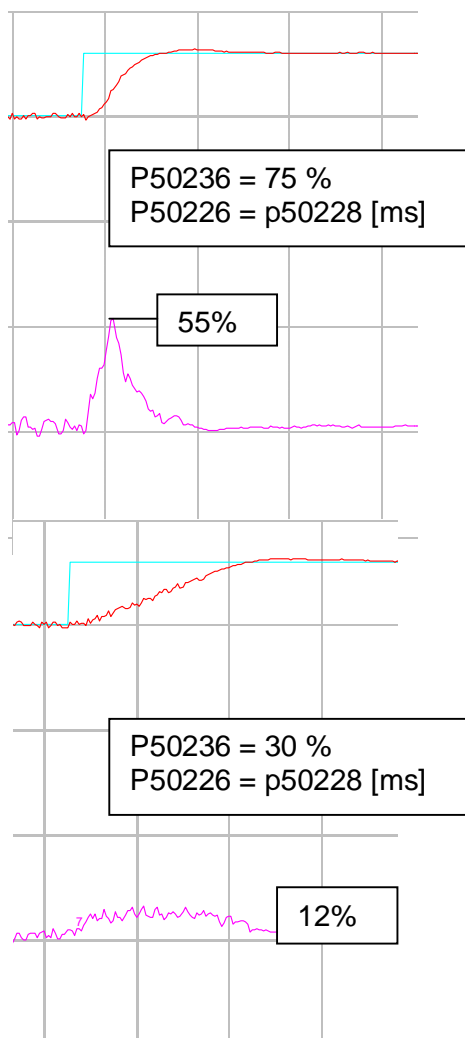
Setpoint step change from 15 % to 18 %
n-set
n-act
i-act

Automatic speed controller optimization
where p50236 = 75 % and p50236 = 30 %
n-set filtering p50228 equal to reset time
p50226 reduces overshooting of n-act

Referencemodel
See operating instructions chapter 10.13 and List Manual chapter 2 sheet 6812, 6815.
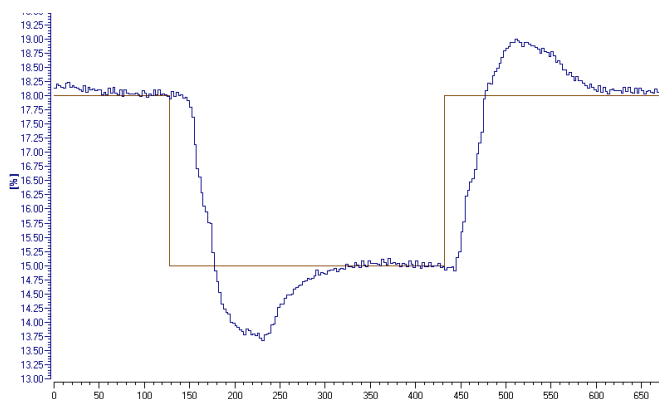
Setpoint change from 15% to
18%
PI controller, p50228 = 0
Without reference model
Speed controller overshoots
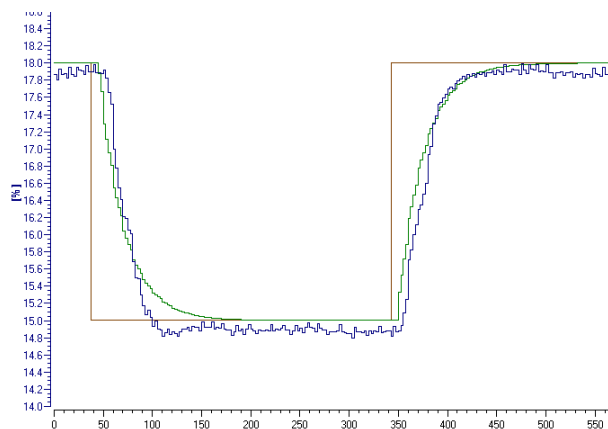
Setpoint change from 15% to 18%
PI controller, p50224 = 0
Without reference model
Blue: actual speed value
Green: r52155 reference model output
Reference model set so that curves are almost flush
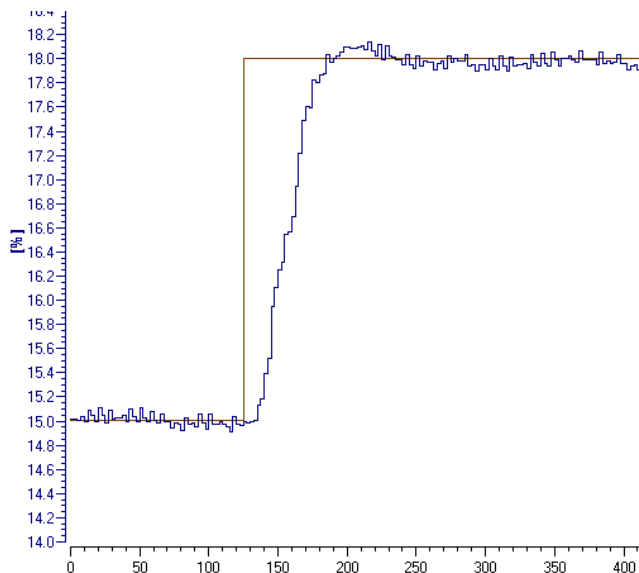
Setpoint change from 15% to 18%
PI controller, p50224 = 1
With reference model; p50240 = 1
Actual speed value blue
Almost devoid of overshoot

Open-Loop Controlled operation
For test purposes it is possible to operate the device in open-loop controlled mode. The resulting device output voltage can be calculated, see below.

Note: The current limits have no affect in controlled operation, only the set firing angle limits for Alpha G and Alpha W have an effect. – End of Note.

The firing angle offset can be changed in fine increments from -100 % to positive values, the resulting current r50019 for the armature actual value: 100% actual current from p50100 or r50035 for the field current actual value: 100 % actual current from p50102, must be checked.

-100 % corresponds to 180 degrees, 0% corresponds to 90 degrees, and 100% corresponds to 180 degrees.

Firing angle in degrees = r52100[%] * 180 / (-200) + 90 for the armature circuit, see parameter r50018

Firing angle in degrees = r52260[%] * 180 / (-200) + 90 for the field circuit, see parameter r50034

Additional measurement of current actual value by means of an ammeter necessary!

Open-Loop Controlled operation for the armature circuit:
Sheet 3100, 6855 and 6860. With p50601[4] = 52401. With the

fixed value connector r52401, its value can be set on the p50401. (set p50601[5] = 0).
p50401 = +10% for positive torque direction, M1, set as current setpoint. The polarity of its output, r520119, specifies the torque direction
(p50401 = -10% for a negative torque direction, set M2).
See also above under Command stage.
p50600[0] = 52402, fixed value connector r520402, its content can be set via p50402 and corresponds to the firing angle.
Procedure: Set p50402 = -100%, the result is Alpha W, value from p50151 (factory setting 150 degrees) as the control angle.
Set p509082 = 0, field supply not active, motor at standstill on SINAMICS DCM, if motor starts to rotate due to remanence, lock the rotor.
Define ON signal via terminal X177.12 and operating enable via terminal X177.13.
The drive must be in "RUN" mode.
If p50151 = 150 degrees, no armature current flow will be selected.
Set delay angle p50402 from -100% to larger values,
R50018 shows delay angle in degrees after limitation with p50150 and p50151.
A current flow will build up as of 120 degrees (approx. -32%).
The device output voltage Ud at 1C1/1D1 is on 3 phase supply of armature supply:
Unetwork * 1.35 * cos(firing angle in degrees) = r50015 * 1.35 * cos(r50018).
Open –Loop Controlled operation for the field circuit: Sheet G166.
Set p50610 = r52403 for CO r52403, the value for r52403 is set as a percentage in p50403.
Set p50403 = -100 % for delay angle 180 degrees
Set p50082 = 3, field permanently "On", an initial ON signal at terminal X177.12 may be required to start the field firing pulses.
The drive must be in operating mode o7.x or a lower number.
Set higher percentage values in p50403, the field delay angle is displayed in r50034 (field firing angle after firing angle limitation p50250, p50251), check field current flow with r50035 and an ammeter in the field current circuit. Motor field as load must be connected.
The output voltage Ud at 3C/3D is:
For 1Q field supply: Circuit B2Hz
Unetwork * 0.9 * (1 + cos(firing angle in degrees)) / 2 = r50016 * 0.9 * (1+ cos(r50034)) / 2.
For 2Q Field supply, or 1 phase armature supply: Circuit B2C
Unetwork * 0.9 * cos(firing angle in degrees) = r50016 * 0.9 * cos(r50034).

Fundamentals of line-commuted converters

Requirements of the supply system

The line voltage must be sinusoidal, supply of a line-commuted converter via a DC voltage source is not possible.

$U_{Netz} = \hat{U} * \sin(\omega*t)$, $\hat{U}$: Peak voltage of the supply network

$\omega = 2 * \pi * f$: Angular frequency, f: Frequency of the line voltage, $1 / f = T$: Period

At 50 Hz line, $T = 1 / 50 = 0.02 = 20$ ms

At 60 Hz line, $T = 1 / 60 = 0.0167 = 16.7$ ms

The rms value U_{RMS} of the line voltage is measured with the voltmeter.

$\hat{U} = U_{RMS} * \text{root}(2) = U_{RMS} * 1.41421$, at 400 $V_{RMS} = 400 * 1.41421 = 566$ V
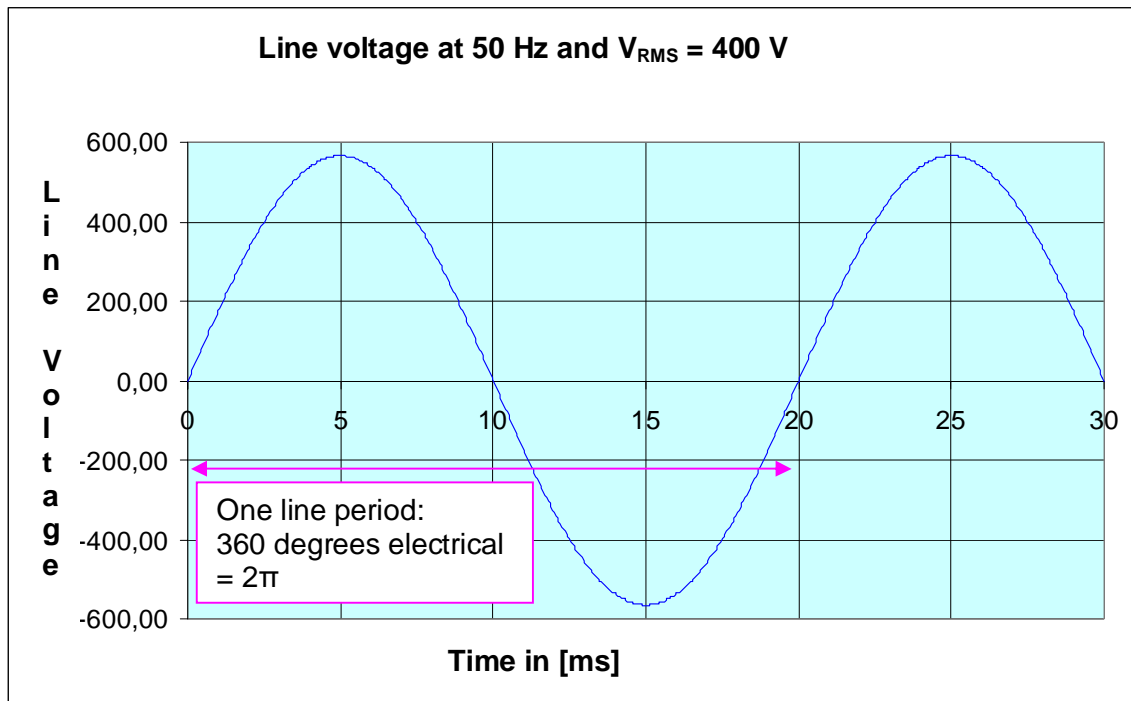
Three-phase system:

A three-phase system comprises three individual phases (U, V, W) of the same voltage and a phase shift by 120 degrees.

Phase voltage, e.g. U_U: The voltage of an individual phase is the line-to-neutral voltage, single voltage measured against the neutral point of the transformer.
Phase-to-phase voltage, e.g. U_{UV}: This is the voltage measured between two phases.
The phase-to-phase voltage is the phase voltage times the root (3).
e.g.: $U_U = 230$ V $\rightarrow$ $U_{UV} = U_U * \text{root}(3) = 230 * 1.732 = 400$ V

The phase-to-phase voltage is always specified on the technical data and on the rating plate of the SINAMICS DCM.

Phases U, V, W with the line-to-neutral voltage and the line-to-line voltage
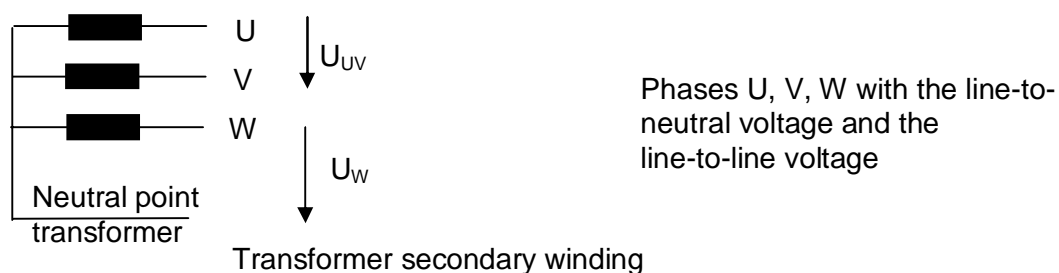
Converter for armature supply using
a fully controlled three-phase bridge connection

B6C connection (6RA80..-..S22-0AA0): Operation in one electric current direction and two voltage directions. Fully controlled three-phase bridge connection, 2Q device acc. to catalog. As this is a fully controlled connection, the output voltage can accept negative values by operation in the inverter range (see formula for calculating the output DC voltage of the converter). This 2Q device allows driving in the speed forward direction and braking in the speed reverse direction without any further measures, simply by offsetting the firing angle. With this characteristic, negative output voltage in the converter range, it is possible by switching over the motor field to implement braking operation in the forward rotation direction and driving operation in the reverse rotation direction. By reversing the polarity of the field current in the motor the induced motor voltage assumes negative values and the motor outputs a negative torque (braking torque) with constant positive current direction and negative motor voltage. So field reversal makes operation in all four quadrants possible (See Operating Instructions Chapter 10.26). Please note that motor field reversal can only be performed within a few seconds, demanding a 4Q device for transition to braking operation in dynamic operations.

However, field reversal can be used to permit braking of large masses in one direction of rotation or if operation in the opposite direction of rotation is required.

Note: For field reversal, an overvoltage protective circuit must be configured at the output of the field converter. This protective circuit must be able to absorb the energy content of the field winding $W[Ws] = L[H] * I^2[A] / 2$.

Any resulting overvoltages must not exceed the value of the blocking voltage of the valves of the field converter.

Connection (B6)A(B6)C (6RA80..-..V62-0AA0): Circulating-current-free inverse-parallel connection of two fully controlled three-phase bridge rectifiers: 4Q device, operation in both current directions and both voltage directions possible. Circulating-current-free means that the current must be reduced to zero in the one current direction before the opposite current direction is enabled. By implementing suitable current actual value acquisition in 6RA80, fast reversal of the torque direction is possible (typically 3.3 ms at 50 Hz), allowing the retrofitting of old circulating-current-carrying converters with 6RA80 with almost no significant disadvantages. With this 4Q device, driving and braking in both motor directions of rotation is possible with high dynamic response of the control without any additional measures.

Motor operation on the converter, speed n and torque M:

B6C one current direction

(B6)A(B6)C or B6C with field reversal
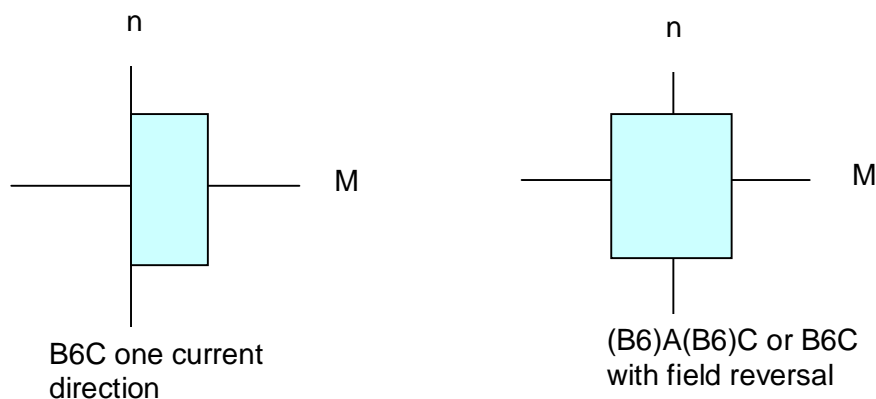
The converter generates a variable direct voltage a function of a variable firing angle by rectification of the line voltage. The firing angle determines the firing time of the thyristor and thus the magnitude of the variable output direct voltage.

The figure below shows the system line-to-neutral voltages and the magnitude of the converter output voltage Ud.

The number defines the firing sequence for the thyristors (valve), 1 - 6, if a clockwise rotating field exists for the line supply.

One valve must always be conducting in two phases for each to permit current flow in the DC circuit.

The figure shows: At the first instance, valve 5 and 6 are conducting, then valve 6 is conducting and 1 is fired; at the next firing instant, valve 1 is still conducting and valve 2 is fired etc. As is shown, each valve must remain conducting for two subsequent firing instances.

A thyristor remains conducting as long as there is a current flow, on current zero, it returns to the off state. Therefore suitable measures are needed to ensure that the valve, i.e. the first thyristor to be fired, remains conducting for continued current flow now via the next thyristor. For this, the firing pulse duration of the thyristor must be greater than 60 degrees, because when stationary, the next thyristor is fired every 60 degrees. Because the firing pulse duration on the 6RA80 is however only 0.89 ms (60 degrees correspond to 3.3 ms at 50 Hz line frequency), to keep the first valve to be fired conducting for a further 60 degrees, another firing pulse, the second pulse is triggered from it. This is above all necessary for discontinuous current.

Figure applies to the clockwise rotating field of the network
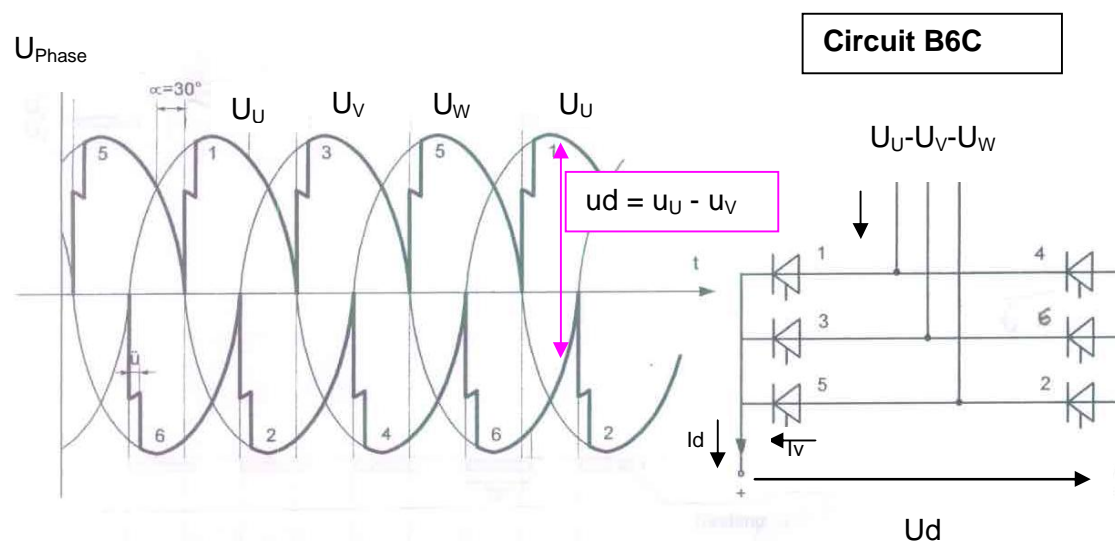
The momentary value of the output direct voltage can be read from the voltage characteristic above for the delay angle α = 30 degrees.
See example: Arrow of direct voltage magnitude Ud in pink.

An overlap o occurs during commutation, i.e. on transfer of current conducting from one valve to the next. At this point in time both thyristors involved are conducting at the same time (commutation short circuit). o lasts longer for longer commutation inductance. o results in a loss of the voltage-time area and thus a loss in the mean direct voltage.
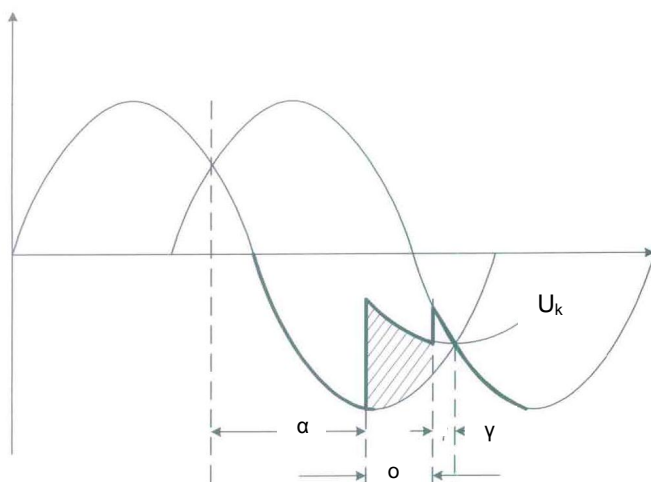
The figure shows the response during converter operation.
α is the firing angle that determines the firing instant,
o: overlap,
γ: protection angle.
U_k: voltage during commutation

In inverter operation, the firing angle must be limited by α_W so that the following valve can take over the current. Commutation is then possible if the voltage at the next valve has a more positive value than that of the valve currently conducting the current.

After overlap o, a safety angle γ must be observed, which takes account of the critical hold-off interval of the thyristors. The thyristor commutating onward must be free of current and able to take up reverse voltage and the next thyristor must have taken over the current before the voltage on the next thyristor has a more negative value then the previous one. The protection angle γ is typically 10 degrees.

On the 6RA80 α_W is set to 150 degrees in the factory setting (p50151), with discontinuous current the delay angle is offset to 165 degrees as then no more current has to be commuted. Offset to 165 degrees can be suppressed with control parameter p50192.

p50192 = 0: When continuous current α_W = p50151; when discontinous current α_W = 165 degrees.

p50192 = 1: α_W always acc. to p50151.

In the case of very weak power systems (large o) it may be necessary to set α_W less than 150 degrees e.g. to 145 degrees.

Maximum firing-angle setting α_G : The maximum firing-angle setting is set in p50150. Factory setting 5 degrees for 2Q devices. For 4Q devices or for 2Q devices with braking by means of field reversal the firing angle must be symmetrically to α_W. That is for α_W = 150 degrees to 30 degrees (factory setting for 4Q). This is caused by the fact that α_G defines the maximum possible motor voltage during operation; if this is too high, the required back-EMF is not reached on transition to braking mode with α_W, resulting in conduction-through. This is monitored on the 6RA80 and deactivated with fault message F60043 if the effect described above occurs, to prevent an overcurrent on transition into braking operation.

For remedy and alternatives to the above rule, see the description for F60043 in this description. See also description for parameter p50272.

Note: When braking with field reversal on 2Q devices, a fuse must be implemented in the direct current circuit like for 4Q devices (for type see comparable 4Q device). Devices with a rated current greater than 900 A, have installed branch fuses which replace both the line fuses as well as the fuse in the DC circuit for semi-conductor protection.

Note: Some of the following formulas are only approximations, but precise enough for practical use.

Formulas:

For 3 phase application:

Ideal direct voltage Udi: This is the direct voltage that is calculated with a firing angle of zero degrees (full firing-angle setting).

Udi = Uvw * 1.35,

Uvw: Line-to-line input voltage at converter, at 400 V: Udi = 540 V

Variable direct voltage Ud depending on firing angle:

Ud = Udi * cos α, (in practical applications an additional voltage loss resulting from overlap o also applies here; this is subtracted so that the resulting measured voltage is slightly lower than that calculated)

α: Firing angle in degrees, cos(α) can be read from the graph below to calculate the output direct voltage.

Control characteristics for B2C, (B2)A(B2)C, B6C, (B6)A(B6)C

Rectifier operation   Inverter operation

cos (Alpha)

Firing angle Alpha in Degree
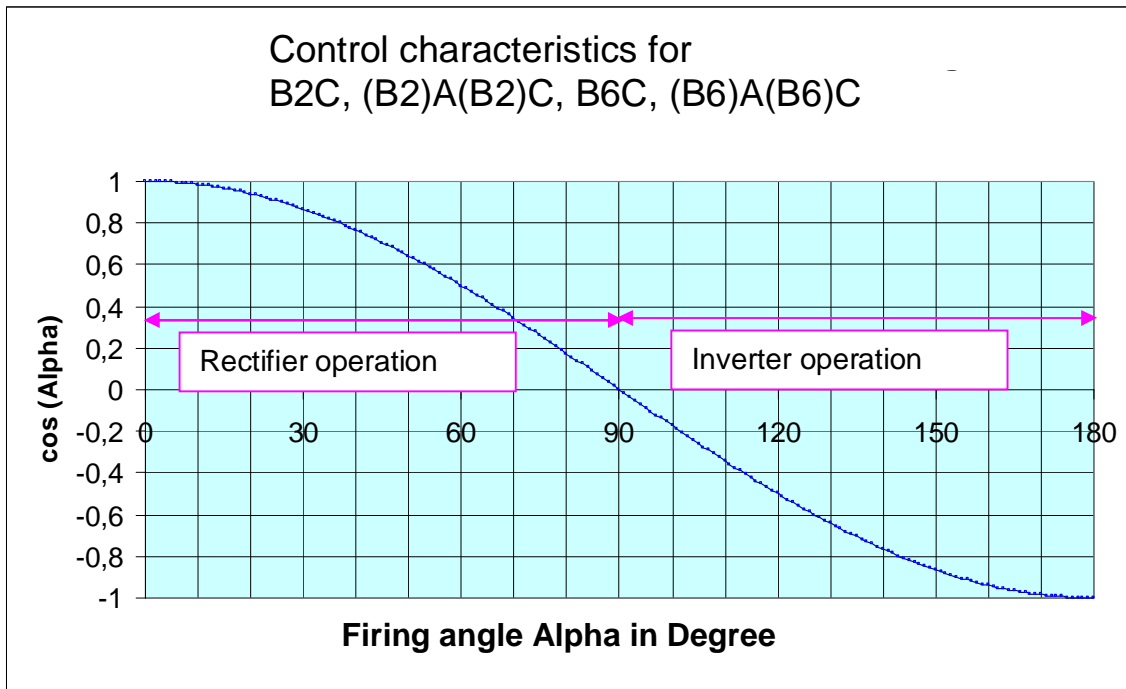
For 3 phase application

Line current I1: I1[A] = Id[A]* root (2/3) = Id * 0.817, where Id: Direct Current

Current in thyristor: Iv [A]= Id * root (1/3) = Id * 0.58

Direct current power: P[W] = Ud[V] * Id

Active power Line: P = 1.05 * Ud * Id

Ideal current power:

Pdi[W] = Udi [V] * Id, use for peak power maximum direct current

Required apparent power of the line transformer:

S_T [VA]= Udi * 1.05 * Id

Phase control reactive power:

Q[Var] = 1.05 * Udi * Id * sin α, at firing angle α

cos φ in the line infeed: cos φ = Ud / Udi

cos φ is zero on motor speed zero,

at rated motor speed and rated motor voltage adjusted to the line voltage, it has the following values: 2Q: 0.9; 4Q: 0,75.

Maximum output voltage for SINAMICS DCM at 5% undervoltage of the nominal line voltage:

2Q device: Ud_{max} = Uvw * 1.2;   4Q device: Ud_{max} = Uvw * 1.05;

Set p50101 as maximum to Ud_{max}

Note: The output voltage of the SINAMICS DCM depends on the voltage of the supply system, not on the rated line-side voltage of the SINAMICS DCM.

The minimum permissible nominal line voltage (set p50078[0] nominal voltage for line) is 50 V up to rated device voltage. For voltage range 10 – 50 V, order device with option L04. (option L04 available for 400 / 460 / 575 V devices). Order L04 ex works, a retrofit involves a lot of work.

Relations between various operating points of the motor:
Example 3 Phase Supply:
Line voltage: 400 V, 50 Hz;
Voltage drop commutating reactor: 4% → voltage at SINAMICS DCM input: 384 V
Motor: 1GG6208-0NH40-1VV3; 2020 UPM; 183 kW
U_N: 420 V, I_N: 466 A, η: 91%, Ra: 43.8 mΩ, La: 0.94 mH
Calculation with motor rating data; no smoothing reactor n_N, I_N, U_N → α = 36 degrees, the resulting current ripple is 11.5 % rms
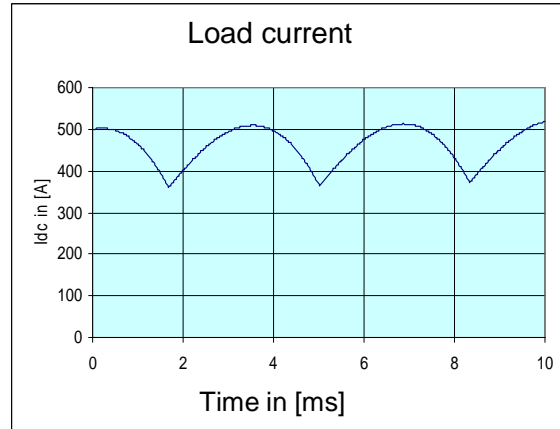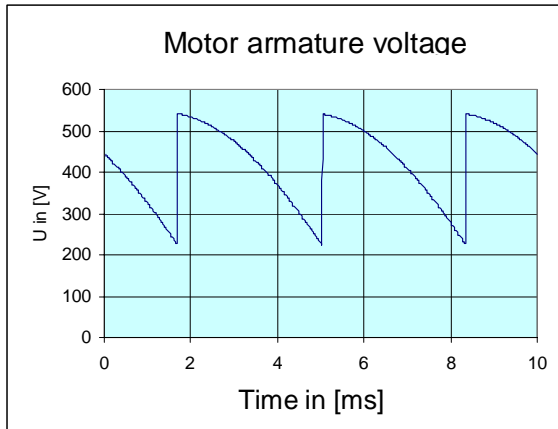
As above for smoothing reactor 1.5 mH, the resulting current ripple is 4.5 % rms
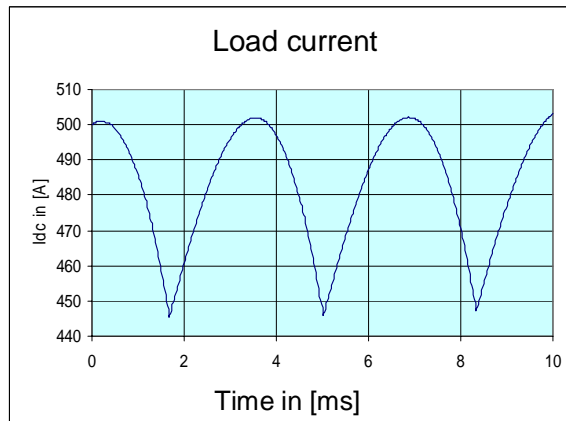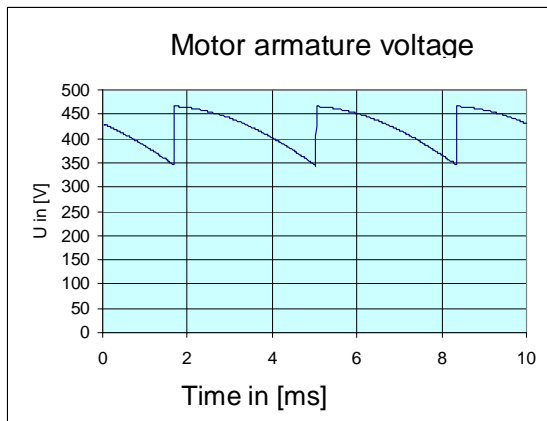
Half the rated motor speed, without smoothing reactor, I_N, → α = 65 degrees
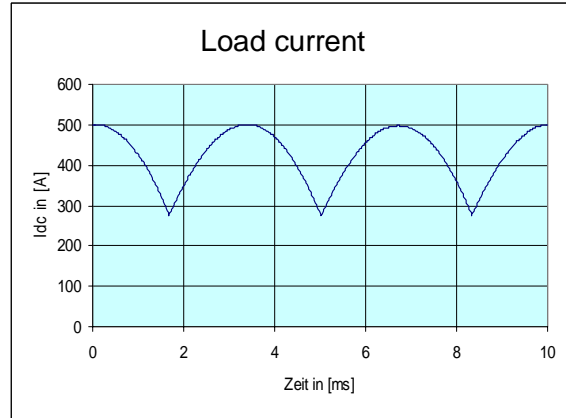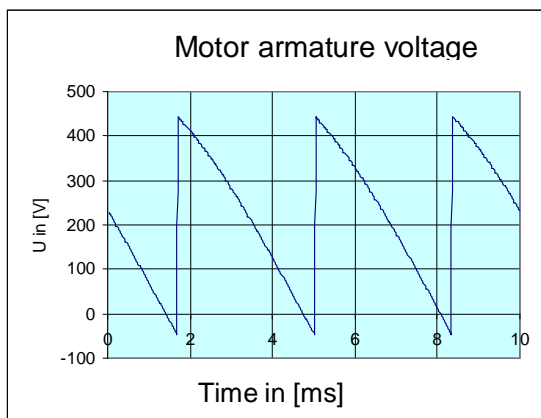
When motor speed is zero, I_N, → α = 88 degrees; the resulting current ripple is 19% rms

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No smoothing reactor

Motor armature voltage

Load current
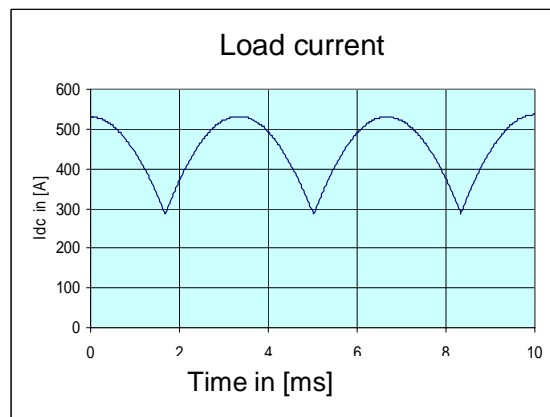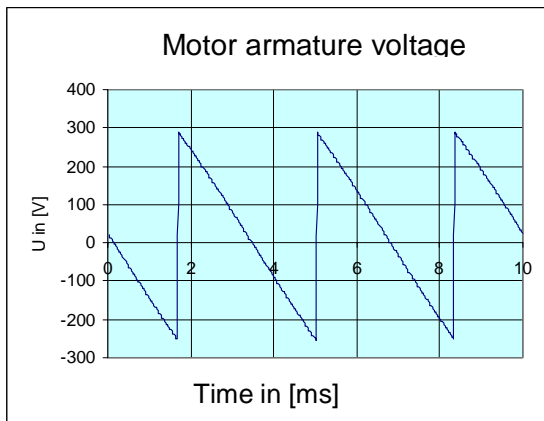
Without smoothing reactor, current at point of transition from discontinuous to continuous current, i.e. current maximum values just touch the zero line; point of transition from discontinuous to continuous current (example half motor nominal speed) is 31 % of I_N. No figure, as above, 1.5 mH smoothing reactor, transition from discontinuous to continuous current is 12 % I_N.

Motor armature voltage
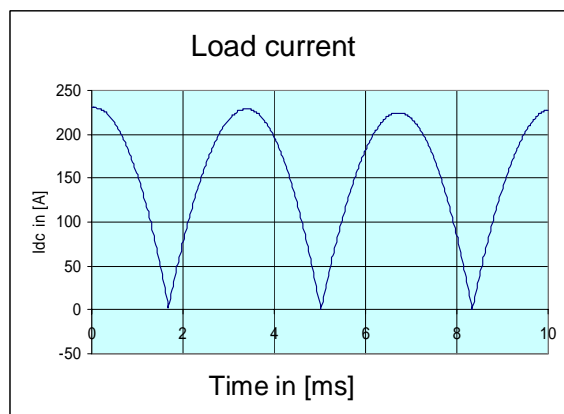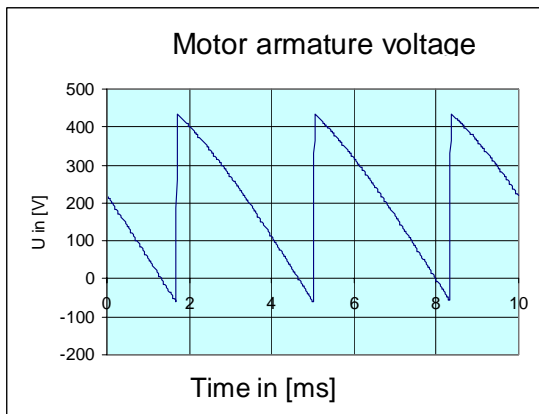
Load current

Discontinous current, half rated motor speed, without smoothing reactor

Load current

Laststrom
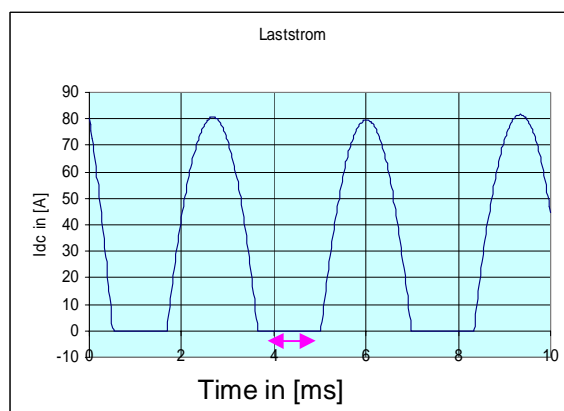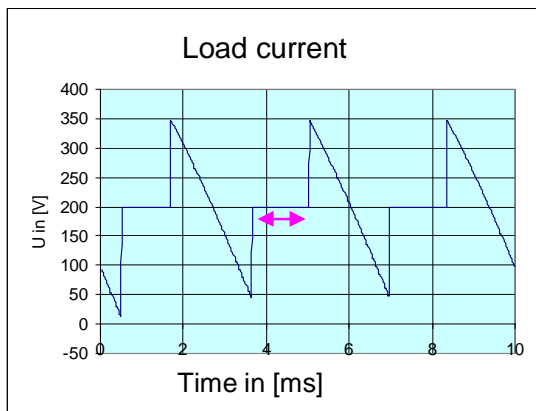
↔: Period of discontinuous current
the motor voltage is the motor EMF, here 200 V

In braking operation (voltage and current have different signs), with negative rated motor speed, positive current, discontinuous current operation, without smoothing reactor; Firing angle 143 degrees.

Motor armature voltage

Load current
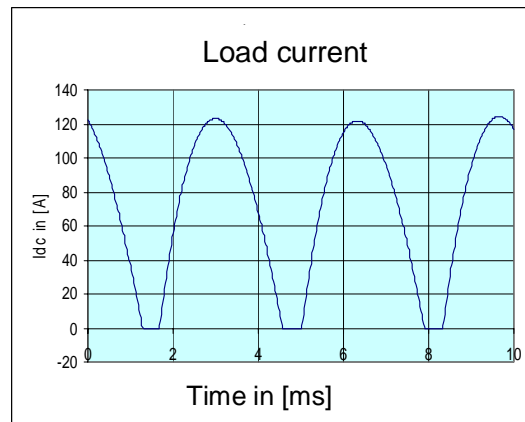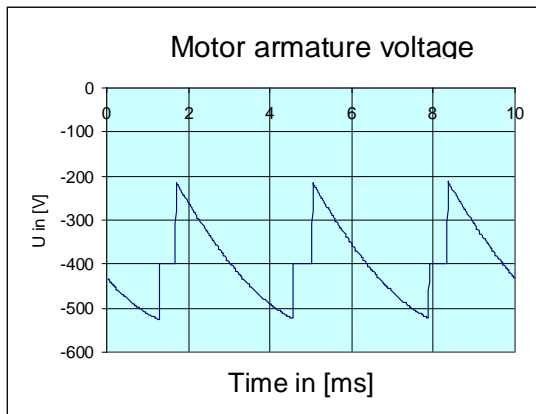
Measurement of current characteristic of line-side current: During the positive half-wave of the line-to-line line voltage, two positive current peaks occur, then a pause for the duration of the current maximum value, then two negative current maximum values during the negative half-wave of the line voltage. If the two positive or negative current maximum values are missing, the thyristor does not fire.

The advantage of current measurement on the infeed side is that an AC probe can be used for current measurement with the oscilloscope or recorder, which is more readily available than a DC probe for measurement in the DC circuit.

The measurement can also be performed on the R805 load resistors (for current converters in line phase U) and R806 (for current converters in line phase W) of the current converters on the power interface module with an oscilloscope (measurement of voltage drop at the load resistor).

Example below: Measurement current at point of transition from discontinous to continuous current
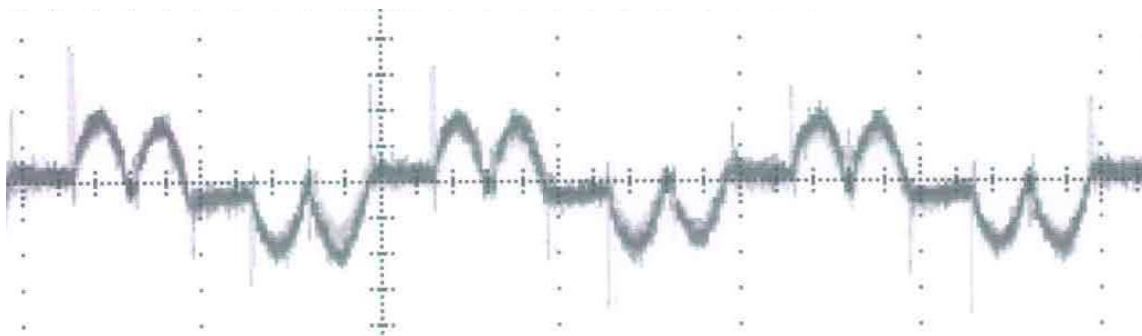
The armature converter in the single-phase mode

Up to a device nominal current of 125 A, the armature circuit of the SINAMICS DCM can also be operated in one phase. Connection to two phases or one phase with respect to the neutral conductor is possible. The line voltage is connected to 1U1 – 1V1.

A 4% commutation inductor or a separate transformer with 4% uk is required at the input.

The permissible output current in the single-phase mode is 67% of the three-phase mode.

Operation on a single-phase line network is selected by means of p51799 = 1

A dynamic overload is not possible in the single-phase mode.

See also Section 10.24 of the Operating Instructions.

Formulas:

Uuv: concatenated AC voltage at the input

Ideal output DC voltage: Udi[V] = 0.9 Uuv[V]

Iuv[A] = Id[A], where Iuv: input AC current, Id: output DC current

Valve current Iv[A] = 0.707 * Id;

Output DC voltage:

B2C: Ud = Udi * cosα; fully controlled circuit,

line power rating/transformer design power: P[W] = 1.11 * Udi * Id

Relationships for some operating points of the motor:
Example for single-phase operation:

Line voltage: 400 V, 50 Hz;

Commutation inductor voltage drop: 4% → voltage at the SINAMICS DCM input: 384 V

Motor: 1GG5114-0GL40-3GU7,3380 UPM, 10.5 kW

U_N: 300 V, I_N: 40 A, η: 85%, Ra: 442 mΩ, La: 3,35 mH

Prescribed smoothing inductor 15 mH   Time in ms

Calculation for motor rated data; n_N, I_N, U_N → α = 25 degrees, the resulting current ripple is 45% rms   Load voltage
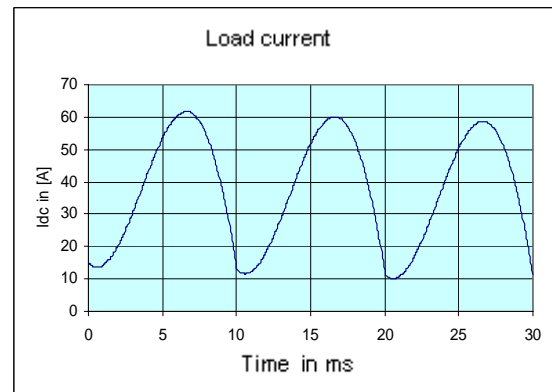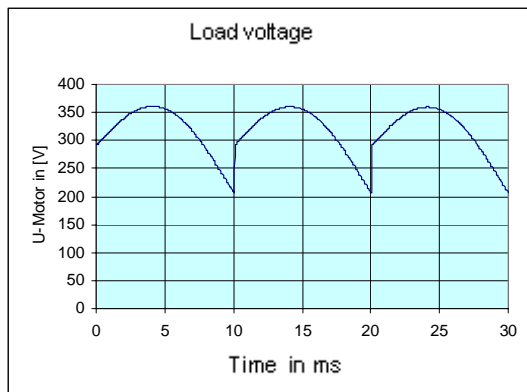
U motor 150 V, 40 A, α = 65 degrees, the resulting current ripple is 69.5% rms
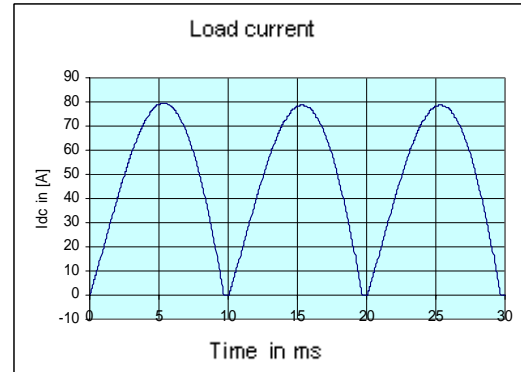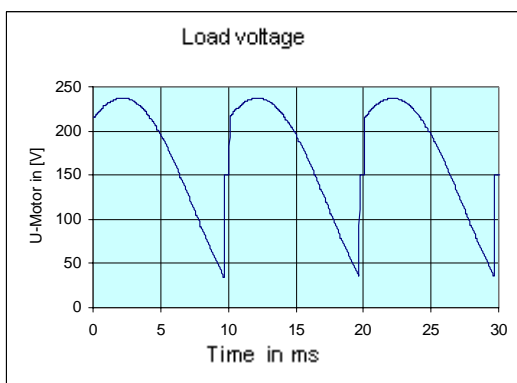
Current converter for field supply with 2-pulse half-controlled bridge circuit in a B2Hz connection

The line connection is either single-phase or two-phase: e.g. 1AC230 V, 2AC400 V.
This is an asymmetrical half-controlled bridge circuit B2Hz.
In the 6RA80, this circuit is installed for the motor field supply.
The bridge circuit comprises two controlled valves (thyristors) and two uncontrolled valves (diodes). By changing the firing angle, the firing instance of the thyristors, a positive variable direct voltage from zero up to the maximum possible value is reached at the output of the converter.
The field supply device is current controlled, i.e. the required field current is adjusted to the constant value depending on the rated value p50102, irrespective of line fluctuations or changes to the resistance of the field winding , the required voltage sets itself automatically (no parameter input required for this).
In the case of nominal field voltages 3C/3D <=180 V, infeed via 3U1/3W1 with
1AC 230 V is recommended. Possible minimum value of the nominal voltage for the infeed is 50 V, see p50078[1] nominal value of line voltage for the field infeed.

Switching the diodes parallel to the load produces a free-wheeling arm, i.e. if an instantaneous value of the output voltage greater than zero occurs, a current flow builds up via the load, if the output voltage is zero, the current is reduced toward zero via the free-wheeling arm.
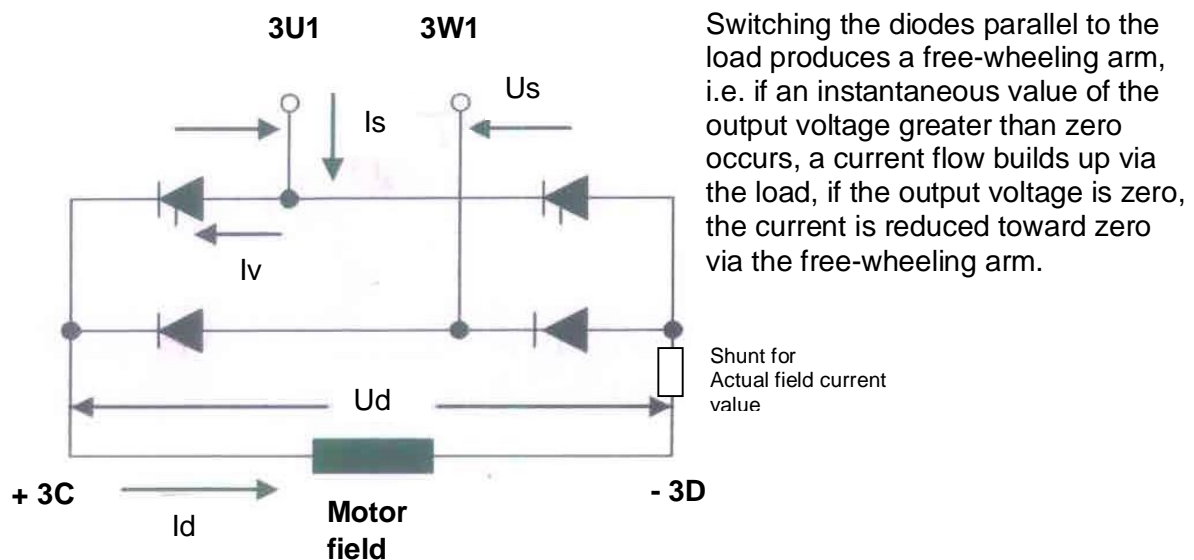
2Q field infeed (option L11):
As an option for devices with an armature current from 60 A, a 2Q field feeding bridge is possible in the B2C circuit. In this case, the power unit for the B2C circuit consists of 4 thyristors in place of 2 thyristors and 2 diodes for the B2Hz circuit.
Negative output voltages are possible through the 2Q circuit (Alpha W operation).
This negative output voltage can be used to reduce the current at a faster speed.
In the case of dynamic drives, this is necessary for fast current reduction when moving into the field weakening range e.g. fast ramp-up time for rolling mill drives with field weakening.

Formulas:
Us: Line-to-line alternating voltage at the input
Ideal output direct voltage: $Udi[V] = 0.9 \, Us[V]$
$Is[A] \sim Id[A]$, where Is: Input alternating current, Id: Output direct current
Valve current $Iv[A] \sim 0.707 * Id$;
Current load of diodes higher than thyristors because the diodes additionally carry the free-wheeling current

Output voltage:
With B2Hz (1Q): Ud[V]:   Ud = Udi * (1 + cos α) / 2
With B2C (2Q): Ud = Udi * cosα; 4 Thyristors instead of 2 Thyristors and 2 Diodes
Line power rating / nominal transformer power: P[W] = 1.11 * Udi * Id
The factor (1+ cos α) / 2 for calculating the Ud can be taken from
the control characteristic.

**Control Characteristic
Two-pulse half-controlled Bridge B2Hz**
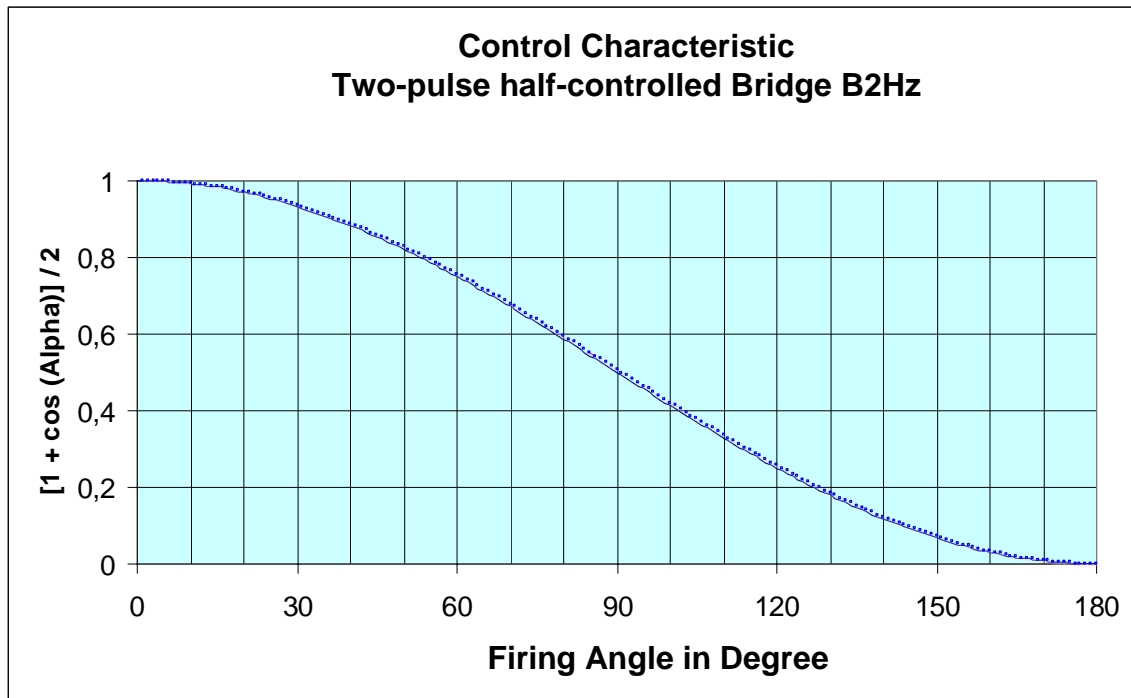
Voltage and current characteristic, Circuit B2Hz:
Us = 400 V, 50 Hz, Id = 0.21 A, L_F = 10 H, R_F = 1475 Ω, Udc = 310 V at α = 45 degrees
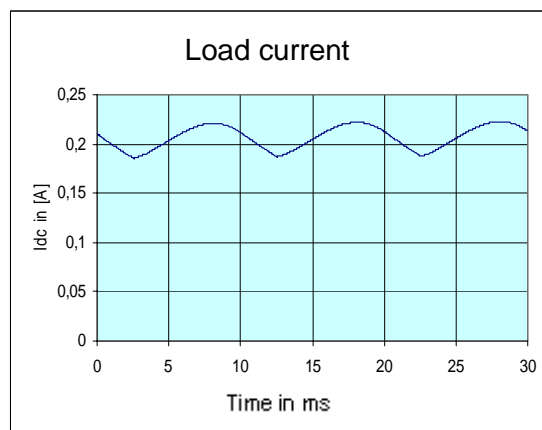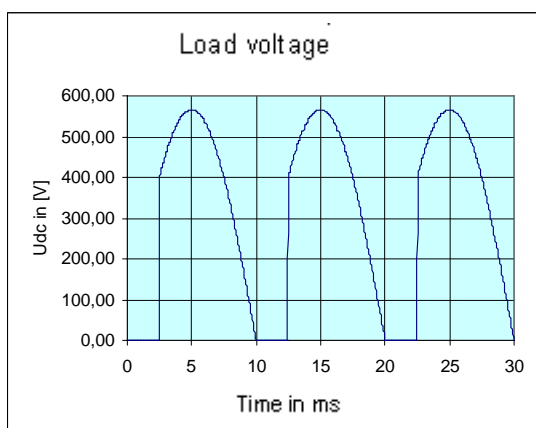
Measurement with current probe.
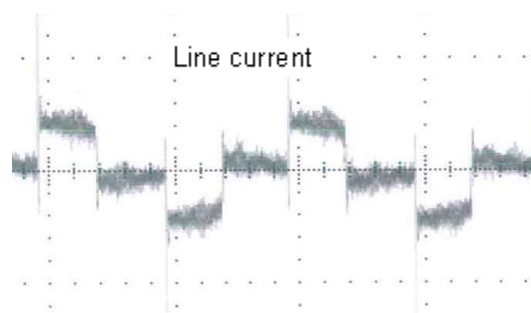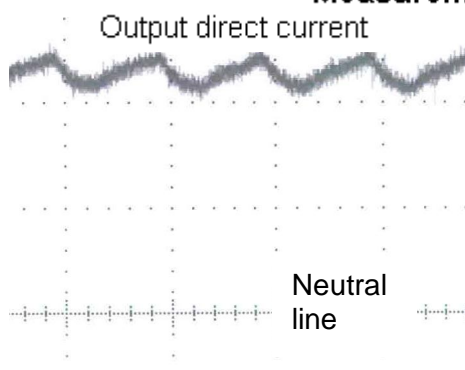
Voltage and current characteristic, Circuit B2C:
Us = 400 V, 50 Hz, Id = 0,21 A, L_F = 10 H, R_F = 1475 Ω, Udc = 310 V bei α = 33 Grad
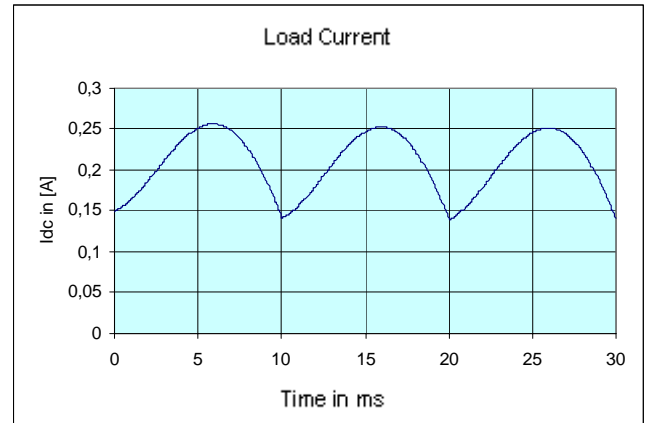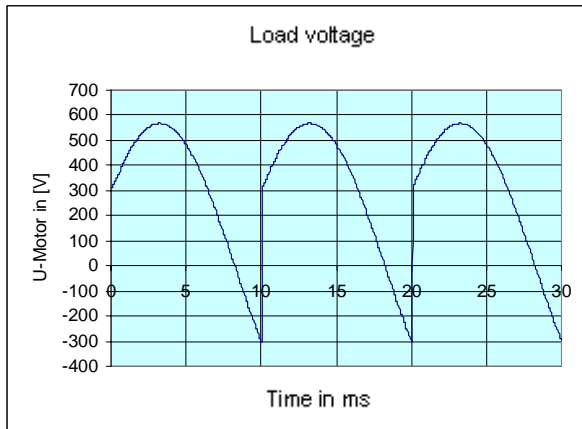
Measurements that can be performed on the SINAMICS DCM

In normal conditions a multimeter can be used as the measuring instrument, because measured value recordings can be performed with the trace function with STARTER.
If an oscilloscope or recorder is also available, more in-depth measurement evaluations will not pose a problem; however, special knowledge is required to handle these devices.

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⚠ WARNING

The warning notices at the beginning of this document and in the instructions of the devices used must be observed to avoid hazards to people.

If the monitoring, limitation or control features implemented in the device are deactivated, for example, by operating the device in controlled operation, this can result in additional danger for the system.

A source of particular danger are the dangerous voltages on the devices, the loads and their power supply cables, as well as the rotating and moving parts, such as the web.

Measurement of electrical variables
Electrical variables that can be measured with a multimeter:
Alternating and direct voltage; voltage U in volts: [V]
Alternating voltage: Preset measuring device to V-AC or V~,
Direct voltage: Preset measuring device to V-DC or V=,
Alternating or direct current; current I in amperes: [A]
Alternating current: Preset measuring device to A-AC or A~
Direct current: Preset measuring device to A-DC or A=
Resistance in ohms: [Ω], the resistance is equal to U divided by I; 1 V / 1 A = 1 Ω
Preset measuring device to Ω
Electrical variables measurable with special measuring devices:
Apparent power S in [VA], or [kVA];
Active power P in watts, [W], or [kW]; P = S * cos φ
Reactive power Q in [Var], or [kVar]; Q = S * sin φ
Power factor: cos φ = P / S;

In the case of direct current cos φ is always equal to 1 (no reactive component, no effective components)
Kilo, k is a factor of 1000; 1 kW = 1000 W.
Milli, m is a thousandth, 1 mA = 0.001 A

Note: Before a measurement can be performed, the measuring device must be set to the required measuring method (voltage, current, resistance) and the measuring range expected for the measurement. Incorrect settings could damage the measuring device.

Measuring the resistance of power semi-conductors
The resistance of the power semi-conductors can be measured at the power terminals: input and output. Please refer to the circuit diagrams of the power section in the Operating Instructions; Section 6.4 for the armature circuit and Section 6.5 for the field circuit.
Note: The following precautions must be taken before measuring the resistance:
1) Clear the line-side supply voltage of the power section
2) Check safe isolation from supply on the input and output of the power section of the current converter
3) Disconnect the load at the output of the current converter
When measuring the power semi-conductor ensure that they are equipped with an RC element (snubber circuit). For this, first charge (or reverse-charge if reversing the poles of the ohmmeter) capacitor C of the circuit via the voltage source of the ohmmeter, this means that for a certain initial time, a low-resistance display will result before the display shows the actual high-resistance value. This resulting charging process is also an indication that the snubber circuit is OK, so the manifestation of this effect can also be used to check the snubber circuit.
Measurements at the power section for the armature supply:
Measure between all phases of infeed 1U1/1V1/1W1 and
between all phases of the infeed and ututs 1C1/1D1, and
between outputs 1C1/1D1 in both polarities of the ohmmeter.
Ideally, all measurements must show a high-resistance value of > 100 kΩ.
Measurements at the power section for the armature supply:
Between infeeds 3U1/3W1, measurements must be high resistance in both polarities.
Between 3U1 and 3C and subsequently 3 D; measurements must be high resistance in both polarities.
For 1Q field supply: Between 3W1 and 3C and subsequently 3 D, measurement must be high polarity in one polarity of the ohmmeter and low resistance in the other.
For 2Q field supply all measurements must show high resistance.

The diode:

Anode +

Cathode -

Technical current direction
from + to -

The thyristor:

Anode +

Gate G

Cathode -

Technical current direction
from + to -
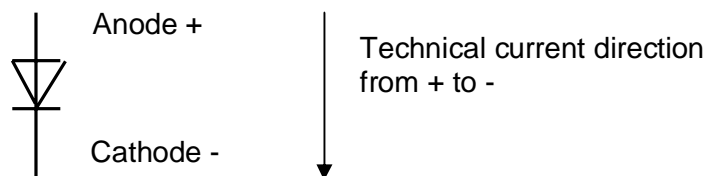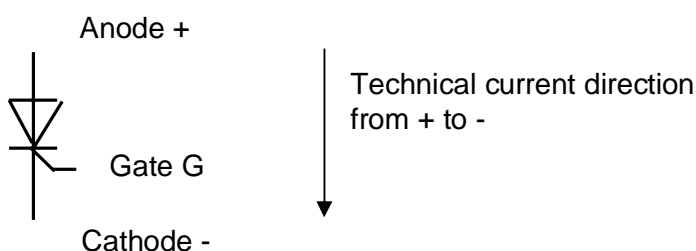
Measurement at the diode:
Perform with measuring range "Diode", approx. 0.5 V voltage drop is displayed in the conducting direction on the diode. Anode diode connected to plus pole, cathode diode connected minus pole of the measuring device: Diode in conducting direction means approx. 0.5 V voltage drop for 1 diode.
Measurement with polarity reversal of measurement device produces high resistance measurement, infinite displayed.

Measurement at thyristor, between anode and cathode: for both polarities of the ohmmeter, High-resistance measurement result: Setpoint > 100 kOhms.

Measurement at thyristor gate:
Gate G connected to plus pole of ohmmeter and cathode connected to minus pole conducting direction and then poles reversed:
Conducting direction and non-conducting direction low resistance result approx. 15 Ohms, with measuring range "diode" approx. 20 to 30 mV voltage drop (measured with a digital measuring device)
The forward direction of the semi-conductor, approx 100 Ohms, clearly differs from a short circuit that produces zero Ohms.
The non-conducting direction differs from an interruption with the value infinite. This depends on the maximum value that can be displayed by the ohmmeter in question.

Measurement of the firing pulses
Pulse during operation:
Short pulses at p50079 = 0, pulse duration 0.89 ms with pulse chopping
Long pulses at pü50079 = 1, pulse duration up to 0.1 ms before the next pulse with pulse chopping
Pulse chopping: First pulse 50 μs and 55 μs pause, following pulse 35 μs and 70 μs pause
Measurement at output of pulse transformer:
No-load voltage approx. 8 V, short-circuit current approx. 1.2 A
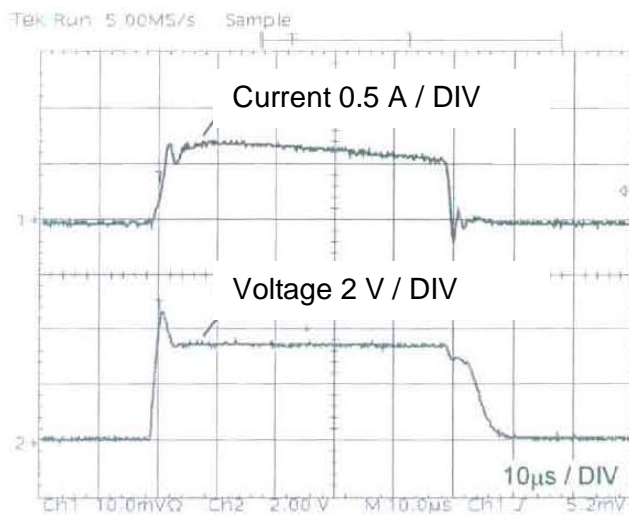
Check the firing trigger:
A dummy load of 4 diodes in series and 20 ohms parallel to it is connected at the pulse transformer output,
Measuring result: Pulse with 3.5 V; 0.7 A
Figure left applies to the initial pulse of 50 μs.
Test with connected thyristor:
The result is a pulse current, depending on the thyristor used in SINAMICS DCM, of approx. 0.3 A.

The individual trigger pulses can also be tested in simulation mode, with settings in parameter p51840.
The number of the thyristor that receives a firing pulse is set in p51840. p51840 = 11 firing line X11-1, thyristor 1 from torque direction 1; p51840 = 21, firing line X21-1, thyristor 1 from torque direction 2 etc. receives firing pulses. For more detailed information see description on p51840, Chapter 11 of Parameter Manual Section 1.
Firing lines: E.g. X21-9, to gate of thyristor 5 from torque direction 2,

See circuit diagram Section 6.3 of the Operating Instructions. The thyristor number defines the firing sequence when there is a clockwise rotating field in the infeed.

Measurements with the Trace-function of STARTER
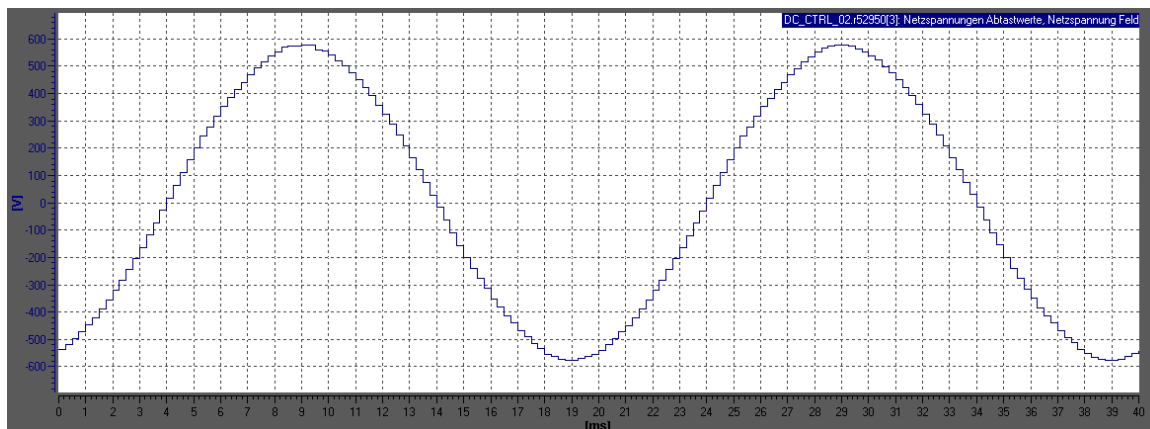
Time slice 2*0.125ms = 0.25 ms for the trace
Line to Line voltage armature circuit 1U1/1V1/1W1
Line voltage UV: r52950[0]: Blue, Line voltage VW: r52950[1]: Green,
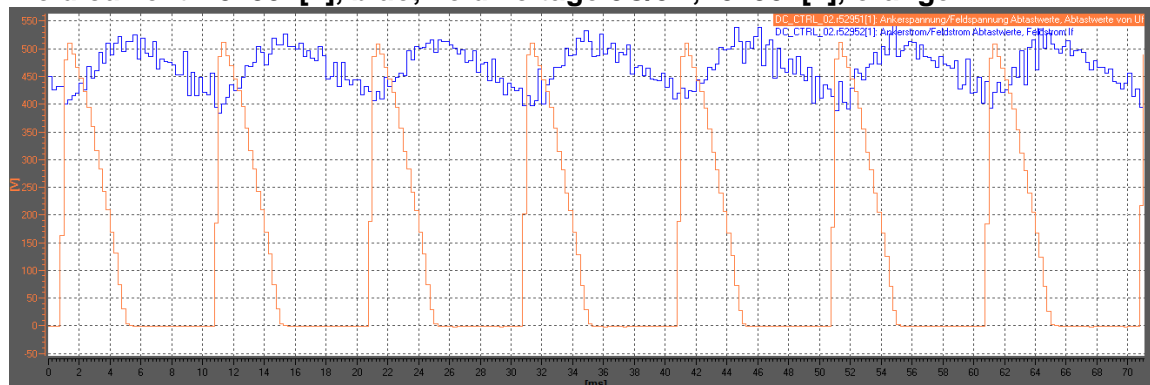Line voltage WU: r52950[2]: Orange
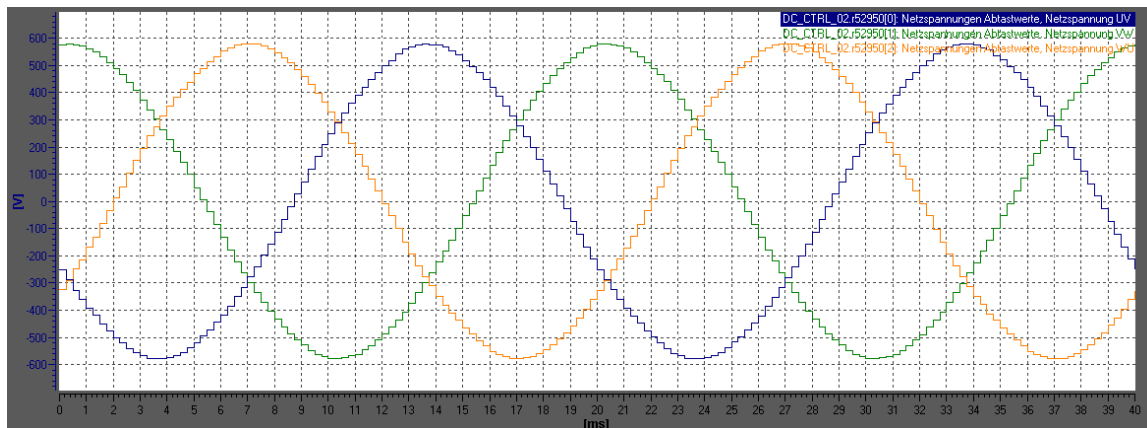
Line to line voltage Field supply 3U1/3W1: r52950[3]

Field current: r52952[1], blue; field voltage 3C/3D, r52951[1], orange

45

Armature current measurement by two current transformer on input
Current transformer I; Iu: r52952[2]; Blue; Current transformer II; Iw: r52952[3], Green
For trace record do following settings
p50082 = 0; p50433[0] = 0, p50601[4] = 52401,
Current reference: p50401[0] = +10 bis +20% Torque direction MI;
-10 bis -20% Torque direction MII
Number of fired thyristor see operating instructions section 6.4
e.g: X11-5: Torque direction I (MI), Thyristor 3; X21-7: Torque direction II (MII), Thyristor 4
If the two positive or negative current maximum values are missing, the thyristor does not fire.
MI: X11-1: Thyristor 1, X11-3: Thyristor 2, X11-5: Thyristor 3
MI: X11-7: Thyristor 4, X11-9: Thyristor 5, X11-11: Thyristor 6
MII: X21-1: Thyristor 1, X21-3: Thyristor 2, X21-5: Thyristor 3
MII: X21-7: Thyristor 4, X21-9: Thyristor 5, X21-11: Thyristor 6
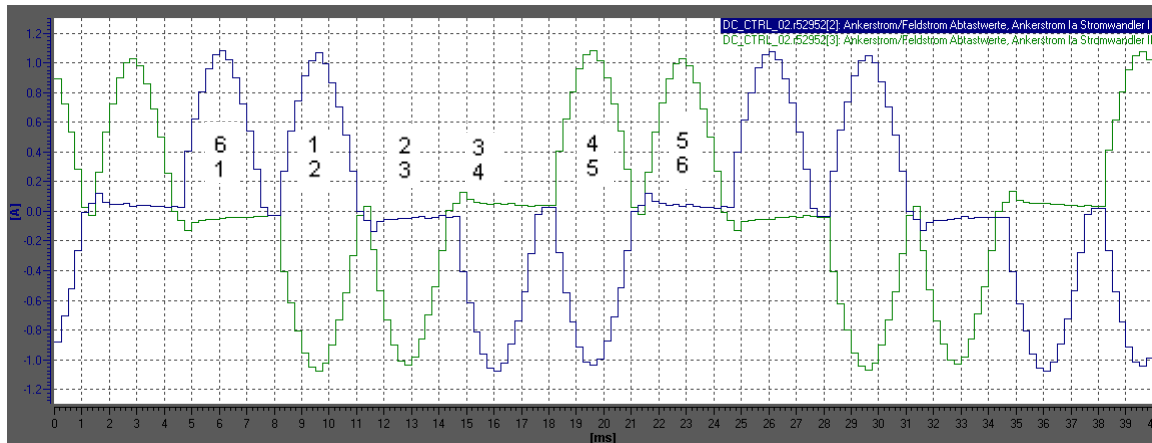
6: Thyristor 6 and thyristor 1 fired
1

Armature voltage 1C1/1D1
Ua: r52951[0]
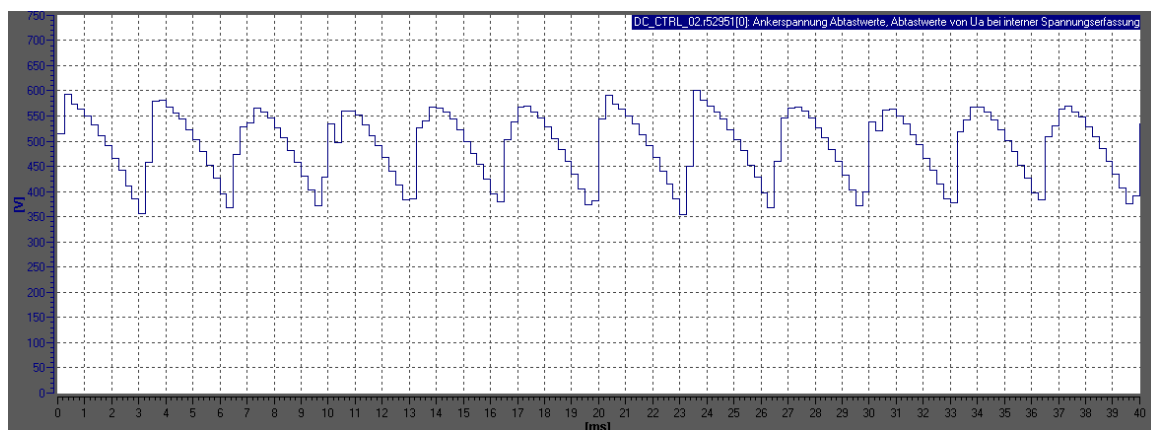
Testing the current converter without load:

The current converter can be tested without a connected motor with variable voltage. Set p50083 = 3, adjust maximum output voltage via p50115. However, this will not work without at least some base load. This is because no control is possible without a slight load current in the thyristors and the output voltage jumps between zero and the maximum possible value. So a current of at least the magnitude of the holding current of the thyristor, approx. 0.25 A, must be flowing. We suggest connecting a load with a current load greater than 1% of the drive nominal current (armature r50072[1], field circuit r50073[1]), however, no less than approx. 0.3 A at the output. For devices with a higher rated current, the rated drive current should be adjusted via p50076 (armature circuit p50076[0], field circuit p50076[1]). A suitable load at 400 V line voltage would be, for example, two 100 watt 230 V light bulbs in series. For higher device nominal currents, implement load with a lower resistance.

Testing the current converter with a short-circuited output:

Testing the current converter with a short-circuited output is not permissible and in the best case (stiff power system) leads to a blown fuse.

It is however possible to insert a smoothing reactor behind the direct voltage output of the SINAMICS DCM with an inductance value of the magnitude of the armature inductance of a direct current motor of similar current or higher and short-circuit it to test the current yield of the SINAMICS DCM.

Additional components on the DC converter

Additional components (catalog D23.1) are required for operation of built-in devices 6RA80. The following section seeks to aid checking for correct rating of the additional components in case of a fault. Catalog D23.1:

https://www.automation.siemens.com/mcms/infocenter/content/de/Seiten/order_form.aspx?nodeKey=key_9181486

Protection with fuses:

Semi-conductor protective fuses are mandatory for protection semi-conductors. Types other than those specified in the catalog/Operating Instructions may only be used if the rated voltage is larger or equal and the I^2t value is less than or equal to the prescribed type. The fuse protects the semi-conductor if the current shows a particular rate of rise during a fault. The fuse may not be able to protect the semi-conductor under the following conditions:

On a bolted short-circuit at the current converter output if a very slight commutation induction is pending (current rise too steep: very high line short-circuit output and commutation reactor too small), or if the current rises too slowly (very weak network or inductance in load circuit too large). In both cases, a smaller fuse type could provide a solution, if the system allows it. In any case, protection is provided by the additional CCP (see below).

Note: Semi-conductor protective fuses of duty class "aR" cannot assume additional protection of the line; in this case, extra precautions must be taken. Semi-conductor protective fuses of duty class "gR" (e.g. 3NE1..) give additional line protection cover. The I^2t value of the 3NE1 type usually means that the prescribed fuses cannot be replaced directly by this type.

Commutation reactor, Catalog D23.1: and

http://support.automation.siemens.com/WW/view/en/84138681

If line-commutated current converters are used, commutation induction is always required in the supply circuit. In the simplest case, a commutation reactor is used.

To protect the current converter, a commutation inductance is required that produces a 4% voltage drop at the rated current of the converter; Vimp = 4%. A separate commutation reactor or separate transformer winding with 4 % Vimp must be used for every current converter used on one power system. The permissible Vimp of the reactor/transformer winding for the current converter is 4% to 10% (worst case 15%).

According to DIN EN 61800-3, voltage dips of up to 20% of peak line voltage are permissible during commutation. The following applies: If the short-circuit power of the power system is higher than the connected load of the current converter by at least a factor of 100, commutation notches of maximum 20 % of the peak voltage of the network will occur if a 4% commutation reactor is used.

If several current converters are installed on the same power system, it can be assumed that these will not commutate at exactly the same time, so the reactor can be dimensioned for each current converter individually as a function of its power, as described above. Normally the commutation reactor is dimensioned as a function of the rated motor current; this saves costs as the rated current of the device is usually higher. If high acceleration currents are required on the motor, the reactor should be designed for a

peak current / 1.6 due to the saturation that occurs during high currents.

The alternating current of the reactor for the armature circuit infeed is: direct current Id * 0.816

Help with calculation of the commutation notches:

$\Delta U[\%] = (x_N + x_T)/ (x_N + x_T + x_D) * 100\%$;

where $(x_N + x_T) = U_N^2 / S'_{k2}$; $x_D = L_D * 2 * \pi * f$; x_D: Reactor reactance, f = line frequency, L_D: Inductance of the reactor; S'_{k2}: Short-circuit power at connecting point of current converter; U_N: Line-to-line nominal line voltage at connecting point of current converter; U_N: Line reactance; x_T :transformer reactance related to the connecting point of the current converter,

ΔU: Commutation notch power system at current converter connecting point (line side directly before the commutation reactor) as a percentage.

If only the short-circuit power S'_{k1} on the high-voltage side of the line transformer is known, S'_{k2} can be calculated as follows:

$S'_{k2} = S_T / (u_k + S_T / S'_{k1})$; S_T: Transformer apparent power, u_k: Short-circuit power transformer in p.u. e.g. 0.06 for 6% uk.

Effects of the commutation notchs on loads in the same power system:

If several 6RA80 are operated in the same network, they do not usually affect each other, so long as the voltage dip is not higher than that defined by the threshold of the phase-failure monitoring in parameter p50353 (factory setting 40% means 60% dip permissible).

However, it cannot be ruled out that these steep-edged voltage dips might damage other loads. Examples of this are switched-mode power supplies for supplying power to automation units, computers and their monitors, but also loads such as fluorescent lamps with electronic starters and power-factor correction capacitors for low-voltage motors.

That is one of the reasons why higher performance current converters are usually supplied via a separate converter transformer, fed from the high-voltage side of the power system. If problems arise with consumers on the same network with line-commuted current converters, the lower-cost solution is usually to provide a separate transformer for the weak network loads rather than implement additional measures on the high-power current converter.

Note: Overcurrent or thyristor damage can occur if a 6RA80 is operated in a power system without sufficient commutating reactance in its infeed.

The commutating reactance is the sum of all reactances in the incoming circuit of the SINAMICS DCM: Line reactance plus transformer reactance plus reactance of the commutating reactor.

RFI suppression filter:

RFI suppression filters reduce conducted radio frequency interference from the power system (RF interference).

The filters listed in Catalog D23.1 / Operating Instructions are used to maintain radio interference level A1. If these requirements are specified by the plant operator, RFI suppression filters must be installed. As RF interference is lower on DC drives than on AC drives with frequency converters, filters are only implemented on the former if the customer makes a special request.

Note: The filters specified in the catalog are intended for grounded power systems. Alternative special filters for use in IT systems are available on request.

The filters must be installed on the line side in front of the commutation reactor (mandatory if using filters). If the filter and commutation reactor are installed in the wrong sequence, this will cause a fuse to blow in the current converter infeed.

Interference suppression filters do reduce RF interference but not the level of the harmonics on the line side.

Smoothing reactor in the DC circuit:

See "DC Motor" – "Old motor"

Reactive-power compensation, series-resonant circuits for harmonics:

These supplementary components with capacities parallel to the power system must be implemented with an inductor to prevent unacceptable resonance levels in the line infeed. See "Cosine Phi" for reactive power levels.

If capacitors are used at the SINAMICS DCM input, e.g. for power factor compensation, commutation reactors of at least 2% uk must be implemented in front of the SINAMICS DCM input to prevent overcurrents occurring in the SINAMICS DCM.

A calculation of the line-side harmonics can be performed by Siemens advisory services on request. In complex converter installations, the harmonics must be measured on the infeed network.

Note: High line-side harmonics can cause damage to other consumers on the same network, for example, to power factor correction capacitors of low-voltage motors.

Line-side overvoltage protection 7VV3002:

If the SINAMICS DCM is connected directly to the winding of a converter transformer without there being an open isolating point in front of the SINAMICS DCM (e.g. open main contactor) when the transformer is disconnected in the primary circuit, an overvoltage protection module

7VV3002 must be implemented on the infeed side of the current converter. Siemens technical advisers will support you with configuration.

More at:

http://support.automation.siemens.com/WW/view/en/19338566

Direct-voltage-side overvoltage protection, SIOV, or 7VV3003...

If a direct current motor is used as the load, no overvoltage protection is required on the direct voltage output to protect the converter.

If a high load inductance occurs, for example, when feeding a motor field or a solenoid with a 6-pulse converter (output of armature voltage output terminals of 6RA80), overvoltage protection parallel to the direct voltage output is always required. This must be configured for the given current and induction of the load.

Converter transformer:

In the case of higher power converters, a separate converter transformer is recommended (connection on high voltage side at the medium voltage level), to prevent overloading and/or damage of weak system consumers by system perturbation from the converter(s) (commutation notches, harmonics).

The transformer apparent power is:

S_T = Unetwork* 1.35 * 1.05 * Id

S_T: Required apparent power of transformer, Unetwork: Line-to-line network voltage at converter input; Id: Direct Current

Converter Commutation Protector, CCP:

The additional component CCP is available from Siemens for protection against the effects of conduction-through.

http://support.automation.siemens.com/WW/view/en/21688372

This CCP can be used with 6RA80 with a nominal direct current (actual value acc. to r50072[1]) from 300 to 2000 A (if 6RA80 is connected in parallel, use, CCPs in parallel) and nominal line voltages from 400 to 690 V.

Siemens technical advisers will support you with configuration.

Conduction-through is a physical effect of the line-commutated converter and is an effect that can occur during braking operation (regenerative feedback, 4Q or 2Q with field reversal) with a blown fuse.

See also the detailed article in the Internet, at the following address:

http://support.automation.siemens.com/WW/view/en/24120447

High-speed DC circuit-breaker:

Besides the CCP, implementation of a high-speed DC circuit-breaker is the only way of protecting the converter against the effects of conduction-through. The CCP is the preferred solution for new systems if the given current and voltage range is adequate. Older systems being retrofitted frequently have a high-speed DC circuit-breaker. We recommend keeping this. The high-speed circuit-breaker should trigger a fault during a current rise in order to prevent a fuse blowing. An air smoothing reactor is usually required in the direct current circuit to limit the rate of rise of the current on a fault. The required induction of the reactor depends on the system size and the type of semi-conductor protective fuse used. When retrofitting the old converter with 6RA80, check the design of these reactors; Siemens advisory services will help you with this.

Main contactor in the 6RA80 infeed:

This is dimensioned for maximum current I_{AC} for AC1 operation.

I_{AC} = 0.816 * Id_{max}. Id_{max} = maximum operational direct current. See Catalog LV1.

Retrofitting an old current converter by implementing SINAMICS DCM:

When retrofitting an old current converter in a B6C / (B6)A(B6)C connection (for other types/circuit types please consult us) with 6RA80, the following procedure is possible: Replace the converter and insert the new semi-conductor fuses prescribed for 6RA80. Other existing components such as the converter transformer or an existing commutation reactor and overvoltage protection can be kept. Any existing smoothing reactor in the direct current circuit should also be kept.

As the old converters did not usually include a closed-loop controlled field device, which made a commutation reactor superfluous, a commutation reactor must be retrofitted for the field circuit if the field supply is used in 6RA80. Its rated alternating current should be equal to the rated current of the motor field; if this is not known, dimension it for the rated current of the field power supply unit.

New 6RA80 converters emit no higher radio interference than older products used previously, which means it is not necessary to retrofit the interference suppression filter when retroftting with 6RA80, as long as the plant operator does not make higher demands than for the old device.

Selection of replacement converter see here:
http://support.automation.siemens.com/WW/view/en/26117006

The separately excited direct current motor

Motor armature and motor field are supplied from separate voltage sources.

The windings in the motor:

The armature winding: The armature winding is located in the movable motor armature and armature current flows through it. The number of turns of the armature winding determines the EMF of the motor.

The commutating winding: This is used to keep the area below the carbon brushes field-free, to ensure good commutation.

The compensation winding: An anchor current causes the distortion of main flux Φ and therefore a reaction that corresponds to a field weakening. As this is dependent on the magnitude of the armature current, for higher motor powers in particular direct current motors are implemented with a compensation winding in the stator to compensate for this effect. Without a compensation winding the following formulas can only be approximations. If, for example, the motor torque is to be determined very precisely as a function of the armature current, or operation without a tachometer with speed control via the EMF is to be performed, a compensation winding is mandatory.

The compound winding: This winding is a stabilizing series winding and strengthens the motor flux proportionally with the armature current. This increases the motor torque. Stabilizing series windings are frequently to be found in old motors.

See under: http://support.automation.siemens.com/WW/view/en/40871945

Armature winding, commutating winding, and compound winding are arranged in series and then led outwards via terminals A1 and A2 for the customer connection. The effective value for resistance Ra and induction La applies to all four windings collectively.

The field winding: Motor flux Φ is applied via the current of the field winding, which produces the EMF as a function of the speed and the torque of the motor as a function of the armature current.

The commutator: The current to the rotating motor armature with its armature winding is led to a commutator via carbon brushes. The commutator supplies the armature winding in the correct polarity (electromechanical commutation) so that a torque is generated in the motor as a function of the armature current using the flux in the torque.
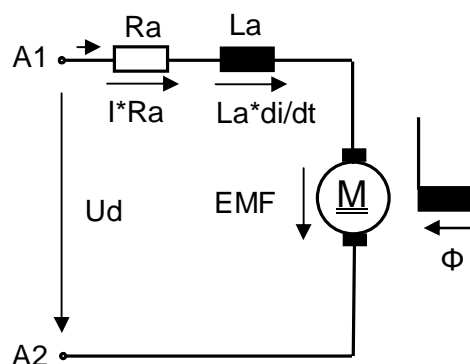
M: DC motor
A1, A2: Terminals, motor armature
F1, F2: Terminals, motor field
Φ: Motor flux
I: Armature current, motor
EMF: Voltage induced in the motor
Ra: Armature resistance, motor
La: Armature inductance, motor
Ud: Terminal voltage, motor armature

The formula for the voltage is as follows:

$$Ud = EMF + I * Ra + La * di / dt$$

I * Ra: Voltage drop at armature resistance of the motor as a function of the armature current
La * di / dt: Induced voltage in the armature induction of the motor that occurs on a current change Δi during the time Δt.
For example, Δi = 500 A during time interval Δt = 10 ms, at an La of 1 mH:

La * Δi / Δt = 0.001 * 500 / 0.01 = 50 V
For stationary state of the motor: Δi = 0,
In this case, only the voltage drop due to the resistance of the armature resistor of the motor has an effect.

EMF (electromotive force):
This is the internal motor voltage which is induced as a function of the speed n and flux Φ of the motor.
EMF = k1 * Φ * n,
The EMF is thus proportional to the flux Φ and the speed n.
Contant k1 depends on the number of pole pairs and the number of armature windings of the motor.
During nominal operation with rated motor speed and nominal flow, a nominal EMF is established, on speed zero the EMF is zero and the required motor voltage is I * Ra.

Motor flux Φ:
Flux Φ is applied to the field winding via the field current. As the result of saturation occurring in the magnetic circuit of the motor, the relationship between the field current and the flux Φ resulting from it is non-linear, i.e. as the excitation current increases the flow increases less than proportionally due to the saturation of the iron core. This relationship is determined by the field characteristic recording with p50051 = 27 in the SINAMICS DCM.
Field current:
The field supply unit in the SINAMICS DCM regulates to a constant field current irrespectively of the temperature-dependent field resistance and the line voltage (assumed to be sufficiently high), the required direct voltage sets itself automatically.

The motor torque:
Motor flux Φ and armature current I determine the torque M of the motor,
M = k2 * Φ * I, M = motor torque in [Nm]
The motor torque is thus proportional to the product of flux Φ and armature current I.
Constant k2 is dependent on the number of armature windings and the dimensions of the machine.

Accelerating torque M_B:
M_B = J * dω / dt,
with moment of inertia J in [kgm^2], ω = 2 * π * f, f = n / 60,
n in revolutions per minute [RPM]
M_B = J * (2 * π / 60) * dn / dt.
M is constant for a constant dn/dt, so differential quantities are to be expected. For example, a speed change of 0 to 1500 RPM results in a Δn of 1500; used in the formula above, it can be used to determine the acceleration time Δt.
The motor torque M required for acceleration is the sum of the load torque M_L to be surmounted and acceleration torque M_B:
M = M_L + M_B

Relationship between torque and power:
M[Nm] = P[kW] * 9550 / n[RPM]
The rated motor power P acc. to the motor rating plate and the rated motor speed equals rated motor torque M.

The electrical/mechanical power:
P_{el} = Ud * I is the electrical power of the motor. Multiplied with efficiency η of the motor it yields mechanical motor power P_{mech}, which is stated on the rating plate of the motor.
P_{mech} = P_{el} * η

Relationship:

n_n: Rated speed
n_{Fmax}: Maximum field weakening speed
where P_n = constant
n_{mech}: Highest permissible operating speed
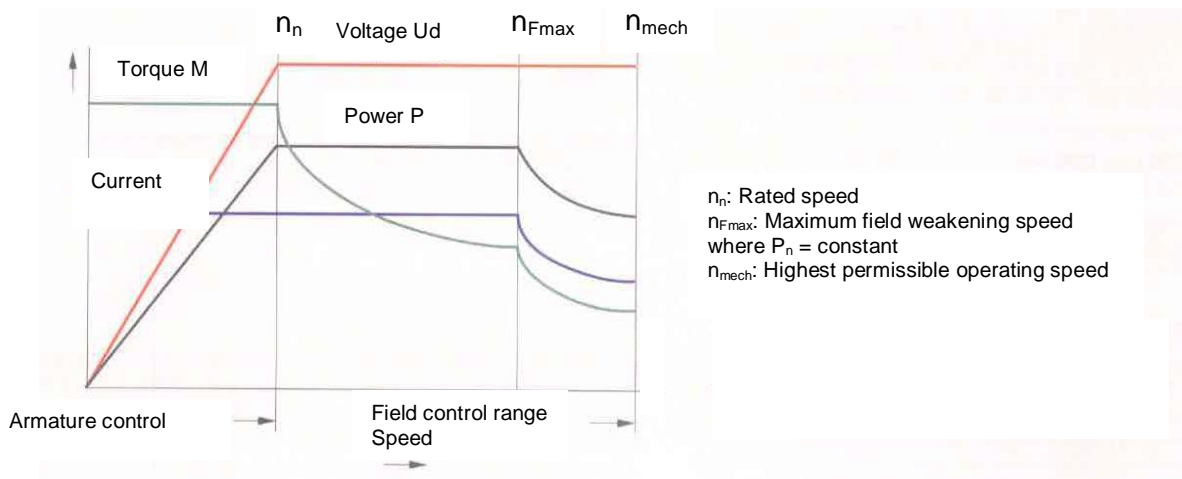
Armature control range: The armature and the power at constant current increase proportionally to the speed. The rated motor voltage is reached when the rated speed is at nominal flux.

Field control range: To increase the speed beyond the rated speed and to prevent the voltage from increasing beyond the rated value, the motor field must be weakened. A constant current and constant voltage therefore results in a constant power and a torque that is reduced inversely proportional to the speed.

Field weakening at constant power is possible up until the maximum field weakening speed n_{Fmax} is reached. At even higher speeds, the current must be reduced while taking account of the commutation (brush sparking!). This is done in the SINAMICS DCM by setting the speed-dependent current limitation, see Section 10.21 of the SINAMICS DCM Operating Instructions. Due to the necessary current reduction in this range, an additional power reduction and as a result an even greater torque reduction will result at constant voltage.

Protection of the motor winding from overtemperature:

A thermal motor protection can be approximated with the I^2*t monitoring implemented in SINAMICS DCM. The resulting winding temperature is calculated with the help of a thermal model of the motor and a warning and fault message are output depending on that result. A thermal equivalent time constant is entered as the required setting value in parameter p50114. The curve depicted in Section 10.19 of the Operating Instructions for p50114 applies to all Siemens direct current motors of type 1G.5/6/7 1H.5/6/7. Please contact the motor manufacturer if non-Siemens motors are to be used.

It is important to remember that this I^2*t monitoring does not provide full motor protection. A temperature sensor is required for that.

The 6RA80 can evaluate the following temperature sensors: PTC thermistor Warning, or switch off, no temperature display possible. NTC, PT100, PT1000, KTY84 temperature display possible, temperature threshholds for warning and switch-off can be set. (see parameters p50490 to p50494 of the 6RA80).

The temperature thresholds for warning and switch-off (required for NTC, KTY; PT100) are motor specific, for which a request for quotation is required, please give the entire order number and factory number of the motor.

Example of a motor power plate / rating plate:

Order No.: MLFB		Serial number/ Factory serial

SIEMENS $C\epsilon$

DC - Motor 1GG6286-0NG40-1VV1-Z

No. N R7 1145783 010 001 / 2004   EN 60034

Wärmekl./Th.Cl. H		IP23 / IC 06	IM B3	Gew./Wt. 1,56 t

V	A	1/min	kW
20 ... 420	985	10 ... 1410	2,76 ... 390
420	990	1410 ... 1620	390

Fremderr./Separate excit.: 310 ... 210 V, 14,5 ... 11,5 A

Fremdkühlung/Separate cooling: 0,75 m³/s

Luftrichtung/ Dir. of Ventilation NDE-DE

B6C, 400 V, 50 Hz

MADE IN GERMANY

Labels pointing to the plate: **Armature control**, **Field control range**, **Exciter data**, **Construction**, **Power**

Rated motor voltage: 420 V, rated motor current 985 A
Rated motor speed: 1410 RPM, maximum field weakening speed: 1620 RPM
Field data: 310 V / 14.5 A at speed zero to rated speed 1410 RPM,
at a maximum field weakening speed of 1620 RPM: 210 V / 11.5 A
Field resistance when winding is warm: 310 V / 14.5 A = 21.4 Ω
And 210 V / 11.5 A = 18.3 Ω

Note: The field resistance for a warm winding is approx. 25% higher than in the cold state, the controlled field device in the SINAMICS DCM compensates for this effect with constant current regulation. The lower resistance at 11.5 A results because the field winding does not heat up so much with a low field current.

The gearing

Gears are used to adapt the speed of the motor to a particular system speed.
Relationships:
Motor speed / load speed = gear ratio i
Convert load variables to the motor side:
$M_L / i = M_{LM}$,
M_L: Torque on the load side, M_{LM}: Load-side torque converted to the motor side.
$J_L / i^2 = J_{LM}$
J_L: Moment of inertia on the load side, J_{LM}: Load-side inertia converted to motor side.
$P_L = P_M$, the power on the load side corresponds to the power on the motor side.

Operation

SINAMICS DCM:

The SINAMICS DCM must be operated within the specification according to the technical data in the Operating Instructions (line voltage, current, ambient conditions).

The maximum ambient temperature is the temperature directly at the air inlet of the heatsink on the SINAMICS DCM and not the room temperature outside the control cabinet.

The rated current printed on the rating plate is the permissible continuous current of the device. If the current is lower than the rated current, the device can be loaded with a higher current for a particular cycle duration but no more than 1.8 x the value of rated current r50072[0]. The possible overload duration is calculated with a thermal model and monitored. See also the overload curves in Catalog D23.1. The response of the device after consumption of the thermal reserves in the devices can be set in parameter p50075.

DC motor:

The current specified on the rating plate is the continuous current (S1 operation), in intermittent operation a higher current is possible.

Operation at partial load (< 50% I) over a longer period results in heavy brush wear and commutation problems and must be avoided.

(Consultation necessary).

Stationary DC motors may be loaded with armature current only for short periods to prevent thermal overload of individual commutator segments. Please ask about permissible values. Low speeds (>0) are permissible.

When the motor is operated with its nominal field current the motor fan must be in operation to avoid overheating of the field winding.

According to the rating plate, the maximum field weakening speed n_{Fmax} or n_2 (when motor is operated in the speed-dependent current limit range) should not be exceeded, as the motor can only be tested for balance and commutation response up to this speed.

Maintenance

The maintenance instructions given in the operating instructions of the components used must be observed.

SINAMICS DCM:

Dirt and contamination: Depending on the degree of contamination, the device must be cleaned at regular intervals, but at least every 12 months, with compressed air at maximum 1 bar or with a vacuum cleaner.

The ribs of the heatsink must be free of dirt to ensure that they can dissipate heat without obstruction.

Dirt on modules reduces the air and creepage distances, this can cause arcing and damage. The modules must always be free of conductive dust.

Depending on their contamination with dirt from the environment, filters in the control cabinet must be replaced at certain time intervals.

Condensation: Condensation on the modules is not permissible. If condensation occurs, the device may not be reconnected to the line voltage until the modules are completely dry.

Where equipment is used in tropical countries, we recommend equipping the control cabinet with cabinet heating to prevent condensation.

If the device is in operation, condensation is prevented by its own heat dissipation. The cabinet heating should therefore be activated when the device is not in operation.

Environmental requirements, see Chapter 4.2 of the Operating Instructions:

Fan: Devices with a current of 210 A or more are equipped with a fan. These fans should be replaced every 30,000 operating hours to ensure the availability of the SINAMICS DCM.

DC motor:

Maintenance intervals: The direct current motor must be maintained at regular intervals. The maintenance intervals and extent are stated in the operating instructions of the motor.

Dirt and contamination: The cooling-air passages to the motor ventilation must be cleaned regularly depending on the extent of contamination. When replacing the brushes, free the inside of the motor from abraded brush material (brush dust), the brush equipment and insulating parts of the commutator must be cleaned. After a protracted operating time, the motor must be dismantled and the winding also freed from brush dust.

Condensation: Condensation inside the motor is not permissible. Possible remedial measures: Use an air-condensation heater, or as an alternative, supply the motor field with approx. 30% of the nominal exciter current without operating motor fan in order to heat up and dry the inside of the motor.

Brushes: The current is fed to the commutator of the motor via carbon brushes. The brush life depends on such plant conditions as diameter of the commutator, motor speed, current level, and environmental conditions. The continuous current of the motor should be greater than 50% of the rated current of the motor, a lower armature current, so-called operation at partial load, results in higher brush wear, which can be partially compensated for with special brush materials. The carbon brushes must rest well on the commutator and the brushes must be able to move freely in the brush-holder. Brushes must not be worn down below the permissible residual brush height (see marking on brushes). When replacing carbon brushes ensure that the original type is inserted according to the printing on the brush.

Brush rocker: The brush rocker must be set to the line mark on the end shield and brush rocker, if positioned incorrectly, brush sparking will result and could damage the brush and the commutator.

Commutator: Keep the slots between the commutator segment clean by cleaning them. Contaminated slots could cause flashovers and arcing on the commutator. Ribbing and burn marks on the commutator must be removed by grinding.

If necessary, remove the rotor and skim the commutator on the lathe, then the slots, for example, must be reworked with a special saw. The minimum permissible commutator diameter is stated in the operating instructions.

Insulation test: Before being installed or after long storage or shutdown periods, the insulation resistance of the windings must be measured to ground with direct voltage. Measurement should be performed when the winding is cooled (20 – 30 degrees room temperature). Please observe the operating instructions of the insulation resistance meter, if the converter is connected, first check that its input is safely isolated from the supply. 500 V is the maximum permissible measuring voltage. When making the measurement, you must wait approx. one minute until the final resistance value is reached.

Measuring circuit voltage: 100 V to 500 V direct voltage, minimum insulation resistance of new or repaired windings: 10 MΩ. Critical insulation resistance: 0.5 MΩ / kV rated voltage of the motor.

Example of 500 V rated voltage: 0.5 kV * 0.5 MΩ / kV = 0.25 MΩ = 250 kΩ

Remedy if insulation resistance of winding is too low: Clean and dry winding.

Note: As the voltage measurement in the SINAMICS DCM is high-resistance, the motor cables at the SINAMICS DCM can remain connected during the measurement of the insulation resistance. --

Motor bearing: The motor bearing is subject to wear, which is dependent on system conditions such as the motor speed and the magnitude of the resulting lateral forces on the bearing. The bearing life is typically between 30,000 to 40,000 operating hours.

Smaller motors are equipped with bearings with permanent lubrication, bearings must be replaced as soon as their useful life has elapsed. Larger motors are equipped with a relubricating device. A lubrication instruction plate is located next to the rating plate of the motor. It provides details of lubrication type, lubrication quantity and relubrication intervals. It also gives details of the bearing type installed in the motor. After the bearing useful life has elapsed, these bearings, too, must be replaced. The bearing cover contains a used lubrication compartment, which must be freed from lubricant after relubrication has been

performed several times. Remember that the fan motor is also equipped with bearings to which the above instructions apply.

Measurements on the motor

Measurement of field current, field voltage, field current with display parameters in the SINAMICS DCM: r50035

Field voltage by means of an external voltmeter and comparison with the calculated voltage, see above.

Measurement of the armature voltage, armature current through display parameters in the SINAMICS DCM:

Current: r50019, voltage: r50038

It may be necessary to check by measurement with an additional measuring instrument.

Field resistance: with ohmmeter, desired result: rated field voltage / rated field current according to the motor rating plate, measured value is approx. 25% lower than calculated for a cold winding.

Armature resistance, several milliohms to ohms depending on motor size, milliohmmeter required.

Precautions when operating the SINAMICS DCM on an old motor

By old motor, we mean a motor that is at least 20 years old that was not originally designed for operation on the converter, e.g. retrofit replacement of motor power supply through a Ward-Leonard generator set by a converter.

Because the old motor was usually designed to have a power margin, no special precautions are usually required with regard to additional losses due to converter operation. However, the current commutation with greater current ripple due to converter operation must be taken into account. The current ripple of the direct current (rms value of the current ripple) is calculated. This should not be greater than 10 % of the rated current of the motor in the worst case.

Siemens technical advisers will support you in calculating the smoothing reactor required in the DC circuit to comply with the above current ripple data. Please state the nominal line voltage and the rating plate data of the motor.

It is helpful to specify the armature resistance and the armature inductance of the motor. If this data is no longer available, we will estimate it and allow a margin in the reactor rating.

If the motor was already being operated with a converter and a smoothing reactor is in use, this must be retained when the 6RA80 is retrofitted.

Lower rates of current change are permissible on old motors than on modern DC motors. High rates of current change on the old motor can result in the occurrence of overcurrent peaks in the armature current (due to commutation problems). Therefore activate the current setpoint integrator in the SINAMICS DCM: Set p50157 = 1, p50158 = approx. 0.04 s.

If an iron-cored smoothing reactor is used, set p50153 = 2.

Special applications of the SINAMICS DCM

The normal application is operation of a separately excited DC motor on the 6RA80. However, the 6RA80 can be used for many special applications in addition to this. Thererfore application notes are available
http://support.automation.siemens.com/WW/view/de/38157755/133300

Operation of a permanent-magnet DC motor, e.g. 1HU3... on the SINAMICS DCM:
A permanent-magnet DC motor has permanent magnets for the motor excitation field. These types of motor can also be used on the 6RA80. The 1HU3 motor has a rated voltage of 160 V. If a 6RA80 is operated in a 400 V 3AC power system, a peak voltage of 560 V occurs at the output. The commutator of the motor is not rated for such a high peak voltage and may be damaged. For that reason, a 150 V 3AC to 230 V 3AC matching transformer is required at the input of the 6RA80 1U1/1V1/1W1. The nominal line voltage is set in parameter p50078[0].
To perform current controller optimization, the motor shaft must be blocked. (The motor must remain stopped during current controller optimization.)

Operation of a series-wound motor or a motor with a stabilizing series winding (compound winding) on the SINAMICS DCM:
See under: http://support.automation.siemens.com/WW/view/en/40871945

Input of a high inductance via SINAMICS DCM:
For operation of a high inductance (field power supply of a DC motor, field power supply of a synchronous generator, solenoid application, eddy-current brake) on the 6RA80, fault-free operation on the standard 6RA80 is possible
Note: An overvoltage protection must be always configured at the direct voltage output of the 6RA80 to protect the thyristors in the 6RA80. This must be suitable for reducing the energy content of the inductive load: $W[Ws] = L[H] * I[A]^2 / 2$ in case of a fault.
http://support.automation.siemens.com/WW/view/en/47362177/0/de
Closed-loop control of a generator set using SINAMICS DCM:
http://support.automation.siemens.com/WW/view/en/54140187
12-pulse parallel connection with SINAMICS DCM:
6-pulse or 12-pulse series connection of SINAMICS DCM:
http://support.automation.siemens.com/WW/view/en/59383636
Parallel connection or series connection of motors on a shared SINAMICS DCM:
See under: http://support.automation.siemens.com/WW/view/en/40960351

DC link infeed from pulse-controlled converters through SINAMICS DCM:
Possible, if required: A DC smoothing reactor is recommended for this application. Siemens technical advisers will support you with configuration.
2Q: For DC link voltage up to approx. line voltage * 1.2
4Q: Maximum controlled DC link voltage up to line voltage * 1.05 possible.
Set p50153 = 2.

Charging batteries with SINAMICS DCM:
Siemens technical advisers will support you with configuration of this application.

Electrolytic applications with SINAMICS DCM:
Siemens technical advisers will support you with configuration of these applications.

Retrofit replacement of the control of old power sections with
6RA80 control via SINAMICS DCM Control Module:

A little control engineering (for those who are interested)

This summary is no substitute for study the theory of closed-loop control but is intended to provide information on some relationships and help with practical application.

Time equation and frequency response

Every linear system can be described by one or more coupled linear differential equations. The solution to a non-homogeneous linear differential equation is composed of a homogeneous and a non-homogeneous partial solution.

If the input variable of a linear system is a harmonic oscillation in a particular case, the non-homogeneous partial solution that characterizes the steady state is also a harmonic oscillation.

Time equation:

Input variable: $x_e = {}^\wedge x_e * \sin(\omega t)$ $^\wedge x$ = peak value of x

Solution method for the output variable: $x_a = {}^\wedge x_a * \sin(\omega t + \varphi)$

Or, in complex notation: $x_e = {}^\wedge x_e * e^{j\omega t}$; $x_a = {}^\wedge x_a * e^{j(\omega t + \varphi)}$

For an nth-order linear differential equation, the following applies:

$x_a + a_1 * dx_a / dt + a_2 * d^2 x_a / dt^2 + ... + a_n * d^n x_a / dt^n = k * x_e$

Where $d / dt \rightarrow j\omega = p$, $d^2 / dt^2 \rightarrow (j\omega)^2 = p^2$ etc applies:

$x_a * e^{j(\omega t + \varphi)} * (1 + p a_1 + p^2 a_2 + ... + p^n a_n) = k {}^\wedge x_e e^{j\omega t}$

Further substitution and transformation then yields the following:

$G(p) = x_a / x_e = k / (1 + p a_1 + p^2 a_2 + ... + p^n a_n)$

G(p) is termed the frequency response.

The frequency response of a linear system is the relation between the non-homogeneous partial solution of the output variable to that of the input variable, where the input variable is a harmonic oscillation.

As can be seen above, the frequency response is obtained from the differential equation by substituting p.

The advantage of the frequency response is that only the fundamental operation of arithmetic: addition, subtraction, multiplication and division have to be applied, unlike solving differential equations.

Frequency response and transfer function

The frequency response equation describes the response of a system for a harmonic oscillation. It is therefore a special case of an equation, similar to the differential equation, that describes the response of a system for any input variables. Such an equation can be obtained by applying the Laplace transform to the system equations.

By means of the integral F(s):

$$F(s) = \int_0^\infty f(t) * e^{-st} * dt$$

a time-dependent function f(t) is transformed into a function F(s) depending on the complex variable

$s = \delta + j\omega$.

In this case, f(t) is the original function and F(s) is the Laplace transform. Applying the Laplace function to an original function in the form of a linear differential equation results in a Laplace transform in the form of a linear algebraic equation. By solving this algebraic equation and re-transformation to the original, this solution can be calculated as a differential equation. Please refer to the extensive literature on this topic.

Using an example of a second-order linear differential equation:

$x_a + a_1 * d/dt * x_a + a_2 * d^2/dt^2 * x_a = k * x_e$

and the addition rule:

$a_1 f_1(t) + ... + a_n f_n(t) \rightarrow a_1 f_1(s) + ... + a_n f_n(s)$ and the differential rule:

$d_n/dt^n * f(t) \rightarrow s^n * f(s) + s^{n-1} * f(0) + s^{n-2} * f'(0) + ... + f^{(n-1)}(0)$

f'(0): Value of the first derivation of f(t) at time t = 0
f''(0): Value of the second derivation of f(t) at time t = 0
With the initial values at t = 0, this results the following Laplace transform:
$x_a + a_1 s x_a + a_2 s^2 x_a = k * x_e$
This yields the transfer function: $G(s) = x_a / x_e = k / (1+a_1 s+a_2 s^2)$.
So, instead of solving closed-loop control problems with differential equations, the Laplace transform is used to calculate the transfer function. With this transfer function it is possible to obtain information about the stability of the system using suitable methods, for example, the root locus method (see the relevant literature).
In drive control loops, frequency response analyses are often the route to success that requires the least effort. The transfer function can be obtained at any time by substituting $p = j\omega$ by the complex expression s.

Below, the transfer function is dealt with as a response to a step change in input for several transfer elements.

Proportional transfer element
There is no time delay between input and output, only the amplitude of the output is less than or greater than the input.
Kp is the gain of the P element.
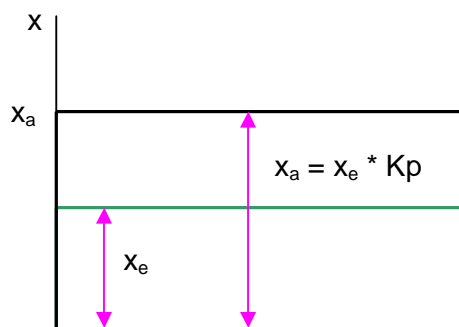
Transfer function,
Time equation:
$F(t) = x_a(t) / x_e(t) = Kp$
Frequency response:
$F(p) = x_a(p) / x_e(p) = Kp$

First-order lag element
Example: Series connection of the resistance and inductance, e.g. in the armature circuit of the motor
This element results in a sluggish time response of the control loop, large time constants having a greater effect. The aim is therefore to compensate for this response with a suitable controller.
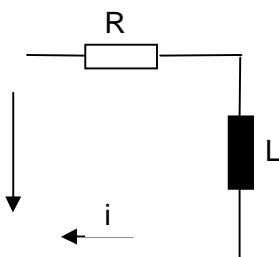
u: voltage, i: current, R: resistance, L: inductance
$u(t) = R * i(t) + L * di(t) / dt$; time constant $T = L / R$
$R * i(t) = U * (1-e^{-t/T})$; $V_P = U / R$
Time equation: $f(t) = x_a(t) / X_e = V_P * (1-e^{-t/T})$
Frequency response: $F(p) = V_P / (1+pT)$
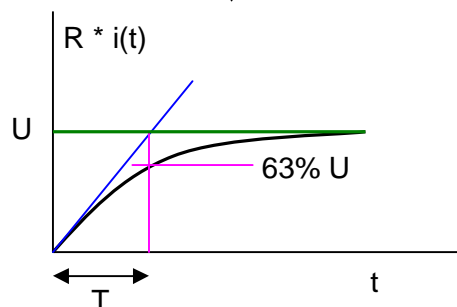
U: step change in voltage at the input

Step response: R * i(t)

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Transfer element with dead time

If the output variable follows the input variable, resulting in a time offset, this is termed a dead time response.

The time constant T_t is the dead time.

You can image the dead-time element as composed of an infinite number of 1st-order lags. If the dead time is sufficiently small, it can be treated like a first-order lag element for calculation purposes.

Let us take the current converter as an example because the output for a control voltage U_{st} on the trigger set can only have a delaying effect depending on the trigger delay angle on the output depending on the instantaneous phase angle of the line voltage. The signal for a phase angle change is only acted upon after a dead time of the output voltage U_a.
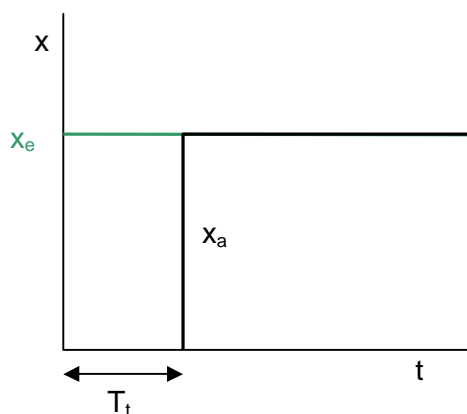
Dynamic response:
$x_a (t) = x_e (t - T_t)$
Frequency response:
$F (p) = e^{-pT_t}$

Integral-action transfer element

Example: Speed ramp-up of a motor with a constant motor and load torque in the armature setting range.
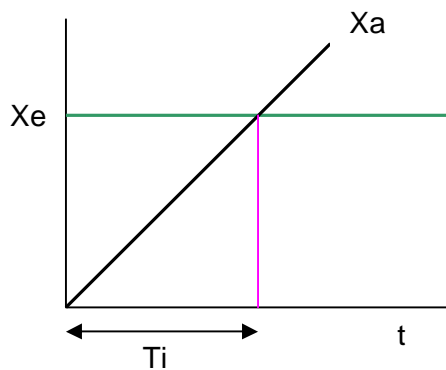
Xe: input variable; Xa: output variable
Transfer function: $f(t) = Xa(t) / Xe = t / Ti$
Frequency response: $F(p) = 1 / (p * Ti)$
In the case of a step change in the input variable, the output variable increases

Proportional-plus-integral controller; PI controller

Frequency response: $G_R = Kp * (1 + p * Tn) / (p * Tn)$

With the factor $(1 + p * Tn)$ it is possible to compensate for a time constant of the control loop here. This always compensates for the greatest time constant.

Kp: gain; Tn: reset time; Xe: input variable; Xa: output variable

The output initially responds with a step change in voltage corresponding the the factor Kp and then with integration of the input voltage over time.

Tn: Time required to reach a magnitude of change corresponding to the Xe *Kp.

Ti: Integral-action time to reach a change in magnitude of the value of Xe.
Transfer function:
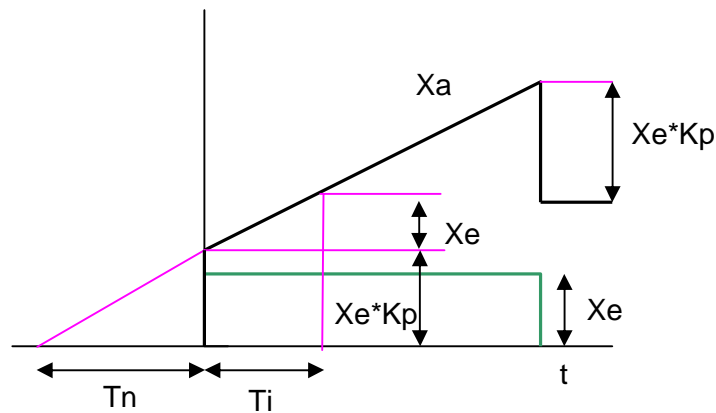
Proportional-plus-integral-plus-derivative controller, PID-controller
Frequency response:
$G_R = Kp * (1+ p*Tn) * (1+ p*Tv) / (p*Tn)$
If there are two larger time constant in the control loop, the greater of the two is compensated by $(1 + p*Tn)$ and the smaller, by $(1 + p*Tv)$.
Kp: P gain, Tn: reset time, Tv: rate time
Transfer function:
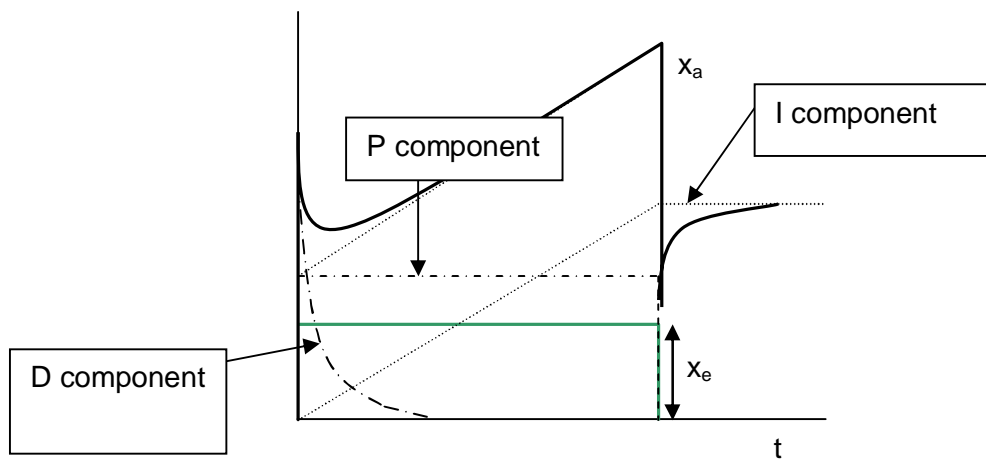
Controller optimization
The control equipment must be adjusted to output a manipulated variable y that has the controlled variable x follow a reference variable w or to compensate for a change in disturbance variable z as precisely as possible and with as little oscillation as possible. An ideal controller therefore as the relation $x(t) / w(t) = 1$ or $x(t) / z(t) = 0$, which would mean that you do not notice any change in the disturbance variable.
However, the lag effect of the controlled system through all its transfer elements is an obstacle to this ideal response of a control loop.

Settling of a control loop on a step change in input:
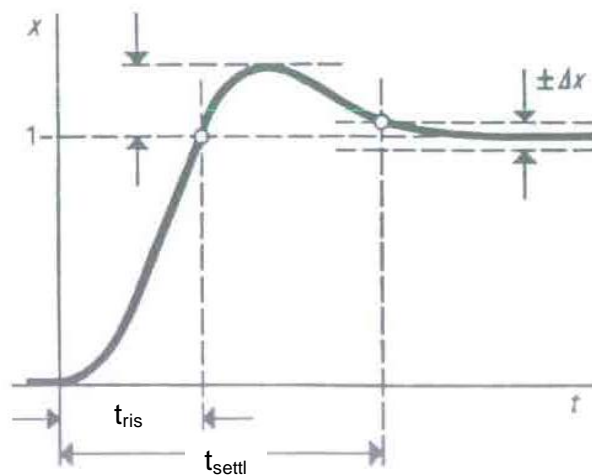
t_{rise}: The rise time characterized by the first moment the reference input reaches the set value.
t_{settle}: Settling time, time that elapses before the new settled final state is reached. This is deem reached when the controlled variable disappears within the tolerance band Δx.
Δx: e.g. 2% of the step change in the reference variable.
The overshoot o is stated as a percentage of the total step change in the reference variable.

Optimization of the PI controller according to the absolute value optimum
The absolute value optimum is used if there is no integral-action element in the controlled system. Approximation of the absolute value of the frequency response to the optimum value 1 is performed for the largest possible frequency range.
If, among multiple small lag elements in the controlled system, there is one that has a greater time constant (e.g. the armature time constant of the motor in relation to the current controller) than the sum of all the other lag elements, this time large time constant must be compensated for to speed up the control process. To avoid a static control error, the controller must have an integral character. To achieve compensation of the large lag using the integral-action controller, a proportional action is required in addition.
To compensate for the large time constant T1 it is necessary for the reset time Tn of the controller to correspond to this T1. Reset time Tn = T1
The Kp of the control is calculated from Kp = T1 / (2 * Vs * σ).
Vs is the controlled-system gain and σ is the sum of the small time constants of the lag elements.
The rise time is t_{rise} = 4.7 * σ; the settling time is t_{settle} = 8.4 * σ for a Δx of 2%.
The overshoot is 4.3%.
If, not one but two especially large lag elements are in a series of the first-order lag, a proportional-plus-integral-plus-derivative-action controller, i.e. a PID controller, is more suitable. The reset time Tn must always be set to the the larger time T1 of the two; Tv, to the smaller time constant T2 in the control loop.
Tn = T1, Tv = T2, Kp = T1 / (2 * Vs * σ).
The frequency response of the PID controller is: F(p) = Kp * (1+p*Tn) * (1+p*Tv) / (p*Tn)
Because 2 larger time constants are compensated for, the remaining σ is smaller, meaning that faster rise times can be achieved.

Optimization of the PI controller according to the symmetrical optimum

If a controlled system contains not only 1st-order lags, proportional-action elements and dead-time elements, but also elements with an integral character, optimization must be performed by a method other than the absolute value optimum to avoid controller oscillation due to series connection of the integral controller and the integral of the controlled system. A differing optimization rule must therefore be found for the reset time Tn. This is achieved by adjustment according to the symmetrical optimum.

If the controlled system contains an integral-action element and also a number of first-order lag element whose time constants can be grouped together into a total time constant σ, you can provide the controller with a PI action.

The frequency response of the open loop $F_0(p) = Kp * Vs * (1 + Tn) / [(pTn)\,(pT_0)\,(1+p\sigma)]$

The control parameters are set as follows:

$Kp = T_0 / (2*Vs*\sigma)$; $Tn = 4*\sigma$;

Vs is the controlled-system gain and σ the sum of the small time constants.

T_0 is the integral-action time of the integral-action element.

The rise time t_{rise} is 3.1*σ; the settling time t_{settle} is 16.5*σ; the overshoot is 43.3% for a Δx of 2%. This also applies of the controlled system contains an integral.

If, among the small lags, there is one with the constant T2 that exceeds the other, this must be compensated for with a derivative-action element, i.e. a PID controller must be used.

The frequency response of the open loop is therefore:

$F_0(p) = Kp *Vs * (1+pTn) *(1+ pTv) / [(pTn)*(1+ pT_2)* (1+p\sigma)]$.

If $T_2 = Tv$, the following results:

$F_0(p) = Kp * Vs * (1 + pTn) / [(pTn) *(pT_0) * (1 + p\sigma)]$, the same expression as above, resulting in the following for the optimization: $Kp = T_0 / (2*Vs*\sigma)$ and $Tn = 4*\sigma$.

If the controlled system consists of first-order lags among which one T_1 is more than four times greater than the sum of the others, the effect of this variable is approximately integral, which should result in optimization according to the symmetrical optimum in this case, too.

The set values are therefore: $Kp = T_1 / (2*Vs*\sigma)$; $Tn = 4\sigma$.

If the controlled system contains two especially large lags, a PID controller must be used with an integral-action time corresponding to the smaller of the two.

Setpoint smoothing

Overshoots of 43.4% are only permitted in very rare cases. Measures must be taken to reduce these.

Setpoint smoothing with $t_{ss} = 4\sigma$, i.e. with the magnitude of the Tn of the controller provides the suitable results, if Ti >=1

The rise time is then 7.6σ, the settling time with reference to a tolerance band of +/- 2% is 13.6σ, and the overshoot is 8.1%, with reference to a change to the settled state of 100%.

If the overshoots of the controlled variable are to disappear completely on a step change in the setpoint channel, stronger setpoint smoothing with $t_{ss} = 6\sigma$ can be connected in front of the symmetrically optimized control loop, that only contains first-order lags in the controlled system.

If you want to avoid the disadvantage of a slower control due to smoothing of the setpoint and still achieve a steeper rise, the smoothing element must be bypassed in the setpoint channel by a derivate-action element $t_{g1} = 4\sigma$.

**Comparison of the absolute value optimum
and the symmetrical optimum**

If you attempt to adjust a control loop according to the absolute optimum or the symmetrical optimum, you will not always succeed in sensing the data of the controlled system correctly, especially as some elements in the controlled system are non-linear, i.e. their characteristic values change on being controlled, inaccuracy in measurement will occur that results in a certain degree of error in adjustment of the control. This can be seen in the transfer function recorded using a recorder or trace function.

The response of the controlled variable to a step change in the reference variable usually reveals the error clearly.

The step responses shown below reveal the response at the optimum and with the characteristic values of the optimum maladjusted by a factor of 2. This show the direction in which the characteristic values have to be change to approach the optimum.

Setting of the correct rate time Tv of a PID controller according to the compensation method described above.

The diagrams for the absolute value optimum show that as the gain of the controller increases, the steepness of the response also increases, causing the overshoot to grow.

As the reset time increases, settling to the final value is performed with more and more pronounced tracking. However, if the reset time is smaller than the optimum value, the controller tends to oscillate more and more as the integral-action time is reduced.

If the gain is reduced by a factor of two, but the reset time has the correct value according to the absolute value optimum, the setting corresponds to the 'linear optimum'. The linear optimum is adjustment to the aperiodic limit case.

With a smaller reset time, the form of the transfer function approximates to that of the symmetrical optimum
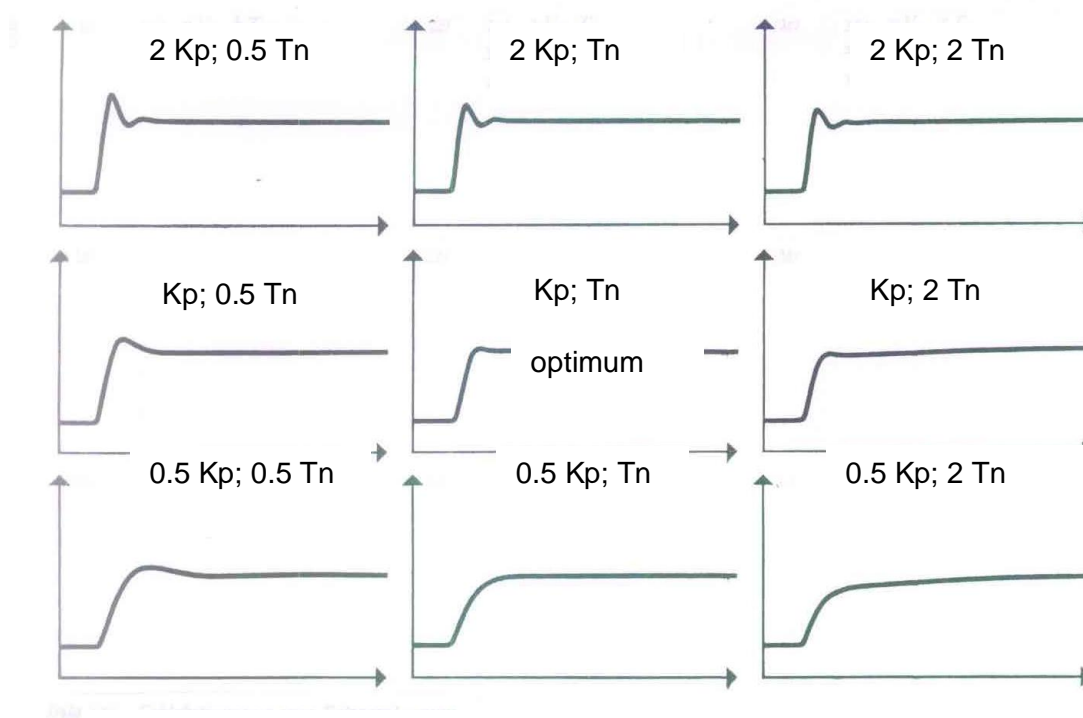
Adjustment to the absolute value optimum

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The transfer functions of the symmetrical optimum exhibit similar tendencies.

As the gain increases, the rise time decreases. An excessively large Kp results in more pronounced hunting, as does an excessively small Tn. If the reset time is too large, this results in a degree of settling, if the Kp is correctly set. If the Kp is too small or too large, the overshoot increases and if Tn is too small, pronounced oscillations whose frequency grows with the gain occur for every Kp.

Moreover, at the symmetrical optimum, the phase offset from critical positive feedback is smaller than for the absolute value optimum. While the absolute value optimized control loop can become more and more stable by reducing the gain, this is only possible for the symmetrically optimized loop by increasing the reset time at the same time as having correct gain.
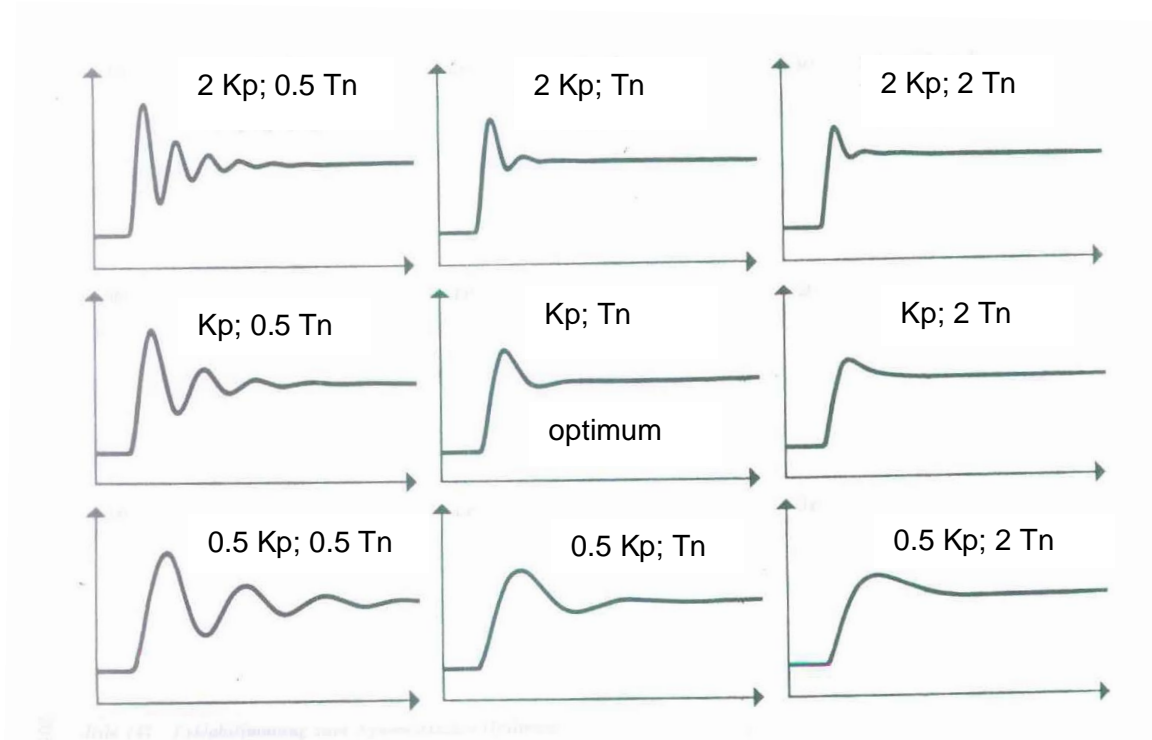
Adjustment according to the symmetrical optimum

Equivalent time constant of the optimized control loop

A controlled system often contains not just two but more time constants and integrals. This sometimes results in impermissibly slow settling.

For example, a drive not only has the speed control as a main controlled variable but also the armature current as an auxiliary variable.

In this case, the current control is therefore subordinate to the speed controller. For the higher-level control loop, the lower-level control must therefore be considered part of the controlled system. To be able to represent the frequency response of the higher-level loop as simply as possible, it is useful to use a first-order function for the lower-level loop.

For a lower-level controller optimized according to the absolute value optimum, the equivalent time constant $t_{eBO} = 2\sigma$ applies.

For a lower-level control loop optimized according to the symmetrical optimum, the following applies:

Equivalent time constant is $t_{eSO} = 4\sigma$

Avoiding overshooting of the controlled variable in an overdriven controller
So far we have assumed that none of the controllers is being overdriven. However, overdrive can be expected in response to large or fast changes in the reference variable. Because the manipulated variable cannot reach the necessary amplitude during the settling process, the controlled variable can only change more slowly. In the case of a controller with an integral-action component, the controller is overdriven and the integral-action component can only integrate back when the sign of the reference variable is inverted. This results in overshoots in the controlled variable. Such overshoots are not desired and can easily result in an unstable response of the control loop.
This can be counter-acted by a PI controller and a D-action component in the actual-value channel with $Tv = 4\sigma$ (controller optimized according to the symmetrical optimum).
Overdrive of the controller can also be reduced by a ramp function generator in the setpoint channel with a suitable choice of ramp time.

Overview tables for optimization
The following tables are used to define optimization method for the control loop according to the time constants of the controlled system and the characteristics of the controller.

Controlled system						Controller	Optimization	Time constant of the setpoint smoothing t_{gs}
Large time constants			Small time constants					
T_0	T_1	T_2	$4\sigma>=T$	$4\sigma<=T$	$4\sigma<<T$			
			X	X	X	I	BO	-
	X		X			PI	BO (SO)	-
	X			X		PI	SO (BO)	$0 < t_{gs} < 4\sigma$
	X				X	P (PI)	BO (SO)	(4σ)
	x	X	X			PID	BO (SO)	-
	x	X		X		PID	SO (BO)	$0 < t_{gs} < 4\sigma$
	x	X			X	PD (PID)	BO (SO)	(4σ)
X			X			PI	SO	4σ
X				X		PI	SO	4σ
X					X	P (PI)	BO (SO)	(4σ)
X		X	X			PID	SO	4σ
X		X		X		PID	SO	4σ
X		X			X	PD (PID)	BO (SO)	(4σ)

BO: absolute value optimum; SO: symmetrical optimum
The optimization state in brackets results in slower compensation
σ: sum of the small time contants;
T: largest first-order lag or integral-action time T_0
T_1: larger of the two large time constants
T_2: smaller of the two large time constants

Calculation of the controller parameters

Optimi-zation	Controller	Controller parameters					Transfer function on step change in setpoint			Equivalent time constant of the optimized control loop
		T_I	Tn	Tv	Kp Only lag	Kp With integral	t_{an}	t_{aus}	o %	
Linear optimum	I	$4V_s\sigma$	-	-	-	-	-	12σ	0	4σ
	P	-	-	-	$T_1/(4V_s\sigma)$	$T_i/4\sigma$				
	PI	$4V_s\sigma$	T_1	-	$T_1/(4V_s\sigma)$	-				
	PD	-	-	T_2	$T_1/(4V_s\sigma)$	$T_i/4\sigma$				
	PID	$4V_s\sigma$	T_1	T_2	$T_1/(4V_s\sigma)$	-				
Absolute value optimum	I	$2V_s\sigma$	-	-	-	-	4.7σ	8.4σ	4,3	2σ
	P	-	-	-	$T_1/(2V_s\sigma)$	$T_i/2\sigma$				
	PI	$2V_s\sigma$	T_1	-	$T_1/(2V_s\sigma)$	-				
	PD	-	-	T_2	$T_1/(2V_s\sigma)$	$T_i/2\sigma$				
	PID	$2V_s\sigma$	T_1	T_2	$T_1/(2V_s\sigma)$	-				
Only lag SO	PI	$V_s8\sigma^2/T_1$	4σ	-	$T_1/(2V_s\sigma)$	-	>3.1σ	<16.5σ	<43,4	$2\sigma+0.5t_{gs}$
	PID	$V_s8\sigma^2/T_1$	4σ	T_2	$T_1/(2V_s\sigma)$	-	<7.6σ	<13.3σ	<8,1	
SO with Integral	PI	$8\sigma^2/T_i$	4σ	-	-	$T_i/2\sigma$	3.1σ	16.5σ	43,4	4σ
	PID	$8\sigma^2/T_i$	4σ	T_2	-	$T_i/2\sigma$	7.6σ	13.3σ	8,1	

t_{rise}: rise time; t_{settle}: settling time, o: overshoot as a percentage

$T_i = T_0/V_s$: integral-action time of the controlled system; T_0: integral-action time, V_s: Controlled system gain

SO: symmetrical optimum

Compensation of disturbance variables

A controlled system is also subject to disturbance variables, such as a load surge on a variable-speed drive.

This load surge results in a system deviation that is corrected by the controller.

The constancy of the control stated in the Operating Instructions refers to a long period of, for example, 10 seconds. It therefore does not take a transient system deviation caused by a disturbance variable into account. This can therefore be greater than the value stated as the constancy.

We do not intend to look at formal derivation of the response to precontrol here. Suffice it to say that a controller adjusted according to the symmetrical optimum is more advantageous than one adjusted according to the absolute value optimum in such cases.

Symmetrical optimum with an integral in the controlled system

Optimized according to: symmetrical optimum

Transfer function on a step response of the disturbance variable: Optimized according to absolute value optimum
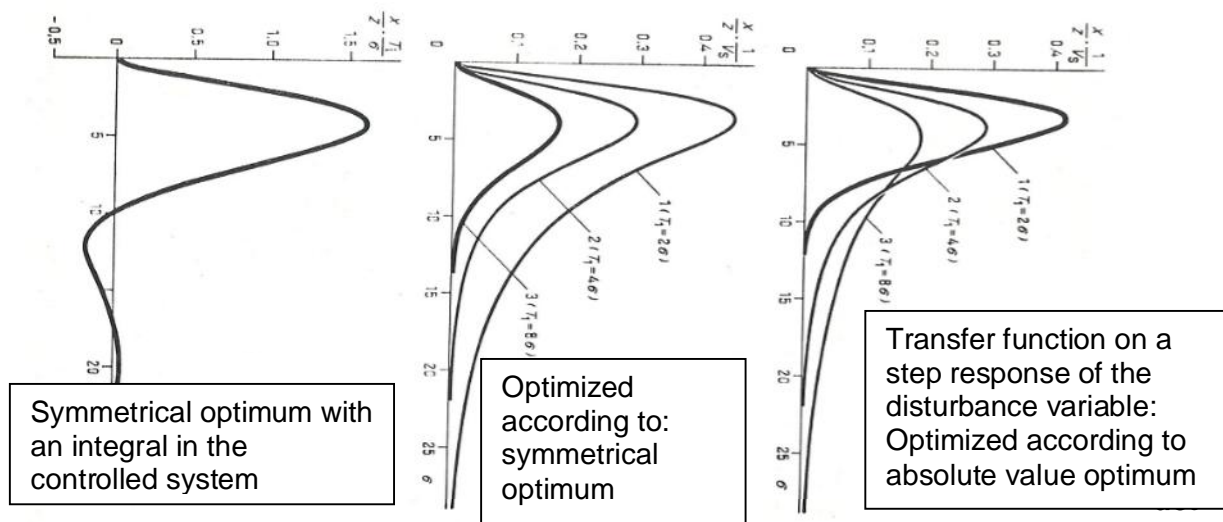
Structure diagram of the entire armature control loop with an example
Speed controller with a lower-level current controller and DC motor as the load.
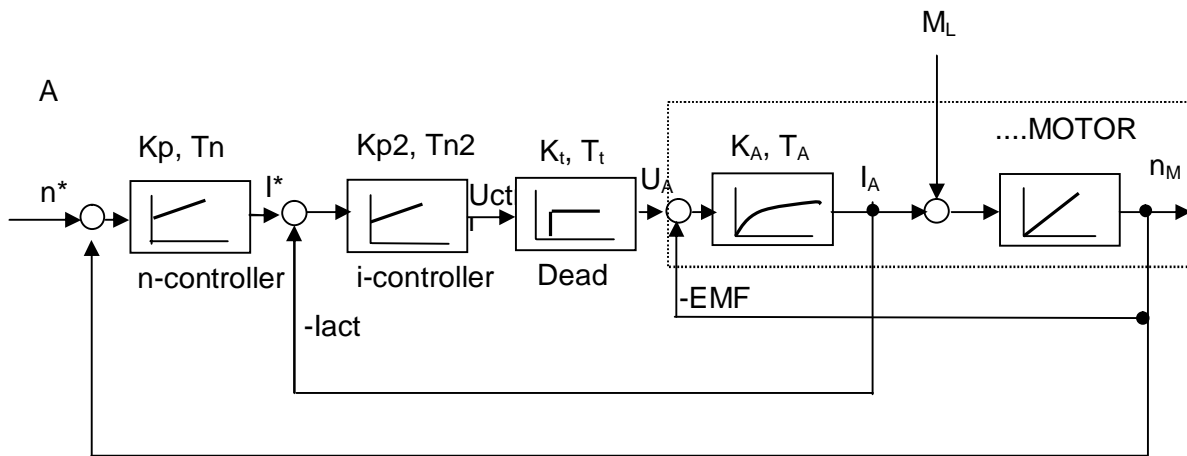
n*: speed setpoint, nact: speed actual value, I*: current setpoint, Iact: actual current value;
Ust: control voltage, U_A: armature voltage, EMF: induced motor voltage,
I_A: armature current motor, T_t: dead time due to power system cycles,
T_M: mechanical ramp-up time constant; M_L: load torque, n_M: the motor speed
n-controller: speed controller, i-controller: current controller
K_A, T_A: PT1 element due to armature circuit inductance and armature circuit resistance;
Kp: controller gain, Tn: controller reset time

Example:
B6C circuit, line voltage Us:3AC400 V, armature circuit inductance motor L_M: 0.5 mH,
rmature circuit resistance motor R_M: 0.02 ohm, inductance of smoothing reactor L_G: 1 mH,
resistance of smoothing reactor R_G: 5 mOhm, cable deemed negligible.
Voltage drop commutating reactor: Vimp = 4%,
Line frequency: 50 Hz, rated armature current I_{AN}: 600 A, rated armature voltage U_{AN}: 420 V,
firing angle range $\Delta\alpha$ = 90 degrees for 100% in the calculation of the software

Parameters of the dead-time element:
Ideal no-load direct voltage = Udi = Us * 1.35 = 540 V
The trigger firing angle for rated armature voltage α_2 is derived from the cosine function of
the control characteristic: cos α_2 = U_{AN} / Udi = 420 / 540 = 0.778 yields α_2 approx. 39 degrees
$K_t = \Delta\alpha / (\alpha_1 - \alpha_2) = 90 / (90 - 39) = 1.76$
Mean (statistical) dead time for 6-pulse bridge connection (p=6) and 50 Hz:
T_t = 20 ms / p = 20 / 6 = 3.33 ms, half of which is postulated as the statistical dead time:
T_t = 1.66 ms
Parameters of the lag element:
$R_A = R_M + R_G + R_S$, d_x = 0.5 * Vimp = 0.02; $R_S = d_x$ * Udi / I_{AN} = 0.02 * 540 / 600 = 0.018
R_A = 0.02 + 0.005 + 0.018 = 0.043
Armature circuit inductance $L_A = L_M + L_G$ = 1.5 mH
Armature circuit gain:
$K_A = U_{AN}$ / (I_{AN} * R_A) = 440 / (600*0.043) = 16.3
Armature time constant = $L_A / R_A = 1.5*10^{-3} / 0.043 = 0.0349$ s = 34.9 ms = T_1
If the set current limit is greater than I_{AN}, this peak current must be substituted in the
formulas. This also applies to the torque M_{MN} for the mechanical ramp-up time constant T_M.

Current controller optimization according to the absolute value optimum with a PI controller:
$V_s = K_t * K_A = 1.76 * 16.3 = 28.7$
$\sigma = 1.66$ ms,
$Tn = T_1 = 34.9$ ms
$Kp = T_1 / (2V_s\sigma) = 0.0349 / (2 * 28.7 * 0.00166) = 0.37$
The rise time of the current controller is $4.7\sigma = 4.7 * 1.66 = 8$ ms
The settling time of the current controller is $8.4\sigma = 14$ ms
Equivalent time constant of the lower-level current controller:
$\sigma = 4\sigma$(current control loop) $= 4 * 1.66 = 6.64$ ms (more suitable than the theoretical 2σ for the digital control 4σ used in this case).

Speed controller optimization according to the symmetrical optimum with a PI controller:
$Tn = 4\sigma = 4 * Tn$ current controller $= 4 * 34.9$ ms $= 0.14$ s.
Let the integral-action time T_0 (mechanical ramp-up time of motor, e.g. measured in a ramp-up experiment) be 4000 ms.
$T_i = T_0 / V_s = 4s / 28.7 = 4000$ ms $/ 28.7 = 139$ ms
$Kp = T_i / (2\sigma) = 139 / (2*34.9$ ms$) = 1.9$
The rise time of the speed controller is $3.1\sigma = 3.1 * 34.9 = 0.109$ s
Values measured for the 6RA80 were typically > 40 ms
The settling time is $16.5\sigma = 16.5 * 34.9 = 0.9$ s

Speed control with an oscillating mechanical system
The mechanical part of the drive is characterized by an I-element with the mechanical time constant T_M. T_M contains the motor inertia and the inertias of the coupled load, including the shaft, gearing, coupling, etc. In real cases, elastic connecting elements, such as couplines, long flexible torsion shafts or elastic belts, often have an effect. In this case, it is a damped multiple-mass oscillator. For this reason, the rise times calculated above can only rarely be achieved in practice. The structure diagram of the control will also deviate if the mechanical system is approximated to a two-mass oscillator.

$M_M = M_{BM} + M_F$
where M_M: motor torque, M_{BM}: accelerating torque of motor, M_F: torque of the springs

$M_{BM} = J_M * dn / dt * 2\pi / 60$; J_M: inertia of motor in m^2kg, n: speed in RPM
$M_{BM} = J_M * 2\pi /60 * p * N_M$; $n_M = 1 / (pT_M) * m_{BM}$, $T_M = J_M * 2\pi * N_{MN} / (M_{MN} * 60)$

$M_F = C_F * 2\pi * (N_M - N_L) / (p * 60)$; C_F: spring rate in Nm / rad
$m_F = (n_M - n_L) / (pT_F)$ where $T_F = 60 * M_{MN} / (2\pi * N_{MN} * C_F)$

The torque transmitted by the spring is used to accelerate the load: $m_F = m_{BL}$
load speed: $n_L = m_{BL} / (pT_L)$ where $T_L = J_L * 2\pi * N_{MN} / (60* M_{MN})$; J_L: Load inertia

In the case of gearing, the load inertia converted to the motor speed is used.

The structure diagram shows a cascade connection of I-elements, which would result in undamped oscillation once the system had been excited. The damping of the springs must therefore also be considered.

Structure diagram of the DC motor with elastically coupled flywheel and damping

K_F

K_A; T_A T_M T_F T_L

u_A m_M n_M m_F n
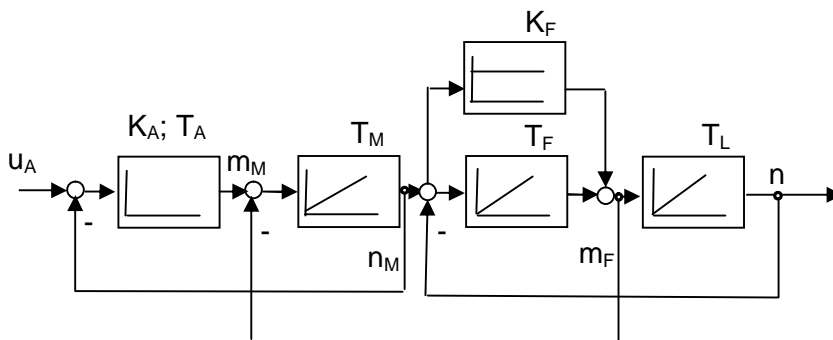
With damping, $m_F = (n_M - n_L) / (pT_F) + k_F * (n_M - n_L)$
With k_F of the gain of the damping element $k_F = d * 2\pi * N_{MN} / (60 * M_{MN})$ and d as the damping.

The characteristic values can be determined experimentally:
T_M: due to acceleration of the uncoupled motor at the current limit up to the rated speed of the motor.
$T_M + T_L$: due to acceleration of the motor with a coupled flywheel.
The natural frequency ω_e of the flexible mechanical system can be calculated by recording the speed with an oscillograph while the couple drive is ramping up at the current limit.

So, you can see that this is a complex issue.
On the SINAMICS DCM, the frequency response of the controlled system is calculated with p50051 = 29 as part of optimization of the drives with oscillating mechanical system and the parameters p50225, p50226, and p50228 required for the speed control loop are automatically set. We will therefore not look any further into this issue because the topic of frequency characteristics has not been dealt with in this document.

Adaptation of the controllers
Speed controllers: The characteristic values of the speed controllers can be adapted depending on an influencing variable (any connector variable), for example, to the actual current value or the speed actual value, see Sheet 6805 in Chapter 2 of Parameter Manual..
For gear stage changing (change of the T_M depending on the gear stage) or C-axis operation on main spindle drives, the Drive Data Set switchover (DDS0 to DDS3) can be used.
The current controller characteristics values can be adapted; each multiplied by one connector variable. The change in firing angle required for a change in current of a certain magnitude is different for discontinuous and continuous current. Thos non-linearity is compensated for by the current controller precontrol.
In the case of field weakening operation, division by PHI is performed after the speed controller (torque calculation can be selected). In this way, the speed controller output is the torque setpoint to adapt the controlled system accordingly.
The relationship between the field current and the motor flux PHI is non-linear because of the magnetization characteristic (non-linearity due to core saturation). The precontrol of the EMF controller takes this into account depending in the magnetization characteristic of the motor (recorded by field characteristic recording by means of p50051 = 27).
If the controlled variable reaches a limit, the integral-action component of the PI controller is stopped so as not to integrate away too much which could only be triggered to integrated

down again by an input variable with a negative sign. This reduces possible overshooting of the output variable.

In this implementation, the digital 6RA80 can make use of its advantages over older analog controls.

Technological controls with the SINAMICS DCM

Various options for technological controls can be implemented for the SINAMICS DCM. These can be implemented on the basic module using free function blocks or the DCC. Furthermore, SIMOTION can also be used.

Current / torque limitation control:

There is sometimes a requirement to limit to a certain speed and torque at the same time. This cannot be implemented without further complications.

The following options for closed-loop control exists: Speed control, with the speed kept constant at a certain speed setpoint and the current / torque is set to a suitable value, so that the speed is kept constant.

Torque control, with the motor torque kept constant and the speed set to a precisely the value that compensates for this torque while remaining constant.

The current limitation control or torque limitation control is a possible compromise. In the armature setting range (no field weakening), the variables for the current and the torque are equal (100% of field current). In the weak field range, the torque is kept constant and the current setpoint necessary to maintain the constant torque in the weak field range is calculated by division of the torque setpoint by the flux Φ. See parameters p50169 and p50170.

For this type of control, the speed setpoint is overdriven by a small percentage, say, 5% of the additional speed setpoint. The drive would like to rotate faster but the speed is kept at the somewhat lower actual value by the web. The speed controller goes to the torque limit. This torque limit can now be set to the desired torque limit value by an external variable. Input of the additional speed setpoint via the connector number set in p50645.

Input of the desired torque limit setpoint via the connector number set in p50605[0].

This type of control is often used for axial winder and tension controls.

With this torque limit at the overdriven speed controller output, control now results in precisely the desired torque value.

If the material now tears, the speed controller will depart from the torque limit because of the missing load torque of the web and the driver will not turn faster than the speed setpoint plus the, for example, 5% additional overdrive setpoint. This prevents a high overspeed and the resulting damage to the winder reel.

No additional option is required for this type of control.

Master-slave switchover

With this type of control, a variable-speed master drive and one or more torque-controlled slave drives are used.

The possible applications are motors on a common shaft, e.g., for line shafts of printing machines or DC motors with a common shaft (tandem drive) or if multiple drives are inputting to a common transmission.

http://support.automation.siemens.com/WW/view/en/48957735

Load sharing control

If drives are coupled via a common web and they are to be controlled to a specific load distribution across the motors, e.g. S roll drives on a foil plant or to implement a converter tilting drive, load sharing control is used instead of master-slave switchover.

http://support.automation.siemens.com/WW/view/en/47216918

Load sharing via the droop function of the speed controller
A typical application example for this are roller conveyer drives for conveying material. The speed controllers of the 6RA80 are given the same speed setpoint (master setpoint), so that the motors turn at the same speed in principle. However, the speed controller has P-feedback in addition to the PI characteristic. As the controller output variable (torque setpoint) increases, this causes via this P-feedback a subtraction variable in the speed setpoint channel, which in turn causes the speed actual value to collapse at a higher load torque, which in turn automatically causes a reduction in the torque output. This results in an even distribution of the load over multiple drives in which this droop function is parameterized without any load sharing control. No further connections between the various devices are required except for the common speed setpoint.
No Option is required for this droop function.

Analog circuit diagram of the droop function:

Settable droop
PI controller
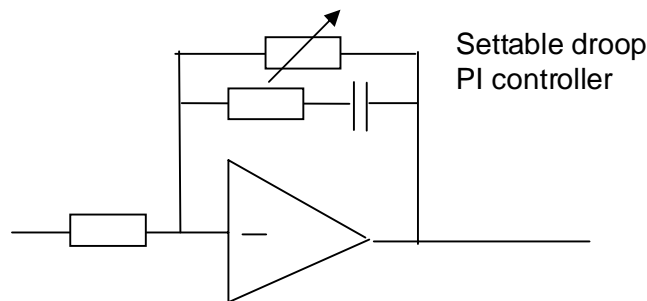
Axial winder
There are several ways of implementing an axial winder
in SINAMICS DCM
1) Implementation using the DCC on the CUD; Application available
http://support.automation.siemens.com/WW/view/de/47627620
2) Implementation by means of SIMOTION
In the majority of cases 1) Implementation using the DCC on the CUD is sufficient as well as being the lowest-cost solution.
An axial winder characterized that fact that the diameter of the wound material varies as winding progresses.
There are various methods of implementating the winding function, such as indirect tension control, direct tension control, dancer roll control and v-constant control. One of these methods is used both for taking up and paying out the material.
The drive is given the web velocity v as the setpoint. The diameter D is calculated by the formula $n * D = v$. This diameter is used to convert the web velocity setpoint to a speed setpoint to obtain the motor speed n as a function of D. The speed controller then receives a correction setpoint via the tension controller (for dancer control or v-constant control) or it is overdriven to control the tension via the torque limitation (for direct and indirect tension control). In addition, the compensation of the inertia and the friction is taken into account and the reeling hardness is open-loop-controlled.

Tension control with constant roll diameter
For this tension control with constant roll diameter, the software for the axial winder above can be used in principle. The only difference is that the diameter is not variable but a constant value. This is taken into account as a constant in the web-velocity-to-speed conversion.

Machine tool drives

Main spindle drive

A main spindle drive can be implemented using a SINAMICS DCM.

Perform current controller optimization, speed controller optimization (possibly, manually re-optimize for the speed controller) and field characteristic recording (p50051 =24, 25, 26, 27).

Messages:

C-axis mode with main spindle drives

For normal main spindle operation, DDS0 is used. Upon selection of
C-axis mode, DDS1 is used (see above under Drive Data Set DDS).

Procedure: After complete parameter assignment and optimization of the main spindle drive in DDS0, copy DDS1 to DDS1 and then perform optimization of C-axis mode in DDS1.

The current controller optimization usually provides suitable settings; manual re-optimization of the current controller only necessary in border-line cases. Optimizations of the speed control that are found (should exhibit the most rigid response possible) can usually be improved by manual re-optimization.

If necessary, perform speed controller adaptation Sheet 6805.

Spindle positioning for main spindle drives

With 6RA26 and 6RA27, there was a separate additional module for spindle positioning. 6RA80 no longer has this.

If SINAMICS is used, spindle positioning can be implemented in the following ways.

Spindle positioning via an NC (SINUMERIK) or SIMOTION.

Feed drives

Old thyristor controllers as the feed drive can be replaced by 6RA80 if the time is taken to perform optimization carefully.

Automatic current controller optimization sometimes has to be improved by manual re-optimization. Always manually re-optimize the speed optimization,

If necessary, perform speed controller adaptation Sheet 6805.

If transistor choppers were used because of high dynamic requirements, retrofitting with AC servo technology (AC servo motor plus converter) is almost always necessary.

Angular synchronous control

SIMOTION can be used in this case.

Can be implemented using the DCC on the CUD or with SIMOTION.

Cross-cutter/shear control

Can be implemented using the DCC on the CUD or with SIMOTION.

Technology control for hoisting gear applications

For technological hoisting gear applications, SIMOTION can be used with specially developed standard software.

The new SIMOCRANE Basic Technology
sector-specific solution is available. The SIMOCRANE Basic Technology
system consists of hardware and software packages for automating
cranes while helping you to achieve maximum performance
with your crane applications. The new solution
includes the following features:

The basic technology includes motion control of all
main crane drives:

- Hoisting gear
- Traversing gear
- Trolley
- Slewing gear
- Holding and closing gear, etc. (e.g. for booms etc.)
• All of the functions proven in practice have been integrated into the
new platform. In so doing, the latest requirements have been

taken into account.
• New closed-loop control concept for positioning with position controller
• Possibility of adapting to customer-specific requirements,
one package enables:
- "Ready-to-run" (for parameter assignment only) as well as
- "Ready-to-Apply" (adjustment by the user) Six software modules are available for this to
control the hoisting gear, holding gear, closing gear, slewing gear, traversing gear and
traversing gear slave drive.
For more on hoisting gear technology applications, please contact
Siemens AG, I DT MC CR. To do so, please contact your local Siemens office.
See also: http://support.automation.siemens.com/WW/view/de/47205467

References:

1...See Internet for specific product documentation SINAMICS DCM
http://support.automation.siemens.com/WW/view/en/38157755/133300

2....“Einführung in die elektronische Regelungstechnik“; by Friedrich Fröhr and Fritz
Orttenburger; in German; published by: Siemens Aktiengesellschaft Berlin-Munich 1970.

3....“Berechnung von Regelkreisen der Antriebstechnik“; by Arne Buchsbaum and Klaus
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5….Catalog DC motors:
https://www.automation.siemens.com/mcms/infocenter/content/de/Seiten/order_form.aspx?n
odeKey=key_516838

Index: