SIEMENS

SIMOREG DC Master

6RA70 Series

Application

Tips on Configuration, Hardware, Software, and Closed-Loop Control

Converters with microprocessor from 6kW to 1900kW for variable-speed DC drives

efesotomasyon.com

Edition 03

NOTE

This application documentation does not purport to handle or take into account all of the equipment details or versions or to cover every conceivable operating situation or application.
If you require more detailed information, or if special problems occur, which are not handled in enough detail in this document, please contact your local Siemens office.

The contents of this application documentation are not part of an earlier or existing agreement or legal contract and neither do they change it. The actual purchase contract represents the complete liability of the A&D Variable-Speed Drives Group of Siemens AG. The warrant conditions, specified in the contract between the two parties, is the only warranty which will be accepted by the A&D Variable-Speed Drives Group. The warranty conditions specified in the contract are neither expanded nor changed by the information provided in this application documentation.

WARNING

These converters contain hazardous electrical voltages, hazardous rotating machinery (fans) and control rotating mechanical components (drives). Death, serious bodily injury or substantial damage to property will occur if the instructions in the relevant operating manuals are not observed.

Only qualified personnel who are thoroughly familiar with all safety notices contained in the operating instructions as well as erection, operating and maintenance instructions must be allowed to work on these devices.

Successful and safe operation of this equipment is dependent on careful transportation, proper storage and installation as well as correct operation and maintenance.

0 Contents

1 Applications

SIMOREG converters are equipped with fully digital open-loop and closed-loop control and are used for the armature and field supply of variable-speed DC drives.

Fully digital with experience: Converters with digital closed-loop control from SIEMENS have been on the market since 1986. Now more than 100 000 digital SIMOREG devices are in use worldwide in all industries that use DC drives, whether in cranes, paper machines, foil machines, or rolling mills – the digital converter from SIEMENS has become the accepted solution as a variable-speed direct current drive.

In the standard version

- Rated supply voltage: 400, 460, 575, 690, 830 V
- Rated current armature circuit: 15 to 2000 A (with parallel connection of SIMOREG up to 12000 A)
- Rated field current 3 to 40 A
- 6 and 12 pulse operation possible
- Field current greater than 40A because of separate 6RA70 / 1Q device

A wide permissible input voltage range and flexible software make the devices suitable for special applications.

Special applications

- Supply for excitation of large generators
- Supply to solenoids
- Supply to controlled direct voltage busbars
- Charging battery sets
- DC link supply of large pulse-controlled converter systems

Catalog DA21·1998 is used to configure the 6RA70 converters. The application documentation answers additional questions about the configuring and characteristics of the devices.

2 Configuring

The formulas used are often approximations but are adequate for the practical definition of variables.

2.1 Direct current motor

Configuring starts by dimensioning the direct current motor as described in Catalog DA12. The armature rated voltage of the motor which is required to dimension the armature circuit is dependent on the supply system and operating mode 1Q / 4Q (one-quadrant/four-quadrant operation)

Rated armature voltage of motor	Line connection 40/60 Hz	Converter connection	Operating mode
420 V	400 V 3AC	(B6)A(B6)C	4Q
470 V	400 V 3AC	B6C	1Q
520 V	500 V 3AC	(B6)A(B6)C	4Q
600 V	500 V 3AC	B6C	1Q
720 V	690 V 3AC	(B6)A(B6)C	4Q
810 V	690 V 3AC	B6C	1Q

For line voltages of 415 / 440 / 460 / 480 V, the next most suitable armature circuit is used. The speed can be finely adapted via the motor field. If deviations between the rated voltage of the motor and the output voltage of the converter are greater, please consult the manufacturer of the motor.
Note: For SIEMENS motors up to size 136, the permissible nominal voltage of the supply network is maximum 440 V.
A calculation example is provided in the next chapter.

The recommended rated voltage for the motor field is 310 V. As 6RA70 devices have an integrated controlled field device, variable-speed field weakening is also possible. The motor is operated with constant power in the field weakening range, the torque decreasing as the speed increases.
The relationship between rated power and torque is calculated as follows:

$M = (9549 * P_N) / n$

M: Motor torque [Nm], P_N: Rated motor power [kW] , n: Motor speed [rpm] .
For speeds with a rated speed (armature speed range) the rated torque of the motor is the torque. Observe overload capability of the motor acc. to DA12.

In many cases, existing plants with older motors are upgraded by installing modern converters.
Important points to observe?

a) As old motors were mainly built for safety, it is usually not necessary to use a smoothing reactor in the direct current circuit for 6-pulse converter supply.

b) On new modern SIEMENS motors, rates of current change up to 200 I_N/s are permissible in dynamic processes. More gentle treatment is required with old motors. For that purpose, the current setpoint integrator is activated in the SIMOREG 6RA70.
Suggestions for parameterization: Set parameter P157 = 1, P158 = 0.040.

c) If the rated motor voltage is considerably lower, e.g. 160 or 220 V and the motor to be operated directly above a converter on the 400 V network, caution is advisable.
Although the average value of the output voltage on the SIMOREG can be regulated between zero and the rated output voltage, the resulting peak voltage is the root of twice the rms value of the line voltage, and in a 400 V network this is as much as 565 V. The motor manufacturer will be able to say whether this value is permissible for the commutator. If in doubt, connect an adapter transformer at the SIMOREG input. The calculation is given in the following chapters.

NOTICE

In the case of permanent-field type 1HU SIEMENS motors, a matching transformer dimensioned for the rated armature voltage of the motors must be installed upstream of the converter (guide value for secondary voltage: $U_{sec} = U_{Armat} * 0.98$).

Features of SIEMENS motors:

- High power to size ratio with compact design
- High operational safety and availability Brush life up to 15000 hours
- High dynamic response Torque rise times below 10 ms during operation on SIMOREG
- High dynamic limit torques with shortest reversing times
- Excellent concentricity: Torque ripple below 1% at 50/min
- Maintenance-friendly, bus-capable diagnostics concept in combination with 6RA70
- Building block system for adaptation to customer requirements

2.2 SIMOREG DC MASTER 6RA70 converter

The SIMOREG is a line-commutated converter which requires the line voltage to commutate the current, it is not possible to maintain the current flow on failure of the line voltage (e.g. on a short interruption).
If regenerative feedback is used with four-quadrant devices, failure of the supply voltage or a line undervoltage can cause a fuse to trip (commutation failure). This is a physical effect of the converter circuit that cannot be prevented by closed-loop control. Single-phase alternating current is fed to the field circuit and three-phase current to the armature circuit. It is not possible to operate the power section from a DC system. The SIMOREG 6RA70 can briefly be overloaded 1.8 fold if the device had previously been operated with a base-load current which is lower than the device rated current. If the device has been operated at rated current over a longer time it cannot be operated at overload. To avoid this, the thermal condition of the thyristors is calculated in the device to ensure the protection of the power semiconductors. Once the thermal limits are reached at overload, the current is automatically reduced to the rated current of the device or the device is switched off with an error message. The overload is configured using Catalog DA21 or the instruction manual.

Range of permissible rated voltage of the supply system

The range of the permissible input voltage depends on the rated supply voltage of the 6RA70 device. For line voltages of 480V / 500V / 575V, devices with a rated supply voltage of 575 V are used. The hardware option L04 is available for extra low voltages of 15 to 85 V input.

Rated line side voltage 6RA70	**Rated voltage range of supply system**
Armature circuit 400V	85 - 415 V 3AC
Armature circuit 400/460575 V with option L04	15 - 85 V 3AC
Armature circuit 460 V	85 - 460 V 3AC
Armature circuit 575 V	85 - 575 V 3AC
Armature circuit 690 V	130 - 690 V 3AC
Field circuit	85 – 460 V 2AC

CAUTION

In 4Q operation with regenerative feedback, the system voltage must always be higher than the motor voltage / 1.17, otherwise commutation failure can occur with fuse tripping.

Output direct voltage on the SIMOREG

The rated output voltage stated in the technical data applies to a rated supply voltage minus 5%. A small margin has therefore been included to cover operational undervoltages of the supply network.
The output voltage can be calculated more precisely in the following context:

Armature circuit:

4Q circuit (B6)A(B6)C: $U_{DC\text{-}output} = U_{SIMOREGin} * 1.35 * \cos 30° = U_{SIMOREGin} * 1.17$

1Q circuit B6C: $U_{DC\text{-}output} = U_{SIMOREGin} * 1.35 * \cos 5° = U_{SIMOREGin} * 1.34$

Field circuit:

Circuit B2HZ: $U_{DC\text{-}output} = U_{SIMOREGin} * 0.9$

For rated field voltages of between 180 and 340 V (normal 310 V), the current converter is configured for a supply voltage of 400 V (except for older motors), a matching transformer on the supply side is recommended for lower rated voltages of the motor field.
Note: For $U_{SIMOREGin}$, the line voltage minus the voltage drop of the commutating reactor (usually 4% of the supply voltage) is used.
$U_{DC\text{-}output}$: Calculated output voltage on the SIMOREG:
If an adapter transformer is used, several % should be included in the calculation as the voltage margin.

Calculation example:

System data: Rated line voltage 415 V, voltage drop commutating reactor 16 V
4Q operation,

$U_{SIMOREGin} = 415 - 16 = 399$ V

$U_{DC\text{-}output} = 399 * 1.17 = 467$ V

The 470 V armature circuit can be selected for the motor.
To ensure additionally a margin for an undervoltage, a motor rated voltage of 440 V is recommended as input (parameter P101).
A motor speed at 440 V referred to 470 V can be converted linearly (the speed in the armature operating range is proportional to the motor voltage). The rated speed can be met by slight field weakening.
A margin is included in the calculation due to: operational undervoltages in the network, undervoltages resulting from other loads, voltage drop on lines, increased voltage drop I*R in motor on acceleration currents.

Power loss on the SIMOREG

Power-independent losses	
Power supply	approx. 200 W
Device fan	approx. 750 W at 400 to 850 A devices
	approx. 570 W at > 850 A
Power-dependent losses	
Armature circuit:	3 V times armature current
Field circuit	3 V times field circuit
Total losses	Sum of all above losses

Power output: Direct voltage times direct current of armature
Power input: Power output plus losses
efficiency Power output divided by power input.

2.3 Converter transformer

The apparent power of the converter transformer for the armature circuit is calculated by the following formula.

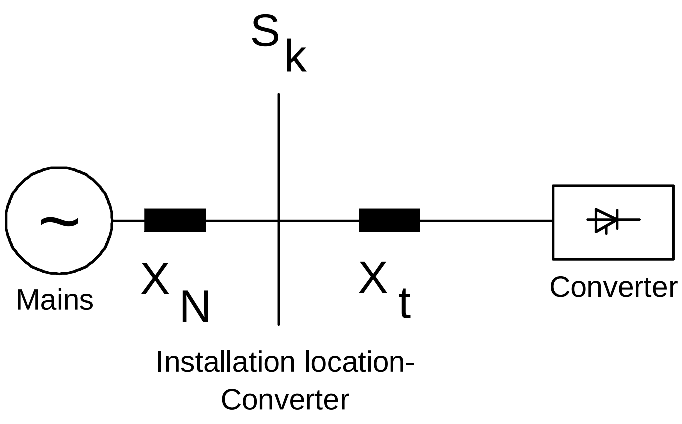
$S = 1.35 * U_{secondary\ network} * \text{direct current} * 1.05$

For the field circuit

$S = U_{secondary\ network} * \text{direct current}$

2.4 Commutation reactor

Inductances on the supply side of the SIMOREG K devices are necessary to limit the commutation notches in the line voltage. Commutation reactors must therefore be connected on the line side of the devices. The required inductive voltage drop, like the short-circuit voltage of the transformer, can be referred to the line voltage and can be specified as a referenced voltage drop.
The minimum value of the transformer short-circuit voltage or the referenced voltage drop of the commutation reactor should be 4%, taking the permissible commutation notches in the supply system into consideration, so that at a ratio of converter connected power to system fault power of 1%, the commutation notches do not exceed 20% according to VDE 0160. This also means that in weak networks, the inductance of the commutation reactor might have to be increased (e.g. two reactors in series).



X_N : Line reactance, X_t : Transformer reactance, U_n : Rated line voltage
S_k : Short-circuit power of the line at the installation location of the converter
P_s : Converter connected load

Voltage loss in supplying network at point S_k :

$$\Delta U / U_n = X_N / (X_N + X_t) \text{ setpoint} \leq 0.2$$

$$\Delta U / U_n = 1 / (1 + u_k * S_k / P_s)$$

u_k is the relative short-circuit voltage of the converter transformer and commutation reactor (normal 0.04 = 4%).
A network can be designated stiff if $P_s / S_k \leq 0.01$. Use 4% reactors on a stiff network.

When is it possible to dispense with a commutation reactor: If a converter is operated on a converter transformer (as only load) at $u_k \geq 4\%$. Autotransformers have a low u_k, an additional commutation reactor is therefore usually necessary.

When is a commutation reactor mandatory: If several converters are operated on a single transformer, a separate commutation reactor is required for each device.

If the commutation reactors are selected as described in Catalog DA93.1, it is possible to proceed as follows: As both the motor and the commutation reactor can be overloaded briefly, the reactor current in the armature circuit is calculated on the basis of the rated motor current. The rated current of the three-phase reactor is the rated motor current multiplied by 0.82. A type suitable for an 80% reactor is selected from the table.
The reactor for the field current circuit is rated for the rated current of the motor field (single-phase reactor).
Note: Rate the reactor 10% higher for a 60 Hz line frequency.

2.5 Main contactor

Use of a main contactor is not mandatory (depends on application). Using relay contact terminal 109/110 of the SIMOREG device for the main contactor protection ensures that the main contactor is switched on and off at no load in normal operation. However, if a fault occurs, overcurrents with direct current components can occur.

2.6 Miniature circuit-breakers

In the SIMOREG device overview, the miniature circuit-breakers for the electronics power supply and field are drawn in.
They are rated for line protection. As an alternative, line protection can be achieved by other means.

2.7 Semi-conductor protection fuses

Semi-conductor protection fuses are prescribed for protecting the thyristors (see Catalog DA21 and the instruction manual).

CAUTION

Any damage to the device that results from the use of impermissible fuses is not covered by the guarantee.
The prescribed semi-conductor protection fuses are not suitable for line protection.

Exception: Type 3NE1 is also suitable for line protection. In addition to semi-conductor protection, measures for line protection must be taken, e.g. with line protection fuses.

The following semi-conductor protection fuses are also suitable for line protection under the following conditions:

Type: Semi-conductor protection fuse	**Line must be rated to following minimum current**
5SD420	15 A
5SD440	22 A
5SD480	26 A
3NE8015	27 A
3NE8003	36 A
3NE4102	36 A

2.8 Leads

The motor leads have been rated for direct current. In the supply circuit of the armature circuit, the motor current multiplied by 0.82 flows.
In the field supply, the direct current is equal to the supply current.
Protective conductors: The protective conductor must be rated to root 3 x the supply current in the case of faults. If ground protection monitoring is used, the protective conductor cross-section can be reduced.
Note: RCCBs on the are not permitted on the SIMOREG

2.9 Interference filters

If standard EN55011 class A1 is met, commutation reactors and interference filters are always necessary. The current rating of the interference filter is the same as that of the commutation reactor. On 400 V networks, several loads (armature circuit, field circuit, power supply) can be connected via a filter. For this, the total current of the loads is calculated for the filter rating.
Please refer to the instruction manual and Catalog DA21 for further information.

2.10 Cosine PHI

As the SIMOREG K device is a controlled rectifier, phase control reactive power and commutation reactive power occur. Depending on the motor speed, cosφ for the armature circuit can be between zero and approx. 0.9 depending on the motor speed. As no sinusoidal currents occur in the converter circuits, it is somewhat more difficult to determine the powers.

For a fully smoothed direct current, the following relations apply:
$S_1 = U_{di} * I_d$, $P = P_1 = U_{di} * I_d * \cos\alpha$, $Q_1 = U_{di} * I_d * \sin\alpha$. $\cos\varphi_1 = \cos\alpha$.
The reactive power is always inductive.

In practice, cosφ can be approximated by the following relation:
$\cos\varphi \cong U_d / U_{di} = U_{motor} / (1,35 * U_{network})$

Calculation example:

Given:
Motor 1GG6164-0JF40-6WV5, armature rated voltage 470 V, rated speed 1800 rpm, rated current 171 A, line voltage 400 V

a) At a rated speed of:
$\cos\varphi \cong 470 / (1.35 * 400) = 0.87$

b) at 900 rpm:
In the armature speed range, the speed and motor voltage are proportional, at half the speed, half the motor voltage therefore applies.
$\cos\varphi \cong (470 / 2) / (1.35 * 400) = 0.44$

c) At 2500 rpm
The motor is in the field weakening range, the direct voltage is constant (motor rated voltage), calculation as for a).

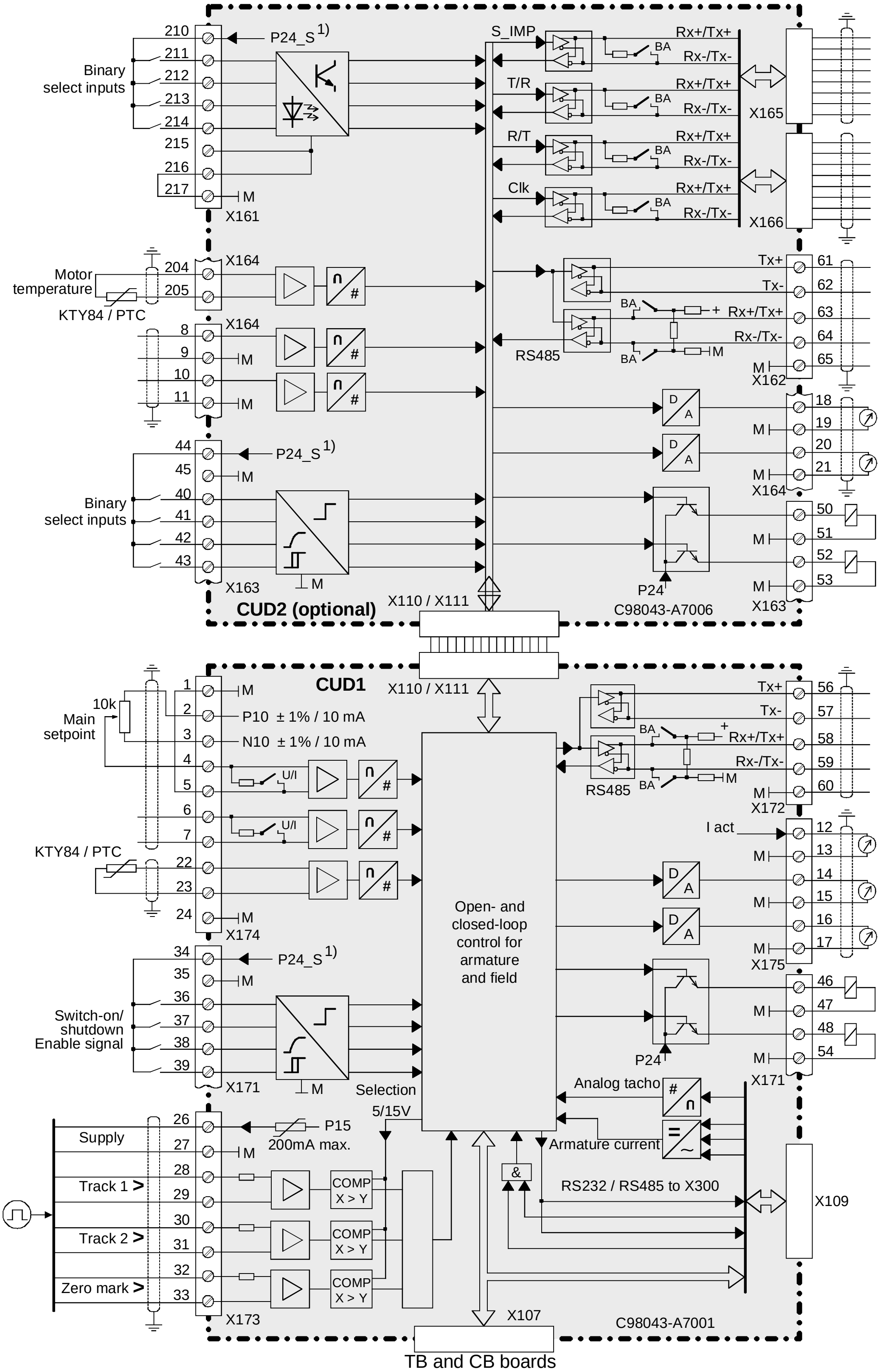
2.11 Line-side harmonic components

Harmonic components occur when the converter loads the system is more or less pronounced square current blocks. Dividing the system current into its frequency components produces the fundamental component and the harmonic component.
A calculation example is given in the instruction manual of the converter device and in Catalog DA21.
With precise knowledge of the network and motor data (short-circuit power, data of the commutation reactor, motor inductance and resistance, transformer data and operating point of the motor), it is possible to calculate the line-side harmonics.
In complex converter system measurement of the harmonics of major importance.

2.12 Compensation equipment

All converters cause reactions on the network. It is the task of the network operator to implement interference suppression measures in the network. The network topology and any possible changes must be known before a network calculation can be performed. Random fitting of series resonant circuits in the network, especially those with compensation equipment without inductors, will not usually provide any improvement and could, in certain circumstances, increase the resonance sensitivity of the networks. The harmonics cannot be calculated simply by adding together the sum of the harmonics of the individual converters (which is lower than the sum). In the case of complex systems, it is in practice possible to resort to measurement of the harmonics. To avoid any question of liability, the network operator should be made aware of the presence of harmonic currents by the converter manufacturer.

3 A Short ABC of Hardware



CUD1: Microprocessor electronics: A variant for the entire series

CUD2: Option terminal expansion

3.1 Microprocessor electronics

The dual-processor system based on the powerful microcontroller of the SIEMENS C166 family, with a 48 MHz switched-mode power supply, is the heart of the closed-loop control.
A C163 is synchronized and coupled with a C167 via a dual-port RAM. This is a powerful microcontroller whose operations set is optimized for a fast response to external events.
"Intelligent" peripheral circuits have been implemented on a chip in addition to the microprocessor to increase the flexibility of the entire controller.

A controller from the C166 range consists of the following function blocks: A high-performance microprocessor, a fully programmable interrupt system, universally applicable input/output channels and independently operational intelligent peripheral circuits.

The most important features of the C163 and C167:

- Command execution cycle 83 ns at 24 MHz internal cycle,
  16-bit multiplication and division in 0.416 and 0.83 µs
- Most commands are performed within a single cycle,
- Comprehensive bit manipulation, commands for powerful program branching
- Flexible bus control with programmable, address-independent properties
- 16-channel 10 bit analog-to-digital converter (-> C167 only!)
- Five 16-bit time generators/meters with a circuit for time acquisition and comparison
- High degree of system reliability with watchdog
- Two integrated serial interfaces

An **ASIC** module (customer-specific module) supports the microcontroller with:

- 4 channels for high-resolution A/D conversion with 14 bits plus sign
- Pulse generator evaluation with two tracks and zero mark for up to 300kHz pulse frequency

3.1.1 Analog inputs / outputs

- Analog speed actual value with 14 bits plus sign, conversion time 1.15 ms
- 2 analog inputs via differential amplifier with 14 bits plus sign.
  The resolution for the main setpoint (terminal 4/5) can be set via P707:
  11 bits plus sign measuring time 0.53 ms
  12 bits plus sign measuring time 0.95 ms
  13 bits plus sign measuring time 1.81 ms
  14 bits plus sign measuring time 3.51 ms
- 2 analog inputs with 10 bits plus sign.
- 4 analog outputs 11 bits plus sign
- A direct analog realtime output for the current actual value, e.g. for connection to a recorder

3.1.2 Pulse generator input

Pulse generators with two tracks offset by 90° are recommended (one track is sufficient for the 1Q, selectable via P140). A zero mark is recommended if an actual position value (hardware counter 24 bit , connector K0043 high-word, K0042 low-word, K0044 number of zero marks) is required.
Measurement is performed using a difference amplifier (caution: also connect minus connection to ground or cross-track).
In the case of HTL pulse generators, the SIMOREG can provide the power supply. 5V generators (TTL) require a separate power supply. The input voltage range can be selected via parameter P142.
1024 pulses per revolution or higher are recommended. A measuring time of between 1 and 4 ms can be selected for evaluation. The longer the measuring time, the better the concentricity at lower speeds.

The lowest speed that can be measured with a pulse generator depends on the number of increments that it has.

n_{min} [rpm] = 14648 / (X * no. of increments)

The highest speed that can be measured with a pulse encoder is:

n_{min} [rpm] = 18.000.000 / no. of increments

X = 1 or 2 or 4 for single, double, or four-fold evaluation.

The number of increments (pulse count pulse encoder) of the pulse encoder is determined by the required minimum/maximum speed (1024 pulses per revolution is usually suitable).

3.1.3 Serial interfaces

The basic SIMOREG unit has two serial interfaces. A third serial interface is located on terminal extension CUD2.
Connector X300 is located on the operator panel of the device either with an RS232 or RS485 interface for the USS protocol. The RS232 interface provides a point-to-point link for connection to a PC. Menu-guided start-up with SIMOVIS is usually performed through this interface. The RS485 interface is suitable for the bus-capable connection of the device to the automation or a PC (converter required on the PC side) or for connection an OP1S.
Maximum baudrates: 19.2 kBd or RS232 and 187.5 kBd for RS485.
One RS485 interface (four-wire or two-wire) is provided on each interface CUD1 and CUD2. These can be used for the USS or peer-to-peer protocol.

3.1.4 Motor interface

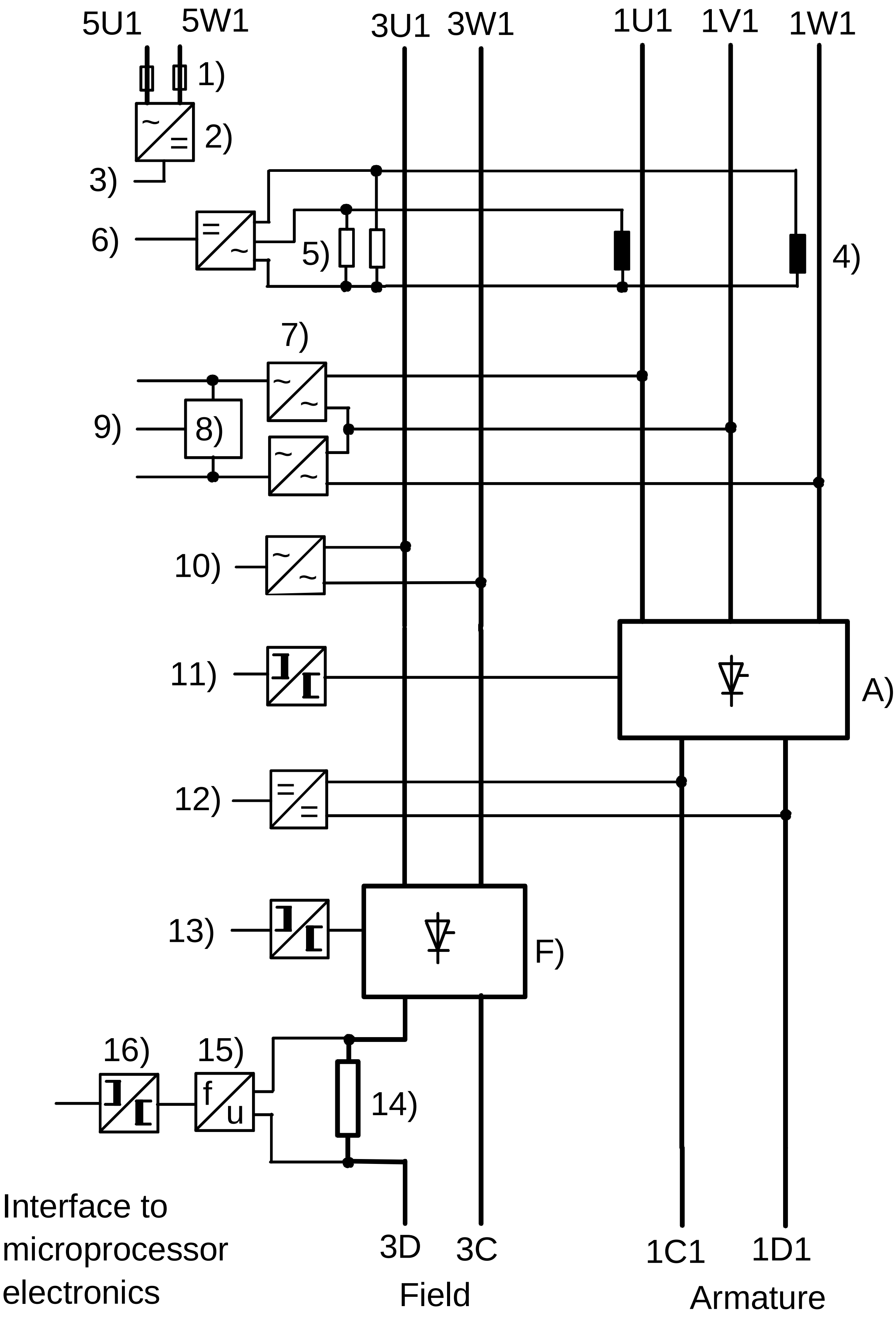
The possibilities of the motor interface on the CUD2 are described in Catalog DA21.

3.1.5 Supplementary modules

Technology module T400 and interface modules CBP are linked via a dual-port RAM.

For more detailed information see Catalog DA21.

3.2 Measured value acquisition in SIMOREG DC Master 6RA70



5U1/5W1: Connection of electronic power supply, any phase angle
3U1/3W1: Incoming field supply, any phase angle
1U1/1V1/1W1: Armature circuit supply, any rotating field

3C/3D: Connection for motor field
1C1/1D1: Connection for motor armature circuit

A) Power section armature circuit, connection B6C for 1Q, connection (B6)A(B6)C for 4Q
B) Power section field, connection B2HZ

1) Medium time-lag fuse power supply 1A order No. 6RY1702-0BA00
2) Floating switched-mode power supply
3) Direct voltages: P5, P15, P24, N15

4) AC converter in phase U/W for armature current measurement and electrical isolation
5) Load impedance for converter with max. 1V compliance voltage for rated current. The rated current of the device is finely adapted via the software without any loss of resolution.
Load adaptation is performed in 10% steps via parameter P76.

6) For electronic rectification of current actual value on the electronics module,
10-bit resolution for rated current.

7) High-resistance voltage measurement via difference amplifier in armature circuit.
8) Simulation of 3rd phase
9) To analog-to-digital converter, voltage measurement, and three-phase synchronization

10) High-resistance voltage measurement for synchronization in field circuit via difference amplifier and evaluation via analog-to-digital converter.

11) Electrical isolation for firing pulses armature circuit via pulse transformer.

12) High-resistance difference amplifier for armature voltage measurement, for operation without tachometer via emf closed-loop control.

13) Electrical isolation for firing pulses field circuit via pulse transformer.

14) Shunt resistance for field current measurement. Load adaptation is performed in 10% steps via parameter P76.

15) Voltage/frequency conversion for measured value acquisition.
16) Transformer for measuring frequency for electrical isolation.

4 The Software – Flexible in Adaptation

The software is modular and can be configured flexibly via the parameters. The software modules available are described in Catalog DA21 and in the SIMOREG instruction manual.

Binectors and connectors allow flexible configuring of the software modules.

5 Characteristics of the Closed-Loop Control

The control is a closed-loop speed control with secondary current control.

5.1 Current control loop

In order to achieve a high dynamic response, a feedforward control is connected in parallel to the PI current controller. The feedforward control calculates the required control angle from the emf and current setpoint and operates as a fast channel parallel to the current control. The current controller with its PI characteristic ensures slower operations.
The rise time for the current control loop is approx. 6.6 ms. Statistically, an additional dead time of 3.3 ms can occur at 50 Hz. The limit frequency for the current control loop is 47.5 Hz.

5.2 Speed control loop

The speed controller is a PI controller with a D component in the actual value channel.
The rise time is 25 ms, the limit frequency for the speed controller is 24 Hz.

5.3 **Automatic optimization runs** support start-up**.**

The optimization run is selected via parameter P051.

P051 = 22 Internal offset matching

P051 = 25 Feedforward control and current controller (armature and field)

P051 = 26 Speed controller

P051 = 27 Field weakening control (field characteristic and emf controller)

P051 = 28 Friction and moment of inertia compensation.

The controller is optimized according to the following criteria:
Armature current controller acc. to the absolute value optimum.
Field current controller acc. to the symmetrical optimum.
Speed current controller acc. to the symmetrical optimum.
EMF controller acc. to the symmetrical optimum.

The current control loop should always be optimized automatically, manual adaptation is not necessary.

The speed controller should be re-optimized manually in the following cases:
Heavy gearless
Belt drives with high moment of inertia
Oscillating mechanical system
Processes that do not permit high dynamic response

5.4 Calculation cycles

The following functions are calculated between two triggering pulses, i.e. in **3.3 ms** at 50 Hz:

Armature current control, speed control, process-oriented controller, motor-actuated potentiometer, setpoint generation, ramp-function generator, analog inputs, analog outputs, binary outputs, interfaces.

In **6.6 ms** at 50 Hz:
Binary inputs

In **10 ms** at 50 Hz:
EMF and field current control
The calculation cycles are 20% shorter at 60 Hz.
Parameterization is performed in **20 ms** cycles.

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